'Radio Spectrum Management: Policies, Regulations, Standards and Techniques' Mazar 2016, Chapter 2 'Main regulated radio services' Section 2.5 'Satellite Communications'. Updated on 20 October 2024

Chapter number **2**

2 Chapter Title: Main Regulated Radio Services, Section 2.5

Contents

2.1 Satellite Communications

2.1.1 Definitions of Satellite Communications

The ITU 2024 Radio Regulations (RR) Article 1 Section I– General terms define at (Article 1 provision No. 8) **1.8** *space radiocommunication:* Any *radiocommunication* involving the use of one or more *space stations* or the use of one or more *reflecting satellites* or other objects in space. Different space terms are addressed by different RR notes and Resolutions; see also Recommendation ITU-R S.673. The following Table details the definition of space services, radio stations and systems.

2.1.1.1 Space: RR Section III– Radio Services

Extracted from RR Article 1 Section III. The following Table defines all space radio services.

Table 2.1: RR Article 1–Space services

RR Note	Definition of space radio service
1.21	*fixed-satellite service:* A *radiocommunication service* between *earth stations* at given positions, when one or more *satellites* are used; the given position may be a specified fixed point or any fixed point within specified areas
1.22	*inter-satellite service:* A *radiocommunication service* providing links between artificial *satellites*
1.23	*space operation service:* A *radiocommunication service* concerned exclusively with the operation of *spacecraft*, in particular *space tracking*, *space telemetry* and *space telecommand*
1.25	*mobile-satellite service:* A *radiocommunication service* between *mobile earth stations* and one or more *space stations*, or between *space stations* used by this service; or between *mobile earth stations* by means of one or more *space stations*; this service may also include *feeder links* necessary for its operation
1.27	*land mobile-satellite service:* A *mobile-satellite service* in which *mobile earth stations* are located on land
1.29	*maritime mobile-satellite service:* A *mobile-satellite service* in which *mobile earth stations* are located on board ships; *survival craft stations* and *emergency position-indicating radiobeacon stations* may also participate in this service.
1.35	*aeronautical mobile-satellite service:* A *mobile-satellite service* in which *mobile earth stations* are located on board aircraft; *survival craft stations* and *emergency position-indicating radiobeacon stations* may also participate in this service.
1.36	*aeronautical mobile-satellite (R)* service:* An *aeronautical mobile-satellite service* reserved for communications relating to safety and regularity of flights, primarily along national or international civil air routes; *(R): route
1.37	*aeronautical mobile-satellite (OR)** service:* An *aeronautical mobile-satellite service* intended for communications, including those relating to flight coordination, primarily outside national and international civil air routes; ** (OR): off-route
1.39	*broadcasting-satellite service:* A *radiocommunication service* in which signals transmitted or retransmitted by *space stations* are intended for direct reception by the general public. In the broadcasting-satellite service, the term “direct reception” shall encompass both *individual reception* and *community reception*
1.41	*radiodetermination-satellite service: A radiocommunication service* for the purpose of *radiodetermination* involving the use of one or more *space stations*
1.43	*radionavigation-satellite service:* A *radiodetermination-satellite service* used for the purpose of *radionavigation*
1.45	*maritime radionavigation-satellite service:* A *radionavigation-satellite service* in which *earth stations* are located on board ships
1.46	*aeronautical radionavigation service:* A *radionavigation service* intended for the benefit and for the safe operation of aircraft
1.47	*aeronautical radionavigation-satellite service:* A *radionavigation-satellite service* in which *earth stations* are located on board aircraft
1.49	*radiolocation-satellite service:* A *radiodetermination-satellite service* used for the purpose of *radiolocation*

2.1.1.2 Space: RR Section IV – Radio Stations, Systems, Networks and Links

The following Table defines the space radio stations, systems, networks and links.

Table 2.2: Space: RR Section IV– definition of radio stations, systems, networks or links

RR Note	Definition of Space Radio Station, System, Network or Link
1.63	*earth station:* A *station* located either on the Earth's surface or within the major portion of the Earth's atmosphere
1.64	*space station:* A *station* located on an object which is beyond, is intended to go beyond, or has been beyond, the major portion of the Earth's atmosphere.
1.68	*mobile earth station:* An *earth station* in the *mobile-satellite service* intended to be used while in motion or during halts at unspecified points.
1.70	*land earth station:* An *earth station* in the *fixed-satellite service* or, in some cases, in the *mobile-satellite service*, located at a specified fixed point or within a specified area on land to provide a *feeder link* for the *mobile-satellite service*
1.110	*space system:* Any group of cooperating *earth stations* and/or *space stations* employing *space radiocommunication* for specific purposes
1.111	*satellite system:* A *space system* using one or more artificial earth *satellites*
1.112	*satellite network:* A *satellite system* or a part of a *satellite system*, consisting of only one *satellite* and the cooperating *earth stations*
1.113	*satellite link:* A radio link between a transmitting *earth station* and a receiving *earth station* through one *satellite*. A satellite link comprises one uplink and one downlink
1.114	*multi-satellite link:* A radio link between a transmitting *earth station* and a receiving *earth station* through two or more *satellites*, without any intermediate *earth station* A multi-satellite link comprises one uplink, one or more satellite-to-satellite links and one downlink
1.115	*feeder link:* A radio link from an *earth station* at a given location to a *space station*, or vice versa, conveying information for a *space radiocommunication service* other than for the *fixed-satellite service*. The given location may be at a specified fixed point, or at any fixed point within specified areas.

2.1.1.3 Space Terms based on Recommendation ITU-R S.673

Recommendation ITU-R S.673 (03/2002) 'Terms and definitions relating to space radiocommunications' provides more definitions relating to space radiocommunications: **Satellite** is a body which revolves around another body of preponderant mass and which has a motion primarily and permanently determined by the force of attraction of that other body; **Spacecraft** is a man-made vehicle which is intended to go beyond the major part of the earth's atmosphere. **Synchronous satellite** is a satellite for which the mean sidereal period of revolution is equal to the sidereal period of rotation of the primary body about its own axis; **Stationary satellite** is satellite which remains fixed in relation to the surface of the primary body, note 1 – a stationary satellite is a synchronous satellite with an orbit which is equatorial, circular and direct; **Geostationary satellite** is a stationary satellite having the Earth as its primary body.

Orbital elements (of a satellite or other body in space) as the parameters by which the shape, dimensions and position of the orbit in space and the period of the body can be defined in relation to a specified frame of reference. **Geostationary satellite orbit** is the unique orbit of all geostationary satellites; **Geosynchronous satellite** is a synchronous earth satellite, note 1 – the sidereal period of rotation of the Earth is about 23 h 56 min. **Inclined orbit** (of a satellite) is a satellite orbit which is neither equatorial nor polar; **LEO** is Low altitude Earth orbit, with an altitude about 1,000 km above sea level; **MEO** is Medium-altitude Earth orbit, with an altitude of about 10,000 km above sea level.

2.1.2 Satellite Orbits and Services

Satellites are used for commerce, government/military, science, research and astronomy. To avoid obstacles and terrestrial signals and to get full-service quality, the elevation angle -the minimum extent of the satellite's position above the horizon- should be above 5°; there are cases that the elevation is lower, e.g. to cover polar regions. The historical background of satellite communications is also found in pages 2-5 at ITU handbook on satellite

communications termed here SAT HB pp. 2-5. SAT HB p. 359 compares orbits for communication applications.
The following Figure depicts geostationary satellite high-quality coverage.

