

CHARACTERISTICS OF SINGLE-SIDEBAND SYSTEMS IN HF BROADCASTING

(Question 44/10)

(1986-1990)

1. Introduction

This Report has been developed in recognition that consideration is being given to the progressive introduction of single-sideband broadcasting systems into the bands now allocated to the Broadcasting Service at HF. Introduction of this form of broadcasting can be accomplished with greater technical harmony if there is sufficient guidance concerning the technical parameters involved. The following considerations will be concentrated on single-sideband amplitude modulation with synchronous demodulation. With respect to a necessary transition period from DSB to SSB, some consideration must also be given to the reception of SSB signals with reduced carrier by receivers with envelope detection. At the end of the transition, all of the advantages of SSB transmissions could then be realized, as follows:

- a more efficient utilization of the frequency spectrum and a reduction of interference;
- the capability of improving the required protection ratio between adjacent channels in the case of a sufficient carrier reduction;
- the capability of improving the quality of reception, in particular under poor propagation conditions (selective fading), with SSB receivers.

The modulation technique considered most suitable for the achievement of bandwidth saving is some form of SSB system. WARC-79 Recommendation 501 and No. 302 of the Radio Regulations suggest the use of SSB emissions to the maximum possible extent in AM systems. There are two types of such systems, namely single-sideband (SSB) and compatible single-sideband (CSSB).

The CSSB system is not suitable for use in amplitude-modulated sound broadcasting, principally because of its increased distortion; furthermore, a greater radiofrequency bandwidth is needed and adequate suppression of out-of-band emissions is likely to be difficult at HF.

In the event of the introduction of single-sideband amplitude modulation broadcasting, it would seem desirable to use the definitions existing in Recommendation 326.

According to this Recommendation, the carrier component is defined in relation to the peak envelope power P_p of a radio transmitter, by the acceptable intermodulation level D_n .

For single-sideband broadcasting transmitters, the acceptable intermodulation level D_n determines the non-linear distortion (quality), and the out-of-band radiation (adjacent channel interference).

In single-sideband reduced carrier systems, the precision of the locally re-inserted carrier is important for the reception quality.

The system parameters for a future SSB-system for sound broadcasting in band 7 (HF) must be chosen in such a way that the different requirements of the transition period (reception of SSB-signals with receivers using envelope detection) as well as those of the period thereafter, when only receivers with synchronous demodulation will be used, are taken into account [CCIR, 1978-82a].

The system specification of SSB is presented in Recommendation 640.

2. Fundamental technical characteristics of single-sideband broadcasting systems

2.1 Nature of single-sideband (SSB) modulation

References to single-sideband (SSB) frequently are made considering the transmitted signal to be amplitude modulated (AM). However, in fact, the transmitted SSB-signal is a composite of both amplitude and phase modulation. Both components of modulation contain the same information, but differ in phase by 90° . Both the amplitude and the phase information can be recovered independently using a synchronous detector that is phase-locked to the incoming carrier. If the phase of the reinserted carrier is the same as that of the incoming carrier, then the amplitude modulation is recovered. On the other hand, if the phase of the reinserted carrier is shifted by 90° relative to the incoming carrier then the phase information is recovered.

For reasons mentioned above, it can be concluded that:

- additional services (data, etc.) using additional phase modulation are difficult to implement in an SSB-signal;
- an SSB-transmission is less affected by selective fading, compared to a DSB transmission. This improved performance results from the constant level of the regenerated carrier, but also from the fact that the synchronous detector's performance is not degraded with shifts in phase of the incoming carrier (during periods of selective fading) because either or both phase and amplitude components of the SSB signal are used in detection.

2.2 Peak envelope power (P_p)

The nominal power of an SSB transmitter is designated by its peak envelope power P_p . This P_p is specified as the mean power produced during peak conditions employing full modulation. Therefore it is difficult to measure utilizing a thermic power meter connected with a dummy load unless the input signal is sinusoidal.

2.3 *Carrier and sideband power relationships in DSB and SSB systems**

The sideband power P_s of a transmitter, depends on the peak envelope power P_p and the chosen carrier reduction, a .

