1 7 0

IE	EEE Radar Bands*		Frequency 3ands [†]		nmon-usage Bands [‡]	count	lectric- ermeasure Bands [§]
Band	Frequency Range (in GHz)	Band	Frequency Range (in GHz)	Band	Frequency Range (in GHz)	Band	Frequency Range (in GHz)
HF	0.003-0.03	HF	0.003-0.03	HF	0.003-0.03	А	0-0.25
VHF	0.03-0.3	VHF	0.03-0.3	VHF	0.03-0.3	В	0.25-0.5
UHF	0.3–1	UHF	0.3–3	UHF	0.3–1	С	0.5-1
L	1–2	SHF	3–30	L	1–2	D	1–2
S	2–4	EHF	30-300	S	2–4	Е	2–3
С	4–8			С	4-8	F	3–4
Х	8-12			Х	8-12.4	G	4–6
Ku	12-18			Ku	12.4–18	Н	6–8
Κ	18–27			Κ	18-26.5	Ι	8-10
Ka	27-40			Ka	26.5-40	J	10-20
mm	40-300			Q	33-50	K	20-40
Antenr	na Engineering I	landboo	k 4ed	v	50-75	L	40-60
J. L. V	olakis, 2007, Mo	Graw-Hi	ll, Inc. Ch. 2	W	75–110	М	60-100

*From Institute of Electrical and Electronic Engineers Standard 521-1976, Nov. 30, 1976.

[†]From International Telecommunications Union, Art. 2, Sec. 11, Geneva, 1959.

[‡]No official international standing.

[§]From AFR 55-44 (AR 105-86, OPNAVIST 3430.9B, MCO 3430.1), Oct. 27, 1964.

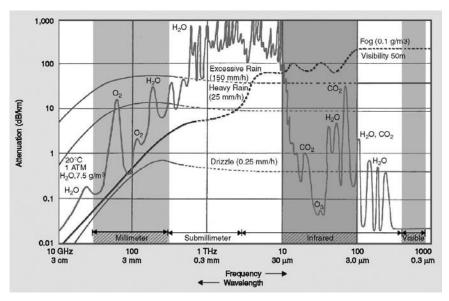


FIGURE 2-1 Attenuation of electromagnetic waves as a function of frequency or wavelength (after L. Yujiri et al¹ © IEEE 2003)

VHF TELEVISION FREQUENCIES

Band	Ch #	Frequency	Band	Ch #	Frequency
VHF LOW	02	54–60 MHz	VHF HIGH	07	174–180 MHz
VHF LOW	03	60–66 MHz	VHF HIGH	08	180–186 MHz
VHF LOW	04	66–72 MHz	VHF HIGH	09	186–192 MHz
VHF LOW	05	76–82 MHz	VHF HIGH	10	192–198 MHz
VHF LOW	06	82–88 MHz	VHF HIGH	11	198–204 MHz
			VHF HIGH	12	204–210 MHz
			VHF HIGH	13	210–216 MHz

	UHF TELEVISION FREQUENCIES											
Ch #	Frequency	Ch #	Frequency	Ch #	Frequency							
14	470–476 MHz	38	614–620 MHz	62	758–764 MHz							
15	476–482 MHz	39	620–626 MHz	63	764–770 MHz							
16	482–488 MHz	40	626–632 MHz	64	770–776 MHz							
17	488–494 MHz	41	632–638 MHz	65	776–782 MHz							
18	494–500 MHz	42	638–644 MHz	66	782–788 MHz							
19	500–506 MHz	43	644–650 MHz	67	788–794 MHz							
20	506–512 MHz	44	650–656 MHz	68	794–800 MHz							
21	512–518 MHz	45	656–662 MHz	69	800–806 MHz							
22	518–524 MHz	46	662–668 MHz	70	806–812 MHz							
23	524–530 MHz	47	668–674 MHz	71	812–818 MHz							
24	530–536 MHz	48	674–680 MHz	72	818–824 MHz							
25	536–542 MHz	49	680–686 MHz	73	824–830 MHz							
26	542–548 MHz	50	686–692 MHz	74	830–836 MHz							
27	548–554 MHz	51	692–698 MHz	75	836–842 MHz							
28	554–560 MHz	52	698–704 MHz	76	842–848 MHz							
29	560–566 MHz	53	704–710 MHz	77	848–854 MHz							
30	566–572 MHz	54	710–716 MHz	78	854–860 MHz							
31	572–578 MHz	55	716–722 MHz	79	860–866 MHz							
32	578–584 MHz	56	722–728 MHz	80	866–872 MHz							
33	584–590 MHz	57	728–734 MHz	81	872–878 MHz							
34	590–596 MHz	58	734–740 MHz	82	878–884 MHz							
35	596–602 MHz	59	740–746 MHz	83	884–890 MHz							
36	602–608 MHz	60	746–752 MHz									
37	608–614 MHz	61	752–758 MHz									