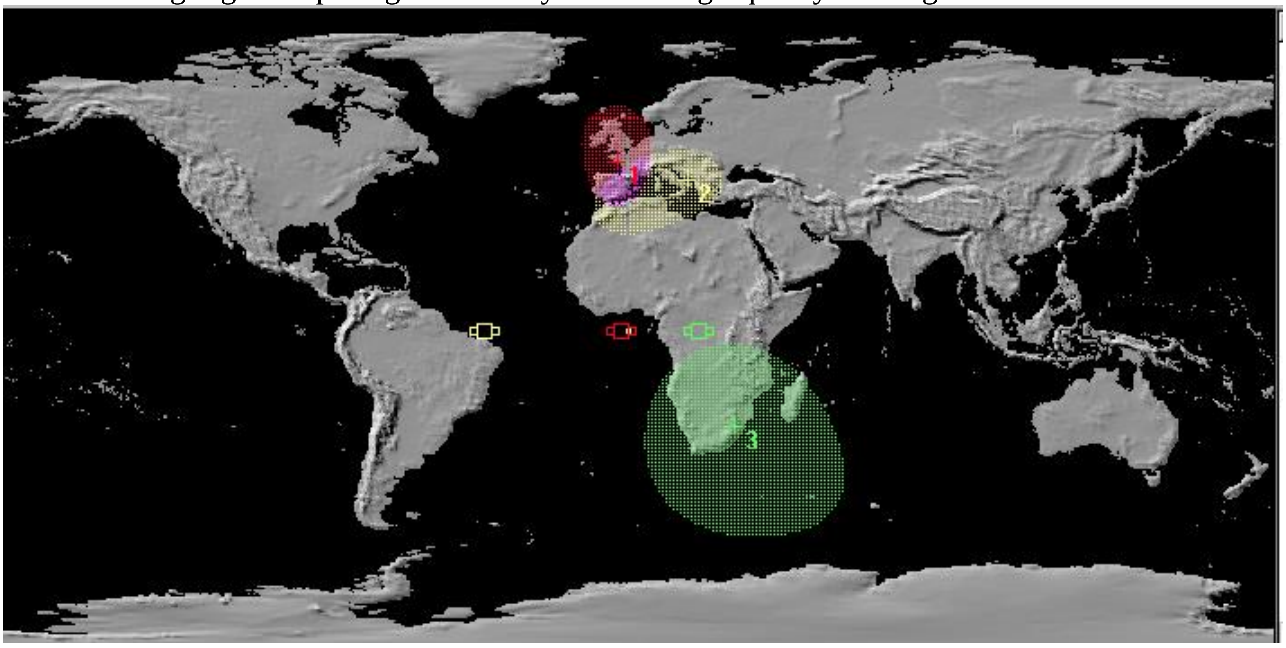

Figure 2. 1 geostationary satellite high-quality coverage

The following Figure depicts blue Marble: Land Surface, Shallow Water, and Shaded Topography "Retrieved 20 October 24, from Transfinite Website
https://visibleearth.nasa.gov/images/57752/blue-marble-land-surface-shallow-water-and-shaded-topography

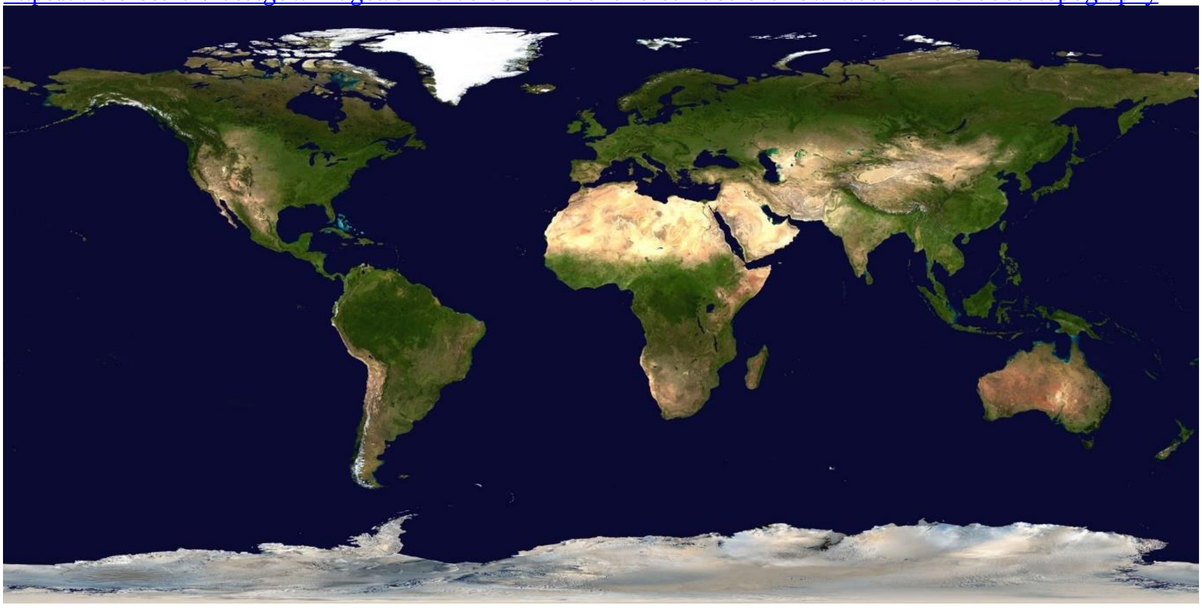

Figure 2. 2 Low Earth Orbit

The following Figure depicts FSS coverage.

