

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Hollow metallic waveguides –
Part 4: Relevant specifications for circular waveguides**

**Guides d'ondes métalliques creux –
Partie 4: Spécifications applicables aux guides d'ondes circulaires**

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INTERNATIONAL
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INTERNATIONAL ELECTROTECHNICAL COMMISSION

HOLLOW METALLIC WAVEGUIDES –**Part 4: Relevant specifications for circular waveguides**

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IEC 60153-4 has been prepared by subcommittee 46F: RF and microwave passive components, of IEC technical committee 46: Cables, wires, waveguides, RF connectors, RF and microwave passive components and accessories. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2017. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) change of the designation scheme for small circular waveguides (e.g. C 25.5k instead of C 25500);
- b) revision of Table 1:
 - correction of two waveguide designations (now C 1.2k, C 12k);
 - correction of three waveguide diameters (C 140, C 1.4k, C 14k);
 - tightening of inner diameter tolerances for waveguides smaller than C 890;
 - deletion of waveguide attenuation values for aluminium, gold, and brass;

- c) deletion of Table 2 (duplication) and replacement with the table of intermediate waveguide sizes originally envisaged here;
- d) addition of an equation for calculating the attenuation of waveguides made of any material.

The text of this International Standard is based on the following documents:

Draft	Report on voting
46F/616/FDIS	46F/621/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all parts in the IEC 60153 series, published under the general title *Hollow metallic waveguides*, can be found on the IEC website.

This International Standard is to be read in conjunction with IEC 60153-1.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

HOLLOW METALLIC WAVEGUIDES –

Part 4: Relevant specifications for circular waveguides

1 Scope

This part of IEC 60153 specifies straight hollow metallic tubing of circular cross section for use as waveguides in electronic equipment.

The aim of this document is to specify the hollow metallic waveguides:

- a) the details necessary to ensure compatibility and, as far as essential, interchangeability;
- b) test methods;
- c) uniform requirements for the electrical and mechanical properties.

No recommendations are made for the materials to be used for waveguides. The choice of materials is to be agreed on between the customer and the manufacturer.

This document is intended to be read in conjunction with IEC 60153-1, which gives general requirements and test methods.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60028:1925, *International standard of resistance for copper*

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at <http://www.electropedia.org/>)

IEC 60153-1, *Hollow metallic waveguides – Part 1: General requirements and measuring methods*

IEC 60261, *Sealing test for pressurized waveguide tubing and assemblies*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

4 General

4.1 Standardized types

The series of circular waveguides covered in this document are shown in Table 1 and Table 2. Table 1 lists the waveguides with preferred sizes. Since the operating frequency ranges of circular waveguides are very small, it is desirable to have densely spaced waveguide sizes available. For this reason, intermediate sizes have been defined¹. In Table 2, these are compiled together with the preferred sizes.

4.2 Type designation

For circular waveguides the type designation comprises the code

$$60153_IEC-C_size$$

where

$_$ is the space character, and

size is a number characterizing a particular size of waveguide. This number expresses approximately in multiples of hundred megahertz (100 MHz) the centre frequency of the recommended operating frequency range. Numbers of one thousand and above are – to keep the designation short – divided by one thousand and followed by a lower-case "k" for kilo (e.g. 25.5k for 25 500 and 29k for 29 000)². A possibly necessary decimal sign is written as a dot.

4.3 Frequency range

Depending on the application of the circular waveguide, a suitable electromagnetic waveguide mode shall be selected. The propagation of this mode is only possible at frequencies above a certain cut-off frequency. Table 1 shows the cut-off frequencies for the technically most important modes³: TE₁₁ (1st and dominant mode), TM₀₁ (2nd mode), TE₂₁ (3rd mode), TE₀₁ (4th mode) and TE₀₂ (14th mode).

The recommended operating frequency range on which this document is based is defined as a pure dominant mode range between 1,15 times the TE₁₁ cut-off frequency and 0,96 times the TM₀₁ cut-off frequency⁴. The centre frequency f_{centre} of the recommended operating frequency range – from which the waveguide type designation is derived – is then calculated as the geometric mean of this range⁵.

¹ The designations and inner diameters for the intermediate waveguides from C 3.3 to C 890 have been taken directly from IEC 60153-4:1973. The designations and inner diameters of the smaller intermediate waveguides have been newly derived from the larger intermediate waveguides by scaling.

² This designation scheme is analogous to that specified in IEC 60153-2:2016 for the ordinary rectangular waveguides.