For a single-sideband broadcasting transmitter, the most appropriate value of a will depend mainly on the carrier recovery requirements in a low cost single-sideband receiver. To be able to produce the reference carrier for the ~~synchronous demodulator~~ at an acceptable cost, carrier reduction must be restricted to between about 6 and 12 dB, at the transmitter.

* According to the Radio Regulations (see also Recommendation 326) the following power terms should be used:

- peak envelope power (PX);
- mean power (PY)
- carrier power (PZ)

To enable uniform presentation in this Report, which includes a large number of other power and voltage terms the following designations differing from those recommended by the Radio Regulations and Recommendation 326 are used:

$$\begin{aligned} PX &= P_p \\ PY &= P_m \\ PZ &= P_c \end{aligned}$$

Figure 1 shows the relation between the sideband power P_s and the carrier reduction, a , for a given peak envelope power of the transmitter. The indication (1) denotes the values for modulation by a sinusoidal signal and (2) denotes the values for noise or programme modulation. The values of the voltages U and the powers P are given as percentages related to their peak envelope values. With programme modulation and a carrier suppression of more than 30 dB, the sideband power P_s (2) will be about 10% of P_p . A transmitter operating with a carrier reduction of 6 dB can, when modulated with a programme signal, only radiate a sideband power P_s (2) of about 2.5% of its nominal peak envelope power.

For the calculation of P_s (2) it has been assumed that the ratio of the mean power to the peak envelope power is 0.1 (see Recommendation 326, Table I).

2.4 Equivalent sideband power

To replace a DSB transmitter (carrier power P_c) for sound broadcasting in band 7 (HF) with an equivalent SSB transmitter, the sideband power of the SSB transmitter must be double the value of the sum of both sideband powers of a DSB transmitter. This is justified at least during the transition period, when SSB emissions will also have to be received by DSB receivers having a bandwidth equal to $2B_v$, twice as large as necessary for reception of the SSB emission, and also because the coverage of the target area must be the same.

After the transition period, when only receivers with ~~synchronous demodulation~~ and half the bandwidth of a DSB receiver will be used, theoretically the sideband-power of all SSB transmitters could be reduced to one half of the original value. The signal-to-noise ratio at the output of the receiver, however, would be unchanged only if the spectrum causing the co-channel and adjacent-channel interference within the receiver passband had a uniform power density. Because of the presence of a carrier and the unequal distribution of power in the spectrum of sound-broadcasting emissions, this condition is not met in practice [Gröschel, 1978].

Thus, for the equivalent sideband power P_s of the future SSB transmitters in HF sound broadcasting the following expression might be more suitable:

$$P_s(\text{SSB}) \approx (1 \text{ to } 2) \times P_s(\text{DSB})$$

A factor nearer to 2 might be realistic.

