REPORT 228-3 *

MEASUREMENT OF FIELD STRENGTH FOR VHF (METRIC) AND UHF (DECIMETRIC) BROADCAST SERVICES, INCLUDING TELEVISION

(Question 7/5)

(1959-1963-1966-1978-1986)

1. Description of coverage

For the purpose of frequency assignment, the description of coverage for VHF (metric) and UHF (decimetric) broadcast services (television broadcasting, frequency-modulation broadcasting, etc.), should be in terms of the extent to which service is provided to potential viewers or listeners. The service may be classified in accordance with the quality of the signal at an individual location. For the purpose of assigning stations, it is probably necessary to consider only one quality of service; however, it may be useful for other purposes to define more than one quality.

Several methods have been proposed for describing the service coverage of broadcast stations in the VHF (metric) and UHF (decimetric) bands.

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* This Report is brought to the attention of Study Groups 10 and 11.

An acceptable method for describing broadcast service should meet the following criteria [TASO, 1959]:

1.1 it should show the location and extent of all areas provided with a given quality of service;

1.2 it should take into account significant variations with time;

1.3 the method of specifying service should be sufficiently fine-grained to be capable of showing the amount (area or population) and location of service in distinct areas and directions from the transmitter;

1.4 it should be capable of showing the effect of interference from one or more stations in terms of the amount and location of service lost;

1.5 it should be capable of showing two or more qualities of service;

1.6 it should be possible to predict the service area by means of a reasonable number of measurements and/or calculations of field strength;

1.7 it should lend itself to simple two-dimensional presentation.

After extensive studies of the various methods for describing VHF (metric) and UHF (decimetric) broadcast services, the location probability has been recommended [TASO, 1959; FCC, 1949 and 1950] as the best statistic for describing services. A brief description of the meaning of this statistic is given for the benefit of those not familiar with the term. Under steady-state laboratory conditions, it has been possible to evaluate statistically the useful signal-to-interfering signal ratios which are required to produce pictures or sound of a quality acceptable to different observers in the presence of various types of interference. The ratio accepted by some percentage of the observers, say 50%, is chosen as the acceptance ratio for each type of interference. At any specific location, the useful signal and/or the interference may vary with time, so that the term "time-availability" is used to indicate the percentage of time for which the acceptance ratio is exceeded. A particular quality of service corresponds to a specified acceptance ratio exceeded for a given percentage of time at an agreed standard receiving installation. The location probability is then defined as the probability of receiving this quality of service, or better. Alternatively, the location probability may be defined as the percentage of locations in a small area, for which this quality of service, or better, is expected. To minimize computations, a single value of 90%, 95% or 99% time availability may be adopted as the satisfactory level. This figure might be changed as found desirable, or several levels and standard receiving installations might be adopted to show different qualities of service.

Location probability describes, in a satisfactory manner, the location and amount of the service available from the point of view of the station assignment and allocation planner, the operating authority, and the viewer or listener. It is believed that this statistic is the most meaningful and practical for the description of television and frequency-modulation broadcast service and easily meets all the above criteria. Location probability is preferable to the signal-to-interference ratio of the useful signal level as a service index, because it provides a comparable measure of the quality of service which is independent of frequency, distance, etc. Although the signal-to-interference ratio might be easier to comprehend, it has the disadvantage of requiring different numbers at different frequencies and distances to describe the same quality of service. The useful signal level is an unsatisfactory index, in that it varies with frequency and cannot take into account interference other than receiver noise. However, when the interference is receiver noise, then contours of constant location probability will also be contours of constant field strength. Procedures for the computation of location probability are relatively simple and rapid [FCC, 1949 and 1950; Kirby, 1957].

Two illustrations of the presentation of service by the use of location probability are given in Figs. 1 and 2. The solid curves represent contours of constant service along which the location probability of a given quality of service is constant for a standard installation. Where service is limited by noise, rather than co-channel interference, the location probability, found at a given distance along any radial in Fig. 1, corresponds to some fixed median-time, median-location value of field strength. For example, a location probability of 0.5 in Fig. 1 corresponds to a median field strength of 57 dB relative to 1 μV/m. Fig. 1 shows a great amount of detail, possibly more than could be shown normally with a practical amount of data. However, such detail might be desired for specific sections of a station service area, depending upon the particular problem at hand. Fig. 2 shows what a service map might look like in a more typical case, where the great amount of data for a more detailed map like Fig. 1 is not available.