Broadcast Frequencies

AM Radio = 535 kHz-1605 kHz (MF) 107 Channels each with 10 KHz separation TV Band I (Channels 2-6) = 54 MHz-88 MHz (VHF) FM Radio Band II = 88 MHz-108 MHz (VHF) 100 Channels each with 200 KHz separation TV Band III (Channels 7–13) = 174 MHz–216 MHz (VHF) TV Bands IV & V (Channels 14–69) = 470 MHz–806 MHz (UHF)

									Antenna Technologies	hnologies
Wireless Frequency	Frequency			Free			Deploy	Comm Devices/		
Technology Band Frequency		Frequency		Space λ	Range	Data Rate	Date	Operation	Traditional	Compact
PRC-150 HF 2–30 MHz		2-30 MHz		10–150 m	30+ miles	9.6–14.4 kbps	2001	secure voice/data/ networking	Mono-Dipole	Sperical Helix
RT-1523 VHF 30–88 MHz		30-88 MHz		3.4–10 m	10-100s miles	9.6–14.4 kbps	1994	SINCGARS single ch gnd&air radio system	Mono-Dipole	Sperical Helix
PRC-148 VHF-UHF 30-512 MHz		30-512 MHz		0.5–10 m	12 miles	NA	2001	Voice/low rate data	Mono-Dipole	Sperical Helix
PRC-117 VHF-UHF 30–512 MHz		30512 MHz		0.5–10 m	10-50 miles	NA	NA	secure voice/data LOS & UHF Satcom	Mono-Dipole	Sperical Helix
PSC-5D VHF-UHF 30–512 MHz		30512 MHz		0.5–10 m	10-50 miles	76.8 kbps	1997	secure voice/data LOS & UHF Satcom	Mono-Dipole	Sperical Helix
RT-1720 EPLRS UHF 20-450 MHz		20-450 MHz		66–71 cm	6-60 miles	486 kbps	2000	secure voice/data/ networking	Mono-Dipole	PIFA
VRC-99 L-band 1308–1484 MHz 1700–2000 MHz		1308–1484 MHz 1700–2000 MHz		15–23 cm	150 miles w/ relay	625 kbps; 10 Mbps bursts	NA	Voice/data/ video/ network radio	Mono-Dipole	Half-Disc Ant
SecNet11 S-band 2.412–2.462 GHz Secure WLAN		2.412-2.462 GH	N	12.5 cm	120 m	1-11 Mbps	NA	Secure Wireless LAN	Mono-Dipole	Patch
UHF TacSat UHF 243-318 MHz		243-318 MHz		.94–1.23 m	Earth to LEO	NA	NA	UHF Tac Sat Comm	Dish Ant	Phased Array
Ku-Satcom Ku-band 11.2–11.7 Ghz domnink: 14–14.5 Ghz		Uplink: 11.2–11.7 Ghz downlink: 14–14.5 GHz		2–2.7 cm	Earth to GEO	.5–5 Mbps	Late 1970s	Ku-band Sat Comm System	Mech Dish Ant Scan Phased Array	Electronic Scan Phased Array
Uplink: 27.5, Uplink: 27.5, 18.3 188, 18.3 188, 19.7,20.2 GHz		Uplink: 27.5, 31 GHz downlin 18.3, 18.8, 19.7,20.2 GHz	÷	1–1.6 cm	Earth to GEO	Uplink 2 Mbps downlink 30 Mbps	April 2005	Ka-band Sat Comm System	Mech Dish Ant Scan Phased Array	Electronic Scan Phased Array

