Wireless Communications Standards

DIGITAL CELLULAR STANDARDS

	5G NR	LTE/LTE-Advanced/ LTE-Advanced Pro	LTE-M	NB-IoT	LTE D2D	WCDMA/HSPA/HSPA+
Frequency range	**3GPP Release 15:** FR 1: 0.45 GHz to 6 GHz FR 2: 24.25 GHz to 52.6 GHz **Sub-6 GHz Bands** (in MHz) **1)** FDD UL: 1920 to 1980 DL: 2110 to 2170 **2)** FDD UL: 1850 to 1910 DL: 1930 to 1990 **3)** FDD UL: 1710 to 1785 DL: 1805 to 1880 **5)** FDD UL: 824 to 849 DL: 869 to 894 **7)** FDD UL: 2500 to 2570 DL: 2620 to 2690 **8)** FDD UL: 880 to 915 DL: 925 to 960 **20)** FDD UL: 832 to 862 DL: 791 to 821 **28)** FDD UL: 703 to 748 DL: 758 to 803 **38)** TDD UL, DL: 2570 to 2620 **41)** TDD UL, DL: 2496 to 2690 **50)** TDD UL, DL: 1432 to 1517 **51)** TDD UL, DL: 1427 to 1432 **66)** FDD UL: 1710 to 1780 DL: 2110 to 2200 **70)** FDD UL: 1695 to 1710 DL: 1995 to 2020 **71)** FDD UL: 663 to 698 DL: 617 to 652 **74)** FDD UL: 1427 to 1470 DL: 1475 to 1518 **75)** SDL UL: - DL: 1432 to 1517 **76)** SDL UL: - DL: 1427 to 1432 **77)** TDD UL, DL: 3300 to 4200 **78)** TDD UL, DL: 3300 to 3800 **79)** TDD UL, DL: 4400 to 5000 **80)** SUL UL: 1710 to 1785 DL: - **81)** SUL UL: 880 to 915 DL: - **82)** SUL UL: 832 to 862 DL: - **83)** SUL UL: 703 to 748 DL: - **84)** SUL UL: 1920 to 1980 DL: - **mmWave Bands (in GHz)** **257)** TDD UL, DL: 26.5 to 29.5 **258)** TDD UL, DL: 24.25 to 27.5 **260)** TDD UL, DL: 37 to 40	**E-UTRA FDD and TDD Bands** (in MHz) **1)** FDD UL: 1920 to 1980 DL: 2110 to 2170 (LTE-M, NB-IoT) **2)** FDD UL: 1850 to 1910 DL: 1930 to 1990 (LTE-M, NB-IoT) **3)** FDD UL: 1710 to 1785 DL: 1805 to 1880 (LTE-M, NB-IoT) **4)** FDD UL: 1710 to 1755 DL: 2110 to 2155 (LTE-M) **5)** FDD UL: 824 to 849 DL: 869 to 894 (LTE-M, NB-IoT) **6)** FDD UL: 830 to 840 DL: 875 to 885 **7)** FDD UL: 2500 to 2570 DL: 2620 to 2690 (LTE-M) **8)** FDD UL: 880 to 915 DL: 925 to 960 (LTE-M, NB-IoT) **9)** FDD UL: 1749.9 to 1784.9 DL: 1844.9 to 1879.9 **10)** FDD UL: 1710 to 1770 DL: 2110 to 2170 **11)** FDD UL: 1427.9 to 1447.9 DL: 1475.9 to 1495.9 (LTE-M) **12)** FDD UL: 699 to 716 DL: 729 to 746 (LTE-M, NB-IoT) **13)** FDD UL: 777 to 787 DL: 746 to 756 (LTE-M, NB-IoT) **14)** FDD UL: 788 to 798 DL: 758 to 768 **15)** FDD UL: 1900 to 1920 DL: 2600 to 2620 (Europe only) **16)** FDD UL: 2010 to 2025 DL: 2585 to 2600 (Europe only) **17)** FDD UL: 704 to 716 DL: 734 to 746 (NB-IoT) **18)** FDD UL: 815 to 830 DL: 860 to 875 (LTE-M, NB-IoT) **19)** FDD UL: 830 to 845 DL: 875 to 890 (LTE-M, NB-IoT) **20)** FDD UL: 832 to 862 