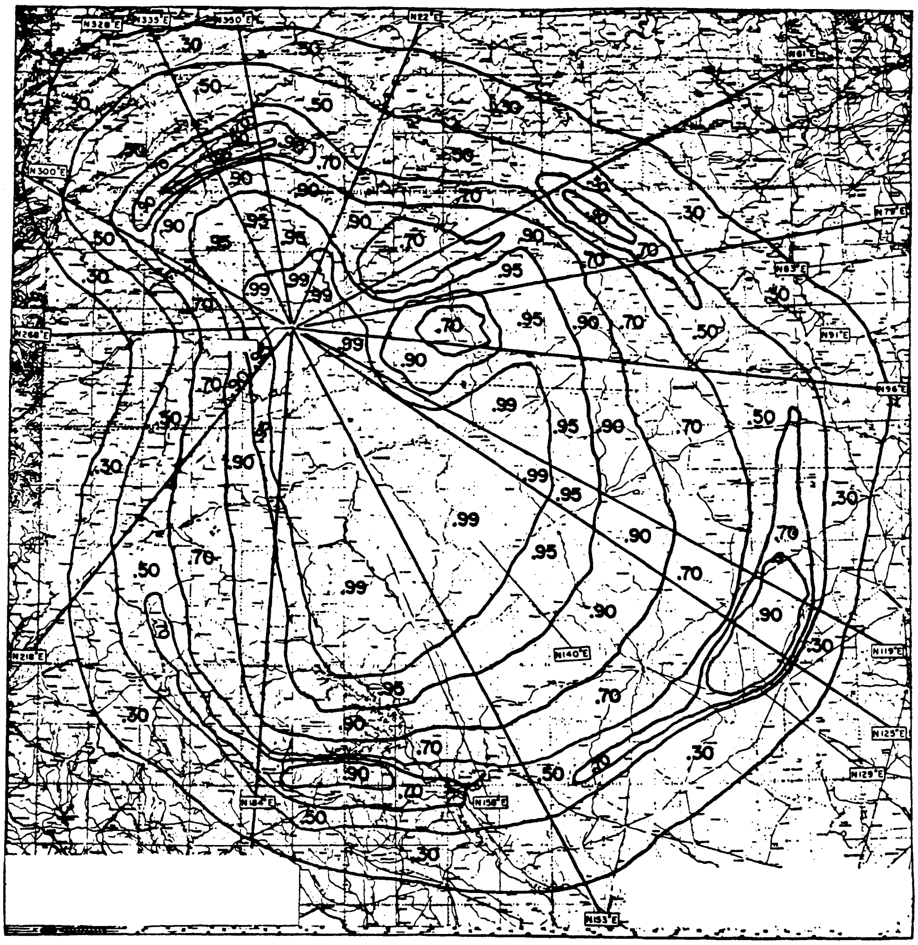

FIGURE 1 – *The concept of service probability*

The numbers indicate the probability of locations receiving an acceptable service for at least 90 % of the time

It is well known, that under practical operating conditions, many people will use an installation just good enough to provide a satisfactory service, but will go to extremes to get the service. Thus, in a strong-signal area many people will use indoor antennas, whereas in weak-signal areas many will employ extremely good installations. Consequently, the number of people receiving a satisfactory signal may well be different than that computed from location probabilities based on a standard receiving installation. However, to provide an objective description of available service, it is desirable to refer always to a fixed quality of service, received on a standard installation. The adoption of a standard receiving installation also makes possible the computation of the combined effects of multiple sources of interference.

Besides meeting all the required criteria, this portrayal of service has several other advantages. The effective service area, or the population served by an individual station, may be computed by adding the products of the location probability, multiplied by the area or the population to which this probability applies [FCC, 1949 and 1950; Kirby, 1957]. However, in the case of non-uniform population distribution, other methods will have to be applied for the assessment of population coverage.