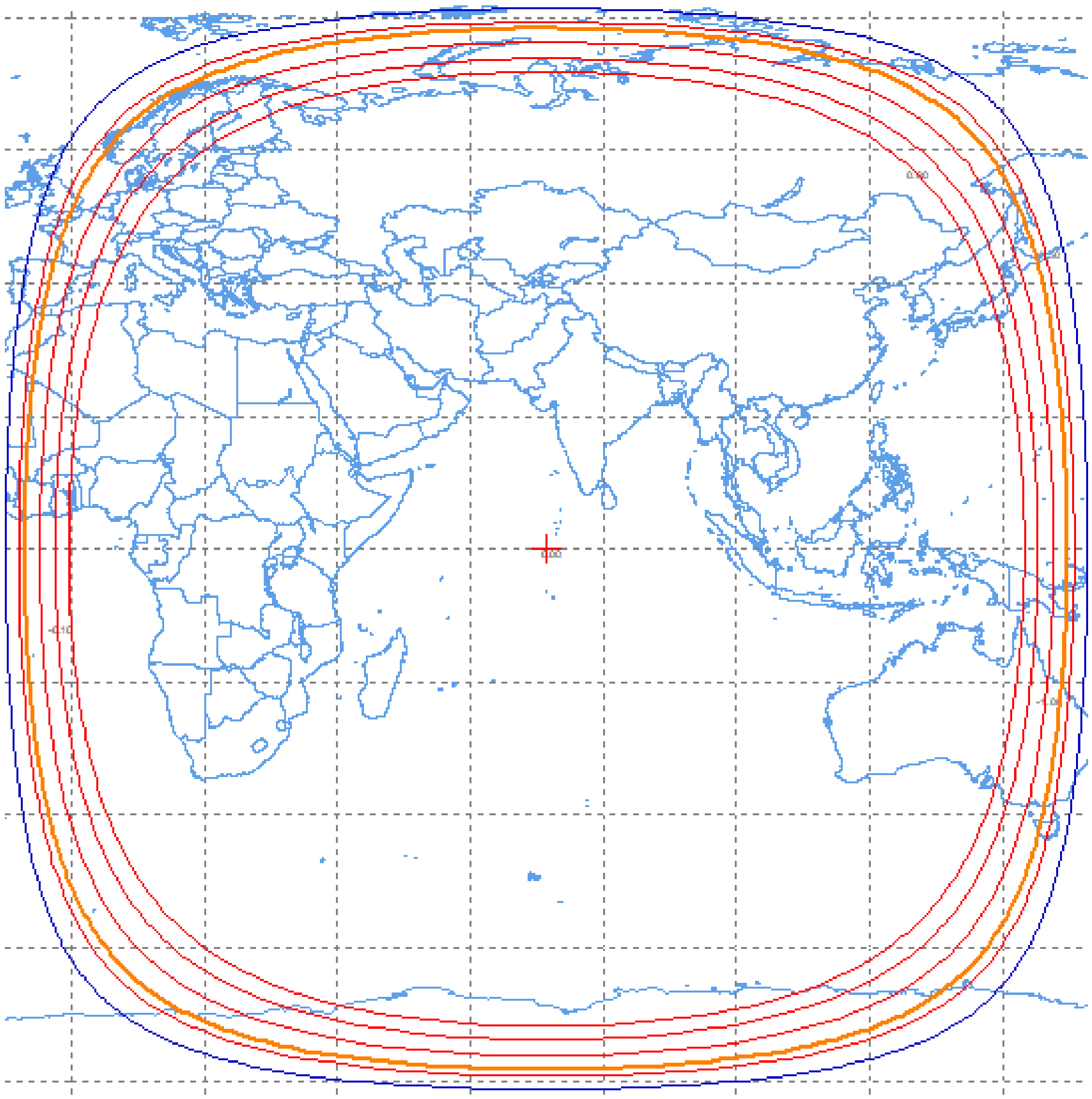

Figure 2. 3 FSS coverage

The following two Tables summarize the main coverage GNSS performances and link constraints; "Retrieved 20 October 24, https://en.wikipedia.org/wiki/Satellite_navigation.

Table 2.3: Orbit comparison- main coverage performances and link constraints; comparing the global GNSS

ORBITS	**LEO**	**MEO**	**HEO**	**GEO**
Environment constraints	Currently low (space debris: growing concern) Van Allen belts: 4 crossings/day	Low/medium	Medium/high	Low; short number of orbital slots; station keeping
Typical orbital period	1.5-2 h	5-10 h	12 h	24 h
Altitude range	500-1,500 km	8,000-25,000 km	Up to 40,000 km apogee (perigee ~ 1,000 km)	35,700 km
Visibility duration	15-20 mn/pass	2-8 h/pass	8-11 h/pass (apogee)	Permanent

Elevation	Rapid variations; high and low angles	Slow variations; high angles	No variations (apogee); high angles near Equator	No variation; low angles at high latitudes
Propagation delay	Several milliseconds	Tens of milliseconds	Hundreds of milliseconds (apogee)	> 250 milliseconds
Link budget (distance)	Favorable; compatible with small satellites and handheld user terminals	Less favorable	Not favorable for handheld or small terminals; requires large and powerful satellites	Not favorable for handheld or small terminals
Instantaneous ground overage (diameter at 10° elevation)	≈ 6,000 km	≈ 12,000-15,000 km	16,000 km (apogee)	16,000 km (~ 0.4 of earth circumference at Equator)
Examples of systems	Iridium,Globalstar, Skybridge, ORBCOMM, International Space Station (ISS) Scientific missions	Odyssey; O3B, GPS, GLONASS, Galileo, BeiDou	Molniya, Archimedes	Intelsat, Inmarsat, Meteosat, MILCOM; Eutelsat, AMOS

Table 2.4: Comparison of GNSS systems

System	**BeiDou**	**Galileo**	**GLONASS**	**GPS**	**NavIC**	**QZSS**
Owner	China	European Union	Russia	United States	India	Japan
Coverage	Global	Global	Global	Global	Regional	Regional
Coding	CDMA	CDMA	FDMA & CDMA	CDMA	CDMA	CDMA
Altitude km (mi)	21,150 (13,140)	23,222 (14,429)	19,130 (11,890)	20,180 (12,540)	36,000 (22,000)	32,600–39,000 (20,300–24,200)[34]
Period	12.88 h (12 h 53 min)	14.08 h (14 h 5 min)	11.26 h (11 h 16 min)	11.97 h (11 h 58 min)	23.93 h (23 h 56 min)	23.93 h (23 h 56 min)
Rev./S. day	13/7 (1.86)	17/10 (1.7)	17/8 (2.125)	2	1	1
Satellites	BeiDou-3: 28 operational (24 MEO, 3 IGSO, 1 GSO) 5 in orbit validation 2 GSO planned 20H1 BeiDou-2: 15 operational 1 in commissioning	By design: 27 operational + 3 spares Currently: 26 in orbit 24 operational 2 inactive 6 to be launched	24 by design 24 operational 1 commissioning 1 in flight tests	24 by design 30 operational	8 operational (3 GEO, 5 GSO MEO)	4 operational (3 GSO, 1 GEO) 7 in the future
Frequency GHz	1.561098 (B1) 1.589742 (B1-2) 1.20714 (B2) 1.26852 (B3)	1.559–1.592 (E1) 1.164–1.215 (E5a/b) 1.260–1.300 (E6)	1.593–1.610 (G1) 1.237–1.254 (G2) 1.189–1.214 (G3)	1.563–1.587 (L1) 1.215–1.2396 (L2) 1.164–1.189 (L5)	1.57542 (L1) 1.17645 (L5) 2.49202 (S)	1.57542 (L1C/A, L1C, L1S) 1.22760 (L2C) 1.17645 (L5, L5S) 1.27875 (L6)
Status	Operational	Operating since 2016; 2020 completion	Operational	Operational	Operational	Operational
Accuracy m (ft)	3.6 (12) (public) 0.1 (0.33) (encrypted)	0.2 (0.66) (public) 0.01 (0.033) (encrypted)	2–4 (6.6–13.1)	0.3–5 (0.98–16.40) (no DGPS or WAAS)	1 (3.3) (public) 0.1 (0.33) (encrypted)	1 (3.3) (public) 0.1 (0.33) (encrypted)
System	**BeiDou**	**Galileo**	**GLONASS**	**GPS**	**NavIC**	**QZSS**

2.1.2.1 Geo-Stationary Orbits (GSO or GEO)

GSO is equivalent to the geostationary earth orbit (GEO) or geo-synchronous equatorial orbit (GEO). There are different satellite orbits: GSO orbit, and non geo-synchronous or non geo-stationary (NGSO) orbits; NGSO is also termed non-GSO or non-GEO. The orbits of GSO satellites are circular above the equator; the angular separation is about one degree, to allow 360 satellites[1]. GSO and GEO are circular orbits, 35,786 kilometres (22,236 miles) directly above the earth's equator, following the direction of the earth's rotation. The ITU Radio Regulations (RR) Article 22 Section III (station keeping of space stations) state at (provision No. 27) for space stations on board geostationary satellites which use any frequency band allocated to the fixed-satellite service or the broadcasting-satellite service: ‘**22.7** *a)*

shall have the capability of maintaining their positions within ±0.1° of the longitude of their nominal positions’[2].

