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Recommendation ITU-R F.339-7
(02/2006)

Bandwidths, signal-to-noise ratios and fading allowances in complete systems

F Series

Fixed service

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Note: *This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R F.339-7*

Bandwidths, signal-to-noise ratios and fading allowances in complete systems

(1951-1953-1956-1963-1966-1970-1974-1978-1982-1986-2006)

Scope

There are a large variety of HF fixed systems in operation or being developed to meet future requirements. Consequently, it is not appropriate to assume and use a single "typical" system as a general purpose model.

This Recommendation shows selected examples of various HF fixed service systems that are currently in use and describes the key system parameters (bandwidths, signal-to-noise ratios (SNRs), and fading allowances) for these systems. The system parameters should be used in the deployment of HF fixed systems.

The ITU Radiocommunication Assembly,

considering

a) that it is desirable to classify the technical aspects with which future studies will have to deal;

b) that there is a need for numerical values which take into account fading and fluctuations in field intensity;

c) that, however, the information contained in Annex 1 to Recommendation ITU-R P.313 gives some results from which provisional data on fading conditions can be derived,

recommends

1 that the values given in Table 1 should be used for the signal-to-noise ratio (SNR) required for the class of emission concerned;

2 that the values given in the fading condition columns of the Tables in Annex 1, in conjunction with the estimate of the intensity fluctuation factor given in Note 4 to these Tables, may be used as an aid to estimate monthly-median values of hourly-median field intensities necessary for the various types and grades of service;

3 that the Note shown below should be considered part of this Recommendation.

NOTE 1 – Use of the provisional values only provides an estimate to be obtained, which may have to be adjusted for radio circuits of different path lengths depending on the grade of service required.

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* Radiocommunication Study Group 9 made editorial amendments to this Recommendation in 2000 in accordance with Resolution ITU-R 44.

Annex 1

TABLE 1

Required signal-to-noise ratios

Class of emission	Pre-detection bandwidth of receiver (Hz)	Post-detection bandwidth of receiver (Hz)	Grade of service	Audio SNR (1) (dB)	RF signal-to-noise density ratio (2)(3) (dB)		
					Stable condition	Fading condition (4)	(5)
						Non-diversity	Dual diversity
A1 A Telegraphy 8 Bd	3 000	1 500	Aural reception (6)	−4	31	38	
A1 B Telegraphy 50 Bd, printer	250	250	Commercial grade (7)	16	40		58
A1 B Telegraphy 120 Bd, undulator	600	600		10	38		49
A2 A Telegraphy 8 Bd	3 000	1 500	Aural reception (6) (19)	−4	35	38	
A2 B Telegraphy 24 Bd	3 000	1 500	Commercial grade (7) (19)	11	50	56	
F1 B Telegraphy 50 Bd, printer $2D$ = 200 Hz to 400 Hz	1 500	100	$P_C = 0.01$ $P_C = 0.001$ $P_C = 0.0001$ (8)		45 51 56 (9)	53 63 74 (9)	45 52 59 (9)
F1 B Telegraphy 100 Bd, printer $2D$ = 170 Hz, ARQ	300	300	(10)		43	52	
F1 B Telegraphy 200 Bd, printer $2D$ = 400 Hz, ARQ			(10)				
F1B Telegraphy MFSK 33-tone ITA2 10 character/s	400	400	$P_C = 0.01$ $P_C = 0.001$ $P_C = 0.0001$ (8)		23 24 26	37 45 52 (25)	29 34 39
F1B Telegraphy MFSK 12-tone ITA5 10 character/s	300	300	$P_C = 0.01$ $P_C = 0.001$ $P_C = 0.0001$ (8)		26 27 29	42 49 56 (25)	32 36 42
F1B Telegraphy MFSK 6-tone ITA2 10 character/s	180	180	$P_C = 0.01$ $P_C = 0.001$ $P_C = 0.0001$ (8)		25 26 28	41 48 55 (25)	31 35 41
F7B Telegraphy							
R3C Phototelegraphy 60 rpm	3 000	3 000			50	59	
R3C Phototelegraphy 60 rpm	1 100	3 000	Marginally commercial (22) Good commercial (22)	15 20	50 55	58 65	
A3E Telephony double sideband	6 000	3 000	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 (18)	50 59 67(14)	51 64 75(14) (20)	48 60 70(14) (15) (20)
H3E Telephony single-sideband full carrier	3 000	3 000	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 (18)	53 62 70(14) (23)	54 67 78(14) (20)	51 63 73(14) (15) (20)
R3E Telephony single-sideband reduced carrier	3 000	3 000	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 (18)	48 57 65(14) (24)	49 62 73(14) (20)	46 58 68(14) (15) (20)
J3E Telephony single-sideband suppressed carrier	3 000	3 000	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 (18)	47 56 64(14)	48 61 72(14) (20)	45 57 67(14) (15) (20)
B8E Telephony independent-sideband 2 channels	6 000	3 000 per channel	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 (18)	49 58 66(14)	50 63 74(14) (20)	47 59 69(14) (15) (20)
B8E Telephony independent-sideband 4 channels	12 000	3 000 per channel	Just usable (11) Marginally commercial (12) Good commercial (13)	6 15 33 (18)	50 59 67(14)	51 64 75(14) (20)	48 60 70(14) (15) (20)
J7B Multichannel V.F. telegraphy 16 channels 75 Bd each	3 000	110 per channel	$P_C = 0.01$ $P_C = 0.001$ $P_C = 0.0001$ (8)		59 65 69 (21)	67 77 87 (21)	59 66 72 (21)