This method of portrayal is also convenient for estimating the interference effects of existing, new, or proposed stations in neighbouring areas. Thus, the overall location probability for service in the presence of a number of interfering services, is approximately the product of the individual location probabilities for service of the useful station in the presence of each source of interference acting alone [FCC, 1949 and 1950]. This approximation is fairly good when the resultant overall location probability is 50% or better and improves as the resultant service increases. More accurate methods for computing the effects of multiple interference are also available [FCC, 1949 and 1950; Norton *et al.*, 1952].

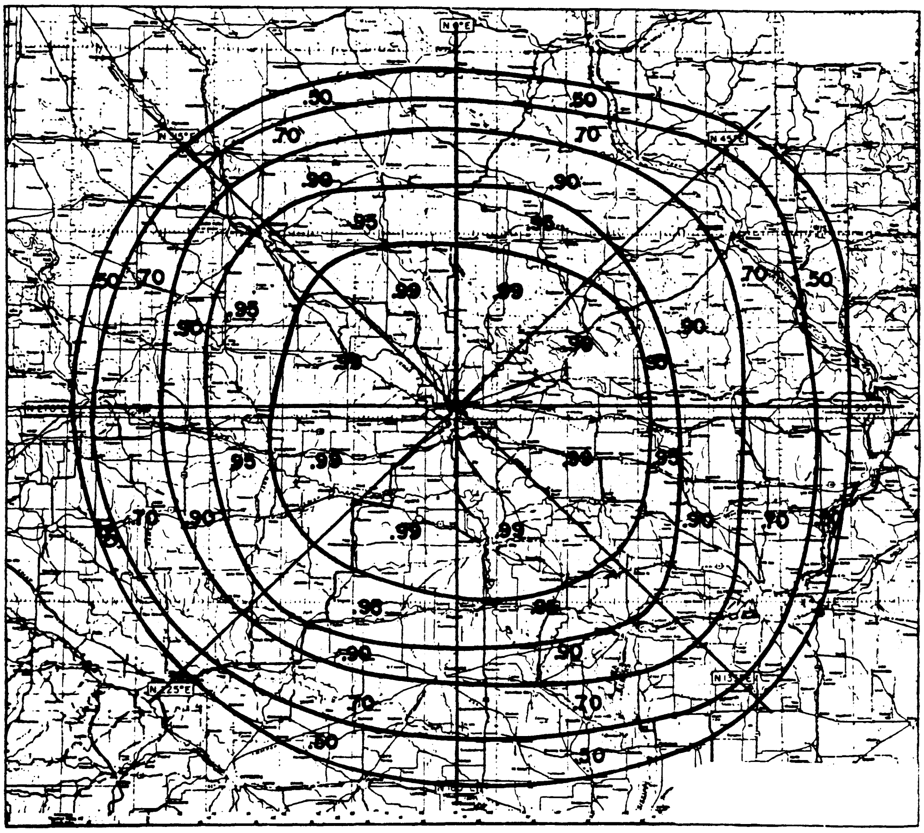

FIGURE 2 – *The concept of service probability*

The numbers indicate the probability of locations receiving an acceptable service for at least 90 % of the time

2. Method of measurement

Field-strength measurements of VHF (metric) and UHF (decimetric) wave broadcasting stations are made to meet the following objectives:

2.1 to provide a basis for assessing the extent of service of any given quality;

2.2 to check the directional pattern and power radiated from a transmitting antenna;

2.3 to provide data with a view to increasing general knowledge concerning propagation conditions in the bands concerned.

In making measurements, the following conditions should be fulfilled:

2.4 measurements should be readily reproducible so that they can be checked subsequently, if required;

2.5 the procedure should provide the required information in an efficient manner;

2.6 the method should not be hazardous nor too expensive.

Various methods of measurement currently in use fulfil the foregoing criteria with varying degrees of success [EBU, 1973].

It is certainly easier to make the measurements, if the wave collector is about 3 or 4 m above the ground, but a height of 10 m is nearer to the height of the receiving antenna of a typical installation. After obtaining results for a height of 3 m in relatively flat and open terrain, they can be suitably corrected for height, but height correction is difficult for very irregular terrain or built-up areas, more particularly at UHF. Therefore, 10 m would seem to be the best height for the measurement antenna and ideally a great many independent sample observations should be obtained at this standard height.

On the other hand, when the height of the transmitting antenna is such that the field strength varies non-linearly with height above the ground for the frequency band concerned, it is desirable to measure the field strength at various heights up to at least 20 m [Gentile, 1966].