³ The cut-off frequency f_c for a particular mode of a circular waveguide is calculated by $f_c = x \cdot c_0 / (\pi \cdot D)$, where x can be approximated by 1,8412; 2,4048; 3,0542; 3,8317; 7,0156 for the mode TE₁₁; TM₀₁; TE₂₁; TE₀₁; TE₀₂, respectively. Furthermore, c_0 is the velocity of light in free-space ($\approx 2,997\,925 \cdot 10^8$ m/s), π is Archimedes' constant ($\approx 3,14159$) and D is the inner waveguide diameter expressed in metres (m).

⁴ There are other common recommendations for the operating frequency range of a circular waveguide. For example, the TIA/EIA-200-A standard recommends the range between 1,15 times the TE₁₁ cut-off frequency and 0,95 times the TE₂₁ cut-off frequency, which is not a pure dominant mode range.

⁵ Due to $(1,15 \cdot 0,96 \cdot 2,4048 / 1,8412)^{0,5} \approx 1,2$, the centre frequency f_{centre} corresponds to 1,2 times the TE₁₁ cut-off frequency.

5 Mechanical requirements

5.1 General

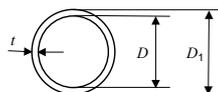
It should be noted that no recommendations are made for the materials to be used for waveguides. The choice of materials is to be agreed on between the customer and the manufacturer.

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Table 1 – Circular waveguides (preferred sizes)