TABLE 1 (*end*)

Class of emission	Pre-detection bandwidth of receiver (Hz)	Post-detection bandwidth of receiver (Hz)	Grade of service	Audio SNR (1) (dB)	RF signal-to-noise density ratio (2)(3) (dB)		
					Stable condition	Fading condition (4)	(5)
						Non-diversity	Dual diversity
J7B Multichannel V.F. telegraphy 15 channels 100 Bd each with ARQ	3 000	110 per channel	(10)				
R7B Multichannel V.F. telegraphy reduced carrier							
B7W Composite 16 channels 75 Bd each 1 telephony channel (16)	6 000	110 per telegraphy channel 3 000 for the telephony channel	$P_C = 0.01$ $P_C = 0.001$ $P_C = 0.0001$ (8)		60 66 70 (17)	68 78 88 (17)	60 67 73 (17)

(1) Noise bandwidth equal to post-detection bandwidth of receiver. For an independent-sideband telephony noise bandwidth equal to the post-detection bandwidth of one channel.

(2) The figures in this column of Table 1 represent the ratio of signal peak envelope power to the average noise power in a 1 Hz bandwidth except for double-sideband A3E emission where the figures represent the ratio of the carrier power to the average noise power in a 1 Hz bandwidth.

(3) The values of the radio-frequency signal-to-noise density ratio for telephony listed in this column, apply when conventional terminals are used. They can be reduced considerably (by amounts as yet undetermined) when terminals of the type using linked compressor expanders (Lincompex) are used (see Recommendation ITU-R F.1111). A speech-to-noise (r.m.s. voltage) ratio of 7 dB measured at audio-frequency in a 3 kHz band has been found to correspond to just marginally commercial quality at the output of the system, taking into account the compandor improvement.

(4) The values in these columns represent the median values of the fading signal power necessary to yield an equivalent grade of service, and do not include the intensity fluctuation factor (allowance for day-to-day fluctuation). In general, a value of 11.5 dB may be added as the intensity fluctuation factor to the values in these columns to arrive at provisional values for the total required signal-to-noise density ratios which may be used as a guide to estimate required monthly-median values of hourly-median field strength. This value of 11.5 dB has been obtained as follows:

The intensity fluctuation factor for the signal, against steady noise, is 10 dB, estimated to give protection for 90% of the days. The fluctuations in intensity of atmospheric noise are also taken to be 10 dB for 90% of the days. Assuming that there is no correlation between the fluctuations in intensity of the noise and those of the signal, a good estimate of the combined signal and noise intensity fluctuation factor is:

$$10 \log\left(\sqrt{10^2 + 10^2}\right) = 11.5 \text{ dB}$$

(5) In calculating the radio-frequency signal-to-noise density ratios for rapid short-period fading, a log-normal amplitude distribution of the received fading signal has been used (using 7 dB for the ratio of median level to level exceeded for 10% or 90% of the time) except for high-speed automatic telegraphy services, where the protection has been calculated on the assumption of a Rayleigh distribution. Notes (6) to (25) refer to protection against rapid or short-period fading.

(6) For protection 90% of the time.

(7) For A1B telegraphy, 50 baud printer: for protection 99.99% of the time. For A2B telegraphy, 24 bauds: for protection 98% of the time.

(8) The symbol P_C stands for the probability of character error.

(9) Atmospheric noise (V_d = 6 dB) is assumed.

(10) Based on 90% traffic efficiency.

(11) For 90% sentence intelligibility.

(12) When connected to the public service network: based on 80% protection.

(13) When connected to the public service network: based on 90% protection.

(14) Assuming 10 dB improvement due to the use of noise reducers.

(15) Diversity improvement based on a wide-spaced (several kilometres) diversity.

(16) Transmitter loading of 80% of the rated peak envelope power of the transmitter by the multi-channel telegraph signal is assumed.

(17) Required signal-to-noise density ratio based on performance of telegraphy channels.

(18) For telephony, the figures in this column represent the ratio of the audio-frequency signal, as measured on a standard VU-meter, to the r.m.s. noise, for a bandwidth of 3 kHz. (The corresponding peak signal power, i.e. when the transmitter is 100% tone-modulated, is assumed to be 6 dB higher.)

(19) Total sideband power, combined with keyed carrier, is assumed to give partial (two element) diversity effect. An allowance of 4 dB is made for 90% protection (8 bauds), and 6 dB for 98% protection (24 bauds).

(20) Used if Lincompex terminals will reduce these figures by an amount yet to be determined.

(21) For fewer channels these figures will be different. The relationship between the number of channels and the required signal-to-noise ratio has yet to be determined.