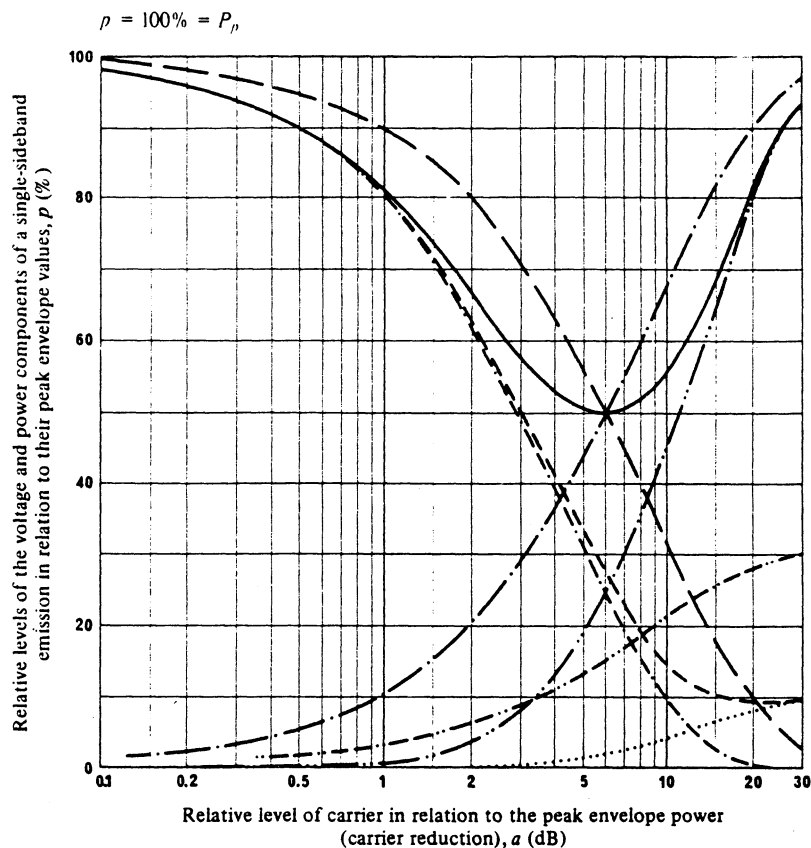


FIGURE 1

- P_p : peak envelope power of the transmitter (defined by means of the acceptable intermodulation level D_n)
- U_c : carrier voltage (r.m.s. value)
- - - $U_s(1)$: sideband signal voltage for modulation with a sinusoidal signal (r.m.s. value)
- · · $U_s(2)$: sideband signal voltage for programme or noise modulation (r.m.s. value)
- · - P_c : carrier power
- · · $P_s(1)$: sideband power for modulation by a sinusoidal signal
- · · $P_s(2)$: sideband power for programme or noise modulation
- $P_m(1)$: transmitter mean power for modulation by a sinusoidal signal
- - - $P_m(2)$: transmitter mean power for programme or noise modulation

Some more details on the necessary peak-envelope power of future SSB transmitters replacing present DSB transmitters in HF sound broadcasting are given in Fig. 2. During the transition period the special receiving conditions will necessitate a peak-envelope power of the transmitter about 4 times higher than will be needed after the transition period [CCIR, 1978-82a].

The WARC HFBC-1987 defined equivalent sideband power in the following manner:

When the carrier reduction relative to peak envelope power is 6 dB, an equivalent SSB emission is one giving the same audio-frequency signal-to-noise ratio at the receiver output as the corresponding DSB emission, when it is received by a DSB receiver with envelope detection. This is achieved when the sideband power of the SSB emission is 3 dB larger than the total sideband power of the DSB emission. (The peak envelope power of the equivalent SSB emission and the carrier power are the same as that of the DSB emission.)

2.5 Comparison of power consumption of equivalent DSB and SSB transmitters

One of the aims of the introduction of SSB modulation in sound broadcasting in the HF bands, apart from a better utilization of the spectrum, is a considerable reduction of transmitter power consumption. Optimum saving of power can eventually be achieved when SSB receivers (having only half the bandwidth of DSB receivers) are in common use, thus permitting a change in carrier level from -6 dB to -12 dB.