Assuming zero signal propagation/processing time in the satellite and equatorial earth station location with the same longitude as the satellite slot, a signal round trip time from Earth to satellite and back to Earth is about 0.24 seconds ($=\frac{36,000\times 2}{300,000}$)[3]; owing to the distance of the geostationary satellite from the Earth, the propagation time between two stations (latency) via the satellite can reach approximately 0.275 seconds[4]. As they appear stationary, generally GEOs do not require dynamic tracking[5].

One GEO satellite may cover up to 40% of the world surface. Satellite networks are needed to cover the globe, or regions; three satellite networks can cover the globe. GEO satellites links allow for communication between any points on the Earth's surface and under conditions (technical, cost, etc.) which are independent of the geographical distance between these points, provided they are located within the satellite coverage area; moreover, inter-satellite links can be used to connect points which are not covered by the same satellite, without employing terrestrial links and additional earth stations. The points to be served by a GEO satellite must be situated, not only in the region of the Earth visible from the satellite, but also within the geographical areas covered by the beams of the satellite antennas: these areas are called the coverage areas of the communication satellite system. The satellite antenna beams can be "shaped" to form specific coverage areas, tailored to the region to be served, in order to reduce power and bandwidth. The principal limitation in GEO coverage is the area above 75 degrees North or South latitude; thus, Polar regions cannot be covered by GEOs[6]. The elevation angle to the geostationary satellite equals approximately 90 minus the absolute latitude (the approximation is not accurate at high latitudes); the latitude of the earth -station defines the elevation angle to the satellite and thus limits the edge of coverage; the longitude determines which of those satellites can be received; see SAT HB pp.81-4. The following Figure depicts the Amos-3 global steerable Ku and Ka footprints.

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[1] Presently, some orbital points contain more satellites, e.g. Telenor (Norway) uses three known satellites, located around 0.8^{O} W; there are also collocated satellite networks and bands.

[2] In the 21th century, satellites maintain their positions at ±0.05° East / West.

[3] Given the earth's radius 6,371kM, the geostationary orbital radius 36,000+6,371=42,371 km , and the speed of light 300,000 km, for earth stations at latitude of φ = ±60° on the same meridian as the satellite, the time taken for a signal to pass from earth to the satellite and back is calculated using the cosine rule to get 264 ms: $\frac{2}{300,000}\sqrt{(42,371)^2+(6,371)^2-2\times 42,371\times 6,371\times\cos 60^0}$

[4] During telephone calls, the round-trip propagation time is approximately 550 ms, and the use of echo control devices is essential to avoid unacceptable deterioration of the subjective transmission quality. Some signalling systems will not work correctly over satellite links since the long propagation delay (240 to 280 ms one way) exceeds that assumed by the line signalling specifications; SAT HB p. 791.

[5] Except where GEO is in an inclined orbit.

[6] In extreme cases where GEO is inclined, the Poles can be covered (few hours a day), using specialised Earth Station.

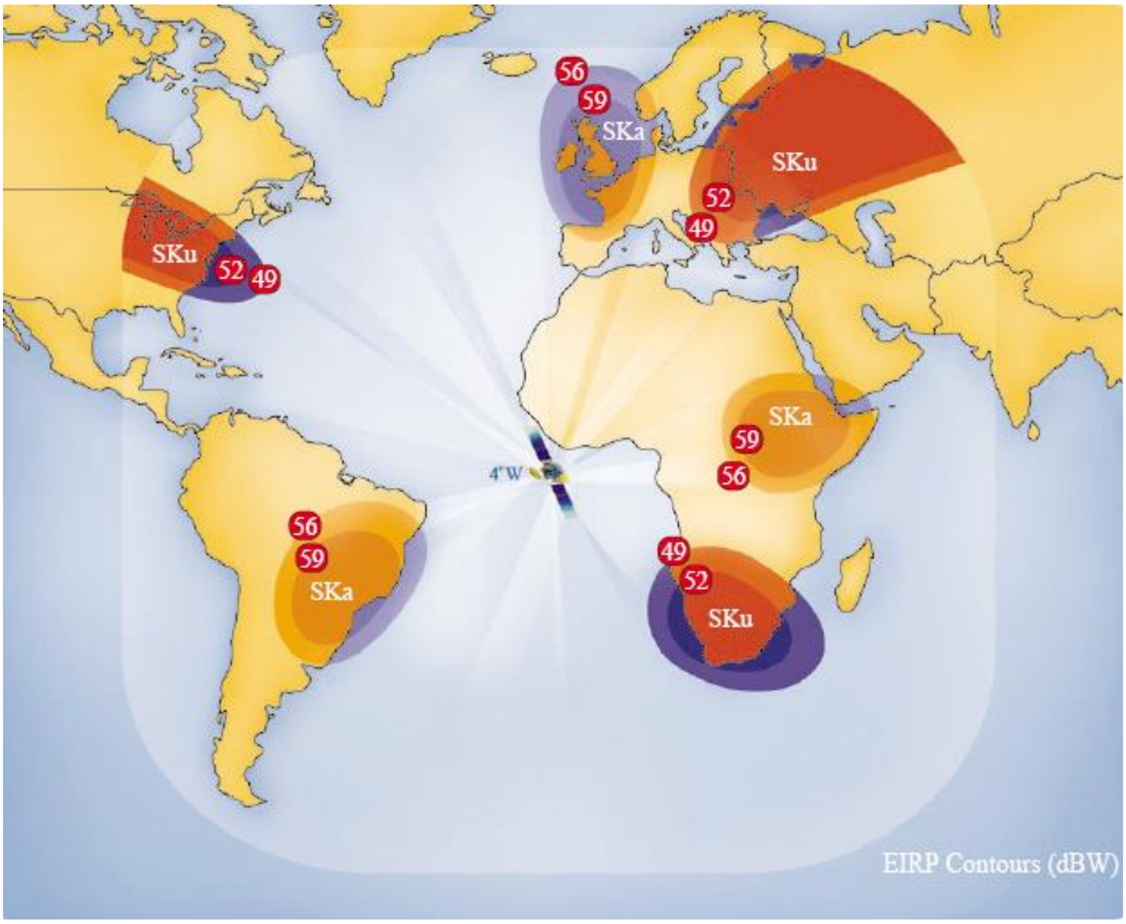

Figure 2. 4 Amos-3 Global steerable changeable Ku and Ka footprints

The following Figure depicts the service area of one European beam of the AMOS 2-B satellite network; the orbital position is 4W, frequency bands 10.95-11.2 and 11.45-11.7 GHz. The area inside the orange contour is the zone where the satellite’s operator determines that the signal power received from the satellite is high enough to provide services.