In making measurements of the coverage of television transmitters, the normal practice in all bands is to measure the field strength of the sound channel and to apply the appropriate factor, so obtaining the peak field strength of the picture signal which is expected to correlate closely with the quality of reception as a general rule.

However, when using directional receiving antennas, it is sometimes insufficient to measure only the strength of the sound signal to determine the coverage of a transmitter for both vision and sound.

It is desirable that the recorded results of a survey should relate to the field strength available for 50% of the time. Within 20 to 30 km from the transmitting site, the fading range will generally be very small and no great error will have been introduced by making measurements at any time, irrespective of the prevailing refractivity of the lower atmosphere. At the greater ranges at which survey measurements are made, as for a high-power transmitter, fading effects may lead to a serious error. At these greater ranges, it is desirable, while a survey is in progress, to make continuous field-strength recordings at a fixed reference point, which may, however, need to be changed as the survey proceeds. From examination of these records, it can be decided whether any particular survey measurements should be rejected or whether they could be adjusted for normal conditions.

In the course of a coverage survey, most of the measurements are made in towns and large villages, sometimes supplemented by measurements along radials from the transmitter site.

2.7 *Measurements at frequencies below 100 MHz*

Normally, below 100 MHz, a continuous record of field strength is made by a travelling vehicle, usually with a suitable chart recorder geared to the road wheels of the vehicle. Ideally, the method of measuring at the full standard receiving antenna height of 10 m is desirable, but there remains the practical consideration of surveying a large area within a reasonable time. A large number of comparative measurements, made at 10 m and at those heights practicable for mobile recording, confirms that a linear correction is of sufficient accuracy at frequencies below 100 MHz. For mobile measurements of this kind, it is clearly convenient to use an omnidirectional antenna.

As a rule, it is not convenient to make measurements at a height of 10 m over long lengths of road, near overhead wires, trees, etc., but short runs (30 to 150 m), or individual spot measurements can be made at this height. As will be described in more detail below, it is possible to use a systematic procedure of statistical sampling for determining the locations at which these short runs or spot measurements should be made. The degree of accuracy, in estimating the area or population provided with a given quality of service, may also be determined. The short distance runs are made along a short section of road, centred on the measurement point selected and the median value of the field measured on this run is referred to this location. As compared with spot measurements made at the given location, the advantage of the short distance runs is that the median value which it gives is more readily reproducible. Spot measurements are more easily made and may also be used to obtain a distribution of the field strength with respect to time over the period involved.

In the presentation of the results, the exact position of the measuring points is plotted on a map and the median or spot value of the field at those points is shown. The following particulars are noted for each point in a separate report; local topography, height and type of vegetation, housing, obstacles, weather conditions, times of day and any other local features likely to affect the received field (if necessary, photographs from measuring sites can be provided). An indication should also be given of the median, maximum and minimum values of field strength for each short mobile run or measurement group and of the direction from which the maximum signal arrives, if other than the direction of the transmitter.

2.8 *Measurements at frequencies above 100 MHz*

At frequencies above 100 MHz, particularly in bands IV and V, field-strength measurements must be made at the required height of 10 m, since linear height-gain between 3 m and 10 m should not be assumed at UHF.

An estimate is made here of the number of independent single-sample measurements required to achieve the desired degree of accuracy. This accuracy is generally required to be greater when measuring field strength within the critical range 46 to 66 dB and 60 to 80 dB relative to 1 μV/m for VHF and UHF respectively. Towns where the median field strength is outside these ranges, can be considered to be either inadequately served or to have good coverage, so that in these cases small errors in measurement of field strength are less important. Figure 3 shows the number of independent sample measurements required to give 95% probability that the probable error ε in a median value will be less than 2 dB or 4 dB. In practice, the acceptable sampling error ε should not be greater than 2 dB in the critical zone, but may be increased to 4 dB where accuracy is less important. The relationship between the necessary number of samples and the "variation factor", *V*, defined as the ratio (in decibels) of the field strengths exceeded at 50% and 90% of the locations within the town or other compact area under consideration, is given in Fig. 3; which is derived from the assumption that the distribution of field strength is log-normal.

