REPORT 485-1

CONTRIBUTION TO THE PLANNING OF BROADCASTING SERVICES

(Question 4/11, Study Programme 4B/11)

(1970–1982)

PART I

STATISTICS OF SERVICE

1. The protection ratio is frequently used in the planning and assignment of broadcast stations and service, both visual and aural. It is usually defined as the minimum permissible power ratio of the wanted-to-interfering signals available at the receiver input, to provide the desired quality grade of service. Because the field strengths which induce the receiver input signals vary with time and from location to location it is necessary to include some of the statistics of this variability in the description of service and for the protection of this service.

The television or frequency-modulation broadcasting service to a relatively small area in the presence of a single source of interference may be described by an algebraic-statistical equation (1). A small area is one for which changes in the type of terrain and in the distance from the pertinent transmitting antennas are negligible in terms of determining the median values of field strength.

$$R(Q) = E_d(50,50) - E_u(50,50) + G_d - G_u - H(T) - H(L) \qquad (1)$$

where

$$H(T) = k(T) \sqrt{\sigma_{td}^2 + \sigma_{tu}^2}$$

$$H(L) = k(L) \sqrt{\sigma_{ld}^2 + \sigma_{lu}^2}$$

$R(Q)$: protection ratio (dB) of the wanted to the interfering signal at the receiver input required to provide a service quality Q under non-varying conditions. Subscripts d and u refer to the wanted and unwanted signals, respectively;

$E(L', T')$: the level of field strength exceeded for T'% of the time in at least L'% of the locations (dB rel. 1 μV/m);

$E(50,50)$: median field strength in time and location (dB rel. 1 μV/m);

G : effective receiving antenna gain in the pertinent direction (dB);

$k(X)$: standard normal variate, tabulated in many statistical textbooks:

$k(50) = 0$; $k(70) = -0.525$; $k(90) = -1.282$; $k(99) = -2.326$;

σ_t : standard deviation for variation in field strength with time (dB);

σ_l : standard deviation for variation in field strength from location to location (dB).

For the purpose of describing service, equation (1) may be interpreted as follows. If service of quality grade Q is defined to be available at a given location only when the protection ratio at the receiver input exceeds the required value $R(Q)$, i.e. the non-varying protection ratio is exceeded for T% of the time, then in the area for which equation (1) holds, at least L% of the locations will have this quality of service, $Q \cdot H(T)$ and $H(L)$ are the factors which represent the effects upon the service to the area of the signal variability in time and with location, respectively.

In equation (1) the following assumptions have been made:

– the various fields have approximately Gaussian distributions both in time and with location. Experience [USA] indicates that this is a fair approximation between the 5% and 95% levels;

- both the time correlation and location correlation between the desired and interfering signals are negligible. Terms including these correlation terms may be added to the radicals of $H(T)$ and $H(L)$, if desired;
- the variability in antenna gain throughout the small area is assumed to be negligible. Terms for the variability in antenna gain may be added to the radical of $H(L)$ but such terms should be minor for outdoor installations compared with the location variability of the field strength.

It is noted from equation (1) that there are three interdependent parameters needed to describe the service to the area – i.e. Q, L, T. For convenience, Q and T are usually standardized and with these standard values of T and Q a value of L may be computed from (1). For example, Q may be chosen as "satisfactory" service and T as 90% or 99%. When several sources, i, of interference, including noise, are present at the area, the L_i for each source of interference acting independently and alone may be computed from equation (1), and the resultant L may be computed as the product of the values of L_i so long as the values of Q and T are the same for the individual computations of L_i [USA].

$$L = \prod_{i=1}^{i=n} L_i = L_1 L_2 \ldots . L_n \tag{2}$$

The above resultant value of L is a reasonably good approximation for values of L equal to 50% or greater.

Equation (1) may be rearranged to give:

$$R(Q) + H(T) + H(L) = Ed(50,50) - E_u(50,50) + G_d - G_u \tag{3}$$

The right-hand side of equation (3) is recognized as being equal to the ratio of the median value of the wanted-to-interfering signal powers at the receiver input. When the signals are of the non-varying type, $H(T)$ and $H(L)$ are zero and the ratio of the median values of the receiver input powers is equal to the ratio $R(Q)$. But, when there is time and location variability (and T or L exceeds 50%) a greater ratio of median receiver input powers is required for the same quality of service Q, the increase being represented by $H(T)$ and $H(L)$ for time and location variability in signal strength, respectively. In effect, a statistical, multi-dimensional protection ratio may be created to represent the left-hand side of equation (3).

For allocation and assignment computations $R(Q)$ may be combined with $H(L)$ and sometimes $H(T)$ to create a new multi-dimensional power input statistical ratio which is more easily used with available propagation data. These ratios have often been confused with the non-varying protection ratios. When possible $H(T)$ should be combined with the median values of field strength to avoid the creation of a statistical protection ratio which varies with distance.