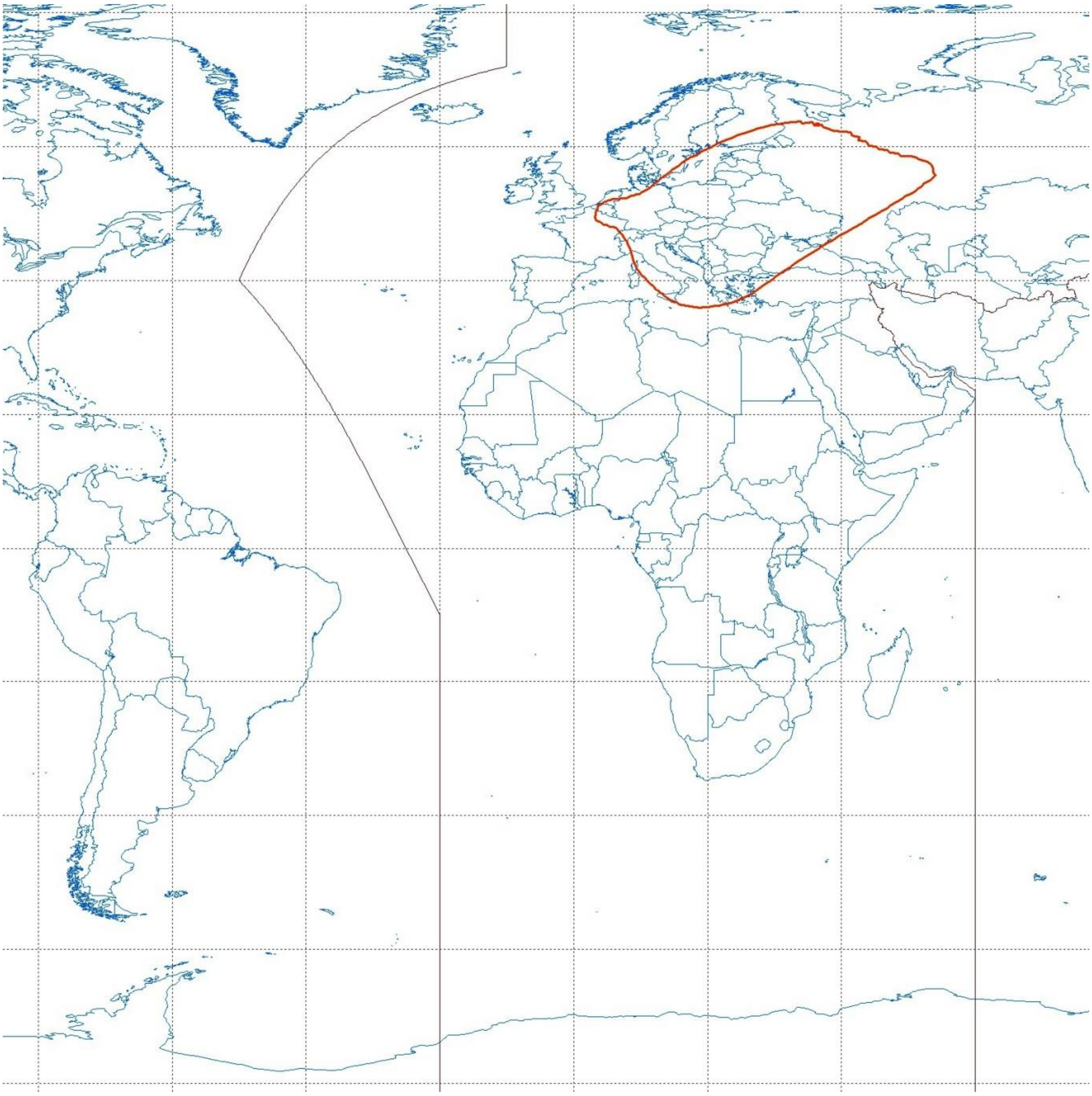

Figure 2. 5 Service area of AMOS 2-B satellite network from 4W

The following Figure depicts the ‘high-capacity payload’ beam coverage of Inmarsat 5 F1: e.i.r.p. contours relative to their peak. The satellite is located at 62.6 degrees East; the antenna is directed towards India.

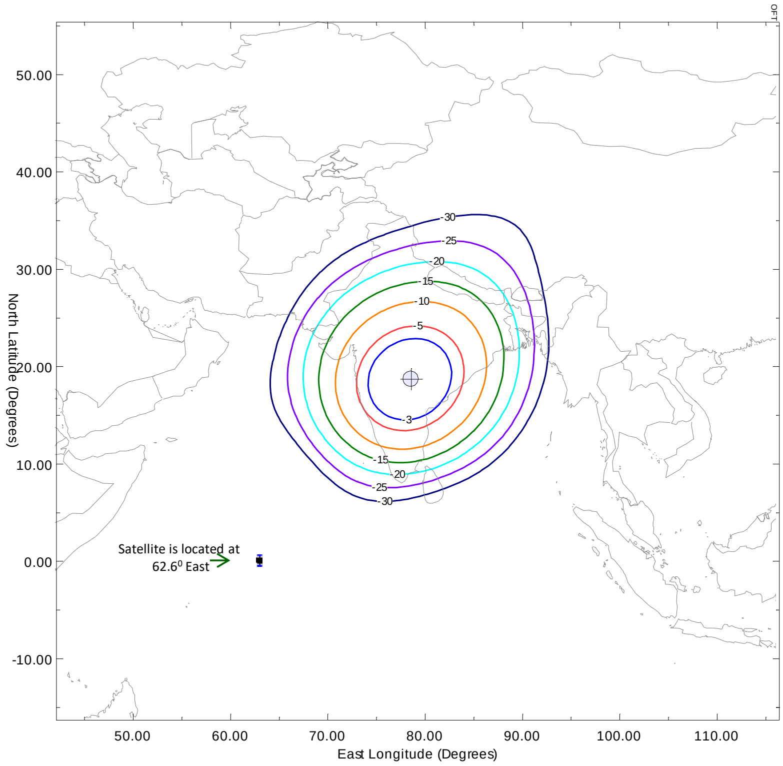

Figure 2. 6 Inmarsat ‘high-capacity payload’ beam coverage

2.1.2.1.1 Fixed-Satellite Services (FSS)

Figure 2. 7 Basic satellite link, source: ITU SAT HB Fig. 2-1, depicts a basic GEO satellite link.

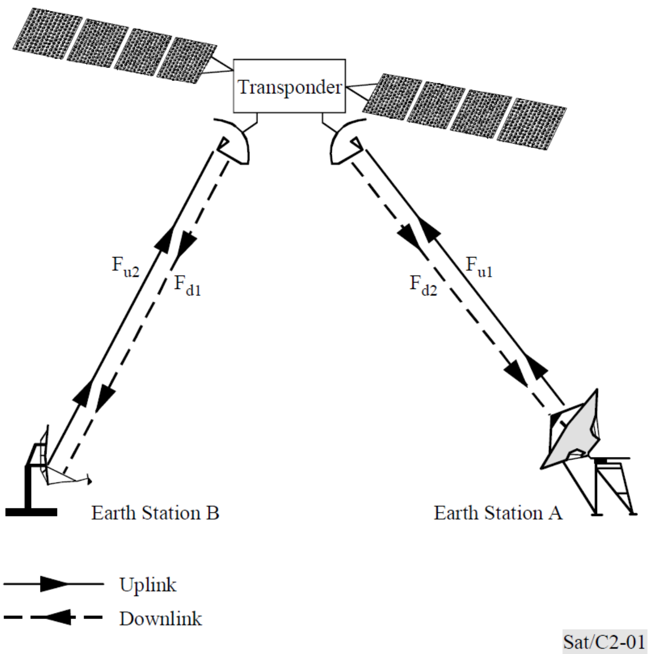

Figure 2. 7 Basic satellite link

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Since the satellite is located at a large distance from the Earth (at least 35,786 km), the high free space propagation loss[7] should be compensated (offset) at the earth and space stations.
The following figure depicts how to calculate altitude above sea level (ASL) of Geo-Satellites; "Retrieved 20 October 24, https://en.wikipedia.org/wiki/Satellite_navigation".