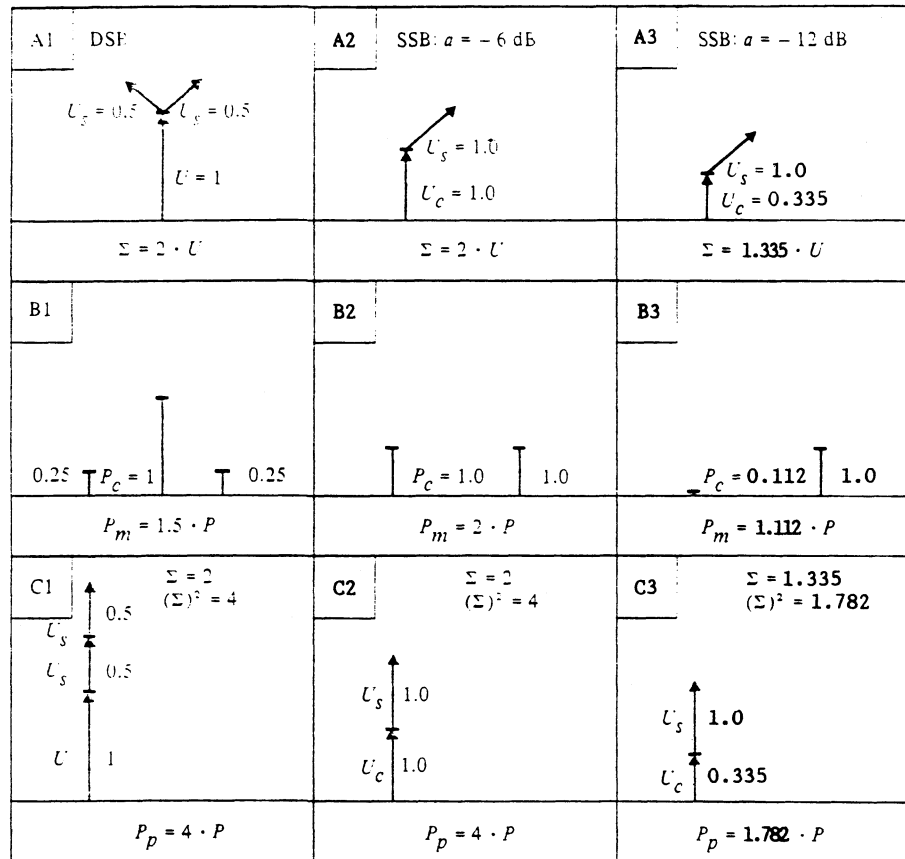


FIGURE 2 – Relation between carrier- and sideband-levels and powers with DSB and SSB transmission depending on carrier reduction

(For comparison, carrier power level of the DSB transmitter was assumed to be equal to 1. Full modulation with a single sinusoidal tone.) $P_S(\text{SSB}) = 2 \times P_S(\text{DSB})$

A1...A3: level of spectral-components (at the output of the transmitter)

B1...B3: average output power of the transmitter

C1...C3: peak-envelope power at the output of the transmitter

Index 1: DSB signal

Index 2: SSB signal, carrier reduction: -6 dB (class of emission H3E)

Index 3: SSB signal, carrier reduction: -12 dB (class of emission R3E)

U : carrier level of the DSB transmitter

U_s : level of sidebands

U_c : carrier level of the SSB transmitter

P : carrier power of the DSB transmitter

P_c : carrier power of the SSB transmitter

P_m : average power

P_p : peak envelope power

On the assumption of programme modulation with 40% effective modulation factor, a value which is reached if the modulation signal is substantially compressed, representative values for the power consumption of transmitters for DSB and SSB modulation with equivalent sideband power have been calculated and are summarised in Tables I and II.

This comparison is based on an overall efficiency factor of 60% for DSB transmitters and of 38% or 60% for SSB transmitters. These values have been derived from existing SSB transmitters. In this case an SSB transmitter with e.g. 12 dB carrier reduction and with an equivalent sideband power (i.e. equal to the DSB sideband power) will have respectively about 40% or 25% of the total power consumption of a DSB transmitter (Figure 2 conditions apply).

During the transition period when reception with DSB receivers must be assumed, a carrier reduction of 6 dB is recommended. In this case an SSB transmitter with double sideband power has respectively about 70% or 7% more power consumption than a DSB transmitter (see Table II).

TABLE I - Output power ratios

Carrier reduction	Sinusoidal modulation $m_{eff} = 100\%$	Programme modulation $m_{eff} = 40\%$
6 dB	2.0	1.16
12 dB	1.11	0.27

Average output power of an SSB transmitter relative to DSB carrier power. ($m = 100\%$, conditions as in Figure 2.)

TABLE II - Power consumption ratio

Carrier reduction	Sinusoidal modulation $m_{eff} = 100\%$		Programme modulation $m_{eff} = 40\%$	
	SSB efficiency		SSB efficiency	
	38%	60%	38%	60%
6 dB	2.11	1.33	1.70	1.07
12 dB	1.17	0.74	0.40	0.25

Power consumption of an SSB transmitter relative to that of a DSB transmitter. DSB efficiency 60%. ($m = 100\%$, conditions as in Figure 2.)