FIGURE 2-2 Wireless technologies for military communication systems

		~	~	-		~			~	~		
hnologies	Compact	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Patch Variant	
Antenna Technologies	Traditional	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	
Comm	Devices/Operation	TDMA cellular phones	Mobile phones on CDMA networks	GSM enabled cell phones, PDAs, pagers	DCS enabled cell phones, PDAs, pagers	PCS enabled cell phones	3GSM-enabled cell phones, PDAs, pagers	Mobile phones on CDMA2000 networks	GPRS enabled cell phones/ networks Inter- face overlaid on existing GSM networks allowing for internet access	AMPS/NAMPS enabled cellular phones	NMT enabled cellular phones	
Deploy	Date	1994	1996	1987 Europe 1995 USA	mid 1990s	1994	ė	Feb 2003 Korea	2001	1978	1986	
	Data Rate	48.6 Kbps	1.2288 Mbps	270.8 Kbps	270.8 Kbps	42 Kbps	2 Mbps	144 Kbps future capability 4.8 Mbps	40–50 Kbps; 171 Kbps limit	NA	ΥN	
	Range	100–10,000 m	100-10,000 m 1.2288 Mbps	100–10,000 m 270.8 Kbps	100–10,000 m	100–10,000 m	100-10,000 m	100–10,000 m	100–10,000 m	100-10,000 m	100–10,000 m	
	Free Space λ	15-36 cm	15-36 cm 14-36 cm 15-34 cm 16-18 cm 20-37 cm 14-16 cm NA								31–69 cm	
1	Frequency	Rx: 869–894 Tx: 824–849 Rx: 1930–1990 Tx: 1850–1910	Rx: 1363-1910 Fx: 1363-1910 Fx: 1363-1910 Fx: 3823-1910 Fx: 13230-1920 Fx: 13230-1920 Fx: 13220-1920 Fx: 13220-1920 Fx: 13220-1930 Fx: 13220-1930 Fx: 13220-1930 Fx: 13230-1930 Fx: 13230-							Rx: 869–894 Tx: 824–849	NMT-450 Rx: 463–468 Tx: 435–458 NMT-900 Rx: 925–960 Tx: 890–915	
Frequency	Band	H H H										
Wireless	Technology	(2G) TDMA IS-54/IS-136 Time Division Multiple Access FDM	253 CTMA Division Multiple Access FDM (2G)CDMA (2G)CDMA (2G)CDMA (2G)GSM (2C) GSM (2C) GSM (2C) DCS1900 (2C) PCS (2C) PC						(3G) GPRS General Packet Radio Service	AMPS/NAMPS Narrow Band Advanced Mobile Phone System FDMA	NMT-900 Nordic Mobile Telephone FDMA	
					Digital Wireless Protocols						Analog Wireless Protocols	
		Commercial Press										