The value of the variation factor, *V*, usually lies within the range 5-10 dB at VHF or 5-15 dB at UHF although in a few cases it may reach 20 dB. Figure 4 shows the distribution of *V* for a number of towns in the United Kingdom at both VHF and UHF. Generally, the median value of *V* taken for Fig. 4 is used for the determination of the required number of independent samples, but if during a survey, it becomes apparent that *V* differs appreciably from the median of those values shown in Fig. 4, the number of samples taken is increased. In general, the number of samples should be between 10 and 100, if the above limits are to be maintained.

Another method of deciding the number of sample measurements required, which may have advantages over the method described above, particularly at UHF, is to measure initially the overall range of scatter *R* of the field strength at a few topographically high and low points. It can be assumed that the range *R* is equal to 6 σ, where σ is the standard deviation. For a log-normal distribution, $V = 0.214R$.

To assess the extent of service, the measurement procedure may be considered a sampling process in which the cumulative distribution of the sample represents an estimate of the variations within a given area of the actual fields. The choice of sampling locations should be free of bias and should as nearly as possible represent typical operating installations. An important factor affecting the choice of sampling location is the tendency for successive measurements made adjacent to each other to be correlated among themselves, that is they are serially correlated. Independent measurements made with sufficient separation to eliminate serial correlation provide an efficient estimate of the variation of the fields. Studies indicate that significant serial correlation between successive measurements will be present at separations normal to the path of propagation up to one or two kilometres [Kirby, 1957; Kirby and Capps, 1956; Kirby *et al.*, 1956]. Serial correlation will be present in radial measurements at even greater separation.

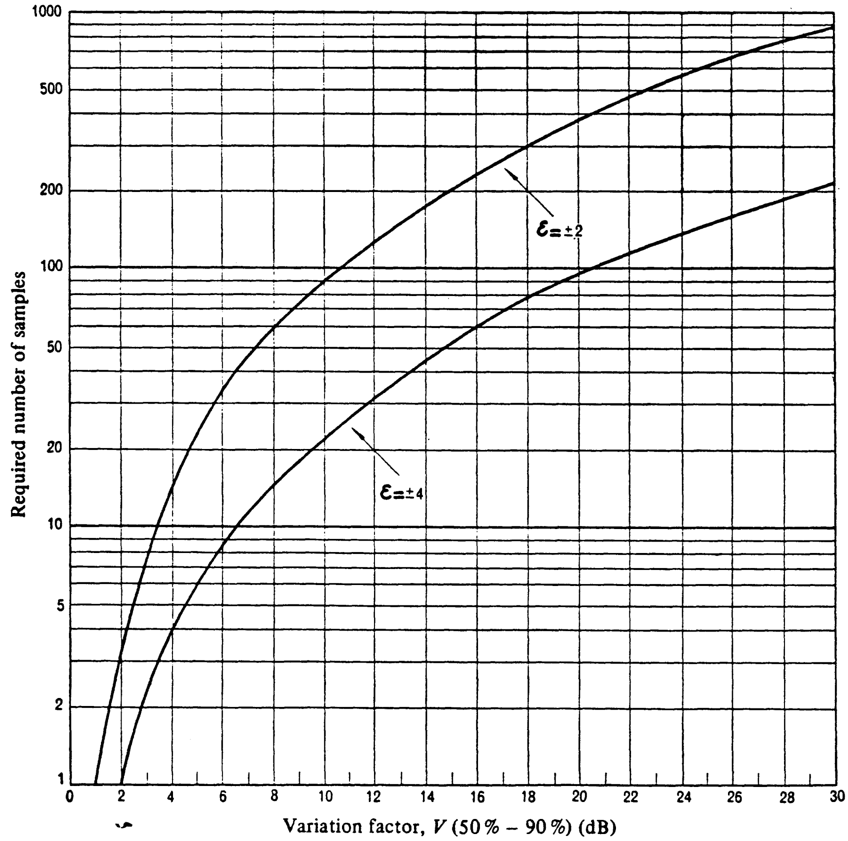

FIGURE 3 – *Number of sample measurements required to give 95% probability that the error, ε, in the median value will be less than 2 dB or 4 dB*