DL: 791 to 821 (LTE-M, NB-IoT) **21)** FDD UL: 1447.9 to 1462.9 DL: 1495.9 to 1510.9 (LTE-M) **22)** FDD UL: 3410 to 3490 DL: 3510 to 3590 **23)** FDD UL: 2000 to 2020 DL: 2180 to 2200 **24)** FDD UL: 1626.5 to 1660.5 DL: 1525 to 1559 **25)** FDD UL: 1850 to 1915 DL: 1930 to 1995 (LTE-M, NB-IoT) **26)** FDD UL: 814 to 849 DL: 859 to 894 (LTE-M, NB-IoT) **27)** FDD UL: 807 to 824 DL: 852 to 869 (LTE-M) **28)** FDD UL: 703 to 748 DL: 758 to 803 (LTE-M, NB-IoT) **29)** FDD UL: – DL: 717 to 728 **30)** FDD UL: 2305 to 2315 DL: 2350 to 2360 **31)** FDD UL: 452.5 to 457.5 DL: 462.5 to 467.5 (LTE-M, NB-IoT) **32)** FDD UL: – DL: 1452 to 1496 **33)** TDD UL, DL: 1900 to 1920 **34)** TDD UL, DL: 2010 to 2025 **35)** TDD UL, DL: 1850 to 1910 **36)** TDD UL, DL: 1930 to 1990 **37)** TDD UL, DL: 1910 to 1930 **38)** TDD UL, DL: 2570 to 2620 **39)** TDD UL, DL: 1880 to 1920 (LTE-M) **40)** TDD UL, DL: 2300 to 2400 (LTE-M) **41)** TDD UL, DL: 2496 to 2690 (LTE-M) **42)** TDD UL, DL: 3400 to 3600 **43)** TDD UL, DL: 3600 to 3800 **44)** TDD UL, DL: 703 to 803 **45)** TDD UL, DL: 1447 to 1467 **46)** TDD UL, DL: 5150 to 5925 **47)** TDD UL, DL: 5855 to 5925 **48)** TDD UL, DL: 3550 to 3700 **50)** TDD UL, DL: 1432 to 1517 **51)** TDD UL, DL: 1427 to 1432 **65)** FDD UL: 1920 to 2010 DL: 2110 to 2200 **66)** FDD UL: 1710 to 1780 DL: 2110 to 2200 (NB-IoT) **67)** FDD UL: – DL: 738 to 758 **68)** FDD UL: 698 to 728 DL: 753 to 783 **69)** FDD UL: – DL: 2570 to 2620 **70)** FDD UL: 1695 to 1710 DL: 1995 to 2020 (NB-IoT) **71)** FDD UL: 663 to 698 DL: 617 to 652 **72)** FDD UL: 451 to 456 DL: 461 to 466 **74)** FDD UL: 1427 to 1470 DL: 1475 to 1518 **75)** FDD UL: – DL: 1432 to 1517 **76)** FDD UL: – DL: 1427 to 1432			**Bands** (in MHz) **E-UTRA Bands** **2)** UL, DL: 1850 to 1910 **3)** UL, DL: 1710 to 1785 **4)** UL, DL: 1710 to 1755 **7)** UL, DL: 2500 to 2570 **14)** UL, DL: 788 to 798 **20)** UL, DL: 832 to 862 **26)** UL, DL: 814 to 849 **28)** UL, DL: 703 to 748 **31)** UL, DL: 452.5 to 457.5 **41)** UL, DL: 2496 to 2690 **68)** UL, DL: 698 to 728 **72)** UL, DL: 451 to 456	**UTRA FDD Bands (in MHz)** **1)** UL: 1920 to 1980 DL: 2110 to 2170 **2)** UL: 1850 to 1910 DL: 1930 to 1990 **3)** UL: 1710 to 1785 DL: 1805 to 1880 **4)** UL: 1710 to 1755 DL: 2110 to 2155 **5)** UL: 824 to 849 DL: 869 to 894 **6)** UL: 830 to 840 DL: 875 to 885 **7)** UL: 2500 to 2570 DL: 2620 to 2690 **8)** UL: 880 to 915 DL: 925 to 960 **9)** UL: 1749.9 to 1784.9 DL: 1844.9 to 1879.9 **10)** UL: 1710 to 1770 DL: 2110 to 2170 **11)** UL: 1427.9 to 1447.9 DL: 1475.9 to 1495.9 **12)** UL: 699 to 716 DL: 729 to 746 **13)** UL: 777 to 787 DL: 746 to 756 **14)** UL: 788 to 798 DL: 758 to 768 **19)** UL: 830 to 845 DL: 875 to 890 **20)** UL: 832 to 862 DL: 791 to 821 **21)** UL: 1447.9 to 1462.9 DL: 1495.9 to 1510.9 **22)** UL: 3410 to 3490 DL: 3510 to 3590 **25)** UL: 1850 to 1915 DL: 1930 to 1995 **26)** UL: 814 to 849 DL: 859 to 894 **27)** UL: – DL: 1452 to 1496
Modulation type	up to 256QAM (DL, UL)	QPSK, 16QAM, 64QAM, 256QAM (DL) QPSK, 16QAM, 64QAM, 256QAM in preparation (UL)	QPSK, 16QAM	BPSK, QPSK	QPSK (discovery) QPSK, 16QAM (communication)	QPSK (DL) 16QAM (DL, HSDPA) 64QAM (DL, HSPA+) Dual BPSK (UL) 16QAM, 64QAM (UL, HSPA+)
Transmission method/ multiple access	CP-OFDM (DL); CP-OFDM, DFT-s-OFDM (UL)	OFDMA (DL) localized SC-FDMA (UL, LTE Rel. 8) localized and distributed SC-FDMA (UL, LTE Rel.10)	OFDMA (DL); localized SC-FDMA (UL, LTE Rel.8) localized and distributed SC-FDMA (UL, LTE Rel.10)	OFDMA (DL) SC-FDMA (UL)	SC-FDMA	WCDMA
Duplex	Dynamic TDD; FDD	FDD, TDD	FDD, TDD	FDD	TDD	FDD
Channel bandwidth	**Network operators:** 100 MHz per CC, max. 800 MHz (8CC) **3GPP:** max. 100 MHz/CC (Sub-6 GHz) max. 400 MHz/CC (mmWave)	Scalable to 20 MHz LTE-A: up to 100 MHz (max. 5 carrier × 20 MHz) LTE-A Pro: up to 640 MHz (max. 32 carrier × 20 MHz) LTE M1: 1.4 MHz	Cat-M1: 1.4 MHz Cat-M2: 5.0 MHz	180 kHz	Scalable to 20 MHz LTE-A: up to 100 MHz (max. 5 carrier × 20 MHz)	5 MHz (WCDMA/HSPA) 10 MHz (HSPA+(DC-HSPA)) 20 MHz (HSPA+(four carrier HSDPA)) 40 MHz (HSPA+(eight carrier HSDPA))
Peak data rate	>20 Gbit/s (DL)	300 Mbit/s (DL, Rel.8, 20 MHz, 4x4 MIMO, UE Cat.5) 75 Mbit/s (UL, Rel.8, 20 MHz, 64QAM, UE Cat.5) 3 Gbit/s (DL, LTE-A, 100 MHz, 8x8 MIMO, UE Cat.8) 1.5 Gbit/s (UL, LTE-A, 100 MHz, 4x4 MIMO, UE Cat.8) 25 Gbit/s (DL, LTE-A Pro, 100 MHz, 8x8 MIMO, UE Cat.17) 9.5 Gbit/s (UL, LTE-A Pro, 100 MHz, UE Cat.14) 1 Mbit/s (DL, UL, LTE M1)	1 Mbit/s (DL, UL, Cat-M1) 2 Mbit/s (DL, UL, Cat-M2)	250 kbit/s	11.6 Mbit/s (discovery) 25 Mbit/s (communication)	384 kbit/s (DL, UL) 14.4 Mbit/s (DL, HSDPA) 5.76 Mbit/s (UL, HSUPA) 28 Mbit/s (DL, HSPA+, 16QAM, MIMO) 84.4 Mbit/s (DL, HSPA+, 64QAM, MIMO, DC) 168 Mbit/s (DL, HSPA+, 64QAM, MIMO, 4C) 337 Mbit/s (DL, HSPA+, 64QAM, MIMO, 8C) 11.5 Mbit/s (UL, HSPA+, 16QAM) 23 Mbit/s (UL, HSPA+, 16QAM, DC) 34 Mbit/s (UL, HSPA+, 64QAM)
Standardization forums	www.3gpp.org	www.3gpp.org www.globalcertificationforum.org www.ptcrb.com				

