RECOMMENDATION ITU-R BS.639*,**

Necessary bandwidth of emission in LF, MF and HF broadcasting

(1986)

The ITU Radiocommunication Assembly,

considering

a) that in amplitude modulated double-sideband (AM-DSB) sound broadcasting, the bandwidth of emission is twice the audio-frequency (AF) bandwidth;

b) that for quality reasons, the AF bandwidth should be as high as possible;

c) that adjacent-channel interference is determined by, among other factors, the bandwidth of the modulating signal, and that some sound processing of the audio programme may significantly increase the higher frequency audio components;

d) that the bandwidth of the complete AM-DSB transmission system (system bandwidth) is determined by the combined effect of the bandwidth of emission and the receiver bandwidth;

e) that in most practical cases the bandwidth of emission considerably exceeds the receiver bandwidth, although receivers with wider or double bandwidths are becoming more prevalent in some parts of the world;

f) that, among other factors, efficiency of spectrum utilization is affected by the carrier spacing and also by the necessary bandwidth of emission;

g) that adjacent-channel interference decreases in areas relatively close to the wanted transmitter, where, for a transmitter of medium to low power, a larger concentration of audience can usually be presumed;

h) that where adjacent-channel interference is minimized by appropriate geographical spacing of stations, some advantage can be taken of bandwidths of emission significantly greater than the channel spacing, thus increasing system bandwidth, particularly where receivers of wider bandwidth are employed,

recommends

that where required, either for optimizing spectrum utilization or for providing an improved overall system AF response, the overall system can be optimized and planning problems can be reduced by taking advantage of the existing knowledge of the interrelation between system bandwidth, channel spacing and adjacent-channel protection ratio, as given in Annex 1.

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* This Recommendation should be brought to the attention of Radiocommunication Study Group 1.

** Radiocommunication Study Group 6 made editorial amendments to this Recommendation in 2002 in accordance with Resolution ITU-R 44.

ANNEX 1

Necessary bandwidth of emission in LF, MF, and HF sound broadcasting

1 Introduction

In an amplitude-modulation double-sideband sound broadcasting system the bandwidth of emission is approximately twice the audio-frequency bandwidth of the programme and, therefore, greatly influences the quality of reception. On the other hand, for a given frequency separation between adjacent channels, a limitation of the bandwidth of emission is desirable to avoid mutual interference.

The difference between the transmitted bandwidth for amplitude-modulation sound broadcasting and the receiver bandwidth has led to research aimed at improving the whole transmission system. It appears that it would be useful to fix values for the audio-frequency bandwidth of the programme to be radiated as well as for the overall response of the receivers and to obtain these values by the use of band-limiting filters. If both these bandwidths are nearly equal and are suitably related to the channel spacing the transmission system provides for the full utilization of the transmitted bandwidth as well as for the most favourable protection against adjacent channel interference.

2 Necessary bandwidth of emission

2.1 Bands 5 (LF) and 6 (MF)

Obviously, the bandwidth of emission, as well as the passband of the receivers, should be chosen in such a way that there is no unnecessary impairment of reception quality or any increase in adjacent-channel interference. In areas where adjacent-channel interference is expected not to be negligible, the use of equal values for channel spacing, bandwidth of emission and receiver passband would be a good solution. In areas where less adjacent-channel interference is to be expected, different values may be suitable, e.g., the bandwidth of emission and the receiver passband may be equal and considerably exceed the channel spacing. This is especially true if the same transmitter network is operated during day and night. In such circumstances receivers, equipped with filters of switchable bandwidths, may be used successfully to improve the reception quality under different propagation conditions.

2.2 Band 7 (HF)

In short-wave broadcasting, the necessary bandwidth of emission for AM-DSB should in no case exceed the value of 9 kHz. Recommendation ITU-R BS.640 specifies a maximum of 4.5 kHz necessary bandwidth for AM-SSB broadcasting.

3 General considerations

3.1 There exists a well-known interrelation between system bandwidth, carrier spacing and adjacent-channel radio-frequency protection ratio.

3.2 The theoretically obtainable optimum value of protection against adjacent channel interference can be assessed by using an ideal receiver with rectangular passband characteristics. In this case the radio-frequency protection ratio is mainly determined by non-linear distortion in the transmitter.