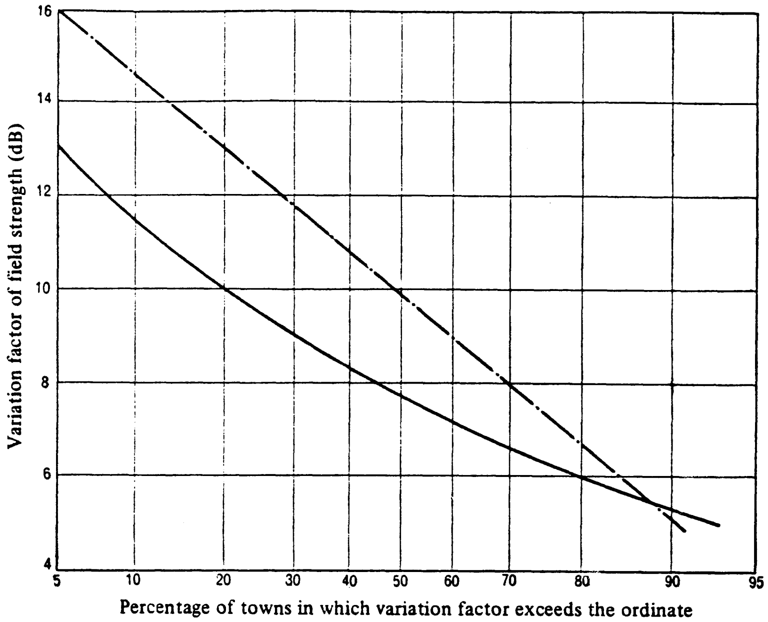

FIGURE 4 – *Distribution of values of variation factor for towns in the United Kingdom*

All measurements made with the receiving antenna 10 m (30 ft) above ground level

—·—·— Band V measurements in 121 towns

——— Band III measurements in 40 towns

2.9 *Selection of sites for measurements*

As far as practicable, the urban measuring locations are usually selected at random by reference to a town map, the density of measurements nevertheless being varied according to the population distribution. At each measuring location, a single sample value of field strength may be obtained or, alternatively, a cluster of some four or five measurements may be made at points separated by only a few metres, and the estimated mean of these four or five values recorded as the "sample location" measurement. It is often found that there is substantial correlation between field-strength measurements separated by only a few metres, particularly if a multi-element antenna is employed, but much greater variations between those widely separated, e.g., over different areas of a town. The "single sample" method is often preferred, because of the additional time that may be taken in making "cluster" measurements (due to the frequent raising or lowering of the receiving antenna), or because of the hazard in moving the measuring vehicle while the antenna is fully erected. However, the mean of a cluster is more readily reproduced than a single sample observation, and it can be shown that a given accuracy in assessing the overall variation factor in the area under consideration can be achieved by some 10% to 15% fewer "cluster" measurements than "single sample" measurements.

All the sample measurements are made using a receiving antenna mounted at the standard height of 10 m. At UHF and at VHF in hilly terrain, typical directional antennas should be used to discriminate against echo signals from surrounding hills and buildings.

For each urban area under consideration, a graph is constructed of the location distribution of field strength from which may be found the percentage of locations at which any given field strength is exceeded.

To arrive at an estimate of the cumulative distribution of field strength in an incremental area within the service area of the transmitter, a sample set of measurements should be obtained in such a way that the propagation characteristics are similar throughout the area of measurement. For example, systematic effects such as large variations of field with distance, should be avoided. One way in which this can be accomplished is to confine each set of sample measurements to an annular area, or segment thereof, centred on the transmitter.

The measurement locations should be laid out on circles or circular arcs centred on the transmitter. The choice of radii for the circles will depend largely upon the location probabilities expected. Therefore, it is extremely helpful to make estimates in advance of the dependence upon distance of the location probabilities for the particular case in question. Figure 5 shows a hypothetical example of this dependence, based on a relationship between field strength and distance for a television station operating in the 54 MHz to 88 MHz frequency band and assuming a log-normal distribution with a standard deviation of 6 dB to represent the dispersion of field-strength values in the incremental areas. Studies of irregular-terrain propagation at these frequencies [FCC, 1949 and 1950; Kirby, 1957; Kirby and Capps, 1956; Kirby *et al.*, 1956; Kühn, 1958], indicate that the logarithm of the field strength has an approximately normal distribution. In this example, the location probabilities indicate the percentage of the areas at the distances shown, that would be expected to have a field strength in excess of 57 dB relative to 1 μV/m. Fig. 6 illustrates a possible distribution of locations for the measurements. It should be noted that, in this example, the greatest concentration of points is proposed at the distance for which the location probability is 0.5, to provide, in the most efficient manner, information about the total area served. The separations between adjacent measurements should be adequate to eliminate, or at least to minimize, the effects of serial correlation.