	TD-SCDMA LCR TDD	GSM/GPRS/EDGE/ EDGE Evolution/VAMOS	CDMA2000® 1xEV-DO Release 0/Revision A/ Revision B	CDMA2000® 1xRTT/ 1xAdvanced	WiMAX™/ WiMAX™ Advanced IEEE 802.16-2012/ IEEE 802.16m
Frequency range	**UTRA Bands** (in MHz) **33)** 1900 to 1920 **34)** 2010 to 2025 **35)** 1850 to 1910 **36)** 1930 to 1990 **37)** 1910 to 1930 **38)** 2570 to 2620 **39)** 1880 to 1920 **40)** 2300 to 2400	**Bands** (in MHz) **T-GSM 380** UL: 380.2 to 389.8 DL: 390.2 to 399.8 **T-GSM 410** UL: 410.2 to 419.8 DL: 420.2 to 429.8 **GSM 450** UL: 450.4 to 457.6 DL: 460.4 to 467.6 **GSM 480** UL: 478.8 to 486 DL: 488.8 to 496 **GSM 710** UL: 698 to 716 DL: 728 to 746 **GSM 750** UL: 777 to 793 DL: 747 to 763 **T-GSM 810** UL: 806 to 821 DL: 851 to 866 **GSM 850** UL: 824 to 849 DL: 869 to 894 **P-GSM 900** UL: 890 to 915 DL: 935 to 960 **E-GSM 900** UL: 880 to 915 DL: 925 to 960 **R-GSM 900** UL: 876 to 915 DL: 921 to 960 **DCS 1800** UL: 1710 to 1785 DL: 1805 to 1880 **PCS 1900** UL: 1850 to 1910 DL: 1930 to 1990 **ER-GSM 900** UL: 873 to 915 DL: 918 to 960	**Band Classes** (in MHz) **BC0)** RL: 815 to 849 FL: 860 to 894 **BC1)** RL: 1850 to 1910 FL: 1930 to 1990 **BC2)** RL: 872 to 915 FL: 917 to 960 **BC3)** RL: 887 to 925 FL: 832 to 870 **BC4)** RL: 1750 to 1780 FL: 1840 to 1870 **BC5)** RL: 410 to 483 FL: 420 to 493 **BC6)** RL: 1920 to 1980 FL: 2110 to 2170 **BC7)** RL: 776 to 788 FL: 746 to 758 **BC8)** RL: 1710 to 1785 FL: 1805 to 1880 **BC9)** RL: 880 to 915 FL: 925 to 960 **BC10)** RL: 806 to 901 FL: 851 to 940 **BC11)** RL: 410 to 483 FL: 420 to 493 **BC12)** RL: 870 to 876 FL: 915 to 921 **BC13)** RL: 2500 to 2570 FL: 2620 to 2690 **BC14)** RL: 1850 to 1915 FL: 1930 to 1995 **BC15)** RL: 1710 to 1755 FL: 2110 to 2155 **BC16)** RL: 2502 to 2568 FL: 2624 to 2690 **BC17)** FL: 2624 to 2690, 1xEV-DO only **BC18)** RL: 787 to 799 FL: 757 to 769 **BC19)** RL: 698 to 716 FL: 728 to 746 **BC20)** RL: 1626 to 1660 FL: 1525 to 1559 **BC21)** RL: 2000 to 2020 FL: 2180 to 2200		**Profiles for WiMAX™** (in MHz) **M2300T-01/02** 2300 to 2400 **M2500T-01** 2496 to 2690 **M3500T-02/03/05** 3400 to 3600 Targeted for WiMAX™Advanced: **UTRA/TDD Bands**
Modulation type	QPSK, 8PSK 16QAM (HSPA) 64QAM (HSPA+)	GMSK 8PSK (EDGE) QPSK, 16QAM, 32QAM (EDGE Evolution) AQPSK (VAMOS)	QPSK, 8PSK, 16QAM (FL) 64QAM (FL, Rev. B) BPSK, QPSK, 8PSK (RL)	QPSK (FL) HPSK, OQPSK (RL)	BPSK, QPSK, 16QAM, 64QAM
Transmission method/ multiple access	TD-SCDMA, FDMA	TDMA, FDMA	TDMA (FL) CDMA (RL)	CDMA	OFDM (256) (16-2012 only) SOFDMA (128, 256, 512, 1024, 2048)
Duplex	TDD	FDD	FDD	FDD	TDD, FDD/HFDD
Channel bandwidth	1.6 MHz	200 kHz (GSM/EDGE) 400 kHz (EDGE Evolution)	1.25 MHz (Rel. 0/Rev. A) 1.25 MHz x N (Rev. B) (N = number of channels, max. 15)	1.25 MHz	16-2012: 5 MHz, 7 MHz, 8.75 MHz, 10 MHz 16m: 5 MHz to 20 MHz optionally 40 MHz
Peak data rate	2.8 Mbit/s (DL, HSDPA) 2.2 Mbit/s (UL, HSUPA) 8.4 Mbit/s (DL, HSPA+) 2.2 Mbit/s (UL, HSPA+)	14.4 kbit/s (GSM) 171.2 kbit/s (DL, 8 slots, GPRS) 128.4 kbit/s (UL, 6 slots, GPRS) 473.6 kbit/s (DL, 8 slots, EDGE) 355.2 kbit/s (UL, 6 slots, EDGE) 1.89 Mbit/s (DL, 8 slots, EGPRS2-B and DL DC) 710 kbit/s (UL, 6 slots, EGPRS2-B)	2.4 Mbit/s (FL, Rel. 0) 153 kbit/s (RL, Rel. 0) 3.1 Mbit/s (FL, Rev. A) 1.8 Mbit/s (RL, Rev. A) 4.9 Mbit/s x N (FL, Rev. B) 1.8 Mbit/s x N (RL, Rev. B) (N = number of channels, max. 15)	153.6 kbit/s (Rel. 0) 307.7 kbit/s (Rev. E)	16-2012: 128 Mbit/s (DL, 20 MHz, 2x2 MIMO) 56 Mbit/s (UL, 20 MHz, 2x2 MIMO) 16m: 300 Mbit/s (DL, 20 MHz, 4x4 MIMO) 135 Mbit/s (UL, 20 MHz, 2x4 MIMO)
Standardization forums			www.3gpp2.org www.globalccf.org		www.ieee802.org/16 www.wimaxforum.org