Patch Variant	NA	NA	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Patch Variant	Circ polar microstrip	Electronic Scan Phased Array	Electronic Scan Phased Array	Electronic Scan Phased Array
Mono- Dipole	Yagi	Yagi	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Mono-Dipole	Helical Ant	Mech Dish Ant	Mech Dish Ant	Mech Dish Ant
TACS enabled cellular phones	6 VHF Ch, 7 FM Ch	56 UHF Ch	Wireless internet access to Laptop computers, PDAs, cell phones	-	-	=	Printers, Cameras, cell phones, PDAs, other peripherals	Bursts of power to extend battery for industrial data transfer, building and home automation	Extended city/rural range wireless access w/ modem, PDA	Unlicensed band worldwide	Satellite phone	C-band Sat Comm System	Ku-band Sat Comm System	Ka-band Sat Comm System
1988 UK	AN	AN	1999	1999	Jun-06	mid 2007	May-99	90-unſ	2004	2007?	Sep-98	1960s	Late 1970s	April 2005
NA	NA	AA	54 Mbps	11 Mbps	54 Mbps	540 Mbps	720 Kbps	100 Kbps	70 Mbps	100s Mbps 1-5 Gbps	2.4 kbps	64 kbps – 1.5 Mbps	.5–5 Mbps	Upload 2 Mbps down 30 Mbps
32–35 cm 100–10,000 m	miles	miles	10–25 m indoors	< 50 m	< 50 m	10-100 m	<10 m	< 50 m	1000–5000 m	10-100 m	Earth to LEO	Earth to GEO	Earth to GEO	Earth to GEO
32–35 cm	1.4–7 m	37-64 cm	6 cm	12.5 cm	12.5 cm	12.5 cm	12.5 am	6 cm, 33 cm, 35 cm	5–12 cm	0.5 cm 6 cm	18 cm	4.7–8.1 cm	2–2.7 cm	1–1.6 cm
NTACS: Rx: 860–870 Tx: 915–925 ETACS Rx: 916–949 Tx: 871–904	44-216 MHz	470-806 MHz	5 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	868 MHz, 915 MHz, 2.4 GHz	2.5-2.69 GHz, 2.7-2.9 GHz, 3.4-3.6 GHz, 5.725-5.86 GHz	5 GHz 59–65 GHz	1.616-1.628 GHz	Uplink 5.925- 6.425 GHz downlink: 3.7- 4.2 GHz	Uplink: 11.2– 11.7 Ghz downlink: 14–14.5 GHz	Uplink: 27.5, 31 GHz downlink: 18.3, 18.8, 19.7,20.2 GHz
	VHF	UHF	C-band			S-band		ISM band Industrial scientific and medical	S-band C-band	C-band W-band	L-band	C-band	Ku-band	Ka-band
TACS Total Access Communication System	VHF TV	UHFTV	802.11a	802.11b Wi-Fi	802.11g	802.11n	802.15.1 Bluetooth	802.15.4 ZigBee	(4G) 802.16 WiMax OFDM FDD/TDD	(4G) Broadway HIPERLAN/2 HIPERSPOT OFDM	Iridium	C-band Satcom	Ku-band Satcom	Ka-band Satoom
	TV/ Discodence	I V Broadcast					<u> </u>	Wireless LAN Protocols					Satellite Comm	
								Commercial						

FIGURE 2-4 Wireless technologies for commercial communication systems

Wireless Protocols	Transmission Rate (Mbps)	Effective Range (m)
802.15.3a UWB (disbanded)	50–500	1–10
802.11n	10–100	1–100
802.11a/g	5–50	1–100
802.16 WiMax	5–10	100–10,000
802.15.3	5–10	1–10
802.15.3c.MMV	100–5000	1–10
802.11b WiFi	1–10	1–100
802.16e/20	1	100–10,000
UMTS/HSDPA/fxEVDO	0.5–1	50–10,000
802.15.1 Bluetooth	0.5–1	1–10
GPRS/EDGE	0.1–0.5	50–10,000
802.15.4 Zigbee	≤0.1	1–50
GSM/TDMA	≤0.1	50–10,000
Blackberry	≤0.1	50–50,000

FIGURE 2-5 Wireless protocols: their transmission rates (Mbps) and effective ranges (meters)

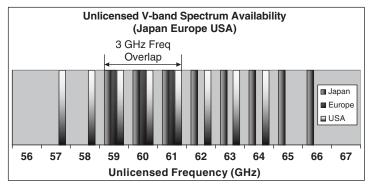


FIGURE 2-6 Available unlicensed global spectrum in the V-band

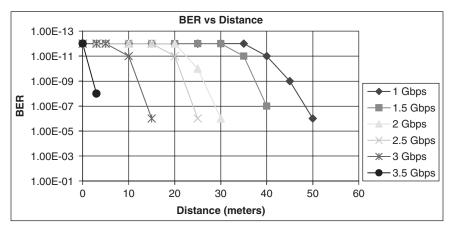


FIGURE 2-7 Measured data rate vs. distance for an early proof of concept system,¹³ which shows the potential for very high data rates at distances traditionally within the WPAN ranges for point-to-point line-of-sight (after R. Emrick et al¹³ \odot IEEE 2005)