2.10 *Presentation of results*

When the proposed measurement locations, determined in a manner similar to Fig. 6, are transposed to an actual map, it will be found that many of them lie in inaccessible areas. In such cases, the measurement will probably be made at a nearby location which is accessible. The important point to consider in choosing alternative locations is to avoid introducing bias, such as might be the case, for example, if these alternative locations were unduly concentrated along highways.

It would be a relatively simple matter to include other observations along with the basic field-strength measurements. At a selected number of the locations, variations with time could be recorded over a reasonably long period of time. Also the effect of antenna height, antenna directivity, picture or sound quality etc., could be observed. Additional measurements could be made in areas of special interest.

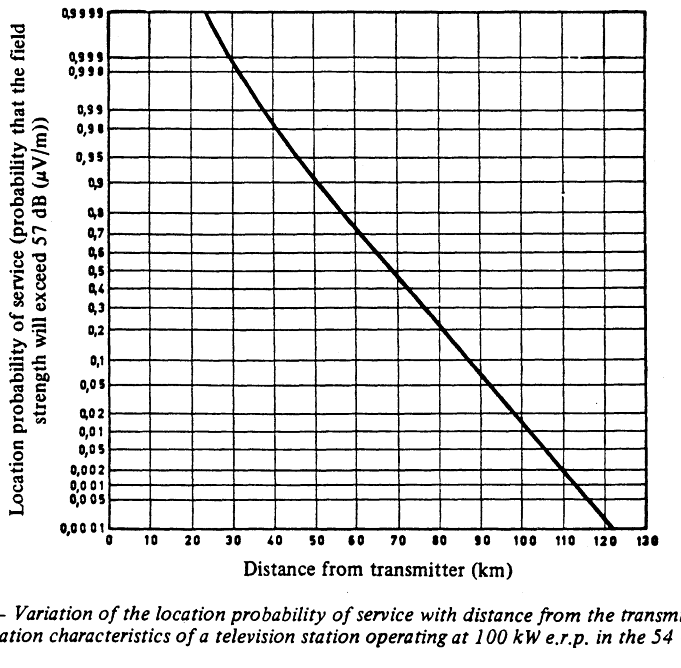

FIGURE 5 – *Variation of the location probability of service with distance from the transmitter. Based on typical propagation characteristics of a television station operating at 100 kW e.r.p. in the 54 – 88 MHz band*

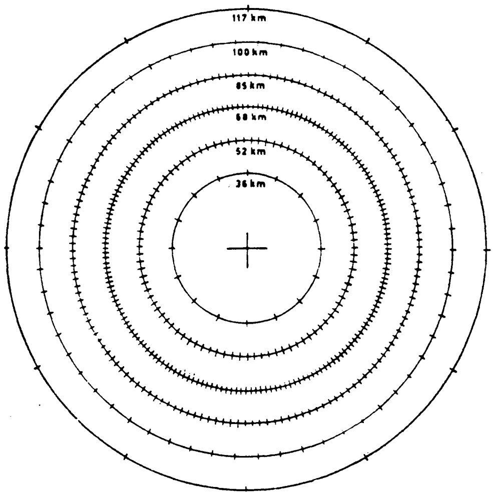

FIGURE 6 – *Possible arrangement of measurement sites for a 100 kW station over average terrain*

(The transmitter is located at the centre of the diagram)

In addition to the method of coverage presentation given in this Report, it is usual to present a field-strength map showing the position of the median contours. The amount of detail that needs to be shown depends upon the degree of irregularity of the terrain and is greater at UHF than at VHF. The supplementary information required with such a map is a table, showing the median field strength and variation factor for 50% to 90% of the locations for each of the more important centres of population.

It may also be useful to present a map similar to Fig. 1, but showing only two or three major demarcations of service zone; for example, the area within which, in any locality, more than 70% or 95% of viewers can obtain a satisfactory service.

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