PUBLIC SAFETY STANDARDS / LPWAN

	TETRA TETRA 2 (TEDS)	Tetrapol	Project 25 APCO-25	SIGFOX	LoRaWAN
Frequency range	**Bands** (in MHz) UL: 351 to 356 DL: 361 to 366 UL: 380 to 390 DL: 390 to 400 UL: 410 to 420 DL: 420 to 430 UL: 450 to 460 DL: 460 to 470 UL: 806 to 825 DL: 851 to 870	**Band** (in MHz) 70 to 520	**Bands** (in MHz) **VHF:** 136 to 174 **UHF:** 380 to 470 **UHF:** 450 to 512 **700/800:** 764 to 870	**Bands** (in MHz) **RC1 (e.g. Europe):** 868.0 to 868.6 **RC2 (e.g. North America):** 902.1375 to 904.6625 **RC3 (e.g. Japan):** 920.5 to 929.7 **RC4 (e.g. Australia):** 920.1375 to 922.6625 **RC5:** 920.8 to 923.4	**Bands** (in MHz) **Europe:** 863 to 870 433 **North America:** 902 to 928 **China:** 779 to 787 470 to 510 **Australia:** 915 to 928 **Asia:** 923 **South Korea:** 920 to 923 **India:** 865 to 867
Modulation type	π/4-DQPSK π/8-D8PSK, 4QAM, 16QAM, 64QAM (TEDS)	GMSK	C4FM, CQPSK	GFSK (DL) DBPSK (UL)	LoRa™, GFSK (Europe) LoRa™ (US)
Transmission method/ multiple access	TDMA	FDMA	FDMA (Phase 1) TDMA (Phase 2)	UNB	CSS
Duplex	FDD	FDD	FDD	TDD/FDD	TDD/FDD
Channel bandwidth	25 kHz; 25 kHz, 50 kHz, 100 kHz, 150 kHz (TEDS)	10 kHz, 12.5 kHz	12.5 kHz (Phase 1) 6.25 kHz (Phase 2)	600 Hz (DL) 100 Hz (UL, Europe) 600 Hz (UL, North America)	125 kHz, 250 kHz, 500 kHz
Peak data rate	36 kbit/s 691.2 kbit/s (TEDS)	7.2 kbit/s	9.4 kbit/s	600 bit/s (DL) 100 bit/s (UL, Europe) 600 bit/s (UL, North America)	0.3 kbit/s to 50 kbit/s
Standardization forums	www.etsi.org www.tetra-association.com	www.tetrapol.com	www.project25.org www.tiaonline.org	www.sigfox.com	www.lora-alliance.org