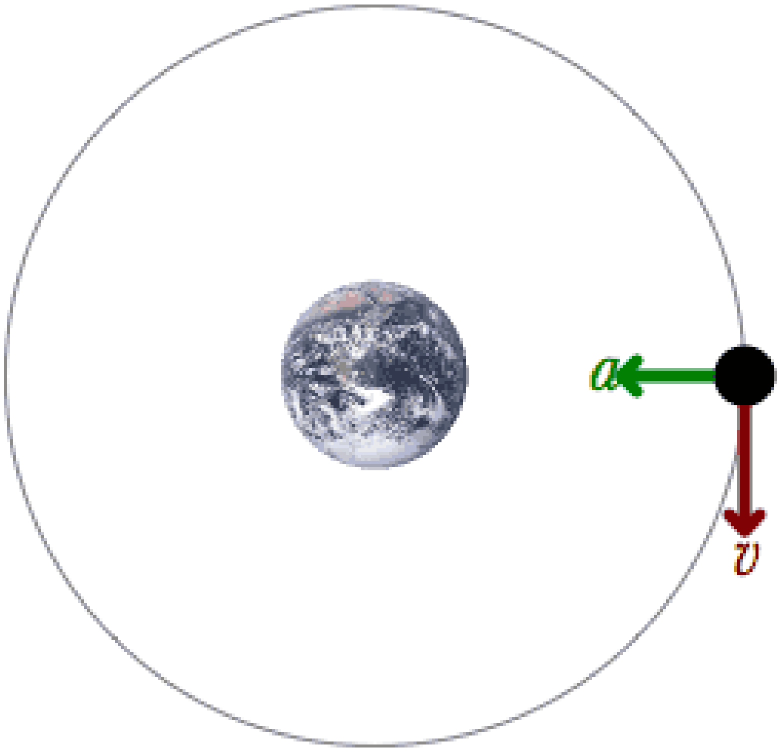

Figure 2. 8 Computing the altitude above sea level of Geo-Satellites

The power requirement to be met by the earth station depends directly on the performance of the satellite transponder. In particular, the smaller the area to be served, the greater can be the directivity of the space borne beam of the antenna and the effective radiated power of the satellite, which results in lower earth station power performance requirements. To reduce satellite power and costs, it is desirable that the coverage area should be only just large enough for the region to be served; see SAT HB pp. 15-6.
The following Figure, source SAT HB Fig. 2-12, depicts the world planisphere with a typical elevation pattern, showing the elevation angle of the line-of-sight (LoS) from an earth surface point towards a GSO satellite. In this Figure, the satellite is located, for illustration purposes, at 30°W (sub-satellite point); if the pattern is copied on a transparency, it can be transferred and centred on any sub-satellite point on the Equator.

[7] The propagation loss p_l depends on frequency; as example, 205.1 dB at 12 GHz (λ=0.025m):
P_l = 92.45 + 20 log 12 + 20 log 35,786; see Chapter 5 of this book.

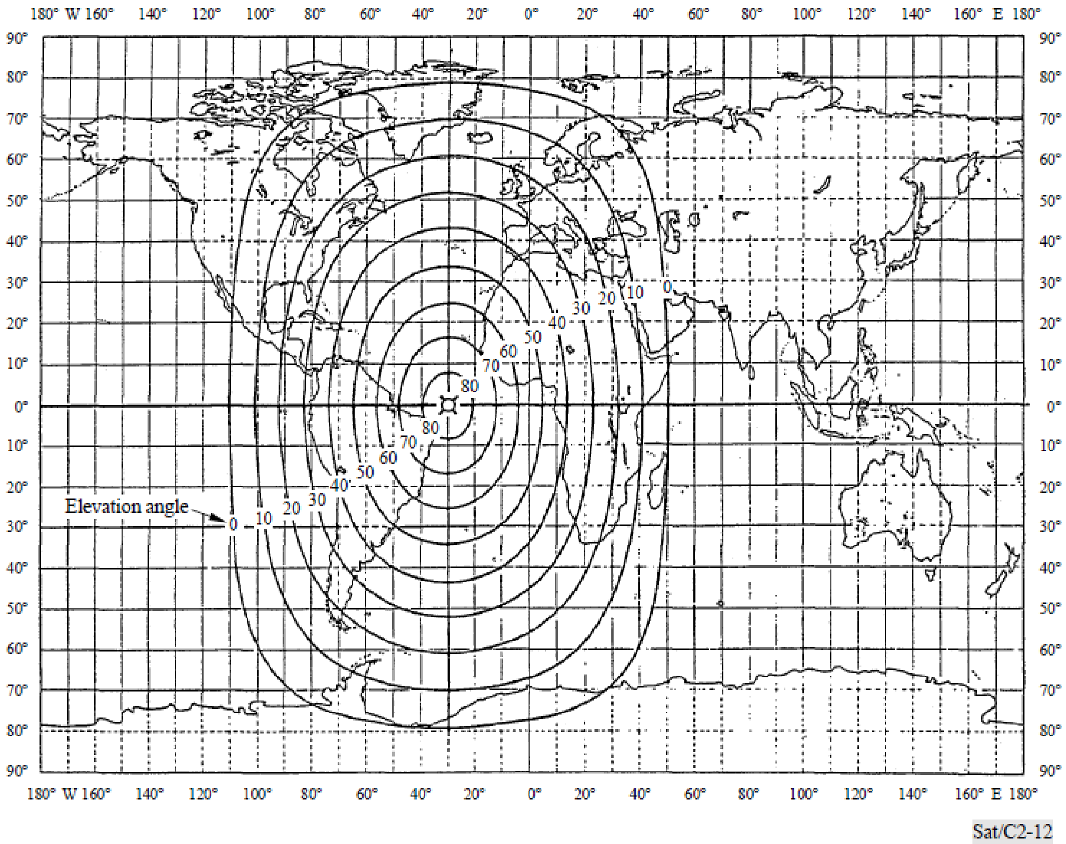

Figure 2. 9 Elevation angle of the LoS from an earth surface towards a GSO satellite