3.3 A theoretical study of the energy spectrum including out-of-band radiation caused by transmitter non-linearities has been performed. Experimental investigations of the energy spectrum of a high-power transmitter operating in band 6 (MF) show that the term occupied bandwidth as defined in Article 1, No. 1.153 of the Radio Regulations does not give an adequate indication of the effects of bandwidth limitation on adjacent channel interference.

4 Relationship between AF bandwidth, RF protection ratio and channel spacing

4.1 Measurement results

Measurements of the radio-frequency protection ratios for the case of various values of audio-frequency bandwidths, which are equal at both transmitter and receiver, and at different channel spacings have been carried out in the Federal Republic of Germany using the objective two-signal measuring method given in Recommendations ITU-R BS.559 and ITU-R BS.560. For the measurements a high quality commercial receiver with an almost ideal passband characteristic was used. The interrelation between the parameters involved is shown in Fig. 1. For a given channel spacing there are many pairs of values of audio-frequency bandwidths and adjacent channel protection ratios. If, however, two of the parameters have been chosen, the third is definitely fixed.

4.2 Computation results

The relationship between system bandwidth, adjacent channel protection ratio and channel spacing can be determined by means of the numerical method (Recommendation ITU-R BS.559).

Studies carried out were based on the assumption that both the carrier spacing and the adjacent channel protection ratio are predetermined values. Using Recommendation ITU-R BS.560, a relative value of the radio-frequency protection ratio of –26 dB corresponding to a channel spacing of 9 kHz has been assumed. Thereby due account has been taken of the characteristics of current types of receivers.

Any amplitude-modulation sound-broadcasting system has, in principle, the same effect on the reception quality as a low-pass filter. Amplitude-modulation systems designed in conformity with the channel spacing and protection ratio requirements mentioned above may, therefore, differ to some extent in bandwidth and rate of cut-off of the overall amplitude/frequency response. The investigations carried out were, therefore, extended to cover this aspect of the problem of the quality of reception.

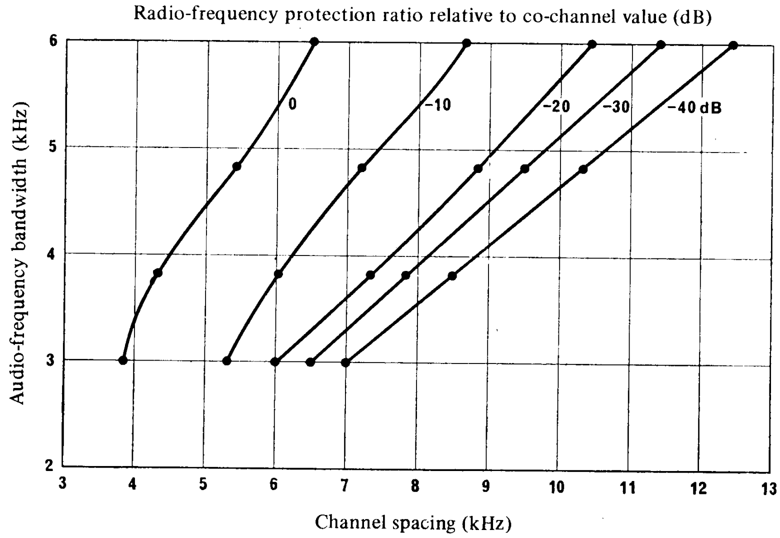

FIGURE 1 – *Use of the frequency spectrum*

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It was assumed that the influence on the overall amplitude/frequency response of the entire system was equally distributed between the transmitting and receiving ends. This approach should, however, be considered as a first attempt only and additional studies will have to be carried out for different conditions. As a result of the calculations made it was found that any one of the three overall amplitude/frequency response curves shown in Fig. 3 would provide satisfactory adjacent-channel protection in an 9 kHz channelling system. The curves of Fig. 2 present pairs of values for the bandwidth, b, and rate of cut-off, a_0, required at either end of the AM sound-broadcasting system. The solid curve is only valid if use is being made of a notch filter in the receiver to eliminate the beat-note between adjacent channel carriers, whereas the broken line applies to the case where there is no notch filter. The particular points in Fig. 2 numbered ①, ② or ③ correspond to terminal equipment characteristics that would provide the overall amplitude/frequency response curves, A, B or C, respectively, in Fig. 3.