WIRELESS CONNECTIVITY

	WLAN/Wi-Fi IEEE 802.11a, b, g, n, p, ac, ax*	WLAN/Wi-Fi HaLow™ IEEE 802.11ah	WLAN/Wi-Fi IEEE 802.11ad, aj*, ay*	Bluetooth®	LR-WPAN ZigBee/Thread/ 6LoWPAN IEEE 802.15.4	NFC, RFID ISO/IEC 18000, NFC Analog Specification	DECT, ULE
Frequency range	**Bands** (in MHz) **11b, g, n, ax:** 2400 to 2497 **11a, n, ac, ax:** 5150 to 5250 5250 to 5350 (DFS required) 5470 to 5725 (DFS required) 5725 to 5850 **11p:** 5850 to 5925 **11p, Japan:** 755 to 765	**Bands** (in MHz) **Europe:** 863 to 868 **US:** 902 to 928 **Japan:** 916.5 to 927.5 **South Korea:** 917.5 to 923.5 **China:** 755 to 787 **Singapore:** 866 to 869 920 to 925	**Bands** (in GHz) **11ad, ay:** **Europe:** 57 to 66 **US:** 57 to 71 **South Korea:** 57 to 64 **Japan:** 57 to 66 **Australia:** 59.4 to 62.9 **China:** 59 to 64 **11aj China:** 42.3 to 48.4 59 to 64	**Band** (in MHz) 2400 to 2483.5	**Bands** (in MHz) 169.4 to 169.475 250 to 750 779 to 787 863 to 879 896 to 960 1427 to 1518 2360 to 2483.5 3244 to 4742 5944 to 10234 **ZigBee 3.0, Thread, 6LoWPAN:** 2360 to 2483.5	125 kHz to 134 kHz 6.7 MHz 13.56 MHz **(NFC)** 27 MHz 433 MHz **Europe:** 865 MHz to 868 MHz **North America:** 902 MHz to 928 MHz 2.45 GHz 5.8 GHz 24.125 GHz	**Bands** (in MHz) **World:** 1900 to 1920 1910 to 1930 **Europe:** 1880 to 1900 **US:** 1920 to 1930
Modulation type	BPSK, QPSK, 16QAM, 64QAM (11a, g, n, p, ac, ax) 256QAM (11ac, ax) 1024QAM (11ax) DBPSK, DQPSK, CCK, PBCC (11b, g)	BPSK, QPSK, 16QAM, 64QAM, 256QAM	SQPSK, QPSK, 16QAM, 64QAM (OFDM), π/2-BPSK, π/2-QPSK, π/2-16QAM (SC) π/2-64QAM (SC, 11aj) 8-PSK (SC, 11ay)	GFSK (BR,LE) GFSK (EDR, Header) π/4-DQPSK, 8DPSK (EDR, Payload)	BPSK, ASK, OQPSK, GFSK, BPM, DQPSK, MPSK, MSK, MR-FSK; OQPSK (ZigBee 3.0, Thread, 6LoWPAN)	FSK, ASK, PSK, PJM, BPSK dependent on standard	GFSK
Transmission method/ multiple access	OFDM, CSMA/CA DL MU-MIMO (11ac, ax) UL MU-MIMO (11ax) OFDMA (11ax)	OFDM, CSMA/CA, CCA	OFDM, CSMA/CA DL MU-MIMO (11ay)	FHSS	DSSS, PSSS, CSMA/CA, UWB, CSS, OFDM; DSSS, CSMA/CA (ZigBee 3.0, Thread, 6LoWPAN)	TDMA, FDMA	FDMA, TDMA
Duplex	TDD	TDD	TDD	TDD	TDD	TDD	TDD
Channel bandwidth	10 MHz (11p) 20 MHz (11a, g, n, ac, ax) 22 MHz (11b) 40 MHz (11n, ac, ax) 80 MHz, 160 MHz (11ac, ax)	1 MHz, 2 MHz (mandatory) 4 MHz, 8 MHz, 16 MHz (optional)	540 MHz (11aj) 1.08 GHz (11aj) 2.16 GHz (11ad,ay) 4.32 GHz (11ay) 8.64 GHz (11ay)	Channel spacing: 1 MHz (BR, EDR) 2 MHz (LE)	600 kHz, 1 MHz, 2 MHz, 499.2 MHz, 1081.6 MHz, 1331.2 MHz, 1354.97 MHz dependent on standard; 2 MHz (ZigBee 3.0, Thread, 6LoWPAN)	typ. 200 kHz/500 kHz	1.728 MHz
Peak data rate	11 Mbit/s (11b) 27 Mbit/s (11p) 54 Mbit/s (11a, g) 600 Mbit/s (11n, 40 MHz, 4 spatial streams) 6.933 Gbit/s (11ac, 160 MHz, 8 spatial streams) 9.607 Gbit/s (11ax, 160 MHz, 8 spatial streams)	346.667 Mbit/s (16 MHz, 4x4 MIMO, short GI)	8.085 Gbit/s (SC, 11ad) 6.756 Gbit/s (OFDM, 11ad) 15 Gbit/s (11aj, 1.08 GHz, 4 spatial streams, short GI) 20 Gbit/s to 40 Gbit/s (11ay)	1 Mbit/s (BR) 2 Mbit/s (LE) 3 Mbit/s (EDR)	40 kbit/s, 100 kbit/s, 250 kbit/s, 1000 kbit/s dependent on standard; 250 kbit/s (ZigBee 3.0, Thread, 6LoWPAN)	106 kbit/s 212 kbit/s 424 kbit/s 848 kbit/s dependent on standard	1 Mbit/s
Standardization forums	www.ieee802.org/11 www.wi-fi.org			www.bluetooth.org	www.ieee802.org/15 www.zigbee.org www.wi-sun.org	www.iso.org www.nfc-forum.org	www.dect.org www.etsi.org www.ulealliance.org