2.1.2.1.2 Broadcasting-Satellite Service (BSS)

GEOs are suitable for broadcasting to cover wide areas. SAT HB pp. 24-5 TV distribution ranges from conventional television direct to home (DTH) programming (entertainment, news, special events), educational/instructional programs to teleconferencing applications. The broadcasting-satellite service BSS eliminates the distance/cost relationship associated with terrestrial delivery of signals. In some instances, satellites provide the only available or cost effective means of signal distribution. The applications include also the processing of satellite news gathering (SNG) information. In a similar way, the FSS and BSS can also provide distribution of radio audio programs (e.g. high-fidelity audio and stereo). BSS comprises in general a transmitting (uplink) from a large antenna (hub/earth station) and receiving (downlink) with a small antenna/earth station, usually receive only 0.6m.
An important advantage of the satellite over the terrestrial TV broadcasting is the low power TV signal, and consequently a lower exposure to human-hazards (see Chapter 9 of this book). Furthermore, TV receivers are normally fixed, therefore, fixed antennas can be directed toward the broadcasting-satellite; this is not the case at the land mobile service; so, BSS (and cables) can deliver the TV signal, and the current UHF terrestrial TV frequencies can serve the land mobile service: IMT and LTE.
As mentioned, BSS is a radiocommunication service in which signals transmitted or retransmitted by space stations are also intended for direct reception by the general public, using television receive-only (TVRO) receiving antennas. The satellite implemented for the BSS is often called direct broadcast satellite (DBS). The direct reception shall encompass both individual reception direct to home (DTH) and community reception cable TV (CATV) and satellite master antenna TV (SMATV) (see Figure 2. 10 Generic illustration of BSS
). The most useful standard that has been adapted to satellite digital television transmission is digital video broadcasting- satellite (DVB-S). The following Figure, source: ITU SAT HB Fig. 1.3, illustrates the BSS networks.

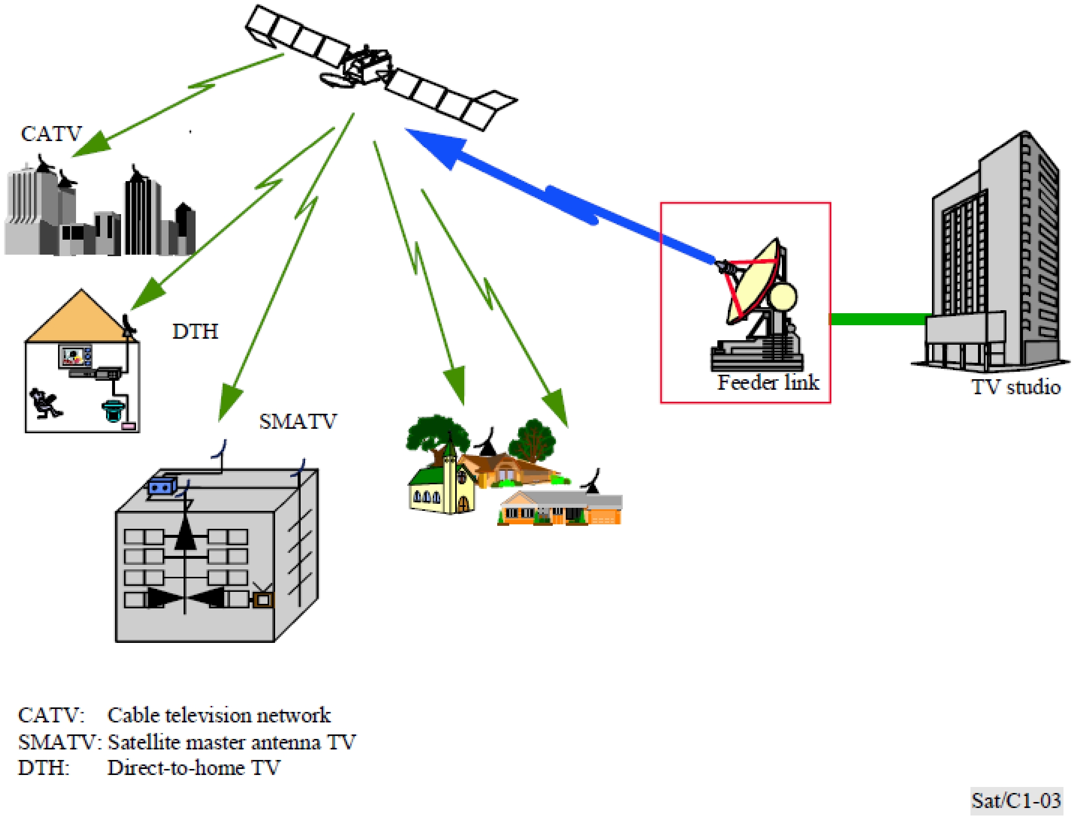

FIGURE 1.3

Generic illustration of broadcasting-satellite services

Figure 2. 10 Generic illustration of BSS

2.1.2.2 Non-Geostationary Orbits (NGSO)

The orbits of low-earth orbit (LEO) satellites are between 200 to 2,000 km. LEOs move quite fast relative to the earth; they require dynamic tracking. The signal to noise can be better with LEOs, as they are closer, relative to GEOs; however, when directive earth antennas are used, they must track the satellite, as LEOs change their position relative to the ground receiver. The delays are shorter, typical figures are between 1 - 10 ms. By operating three or four satellites, elliptical orbits can be used to provide quasi stationary behavior, during which the ground footprint moves only slightly viewed from earth.

NGSO serve both for mobile-satellite service (MSS) and fixed-satellite service (FSS). Many (but not all) of these systems are based on constellations of low-earth orbit (LEO) satellites. From the NGSO satellite the communication is transferred, either directly, through inter-satellite links (ISL), or through a gateway earth station, to its destination, which can be either another user terminal or a terrestrial communication node.

Many NGSO satellite systems perform special functions and services such as weather observations, remote earth exploration, radionavigation, communications, surveillance, etc. One of the unique features of these satellites is the ability to view the entire earth's surface periodically from a single satellite. If simultaneous viewing of the Earth is required, a number of satellites can be employed depending on their orbit altitude. These systems include:

- low-earth orbit (LEO) satellites such as several weather satellite systems;
- medium-earth orbit (MEO) satellites;
- high elliptical (eccentric) orbit (HEO) satellites such as the navigational satellites GPS and GLONASS.

2.1.2.2.1 Mobile-Satellite Service (MSS)

The following Figure, source: ITU SAT HB Fig. 1.2, illustrates the MSS networks.

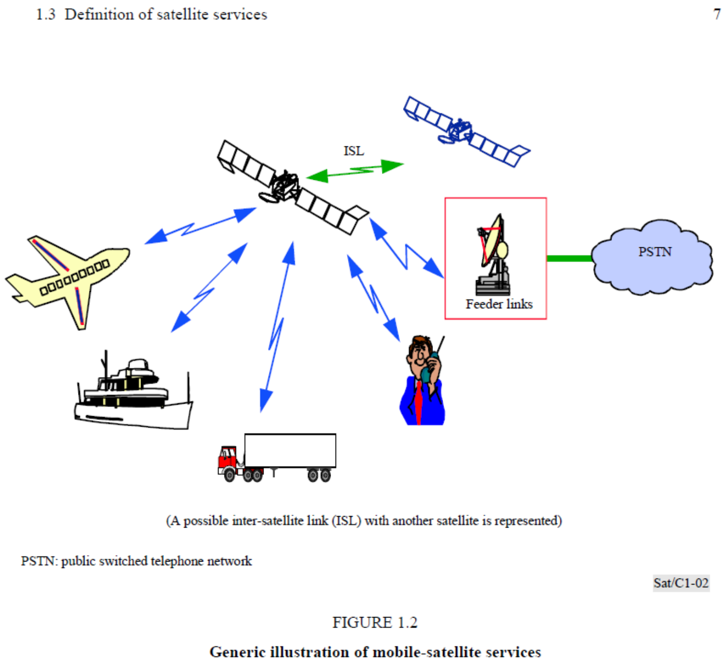

Figure 2. 11 Generic illustration of MSS

The following Figure depicts ITU type F Low Earth Orbit (LEO)- Intermediate Circular Orbit (ICO- of the International Space Station (ISS); it exemplifies several non-GSO LEO satellites providing mobile service.