The results obtained are in close agreement with Fig. 1 which should be considered to provide limiting values, since it applies to the ideal case of rectangular passband characteristics. The system bandwidth thus decreases rapidly with decreasing rate of cut-off.

4.3 Listening tests

The influence of reproduction quality of an amplitude-modulation sound-broadcasting system with 9 kHz channel spacing and a relative protection-ratio value of –26 dB for adjacent channel interference can be simulated by using three specified low-pass filters. The passband characteristics of these filters are those of curves A, B and C in Fig. 3.

Subjective listening tests then show quite clearly that a better subjective quality impression can be obtained with frequency response curves A and B than with curve C. However, the difference in quality obtained with curves A and B is very small, a fact which may be of considerable economic interest, since the rate of cut-off of the receiver is 40 dB/octave less with curve B than with curve A.

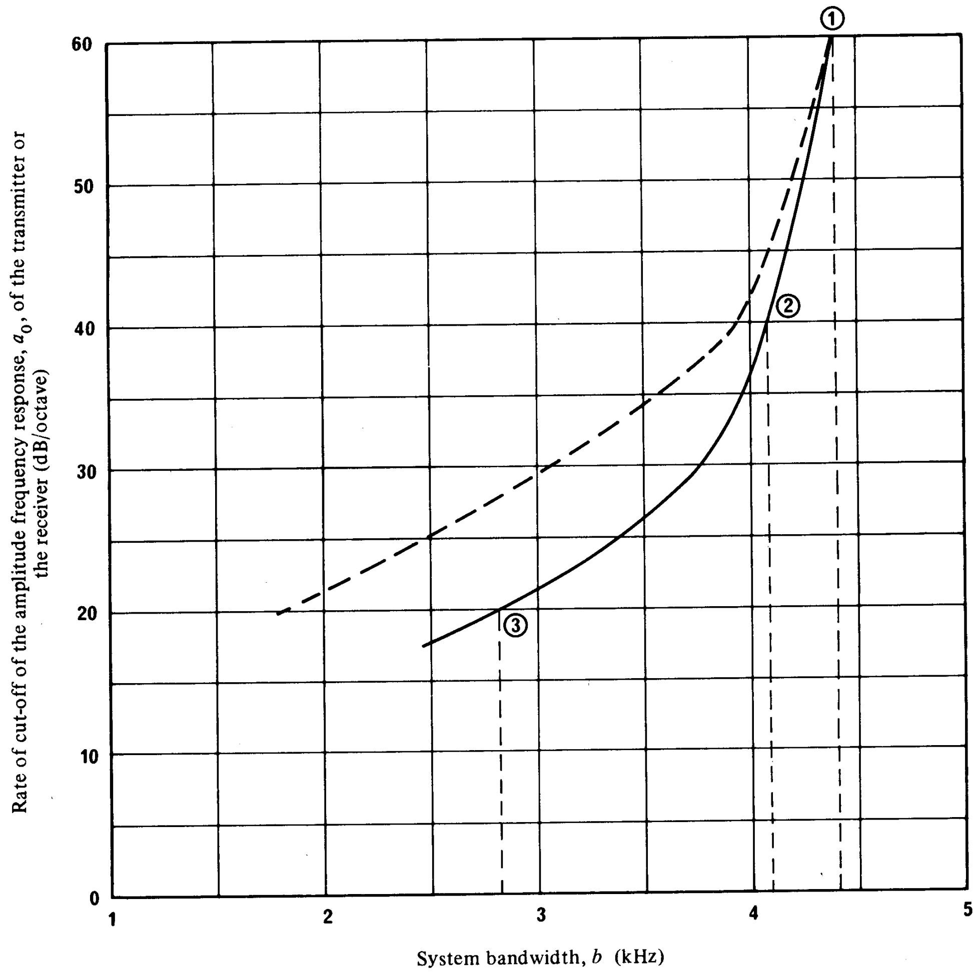

FIGURE 2 – *Characteristics of an amplitude-modulation sound-broadcasting system for optimum quality of reproduction*

Basic assumptions:
Channel spacing: 9 kHz
Relative adjacent-channel protection ratio: – 26 dB

————— : characteristics including the effect of a notch filter for elimination of the carrier beat
— — — — : characteristics without notch filter

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5 Radio-frequency and intermediate-frequency passband characteristics of current types of receiver

Radio-frequency and intermediate-frequency passband values between the 6 dB points are quoted ranging between 5 and 10 kHz. It should be noted that the reproduced audio-frequency bands are about half these values. The highest values mentioned are those of “first category” receivers in the USSR with variable selectivity.

