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Recommendation **ITU-R F.339-8**
(02/2013)

Bandwidths, signal-to-noise ratios and fading allowances in HF fixed and land mobile radiocommunication 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.*

RECOMMENDATION ITU-R F.339-8

Bandwidths, signal-to-noise ratios and fading allowances in HF fixed and land mobile radiocommunication systems

(1951-1953-1956-1963-1966-1970-1974-1978-1982-1986-2006-2013)

Scope

This Recommendation shows selected examples of various HF (3-30 MHz) fixed and land mobile service systems that are currently in use and describes the key system parameters (bandwidths, signal-to-noise density ratios and fading allowances) for these systems. The system parameters should be used in the deployment of HF systems and could be used in sharing studies.

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;

d) that there are a large variety of HF fixed and land mobile systems in operation or being developed to meet future requirements. Consequently, there is no one single "typical" system as a general purpose model,

recommends

1 that the values given in Tables 1 to 4 of Annex 1 should be used for the signal-to-noise density ratio (SNR) required for the class of emission concerned;

2 that the values given in the fading condition columns of Table 1 in Annex 1, in conjunction with the estimate of the intensity fluctuation factor given in Note 4 to Table 1, 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 – Use of the recommended 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.

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)	Average RF SNR[2][3] (dB/Hz) 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]

TABLE 1 (*continued*)

Class of emission	Pre-detection bandwidth of receiver (Hz)	Post-detection bandwidth of receiver (Hz)	Grade of service	Audio SNR[1] (dB)	Average RF SNR[2][3] (dB/Hz)		
					Stable condition	Fading condition [4] [5]	
						Non-diversity	Dual diversity
B8E Telephony independent-sideband 4 channels	12 000	3 000 per channel	Just usable [11] Marginally commercial [12] Good commercial [13]	6 15 } (18) 33	50 59 67([14])	51 64 } (20) 75([14])	48 60 } (15) 70([14]) } (20)
J7B Multichannel V.F. telegraphy 16 channels 75 Bd each	3 000	110 per channel	$P_C = 0.01$ $P_C = 0.001$ } (8) $P_C = 0.0001$		59 65 } (21) 69	67 77 } (21) 87	59 66 } (21) 72
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	$P_C = 0.01$ $P_C = 0.001$ } (8) $P_C = 0.0001$		60 66 } (17) 70	68 78 } (17) 88	60 67 } (17) 73

[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.

Notes relative to Table 1 (end):

[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 Recommendation ITU-T T.22 – Standardized test charts for document facsimile transmissions.

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

a)

Average SNR (dB/Hz)	BER			
	Data rate 2 400 bit/s		Data rate 1 200 bit/s	
	AWGN channel[d]	Fading condition[a] [b] [c]	AWGN channel[d]	Fading condition[a] [b] [c]
39		8.6×10^{-2}		6.4×10^{-2}
44		3.5×10^{-2}		4.4×10^{-3}
49		1.0×10^{-2}		3.4×10^{-4}
54		1.0×10^{-3}		9.0×10^{-6}
64		1.8×10^{-4}		2.7×10^{-6}

b)

Average SNR (dB/Hz)	BER			
	Data rate 300 bit/s		Data rate 75 bit/s	
	AWGN channel[d]	Fading condition[a] [b] [c]	AWGN channel[d]	Fading condition[a] [b] [c]
34		1.8×10^{-2}		4.4×10^{-4}
36		6.4×10^{-3}		5.0×10^{-5}
38		1.0×10^{-3}		1.0×10^{-6}
40		5.0×10^{-5}		1.0×10^{-6}
42		1.5×10^{-6}		1.0×10^{-6}

Notes relative to Table 2 (end):

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

[b] 72-frame "very long" interleaver.

[c] The values in these columns represent the RMS values of the fading signal power necessary to yield an equivalent grade of service.

[d] "AWGN": Un-faded channel with additive white Gaussian noise.

TABLE 3

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

a)

User data rate (bit/s)	Modulation	Average SNR (dB/Hz)			
		BER 1.0×10^{-4}		BER 1.0×10^{-5}	
		AWGN channel[d]	Fading condition [a] [b] [c]	AWGN channel[d]	Fading condition [a] [b] [c]
12 800	64-QAM	61	–	62	–
9 600	64-QAM	55	64	56	66
8 000	32-QAM	53	60	53	62
6 400	16-QAM	50	57	50	58
4 800	8-PSK	47	54	48	55
3 200	QPSK	43	48	43	49

b)

User data rate (bit/s)	Modulation	Average SNR (dB/Hz)			
		BER $< 1.0 \times 10^{-2}$		BER $< 1.0 \times 10^{-3}$	
		AWGN channel[d]	Fading condition [a] [b] [c]	AWGN channel[d]	Fading condition [a] [b] [c]
1 200	8-PSK	43		44	54
2 400	8-PSK	44	49	49	59
3 600	8-PSK	51	54	53	74

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

[b] 72-frame "very long" interleaver.

[c] The values in these columns represent the RMS values of the fading signal power necessary to yield an equivalent grade of service.

[d] "AWGN": Un-faded channel with additive white Gaussian noise.