GNSS

	GPS USA (global)	Galileo EU (global)	GLONASS Russia (global)	BeiDou China (global)	QZSS Japan (regional)	IRNSS India (regional)
Frequency range	**L1-C/A, L1C, P(Y), M:** 1575.42 MHz **L2, L2C:** 1227.60 MHz **L5:** 1176.45 MHz	**E1:** 1575.42 MHz **E5:** 1191.795 MHz **E5a:** 1176.45 MHz **E5b:** 1207.14 MHz **E6:** 1278.75 MHz	**L1OF, L1SF (FDMA):** 1602 MHz + n × 0.5625 MHz **L1OC, L1SC (CDMA):** 1600.996 MHz **L2OF, L2SF (FDMA):** 1246 MHz + n × 0.4375 MHz **L2OC, L2SC (CDMA):** 1248.06 MHz **L3 (CDMA):** 1202.025 MHz	**B1:** 1575.42 MHz **B2:** 1191.79 MHz **B3:** 1268.52 MHz	**L1-C/A, L1C, L1-SAIF:** 1575.42 MHz **L2C:** 1227.60 MHz **L5:** 1176.45 MHz **L6:** 1278.75 MHz **S-band:** 2 GHz band	**L5:** 1176.45 MHz **S:** 2492.028 MHz
Modulation type	TMBOC(6,1,1/11) (L1C) BPSK, (L1-C/A)	CBOC(6,1) BPSK (E6)	BPSK (L1, L2) QPSK (L3)	MBOC(6,1,1/11) AltBOC(15,10) QPSK(10) BOC(15,2,5)	BOC(1,1) (L1C) BPSK	BOC(5,2) BPSK
Transmission method/ multiple access	CDMA	CDMA	FDMA (L1, L2) CDMA (L1, L2 L3)	CDMA	CDMA	CDMA
Duplex						
Channel bandwidth	20.46 MHz	24.552 MHz (E1) 51.15 MHz (E5) 20.46 MHz (E5a) 20.46 MHz (E5b) 40.92 MHz (E6)	562.5 kHz (L1) 473.5 kHz (L2) 20.46 MHz (L3) per satellite	16 MHz (B1) 36 MHz (B2)	24 MHz (L1, L2) 24.9 MHz (L5) 39 MHz (L6)	24 MHz (L5) 16.5 MHz (S)
Peak data rate	50 bit/s	250 sps (E1) 50 sps (E5a) 250 sps (E5b) 1000 sps (E6)	50 bit/s	25/50/100/ 500 bit/s	50 bit/s (L1, L2, L5) 250 bit/s (L1-SAIF) 2000 bit/s (L6)	50 bit/s /100 sps
Standardization forums	www.gps.gov	www.gsa.europa.eu	www.glonass-ianc.rsa.ru	www.beidou.gov.cn	http://qzss.go.jp/	irnss.isro.gov.in/