For protection of service areas iso-service contours of equal location probability L(Q and T being preset) are drawn to depict the coverage of the broadcasting station and these iso-service contours are protected. Standard values for L need to be adopted by the CCIR in addition to presently recognized standards for T and Q, to set protection standards for iso-service contours under conditions of signals variable in time and with location.

2. Co-channel television interference

For this type of protection, $H(L)$ is combined with $R(Q)$, and $H(T)$ is merged with $E_u(50,50)$. Thus, under the assumption that the time fading ranges of the interfering fields are at least twice as great as those for the wanted fields:

$$R(L, Q) = R(Q) + H(L) \approx E_d(50,50) - E_u(50,100 - T) + G_d - G_u \tag{4}$$

$$E_u(50,50) + H(T) \approx E_u(50,100 - T)$$

$R(L, Q)$ is convenient for use in computations to protect the service of the wanted station, especially since it is not dependent upon distance. However, $R(L, Q)$ may be frequency dependent, since $H(L)$ is frequency dependent, as shown in Table I. This Table is given as an example only and for various types of terrain, the values of σ may be higher or lower than those given.

3. Adjacent-channel interference

When the fading of the interfering signal is much smaller than that for the wanted signal, $H(T)$ may be combined with $E_d(50,50)$. Such would be the case for adjacent-channel interference in System M, if the value of $R(Q) = -20$ dB, as proposed in [CCIR, 1966-69] is adopted. For such conditions:

$$R(L, Q) = R(Q) + H(L) \approx E_d(50,T) - E_u(50,50) + G_d - G_u \quad (5)$$

$$E_d(50,50) - H(T) \approx E_d(50,T)$$

When the time fading of the wanted and interfering signals are approximately the same, $H(T)$ cannot be conveniently combined with one of the median field strength signals. $H(T)$ is then assumed to have a typical value which is independent of distance, and is combined with $R(Q)$ and $H(L)$.

$$R(L, T, Q) = R(Q + H(L) + H(T) \approx E_d(50,50) - E_u(50,50) + G_d - G_u \quad (6)$$

4. Conclusion

It is concluded that defining only the non-varying protection ratio for the broadcast services is not sufficient to define the quality of a service nor to define protection requirements for such service. It is also necessary to define the percentage of time T for which this ratio is to be exceeded as well as the percentage of locations L for which the desired quality of service Q is desired. Given this more completely specified statistical quality of service, available propagation and antenna pattern data may be employed to determine the ratio of wanted to interfering field strengths which may be needed to provide the required protection. From these field strengths the required service contours and station separation may be compiled.

TABLE I – *Examples of values for H(L)*

Frequency (MHz)		70	100	200	700
$\sigma_{ld} = \sigma_{lu} = \sigma_l$	(dB)	7	7	8	12
$H(50)$	(dB)	0	0	0	0
$H(70)$	(dB)	– 5	– 5	– 6	– 9
$H(90)$	(dB)	–12	–12	–15	–22
$H(99)$	(dB)	–23	–23	–26	–39

REFERENCES

UNITED STATES OF AMERICA Report of the *ad hoc* Committee for the evaluation of the radio propagation factors concerning the TV and FM broadcasting services in the frequency range between 50 and 250 Mc. Vols. I and II – Available from Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, US Department of Commerce, Vol. I PB 166696, Vol. II PB 166697.

CCIR Documents

[1966-69]: XI/35 (USA).

BIBLIOGRAPHY

CCIR Documents

[1966-69]: XI/143 (USA).

PART II

DEFINING QUALITY OF SERVICE FOR TELEVISION BROADCASTING

1. Introduction

Part I indicates that three inter-dependent parameters, i.e. quality grade, location and time, are required to describe service to an area. Standardization on these parameters is essential in planning for the protection of a television service and an approach towards this objective is outlined in the following sections.

2. Grading system

Before agreement can be reached on which grade of service should become standard, it is essential to agree on the classification system to be used. The 5-point scale system used in Recommendation 500 appears satisfactory for this purpose. It would, however, be useful to have the grade identified in terms of the median as required in the calculation methods suggested in Part I, § 1. While Annex II to Report 405 indicates methods for assessing the impact of additional interfering signals on quality grade, these approaches do not take the location parameters into account.

3. Percentage of time

Recommendations 417 and 418 indicate that the broadcasting service should be protected for a period of time between 90% and 99%. If the period of time selected is 90% it means that the desired quality of service will not be met 10% of the time. Moreover, since the minimum quality of service during that 10% of the time is not specified it could be of unusable quality and still meet the indicated objective for broadcasting. The quality of service during the worst 1% to 10% of the time is a factor which, under certain conditions, must be taken into account.

In the case of interference from other television broadcasting stations it is not really essential to specify the quality of service during the worst 1% to 10% of the time because of the nature of propagation variation, i.e. if good quality is available 90% of the time, the quality would not be unusable in the remaining 10% of the time but rather it would deteriorate gradually for smaller time intervals. If, however, the interference source is intermittent (e.g. from a land mobile system) and the percentage of "on" time is factored into the protection criteria for broadcasting, it is evident that the normal 90% to 99% protection times may have to be increased in order to avoid the possibility of unusable signals 10% to 1% of the time. Moreover, in some cases the "on" time interval is difficult to establish or control especially if multiple interference sources are permitted. It is therefore suggested that such interference sources may have to be considered as transmitting continuously when assessing their impact on television.