TABLE 4a

**Data rates and modulation (J2D Class of Emission) in 3 to 24 kHz bandwidths
for scalable digital modulation system**

Waveform number	Modulation	Data rate (bit/s)							
		3 (kHz)	6 (kHz)	9 (kHz)	12 (kHz)	15 (kHz)	18 (kHz)	21 (kHz)	24 (kHz)
0	Walsh	75	150	300	300	300	600	300	600
1	BPSK	150	300	600	600	600	1 200	600	1 200
2	BPSK	300	600	1 200	1 200	1 200	2 400	1 200	2 400
3	BPSK	600	1 200	2 400	2 400	2 400	4 800	2 400	4 800
4	BPSK	1 200	2 400	–	4 800	4 800	–	4 800	9 600
5	BPSK	1 600	3 200	4 800	6 400	8 000	9 600	9 600	12 800
6	QPSK	3 200	6 400	9 600	12 800	16 000	19 200	19 200	25 600
7	8-PSK	4 800	9 600	14 400	19 200	24 000	28 800	28 800	38 400
8	16-QAM	6 400	12 800	19 200	25 600	32 000	38 400	38 400	51 200
9	32-QAM	8 000	16 000	24 000	32 000	40 000	48 000	48 000	64 000
10	64-QAM	9 600	19 200	28 800	38 400	48 000	57 600	57 600	76 800
11	64-QAM	12 000	24 000	36 000	48 000	57 600	72 000	76 800	96 000
12	256-QAM	16 000	32 000	48 000	64 000	76 800	90 000	115 200	120 000
13	QPSK	2 400							

TABLE 4b

**Required SNRs (dB/Hz) in 3 to 24 kHz bandwidths for scalable digital modulation
system for BER ≤ 1.0×10^{-5}[e]**

Bandwidth	3 (kHz)[a]		6 (kHz)[a]		9 (kHz)[a]		12 (kHz)[a]	
Waveform number	AWGN channel [b]	Fading channel [c] [d]	AWGN channel [b]	Fading channel [c] [d]	AWGN channel [b]	Fading channel [c] [d]	AWGN channel [b]	Fading channel [c] [d]
0	29	34	32	37	34	40	35	40
1	32	38	35	41	37	43	38	44
2	35	40	38	43	40	45	41	46
3	38	42	41	45	44	48	44	48
4	40	45	43	48	–	–	46	51
5	41	46	44	49	46	51	47	52
6	44	49	47	52	49	54	50	55
7	48	54	51	57	53	59	54	60
8	51	58	54	61	56	63	57	64
9	54	62	57	65	59	67	60	68
10	56	66	59	69	61	71	62	72
11	59	–	62	–	64	–	65	–
12	65	–	68	–	70	–	71	–
13	41	46	–	–	–	–	–	–

TABLE 4b (*end*)

Bandwidth	15 (kHz)[a]		18 (kHz)[a]		21(kHz)[a]		24 (kHz)[a]	
Waveform number	AWGN channel [b]	Fading channel [c] [d]	AWGN channel [b]	Fading channel [c] [d]	AWGN channel [b]	Fading channel [c] [d]	AWGN channel [b]	Fading channel [c] [d]
0	36	41	37	42	37	42	38	43
1	39	45	40	46	40	46	41	47
2	42	47	43	48	43	48	44	49
3	45	49	46	50	46	50	47	51
4	47	52	–	–	48	53	49	54
5	48	53	49	54	49	54	50	55
6	51	56	52	57	52	57	53	58
7	55	61	56	62	56	62	57	63
8	58	65	59	66	59	66	60	67
9	61	69	62	70	62	70	63	71
10	63	73	64	74	64	74	65	78
11	66	–	67	–	67	–	68	–
12	72	–	73	–	73	–	74	–
13	–	–	–	–	–	–	–	–

[a] The figures in columns of Table 4b represent the ratio of average signal power to the average noise power (dB) in a 1 Hz bandwidth.

[b] "AWGN": Un-faded channel with additive white Gaussian noise.

[c] "Fading channel": Two independent equal average power Rayleigh fading paths, with a fixed 2 ms delay between paths, with 1 Hz fading (corresponds to Mid-latitudes "disturbed conditions" in Recommendation ITU-R F.1487).

[d] The values in Table 4b "Fading channel" columns represent the median values of the fading signal power necessary to yield an equivalent grade of service.

[e] The waveform numbers 11 and 12 are suitable for groundwave channels and skywave fading values are not available. The waveform number 4 is not available in 9 or 18 kHz channels, and waveform number 13 is only available in a 3 kHz bandwidth system.

Table 4 presents digital modulation for wider bandwidth HF systems. Tables 4a and 4b are to be used together, first identify waveform number for the bandwidth and data rate of a particular system from Table 4a then use Table 4b to determine the required signal-to-noise ratio.

An example for the use of Tables 4 for a data rate of 38 400 bits/s in 24 kHz bandwidth is shown below:

1) From Table 4a find the 24 kHz bandwidth column and determine the waveform number for 38 400 bit/s, which is waveform number 7 in this case.

2) Find the row for waveform number 7 in Table 4b and find its intersection with the 24 kHz bandwidth column.

3) For a grade of service BER of 1×10^{-5}, the required SNRs are 57 and 63 dB/Hz in non-fading and fading channels respectively, which are presented in Table 4b.

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