Glossary:
1xEV-DO = Single Carrier EV-DO; **1xRTT** = Single Carrier Radio Transmission Technology; **4C** = Four Carrier; **AltBOC** = Alternative BOC; **AQPSK** = Adaptive QPSK; **ASK** = Amplitude Shift Keying; **AWS** = Advanced Wireless Services; **BOC** = Binary Offset Carrier; **BPM** = Burst Position Modulation; **BPSK** = Binary PSK; **BR** = Basic Rate; **C4FM** = Continuous 4 Level FM; **CBOC** = Composite BOC; **CC** = Component Carrier; **CCA** = Clear Channel Assessment; **CCK** = Complementary Code Keying; **CDMA** = Code Division Multiple Access; **CP-OFDM** = Cyclic Prefix OFDM; **CQPSK** = Compatible QPSK; **CS** = Carrier Sense; **CSMA/CA** = Carrier Sense Multiple Access with Collision Avoidance; **CSS** = Chirp Spread Spectrum; **D2D** = Device to Device; **D8PSK** = Differential 8PSK; **DBPSK** = Differential BPSK; **DC** = Dual Carrier; **DCS** = Digital Cellular System; **DECT** = Digital Enhanced Cordless Telecommunication; **DFS** = Dynamic Frequency Selection; **DFT-s-OFDM** = Discrete Fourier Transform-spread-OFDM; **DL** = Downlink; **DPSK** = Differential PSK; **DQPSK** = Differential QPSK; **DSSS** = Direct Sequence Spread Spectrum; **E-GSM** = Extended GSM; **E-UTRA** = Evolved UTRA; **EDGE** = Enhanced Data Rates for GSM Evolution; **EDR** = Enhanced Data Rate; **EGPRS2** = Enhanced GPRS Phase 2; **EV-DO** = Evolution – Data Optimized; **FDD** = Frequency Division Duplex; **FDMA** = Frequency Division Multiple Access; **FHSS** = Frequency Hopping Spread Spectrum; **FL** = Forward Link; **FR** = Frequency Range; **FSK** = Frequency Shift Keying; **GFSK** = Gaussian FSK; **GI** = Guard Interval; **GLONASS** = Global Navigation Satellite System; **GMSK** = Gaussian Minimum Shift Keying; **GNSS** = Global Navigation Satellite System; **GPRS** = General Packet Radio Service; **GPS** = Global Positioning System; **GSM** = Global System for Mobile Communications; **HD** = High Definition; **HFDD** = Hybrid FDD; **HPSK** = Hybrid PSK; **HS(D/U)PA** = High Speed (Downlink/Uplink) Packet Access; **IEC** = International Electrotechnical Commission; **IEEE** = Institute of Electrical and Electronics Engineers; **IMT** = International Mobile Telecommunications; **IRNSS** = Indian Regional Navigation Satellite System; **ISO** = International Organization for Standardization; **JTACS** = Japan TACS; **LCR** = Low Chip Rate; **LE** = Low Energy; **LoRaWAN** = Low Range Wide Area Network; **LPWAN** = Low Power Wide Area Network; **LR-WPAN** = Low Rate WPAN; **LTE** = Long Term Evolution; **LTE-M** = LTE-MTC; **MBOC** = Multiplexed BOC; **MIMO** = Multiple Input Multiple Output; **MPSK** = M-ary PSK; **MR-FSK** = Multi-Regional FSK; **MSK** = Minimum Shift Keying; **MTC** = Machine Type Communications; **MU-MIMO** = Multi-User MIMO; **NB-IoT** = Narrow Band Internet of Things; **NFC** = Near Field Communication; **NR** = New Radio; **OFDM** = Orthogonal Frequency Division Multiplex; **OFDMA** = Orthogonal Frequency Division Multiple Access; **OQPSK** = Offset QPSK; **P-GSM** = Standard or Primary GSM; **PAMR** = Public Access Mobile Radio; **PBCC** = Packet Binary Convolutional Coding; **PCS** = Personal Communications System; **PJM** = Phase Jitter Modulation; **PSK** = Phase Shift Keying; **PSSS** = Parallel Sequence Spread Spectrum; **QAM** = Quadrature Amplitude Modulation; **QPSK** = Quadrature PSK; **RC** = Radio Configuration; **RFID** = Radio Frequency Identification; **QZSS** = Quasi-Zenith Satellite System; **R-GSM** = Railway GSM; **RL** = Reverse Link; **SC** = Single Carrier; **SDL** = Supplemental Downlink; **SOFDMA** = Scalable OFDMA; **SPS** = Samples per Second; **SQPSK** = Spread QPSK; **SUL** = Supplementary Uplink; **T-GSM** = Trunking GSM; **TACS** = Total Access Communications Systems; **TD-SCDMA** = Time Division Synchronous CDMA; **TDD** = Time Division Duplex; **TDMA** = Time Division Multiple Access; **TEDS** = TETRA Enhanced Data Service; **TETRA** = Terrestrial Trunked Radio; **TMBOC** = Time-Multiplexed BOC; **UE** = User Equipment; **UHF** = Ultra High Frequency; **UL** = Uplink; **ULE** = Ultra Low Energy; **UNB** = Ultra-Narrow Band; **UTRA** = Universal Terrestrial Radio Access; **UWB** = Ultra Wideband; **VAMOS** = Voice Services Over Adaptive Multi-User Channels on One Slot; **VHF** = Very High Frequency; **WCDMA** = Wideband CDMA; **WiMAX** = Worldwide Interoperability for Microwave Access; **WLAN** = Wireless Local Area Network; **WPAN** = Wireless Personal Area Network

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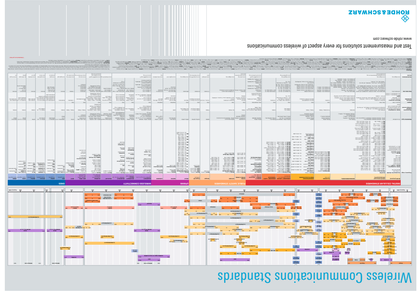

Wireless Communications Standards

Poster

Service that adds value

- Worldwide
- Local and personalized
- Customized and flexible
- Uncompromising quality
- Long-term dependability

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