4. Standardization of Q and T

Equation (3) in Part I describes the relationship between the "service quality" grade Q, percentage of locations L, and percentage of time T. In terms of Recommendation 500, Q must be interpreted as the *impairment* grade due to interference and/or noise.

It is evident that it is possible to describe the same service in terms of all three parameters Q, T, L in an infinite number of ways. If, however, two of the parameters are fixed, the third variable may be used to complete the description of service. Thus if appropriate values for Q and T are fixed, the service can be described in terms of the corresponding L.

Since Q and T may take on a range of values it is suggested that boundaries on these values be determined. Recommendation 417 implies that at least a satisfactory grade of service is required in the absence of interference before protection may be sought. It is recommended therefore that Grade 3.5 be used as the lower boundary. Within the prime coverage area of a television transmitter however, a performance somewhat better than Grade 3.5 is generally expected at most locations. Since Grade 5, for various reasons, is often unachievable in practice, it seems inappropriate to standardize on it. On the other hand, Grade 4.5 with its minor imperfections, is usually achievable with adequate signal strengths and it is therefore recommended that Grade 4.5 be used as the upper boundary in terms of picture impairment for standardization purposes.

Recommendation 417 indicates that the percentage of time for which protection may be sought should lie between 90% and 99%. It is therefore recommended that 90% and 99% of the time be used as the lower and upper boundaries of time for standardizing on quality of service in the absence of interfering signals.

It is suggested that if the two lower boundaries (i.e. Grade 3.5, 90% of the time) are applied to the extremity of the coverage area and the two upper boundaries (i.e. Grade 4.5, 99% of the time) are applied to the prime coverage area, it will agree with the general expectations of planners for television service.

5. Percentage of locations

While this parameter is an essential factor in describing the quality of broadcast service no attempt has been made at standardization. Several approaches to standardization are possible and a relative rather than an absolute standard is proposed herein. The reference impairment proposed in this case is that ensuing from thermal noise as the only source of impairment. The objective of this approach is to ensure that a significant percentage of viewers are unaffected by the introduction of interfering sources.

With respect to standardizing on the percentage of locations which should receive the standardized values of Q and T, two options exist. It is possible to specify the percentage of locations directly and, by making estimates regarding typical receiving installations, determine the corresponding median field strength. Alternatively, it is possible to specify a median field strength and, by making estimates regarding typical receiving installations, determine the corresponding percentage of locations. Of these two, the second option is preferred, firstly because a field strength level is more readily confirmed than a percentage of locations, secondly because the percentage of locations does not have to be determined with accuracy for the purpose of calculating protection from interfering sources, and thirdly because a definite field strength for the desired signal is the most useful parameter for the purpose of calculating protection ratios. The relationship between field strength, quality of service and assumptions is described elsewhere [O'Connor, 1968]. In the absence of interference the field strengths close to those given in Recommendation 417 can provide Grade 3.5 service 90% of the time at approximately 60% of the locations (5-point scale). Field strengths some 17 dB greater can provide Grade 4.5 service 99% of the time at approximately 75% of the locations [CCIR 1978-82].

6. Suggested standard

It is therefore suggested that agreement be reached to adopt impairment Grade 3.5 for 90% of the time at the extremity of the protected area and Grade 4.5 for 99% of the time at locations where median field strengths are at least 17 dB greater than at the extremity. If agreement can be reached on these or similar criteria, a simple method of assessing the impact of interfering sources on reception quality becomes available.

7. Interfering sources

Part I shows that, where an interfering source is present and is expressed in terms of the same Q and T of the desired signal, the resulting L (provided L is greater than 50%) may be estimated as the product of L_d and L_i, where L_d is the percentage of locations receiving the desired quality in the absence of interfering signals, and L_i is the percentage of locations which would receive the desired quality if the interfering signal were the only additional source of degradation. L_i is therefore proportional to the number of locations which would continue to receive the stated Q and T after the introduction of the interfering signal. Thus once agreement has been reached on standardized values of Q and T, the impact of an interfering source can be estimated simply by requiring the interfering source to be expressed in terms of the same Q and T and then specifiying the value of L_i. For example, L_i would have to have a value of 90% if it is desired to ensure that service in a coverage area is not degraded at more than 10% of the locations receiving the desired quality in the absence of interference.

The value of L_i which is acceptable may vary depending on the nature of the interference, the location within the coverage area for which protection is sought, and the protective measures which might be taken.

REFERENCES

O'CONNOR, R. A. [December, 1968] Understanding television's Grade A and Grade B service contours. *IEEE Trans. Broadcasting*, Vol. BC-14, 4, 137-143.

CCIR Documents

[1978-82]: 11/103 (Canada).