(22) Quality judged in accordance with ITU-T Recommendation T.22 – Standardized test charts for document facsimile transmissions.

Notes relative to Table 1 (end):

(23) For class of emission H3E the levels of sideband signals and pilot-carrier corresponding to 100% modulation are each – 6 dB relative peak envelope power (p.e.p.). SSB receiver used for reception.

(24) For class of emission R3E the pilot-carrier level of – 20 dB relative to p.e.p. is applied and the level of the sideband signal corresponding to 100% modulation is 1 dB lower than the p.e.p.

(25) Dependent on fading rate, typical values shown.

TABLE 2

Required SNRs for 39-tone QDPSK HF modem (J2D Class of emission)

a)

SNR(1) (2) (3) (dB)	BER			
	Data rate 2400 bit/s		Data rate 1 200 bit/s	
	AWGN channel	Fading condition	AWGN channel	Fading condition
5		8.6×10^{-2}		6.4×10^{-2}
10		3.5×10^{-2}		4.4×10^{-3}
15		1.0×10^{-2}		3.4×10^{-4}
20		1.0×10^{-3}		9.0×10^{-6}
30		1.8×10^{-4}		2.7×10^{-6}

b)

SNR(1) (2) (3) (dB)	BER			
	Data rate 300 bit/s		Data rate 75 bit/s	
	AWGN channel	Fading condition	AWGN channel	Fading condition
0		1.8×10^{-2}		4.4×10^{-4}
2		6.4×10^{-3}		5.0×10^{-5}
4		1.0×10^{-3}		1.0×10^{-6}
6		5.0×10^{-5}		1.0×10^{-6}
8		1.5×10^{-6}		1.0×10^{-6}

(1) Figures represent the ratio of the carrier power to the average noise power in a 3 kHz bandwidth.

(2) Two independent equal average power Rayleigh fading paths, with a fixed 2 ms delay between paths, with 1 Hz fading.

(4) The values in these columns represent the median values of the fading signal power necessary to yield an equivalent grade of service, and do not include the intensity fluctuation factor (allowance for day-to-day fluctuation). In general, a value of 11.5 dB may be added as the intensity fluctuation factor to the values in these columns to arrive at provisional values for the total required signal-to-noise density ratios which may be used as a guide to estimate required monthly-median values of hourly-median field strength. This value of 11.5 dB has been obtained as follows:

The intensity fluctuation factor for the signal, against steady noise, is 10 dB, estimated to give protection for 90% of the days. The fluctuations in intensity of atmospheric noise are also taken to be 10 dB for 90% of the days. Assuming that there is no correlation between the fluctuations in intensity of the noise and those of the signal, a good estimate of the combined signal and noise intensity fluctuation factor is:

$$10 \log\left(\sqrt{10^2 + 10^2}\right) = 11.5 \text{ dB}$$

TABLE 3

Required SNRs for data rates and modulation shown (J2D Class of Emission)

a)

User data rate (bit/s)	Modulation	Average SNR[1] (dB)			
		BER 1.0×10^{-4} [2]		BER 1.0×10^{-5} [2]	
		AWGN channel	Fading condition[3], [4]	AWGN channel	Fading condition[3], [4]
12 800	64-QAM	27	–	28	–
9 600	64-QAM	21	30	22	32
8 000	32-QAM	19	26	19	28
6 400	16-QAM	16	23	16	24
4 800	8-PSK	13	20	14	21
3 200	QPSK	9	14	9	15

b)

User data rate (bit/s)	Modulation	Average SNR[1] (dB)			
		BER $<1.0 \times 10^{-2}$		BER $<1.0 \times 10^{-3}$	
		AWGN channel	Fading condition[3], [4]	AWGN channel	Fading condition[3], [4]
1 200	8-PSK	9		10	20
2 400	8-PSK	10	15	15	25
3 600	8-PSK	17	20	19	40

NOTE 1 – Implementation techniques of system reported in the lower portion of this Table predates systems reported in the upper portion of this Table and Table 2.

(1) Figures represent the ratio of the carrier power to the average noise power in a 3 kHz bandwidth.

(2) 72-frame “very long” interleaver.

(3) Two independent equal average power Rayleigh fading paths, with a fixed 2 ms delay between paths, with 1 Hz fading.

(4) The values in these columns represent the median values of the fading signal power necessary to yield an equivalent grade of service, and do not include the intensity fluctuation factor (allowance for day-to-day fluctuation). In general, a value of 11.5 dB may be added as the intensity fluctuation factor to the values in these columns to arrive at provisional values for the total required signal-to-noise density ratios which may be used as a guide to estimate required monthly-median values of hourly-median field strength. This value of 11.5 dB has been obtained as follows:

The intensity fluctuation factor for the signal, against steady noise, is 10 dB, estimated to give protection for 90% of the days. The fluctuations in intensity of atmospheric noise are also taken to be 10 dB for 90% of the days. Assuming that there is no correlation between the fluctuations in intensity of the noise and those of the signal, a good estimate of the combined signal and noise intensity fluctuation factor is:

$$10 \log\left(\sqrt{10^2 + 10^2}\right) = 11.5 \text{ dB}$$