REPORT 562-4

PROPAGATION DATA REQUIRED FOR TERRESTRIAL BROADCASTING AND POINT-TO-MULTIPOINT COMMUNICATION SYSTEMS IN THE FREQUENCY BANDS ABOVE 10 GHz

(Question 13/5)

(1974-1978-1982-1986-1990)

1. Introduction

The increasing demand for broadcasting services in the bands below 1 GHz has required that consideration be given to the use of frequencies above 10 GHz and in particular the 12 GHz band for sound and television broadcasting.

This Report gives a —— preliminary description of the propagation effects which are of importance for the planning of networks in the 12 GHz band. Results are given of measurements carried out in the Federal Republic of Germany, France, Japan, Switzerland and the USA.

2. General considerations

2.1 *Propagation in the service area*

For the planning of a broadcasting system the most important factor to consider is the coverage probability, which is affected by diffraction losses caused by the terrain. In the frequency band above 10 GHz, the losses due to diffraction by buildings are of particular importance.

Consideration should also be given to attenuation due to precipitation and multipath propagation. Measurements in the Federal Republic of Germany indicate that in heavily built-up areas multipath effects caused by reflecting layers in the atmosphere are of minor importance. However, special attention should be given to multipath propagation due to the reflection from large buildings and other terrain features. The relatively high directivity of receiving antennas in this band may alleviate multipath problems of this kind.

2.2 *Interference to other service areas*

The propagation characteristics in this frequency band are such that the effective coverage range of each transmitter will be small and hence, to achieve the necessary coverage probability, high transmitter densities may be required. Estimation of the minimum separation distance between co-channel transmitters is therefore of particular importance. This estimation should not be based solely on a calculation of long-term median values of transmission loss, but consideration should also be given to abnormal conditions causing important signal enhancement over long distances for small percentages of the time.

If atmospheric conditions are such that ducting is possible at the transmission frequency, then the interference field strength may be considerably increased, depending on whether the station antenna is located within the duct. Although these effects can be determined for specific cases by various methods [Dougherty and Hart, 1976], a broad probabilistic approach, such as in Report 724, is generally more useful for determining coordination distance, while separation distances between co-channel transmitters may be estimated by means of the methods set out in Report 569.

3. Propagation data

3.1 *Propagation in the service area*

Field-strength measurements at about 12 GHz have been carried out by the Federal Republic of Germany [Sakowski, 1970a and b], using an experimental network in Berlin (West) with three transmitters having different effective antenna heights. These measurements show the importance of providing adequate antenna heights to overcome obstruction by buildings. It was found that a more reasonable interpretation of the results in this particular area could be achieved if the receiving antenna heights were not referred to the ground but to the average height of the roof tops near each reception point. Height-gain values for the receiving antenna heights so defined are given in [Sakowski, 1975]. As the relation between field strength and antenna height is highly dependent on the variations in dimensions of the buildings of a town, it is not possible to draw general conclusions from these particular results (the measurements were carried out in a city with relatively standardized roof heights). In a large number of tests [Sakowski, 1977] the influences of single objects were identified. Reflections from buildings turned out to be rather unimportant since the reflection losses were larger than expected. Single trees on the direct path caused attenuations up to several 10 dB, rapidly fluctuating during wind and strongly varying with season in the case of deciduous trees. In comparison to UHF (600 MHz), measured attenuations at 12 GHz in the deep shadow regions were larger by about 10 to 20 dB. Simultaneous measurements with horizontal and vertical polarization showed the difference in attenuation due to obstacles to be generally negligible except that a slight advantage exists (of 4 dB on the average) for horizontally polarized waves in the case of disturbing reflections from vertical surfaces.

The availability of three alternative transmitters in this experiment enabled an assessment to be made of the benefits of threefold coverage of an area. It was concluded that, when using a transmitter height of 200 m in this relatively flat area, single station coverage was only slightly worse than a threefold coverage, the latter being expensive both in transmitter costs and frequency usage.

Similar field-strength measurements, using one 12 GHz transmitter, have been carried out in Switzerland in the urban area of Bern, as well as in flat and mountainous areas of its surroundings [Bärfuss, 1976]. From the results, percentages of coverage within the different areas are derived, based on either a vestigial sideband amplitude modulation system or a frequency modulation system.

In France, propagation measurements were carried out over a period of two years, with 12 GHz broadcasting transmitters situated in central and western France, at path lengths of 74 and 28 km, respectively [CCIR, 1978-82]. The specific attenuations exceeded during 1% and 0.1% of the time were comparable on both paths. However, these attenuations were significantly different for 0.01% of the time.

For an estimation of the attenuation due to precipitation, or due to multipath propagation via atmospheric layers, reference is made to Reports 338 and 723 (worst month attenuation statistics were also obtained in the above-mentioned experiments in Switzerland).

Measurements of broadcast transmissions at 12 GHz in the United States of America [Bentz, 1982] demonstrated the importance of line-of-sight paths for service in this band. In a hilly urban area in San Francisco, where 38% of the paths were obstructed by terrain or buildings, the obstructed paths had a median attenuation 20 dB greater than the line-of-sight paths. At 60% of the obstructed sites, reflected signals were measured with a median level 3 dB greater than the median for other obstructed sites.

Since the received signal level due to reflections from a building results from a number of reflected waves and exhibits a strong frequency dependence according to the building material and structure, a statistical method is necessary to evaluate the reflection loss. An example of measured results is presented in § 3 of Report 1146.

3.2 *Interference to other service areas*

Measurements of interference wave intensities have been carried out in Japan in different urban areas of Tokyo, using horizontally polarized and circularly polarized waves at 12 GHz [Saito *et al.*, 1977]. From the results, transmission loss distributions in the range of 5 to 10 km, in relation to the height and number of buildings around the receiving sites, are derived; an advantage in using horizontally or vertically polarized transmission over circularly polarized transmission is found, indicated by reduced interference to other service areas where orthogonal polarization is used.

Methods for calculating field strength or transmission loss for distances which are of interest for assessing long-range interference probabilities are given in Report 569. For network planning at 12 GHz, ranges below about 300 km are of particular interest. Measurements in the Federal Republic of Germany [Abel, 1972] compared with predictions based on [NBS, 1967] showed that the reduction of field strength with increasing distance was less than predicted.

4. Propagation path visibility

As mentioned in § 2, predicting coverage probability is one of the most important problems for the planning of point-to-multipoint networks, such as broadcasting and local radio distribution systems. For frequencies above 10 GHz, visibility, defined here as the probability of success in achieving line-of-sight propagation paths, mainly affects the size of the service area in densely built-up areas, where many shadow regions are produced by large buildings.

A method of estimating visibility has been derived from a building distribution model [Ogawa and Satoh, 1984]. The visibility between a base (nodal) station and its subscribers may be calculated using parameters such as the height of the station, distance, the density of buildings and their mean height, and the ground level. Such estimations agree with measurements made in Tokyo. In a system where several radio zones overlapped, factors such as the size of the radio zone and distances from the nodal station were considered from the point of view of visibility. An estimate of the number of waves reflected by buildings is also given in the above-mentioned reference.

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