Type designation	Cut-off frequency in GHz for the mode					Inner diameter D in mm		Wall thckn. t in mm	Outer diameter D_1 in mm		attenuation coefficient in dB/m for TE ₁₁ in an ideal copper waveguide		
	TE ₁₁	TM ₀₁	TE ₂₁	TE ₀₁	TE ₀₂	Nominal value	Tolerance \pm	Nominal value	Nominal value	Tolerance \pm	f_{centre} in GHz	Theoretical value	Maximum value
C 3.3	0,271	0,354	0,450	0,564	1,03	647,90	0,65	not specified			0,325	0,00067	0,00088
C 4	0,317	0,415	0,527	0,661	1,21	553,49	0,55				0,381	0,00085	0,0011
C 4.5	0,372	0,485	0,616	0,773	1,42	472,85	0,47				0,446	0,0011	0,0014
C 5.3	0,435	0,568	0,722	0,905	1,66	403,94	0,40				0,522	0,0014	0,0018
C 6.2	0,509	0,665	0,845	1,06	1,94	345,06	0,35				0,611	0,0017	0,0023
C 7	0,596	0,778	0,989	1,24	2,27	294,79	0,29				0,715	0,0022	0,0029
C 8	0,698	0,911	1,16	1,45	2,66	251,84	0,25				0,837	0,0028	0,0036
C 10	0,817	1,07	1,35	1,70	3,11	215,14	0,22				0,980	0,0035	0,0046
C 12	0,956	1,25	1,59	1,99	3,64	183,77	0,18				1,147	0,0045	0,0058
C 14	1,12	1,46	1,86	2,33	4,26	157,00	0,16				1,343	0,0057	0,0073
C 16	1,31	1,71	2,17	2,73	4,99	134,11	0,13	1,572	0,0072	0,0093			
C 18	1,53	2,00	2,54	3,19	5,84	114,58	0,11	3,300	121,180	0,130	1,840	0,0091	0,0118
C 22	1,80	2,34	2,98	3,74	6,84	97,866	0,098	3,300	104,466	0,110	2,154	0,0115	0,0149
C 25	2,10	2,74	3,49	4,37	8,01	83,617	0,084	3,300	90,217	0,110	2,521	0,0145	0,0189
C 30	2,46	3,21	4,08	5,12	9,37	71,425	0,071	3,300	78,025	0,095	2,952	0,0184	0,0239
C 35	2,88	3,76	4,78	5,99	11,0	61,036	0,061	3,300	67,636	0,095	3,454	0,0233	0,0303
C 40	3,38	4,41	5,61	7,03	12,9	51,994	0,052	2,540	57,074	0,095	4,055	0,0296	0,0385
C 48	3,95	5,16	6,56	8,23	15,1	44,450	0,044	2,540	49,530	0,080	4,743	0,0375	0,0488
C 56	4,61	6,02	7,65	9,60	17,6	38,100	0,038	2,030	42,160	0,080	5,534	0,0473	0,0614
C 65	5,40	7,05	8,96	11,2	20,6	32,537	0,033	2,030	36,597	0,080	6,480	0,0599	0,0779
C 76	6,32	8,26	10,5	13,2	24,1	27,788	0,028	1,650	31,088	0,080	7,587	0,0759	0,0987
C 89	7,37	9,63	12,2	15,3	28,1	23,825	0,024	1,650	27,125	0,065	8,850	0,0956	0,124
C 104	8,68	11,3	14,4	18,1	33,1	20,244	0,020	1,270	22,784	0,065	10,41	0,122	0,159
C 120	10,1	13,1	16,7	20,9	38,3	17,475	0,017	1,270	20,015	0,065	12,07	0,152	
C 140	11,6	15,2	19,3	24,2	44,4	15,088	0,015	1,015	17,118	0,055	13,97	0,190	
C 165	13,8	18,1	22,9	28,8	52,7	12,700	0,013	1,015	14,730	0,055	16,60	0,246	
C 190	15,8	20,6	26,2	32,9	60,2	11,125	0,010	1,015	13,155	0,050	18,95	0,300	
C 220	18,4	24,1	30,6	38,4	70,3	9,5250	0,010	0,760	11,045	0,050	22,14	0,378	
C 255	21,1	27,5	35,0	43,9	80,4	8,3312	0,0076	0,760	9,851	0,050	25,31	0,462	
C 290	24,6	32,2	40,8	51,2	93,8	7,1374	0,0076	0,760	8,657	0,050	29,54	0,583	
C 330	27,7	36,1	45,9	57,6	105	6,3500	0,0076	0,510	7,370	0,050	33,20	0,695	
C 380	31,6	41,3	52,4	65,7	120	5,5626	0,0076	0,510	6,583	0,050	37,90	0,847	
C 430	36,8	48,1	61,0	76,6	140	4,7752	0,0076	0,510	5,795	0,050	44,15	1,07	
C 495	40,2	52,5	66,7	83,7	153	4,3688	0,0076	0,510	5,389	0,050	48,26	1,22	
C 580	49,1	64,1	81,4	102	187	3,5814	0,0076	0,510	4,601	0,050	58,87	1,64	
C 660	55,3	72,3	91,8	115	211	3,1750	0,0076	0,380	3,935	0,050	66,41	1,96	
C 765	63,5	82,9	105	132	242	2,7686	0,0076	0,380	3,529	0,050	76,15	2,41	
C 890	73,6	96,1	122	153	280	2,3876	0,0076	0,380	3,148	0,050	88,31	3,01	
C 1.04k	86,8	113	144	181	331	2,0244	0,0050	not specified			104,1	3,86	for subsequent study
C 1.2k	101	131	167	209	383	1,7475	0,0050				120,7	4,81	
C 1.4k	116	152	193	242	444	1,5088	0,0050				139,7	6,00	
C 1.65k	138	181	229	288	527	1,2700	0,0050				166,0	7,77	
C 1.9k	158	206	262	329	602	1,1125	0,0050				189,5	9,47	
C 2.2k	184	241	306	384	703	0,9525	0,0050				221,4	12,0	
C 2.55k	211	275	350	439	804	0,8331	0,0035				253,1	14,6	
C 2.9k	246	322	408	512	938	0,7137	0,0035				295,4	18,4	
C 3.3k	277	361	459	576	1050	0,6350	0,0035				332,0	22,0	
C 3.8k	316	413	524	657	1200	0,5563	0,0035				379,0	26,8	
C 4.3k	368	481	610	766	1400	0,4775	0,0035	441,5	33,7				
C 4.95k	402	525	667	837	1530	0,4369	0,0035	482,6	38,5				
C 5.8k	491	641	814	1020	1870	0,3581	0,0025	588,8	51,9				
C 6.6k	553	723	918	1150	2110	0,3175	0,0025	664,1	62,1				
C 7.65k	635	829	1050	1320	2420	0,2769	0,0025	761,4	76,3				
C 8.9k	736	961	1220	1530	2800	0,2388	0,0025	882,9	95,3				
C 10.4k	868	1130	1440	1810	3310	0,2024	0,0025	1042	122				
C 12k	1010	1310	1670	2090	3830	0,1748	0,0025	1206	152				
C 14k	1160	1520	1930	2420	4440	0,1509	0,0015	1397	190				
C 16.5k	1380	1810	2290	2880	5270	0,1270	0,0015	1660	246				
C 19k	1580	2060	2620	3290	6020	0,1113	0,0015	1894	299				
C 22k	1840	2410	3060	3840	7020	0,0953	0,0015	2212	378				
C 25.5k	2110	2750	3500	4390	8040	0,0833	0,0015	2531	462				
C 29k	2460	3210	4080	5120	9380	0,0714	0,0015	2953	583				