It is known that there are many receivers with even smaller passbands. It has, however, been indicated that in some areas there exist receivers with larger passbands.

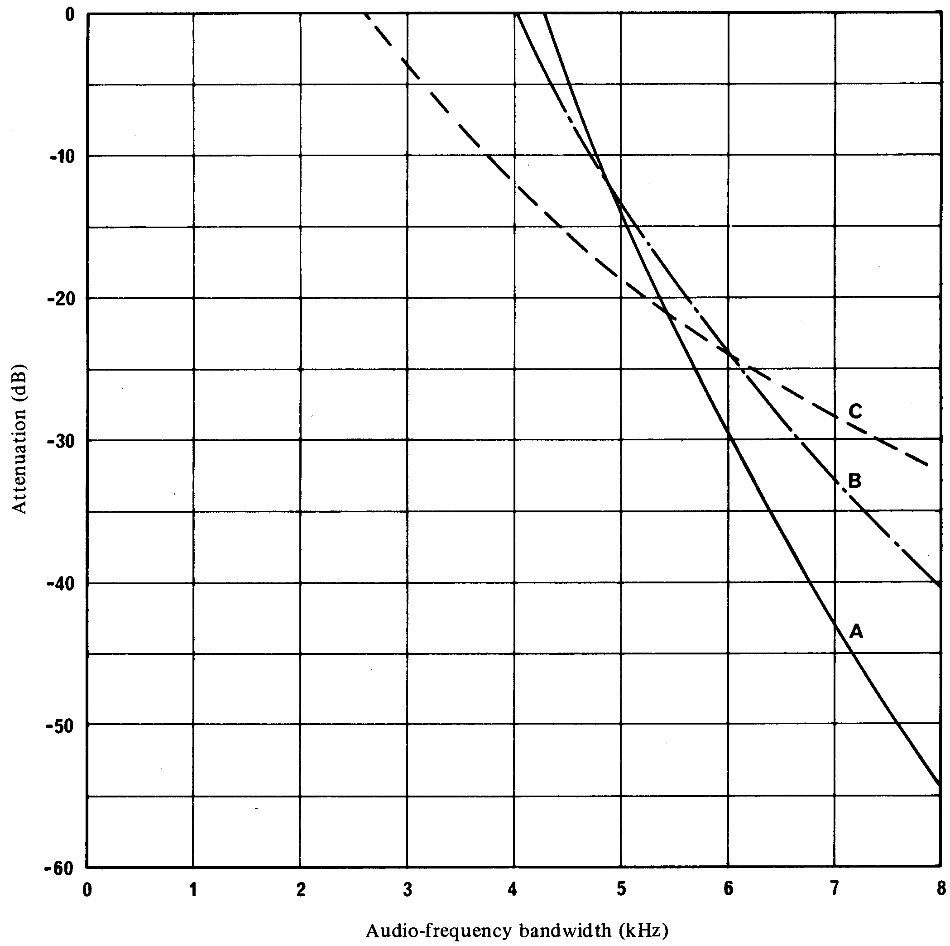

FIGURE 3 – *Overall amplitude/frequency response for an amplitude-modulation sound-broadcasting system for optimum quality of reproduction*

Curve A : overall rate of cut-off for system – 120 dB per octave
B : overall rate of cut-off for system – 80 dB per octave
C : overall rate of cut-off for system – 40 dB per octave

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6 Use of bandwidth limitation in operational practice

Even though the use of bandwidth limitation has been common practice for many years, the public reaction to the effect on programme quality has been negligible. On the other hand, improved reception has been reported in many cases where adjacent channel interference had previously been severe.

According to the Geneva Plan, a large number of transmitters are not operating in bands 5 (LF) and 6 (MF) with a limited bandwidth. In the LF band 50.6% of the total number of transmitters has a bandwidth of emission equal to or less than 10 kHz, whereas in the MF band this value is only 31.3%.

