indicate that there are no significant differences between the field strength predictions using these methods except for the longer paths.

From Table 6, it can be observed that for paths <2000 km, the differences between the predicted MF field strengths for the different prediction methods is insignificant; the rms error is approximately 4.0 dB for all methods. However, for the U.S. paths >2000 km (21 through 27), there is more variability in the predicted MF field strengths. Beyond 2200 km, propagation of the radio wave would involve two ionospheric reflections. The rms error for these seven paths is 15.6 dB for Cairo, 12.4 dB for Brasilia, 7.1 dB for CCIR 1974 and 1978, 5.3 dB for Wang 1979, and 5.4 dB for the IWP 6/4 predictions. From these results, it appears that either the Wang 1979 or the IWP 6/4 predictions are more reasonable for MF paths between 2200 and 3500 km in Region 2.

However, for paths >8000 km (23, 24, 25, 26, and 29), there is less variability between the predictions than for the U.S. paths 21 through 27. The rms error for the predictions for these five paths is 2.3 dB for Cairo, 5.4 dB for Brasilia, 8.9 dB for CCIR 1974, 8.3 dB for CCIR 1978, 10.6 dB for Wang, and 6.5 dB for IWP 6/4. (The Wang 1979 method would give approximately the same results as the IWP 6/4 method if the loss factor, k, is limited to 3 in the calculation of the field strengths for these paths.) The Cairo North-South Curve predictions appear to be the preferred method for very long paths in Region 2.

5. RELIABILITY OF MF FIELD STRENGTH MEASUREMENTS

When comparing measurements with predictions, lack of information about the reliability of the data makes it difficult to realistically assess the accuracy and/or suitability of any prediction method. There are a number of uncertainties concerning the controls and conditions under which many of these observations were made. For example, the measurements used for the Cairo Curves were normalized to 1 kW radiated, but the transmitting antennas were one-half wavelength long. Should an additional correction factor be applied to the measurements before comparing them with predictions that have assumed a short vertical antenna? As the CCIR and Wang prediction methods only approximate the correction to account for the transmitting antenna gains, this could also explain some of the discrepancies between the measurements and predictions. Some of the measurement campaigns extended over several years, and in some areas these measurements indicate a seasonal variation. The Cairo measurements were made only in local winter and summer; if there is a seasonal dependence, the comparison of these measurements with predictions of an annual median field strength may be biased.

Altogether, there are approximately 300 field strength measurements available for comparisons. In most cases, the measurements have been normalized to represent F_0 as defined by CCIR and include corrections for the transmitting antennas and solar activity when appropriate. In many cases, no information was available concerning the antennas and there were insufficient data to determine a solar activity effect. Some of the measurements were made at intermediate solar activity levels; and, in this case, the annual medians are averaged over all of the years. If the measurements were made at high solar activity in a region where a variation with solar activity is assumed, the measurements were adjusted to represent minimum solar activity. As mentioned in Section 4.4.1, if the measurements were not made at a time when the ionosphere would not be affected by solar radiation, corrections were made to adjust the measurements accordingly.

The intent here is not to criticize the methods used to normalize the measurements, but to emphasize the necessity for the process. Considering the possible deficiencies in the measurements used for the comparisons, the question that needs to be answered is not whether one particular prediction method is better than the others, but are the measurements sufficiently accurate and reliable to make this determination?

6. CONCLUSIONS

The apparent need for the use of so many different variables in the MF field strength prediction methods is indicative of the complexity and uncertainty regarding the physical properties that are involved in long-distance MF sky-wave propagation. Among these is a correlation with a geomagnetic coordinate; however, a correlation between the measurements and the solar zenith angle might be as significant and might also explain the seasonal variation. As annual medians of predicted field strengths are desired, it would seem desirable to perform a multiple regression analysis of all available monthly median MF field strength measurements to determine the interrelationships with variables such as the solar zenith angle, geographic and geomagnetic coordinates, frequency, distance, and solar activity. From this analysis, improved estimates of annual median field strengths could be derived and applied in the development of a more accurate and consistent worldwide MF field strength prediction method.

In addition, and particularly significant for inter-regional applications, there is a need for controlled measurement programs that would provide more reliable measurements, especially for very long paths at low latitudes. Controlled experiments to better determine the effects of multi-hop propagation, sea gain, polarization losses, and to verify nonreciprocal propagation would be useful.

When planning a broadcast service, the service area covered would be determined by the annual hourly median field strengths. For determining interference from one or more signals, it is assumed that interference is produced when the field strength is exceeded at least 10% of the time. The CCIR suggests that 8 dB be added to the annual median of the hourly median field strength to obtain the field strength exceeded 10% of the time. As an estimate of the maximum field strengths or the worst case conditions is required, until a more reliable prediction method is available, the preferred method would be the method that predicts the maximum field strengths. For very long paths, the Cairo Curve method, in general, predicts the highest field strengths. For shorter paths, the preferred method would depend on the geographical area of interest.

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