Table 2 – Circular waveguides (intermediate and preferred sizes)

Type designation	Inner diameter <i>D</i> in mm	Type designation	Inner diameter <i>D</i> in mm	Type designation	Inner diameter <i>D</i> in mm	Type designation	Inner diameter <i>D</i> in mm
60153 IEC-	Nominal value						
C 3.3	647,90	C 40	51,994	C 430	4,7752	C 4.3k	0,4775
C 3.43	623,00	C 42.7	50,000	C 457	4,6700	C 4.57k	0,4670
C 3.56	599,00	C 44.4	48,100	C 467	4,5700	C 4.67k	0,4570
C 3.71	576,00	C 46.2	46,200	C 478	4,4700	C 4.78k	0,4470
C 4	553,49	C 48	44,450	C 495	4,3688	C 4.95k	0,4369
C 4.01	532,00	C 49.9	42,800	C 512	4,1700	C 5.12k	0,4170
C 4.17	512,00	C 51.8	41,200	C 539	3,9600	C 5.39k	0,3960
C 4.34	492,00	C 53.9	39,600	C 568	3,7600	C 5.68k	0,3760
C 4.5	472,85	C 56	38,100	C 580	3,5814	C 5.8k	0,3581
C 4.69	455,00	C 58.3	36,600	C 613	3,4800	C 6.13k	0,3480
C 4.88	437,00	C 60.6	35,200	C 632	3,3800	C 6.32k	0,3380
C 5.08	420,00	C 63.2	33,800	C 651	3,2800	C 6.51k	0,3280
C 5.3	403,94	C 65	32,537	C 660	3,1750	C 6.6k	0,3175
C 5.50	388,00	C 68.2	31,300	C 696	3,0700	C 6.96k	0,3070
C 5.72	373,00	C 70.9	30,100	C 721	2,9600	C 7.21k	0,2960
C 5.95	359,00	C 73.9	28,900	C 746	2,8600	C 7.46k	0,2860
C 6.2	345,06	C 76	27,788	C 765	2,7686	C 7.65k	0,2769
C 6.43	332,00	C 80.0	26,700	C 799	2,6700	C 7.99k	0,2670
C 6.69	319,00	C 83.1	25,700	C 831	2,5700	C 8.31k	0,2570
C 6.95	307,00	C 86.1	24,800	C 876	2,4400	C 8.76k	0,2440
C 7	294,79	C 89	23,825	C 890	2,3876	C 8.9k	0,2388
C 7.54	283,00	C 93.2	22,900	C 932	2,2900	C 9.32k	0,2290
C 7.85	272,00	C 97.0	22,000	C 970	2,2000	C 9.7k	0,2200
C 7.99	262,00	C 101	21,100	C 1.01k	2,1100	C 10.1k	0,2110
C 8	251,84	C 104	20,244	C 1.04k	2,0244	C 10.4k	0,2024
C 8.82	242,00	C 109	19,500	C 1.09k	1,9500	C 10.9k	0,1950
C 9.16	233,00	C 114	18,800	C 1.14k	1,8800	C 11.4k	0,1880
C 9.53	224,00	C 118	18,150	C 1.18k	1,8150	C 11.8k	0,1815
C 10	215,14	C 120	17,475	C 1.2k	1,7475	C 12k	0,1748
C 10.3	207,00	C 127	16,850	C 1.27k	1,6850	C 12.7k	0,1685
C 10.7	199,00	C 129	16,250	C 1.29k	1,6250	C 12.9k	0,1625
C 11.2	191,00	C 136	15,650	C 1.36k	1,5650	C 13.6k	0,1565
C 12	183,77	C 140	15,088	C 1.4k	1,5088	C 14k	0,1509
C 12.1	176,50	C 148	14,450	C 1.48k	1,4450	C 14.8k	0,1445
C 12.6	170,00	C 154	13,850	C 1.54k	1,3850	C 15.4k	0,1385
C 13.1	163,50	C 161	13,250	C 1.61k	1,3250	C 16.1k	0,1325
C 14	157,00	C 165	12,700	C 1.65k	1,2700	C 16.5k	0,1270
C 14.1	151,00	C 174	12,300	C 1.74k	1,2300	C 17.4k	0,1230
C 14.7	145,00	C 179	11,900	C 1.79k	1,1900	C 17.9k	0,1190
C 15.3	139,50	C 186	11,500	C 1.86k	1,1500	C 18.6k	0,1150
C 16	134,11	C 190	11,125	C 1.9k	1,1125	C 19k	0,1113
C 16.5	129,00	C 198	10,760	C 1.98k	1,0760	C 19.8k	0,1076
C 17.2	124,00	C 207	10,300	C 2.07k	1,0300	C 20.7k	0,1030
C 17.9	119,00	C 219	9,7000	C 2.19k	0,9700	C 21.9k	0,0970
C 18	114,58	C 220	9,5250	C 2.2k	0,9525	C 22k	0,0953
C 19.4	110,00	C 232	9,2200	C 2.32k	0,9220	C 23.2k	0,0092
C 20.1	106,00	C 239	8,9200	C 2.39k	0,8920	C 23.9k	0,0892
C 20.9	102,00	C 248	8,6200	C 2.48k	0,8620	C 24.8k	0,0862
C 22	97,866	C 255	8,3312	C 2.55k	0,8331	C 25.5k	0,0833
C 22.7	94,000	C 266	8,0200	C 2.66k	0,8020	C 26.6k	0,0802
C 23.6	90,400	C 277	7,7200	C 2.77k	0,7720	C 27.7k	0,0772
C 24.5	87,000	C 288	7,4200	C 2.88k	0,7420	C 28.8k	0,0742
C 25	83,617	C 290	7,1374	C 2.9k	0,7137	C 29k	0,0714
C 26.6	80,400	C 308	6,9400	C 3.08k	0,6940		
C 27.7	77,200	C 317	6,7400	C 3.17k	0,6740		
C 28.7	74,400	C 327	6,5200	C 3.27k	0,6520		
C 30	71,425	C 330	6,3500	C 3.3k	0,6350		
C 31.1	68,600	C 348	6,1400	C 3.48k	0,6140		
C 32.3	66,000	C 359	5,9400	C 3.59k	0,5940		
C 33.7	63,400	C 372	5,7400	C 3.72k	0,5740		
C 35	61,036	C 380	5,5626	C 3.8k	0,5563		
C 36.4	58,600	C 398	5,3600	C 3.98k	0,5360		
C 37.8	56,400	C 414	5,1600	C 4.14k	0,5160		
C 39.4	54,200	C 429	4,9500	C 4.29k	0,4950		