7 A bandwidth-saving overtone transmission and reception system

A new method has been described, applicable in bands 5 (LF), 6 (MF) and 7 (HF), which allows improved sound quality at the receiver while the audio-frequency modulating signal is restricted in bandwidth. The system is based on the fact that the human ear is unable to identify overtone frequencies above about 4 kHz in relation to the fundamental tone.

The improvement of the sound quality is effected by the addition of artificial overtones generated in the receiver. The amplitudes of the overtones are controlled by a pilot tone at the upper end of the audio-frequency passband. The pilot tone carries the information on the amplitude of the overtones and the necessary synchronizing signal in the form of a single-sideband modulation.

8 Out-of-band spectrum of double-sideband sound-broadcasting emissions

Recommendation ITU-R SM.328, § 3.5.1, gives the limit curves for the level of the out-of-band radiation of amplitude modulated double-sideband broadcast emissions. The curves have no fixed relation to the level of the carrier since this relation depends on:

– the modulation factor of the transmitter (r.m.s. value);

– the necessary bandwidth of the emission;

– the bandwidth of the spectrum analyser.

However, the limit curves have a fixed relationship to the maximum level of the sideband components which depends only on the power distribution within the sidebands.

9 The effect of audio signal processing on bandwidth

Some transmitters operating in band 7 (HF) employ an audio shaping filter and limiter to achieve higher average modulation. The use of the filter is commonly referred to as the trapezoidal modulation technique. Measurements in India have indicated that in the case of trapezoidal modulation, the occupied bandwidth of emission is greater than in the case of conventional modulation. Table 1 summarizes the results of the measurements.

TABLE 1

Occupied bandwidth for trapezoidal and conventional modulation

Percentage modulation (%)	Occupied bandwidth (kHz)			
	Trapezoidal modulation		Conventional modulation	
	Upper limit of modulating frequency (kHz)		Upper limit of modulating frequency (kHz)	
	4.5	5.0	4.5	5.0
30	11.0	12.0	10.3	11.5
50	11.7	12.9	11.1	12.0
70	13.7	14.6	12.1	13.0

However, when the highest frequency of a coloured-noise modulating signal (see Recommendation ITU-R BS.559) is not restricted to a value of 10 kHz by a low-pass filter, the occupied bandwidth in the case of trapezoidal modulation becomes less than in the case of conventional modulation. This result is attributed to the sound-shaping filter used for trapezoidal modulation which actually reduces the frequency components beyond about 8 kHz in the modulating signal.

10 Conclusions

10.1 Figure 1 shows the relationship between the adjacent-channel radio-frequency protection ratio, the channel spacing and the audio-frequency bandwidth and assumes that the audio-frequency bandwidth of the radiated programme is the same as that reproduced by the receiver. When two of the three parameters are selected, the third is definitely fixed. In general the channel spacing will be given and a particular value of radio-frequency protection ratio will be required. Then the full audio-frequency bandwidth as taken from Fig. 1 can be transmitted but full use of the bandwidth of the radiated signal can only be made if the receivers have selectivity characteristics corresponding to that of the audio-frequency filter at the transmitter.

10.2 The predetermination of values of channel spacing and adjacent-channel protection ratio in an amplitude-modulation sound-broadcasting system is equivalent to a determination of the quality of audio-frequency reproduction. For example, in the case of 9 kHz channel spacing and –26 dB adjacent-channel protection ratio, Fig. 2 shows that, with reasonable values for the rate of cut-off, an audio-frequency bandwidth of 4.4 kHz can hardly be exceeded. Moreover, it is evident from this figure that decreasing rates of cut-off imply decreasing values of audio-frequency bandwidth.

From subjective listening tests it is apparent that, within the predetermined limits shown in Fig. 2, the reception quality mainly depends on the audio-frequency bandwidth. However, when approaching the limits, a slight increase in audio-frequency bandwidth may imply a substantial increase in rate of cut-off, whereas the increase in reception quality may hardly be noticeable.

Similar studies for 8 and 10 kHz channel spacings led to corresponding results showing the same tendencies. The apportionment of the overall amplitude/frequency response equally to the transmitter and receiver does not necessarily correspond to optimum conditions. On the contrary, computations indicate that the adjacent-channel protection ratio is more sensitive to a modification of the amplitude/frequency response at the receiving end than at the transmitting end of the system. From an economic point of view, however, it may be undesirable to improve receiver selectivity. Further studies are necessary before a final decision can therefore be made.