5.2 Dimensions

5.2.1 Inner dimensions

5.2.1.1 Inner diameters and their tolerances

Table 1 specifies the nominal values and the tolerances of the inner diameters for the preferred sizes of circular waveguides. Table 2 specifies the nominal inner diameters for circular waveguides of intermediate and preferred sizes.

The inner diameter tolerances specified in Table 1 are based on the general principle given in Table 3.

Table 3 – Inner diameter tolerances

Range of sizes	Tolerance ±
C 3.3 to C 165	0,1 % of the nominal inner diameter
C 190 to C 220	0,010 mm
C 255 to C 890	0,007 6 mm
C 1.04k to C 2.2k	0,005 0 mm
C 2.55k to C 4.95k	0,003 5 mm
C 5.8k to C 12k	0,002 5 mm
C 14k to C 29k	0,001 5 mm
NOTE The smallest circular waveguide (C 29k) has the series' largest tolerance relative to its inner diameter (± 2,1 %) ⁶ .	

5.2.1.2 Ellipticity

The ellipticity E is defined as

$$E = \frac{D_{\max} - D_{\min}}{D}$$

where

D is the nominal inner diameter;

D_{\max} is the largest measured inner diameter; and

D_{\min} is the smallest measured inner diameter.

For waveguides from C 3.3 to C 165, the ellipticity E shall not exceed 0,1 %. For smaller waveguides, the requirement for ellipticity is for further study.

5.2.2 Wall thickness

The wall thickness t is defined as half the difference between the outer and the inner diameter. The nominal values are specified in Table 1.

⁶ This relative tolerance agrees well with that of the smallest ordinary rectangular waveguide (60153 IEC-R 26k), which has approximately the same centre frequency as the 60153 IEC-C 29k. For the R 26k waveguide, the relative width tolerance is ± 2 %, which is also the largest value in its series.