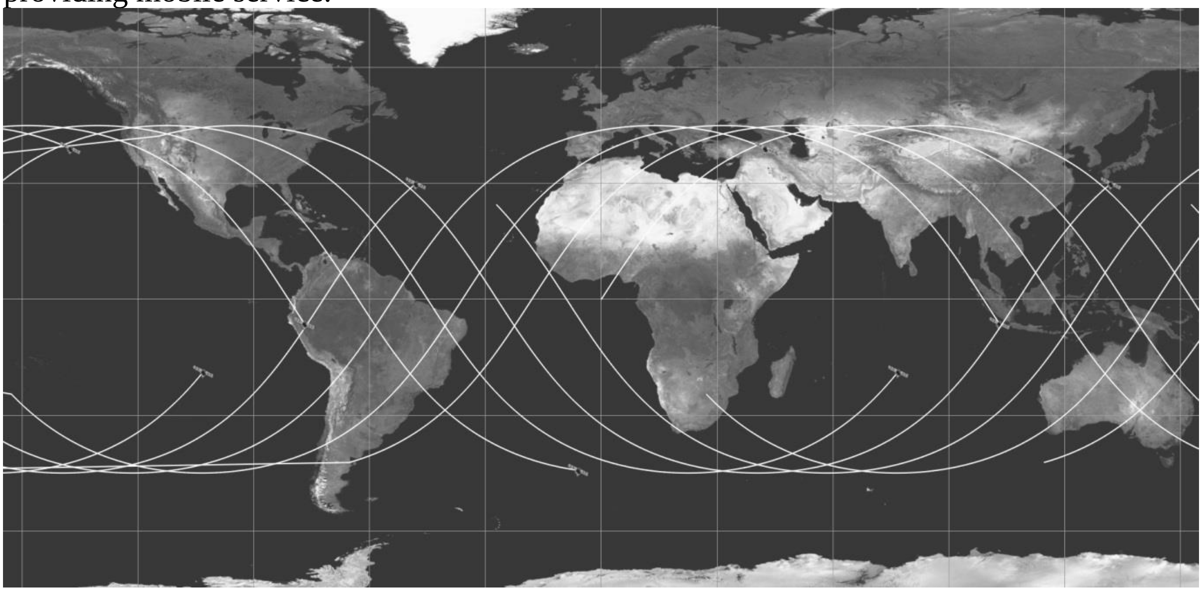

Figure 2. 12 Ground track screenshot of MSS

2.1.2.2.2 High Earth Orbit (HEO)

HEO[8] is a non-GSO system; HEO is a type of LEO and FSS. Recommendation ITU-R S.1758 determines HEO: a satellite or satellites using an elliptical orbit with all the following orbital and operational characteristics:

[8] HEO abbreviates high earth orbit, highly elliptical orbit and highly eccentric orbit

- A geosynchronous period (23 h 56 min) multiplied by *m*/*n*, where *m* and *n* are integers, resulting in *n* apogees every *m* days. The ratio *m*/*n* may be less than, equal to, or greater than 1, resulting in the following three kinds of orbits:
  - *Geosynchronous HEO:* HEO with an orbital period of 23 h and 56 min (*m*/*n* = 1).
  - *Sub-geosynchronous HEO:* HEO with a geosynchronous period multiplied by *m*/*n* less than one (e.g. 11 h and 58 min, 5 h and 59 min, etc.).
  - *Super-geosynchronous HEO*: HEO with a geosynchronous period multiplied by *m*/*n* larger than one (e.g. 47 h and 52 min, etc.).
- An inclination between 35° and 145°.
- An apogee altitude that is at least 18,000 km.
- Service carrier transmissions other than telemetry and command carrier transmissions are confined to one or more active arc or arcs within an orbit.

The following Figure, source: Recommendation ITU-R S.1758 Fig. 1, illustrates an HEO active arc that is limited so that it does not intersect any line between the GSO and the earth's surface.

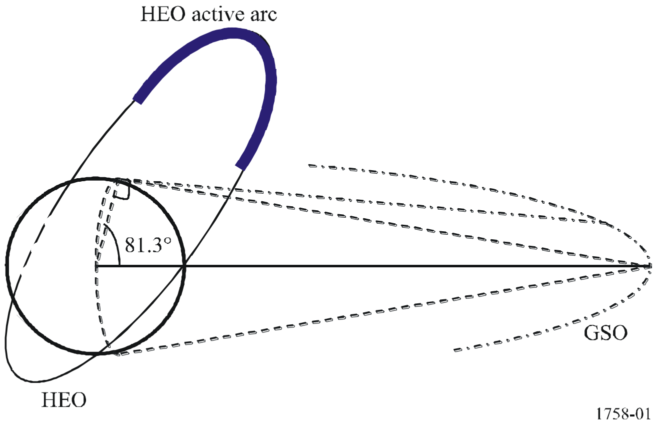

Figure 2. 13 Illustration of an HEO active arc that is limited

One HEO satellite covers the targeted region for eight hours a day; a constellation of three satellites (plus in-orbit standby) provides uninterrupted coverage. The Molniya satellite system is HEO typical; it uses a highly elliptical orbit to provide coverage in latitudes of 60-70°: *Молния* satellite covers the Russian territory. The inclination guarantees good elevation over selected positions, during the northern portion of the orbit; covering Siberia, not reachable by GEO satellite coverage.

2.1.2.2.3 Radio- determination satellite service (RDSS) and Radionavigation-satellite service (RNSS)

As specified before: RR **1.43** *radionavigation-satellite service:* A *radiodetermination-satellite service* used for the purpose of *radionavigation.* Most significant applications of MSS are RNSS. Networks in the RNSS provide worldwide accurate information for many positioning, navigation and timing applications, including safety aspects. Billions around the world use the global navigation satellite system (GNSS), satellite networks with global coverage: the American NAVSTAR global positioning system (GPS) (the world's most utilized navigation system) and the Russian GLONASS (*Global'naya Navigatsionnaya Sputnikovaya Sistema*); in the future also the European Galileo will operate. The regional (currently coverage area limited to Asia and the West Pacific) Chinese 'BeiDou' may be expanded into the global navigation system 'Compass', and the European Galileo navigation system is in initial deployment phase.
Based on Monitoring Handbook 2011 Section 6.1.2.1[9] up to 32 GPS (at least 24) satellites orbit in six inclined orbit planes at altitude about 20,000 km provide both position and time information to users worldwide, through synchronized signals. Measuring those signals from at least three different satellites makes it possible to

[9] The author wrote the original material on global positioning: chapter 5.1 at the ITU 1995 *Handbook on Spectrum Monitoring;* including table 49- comparison of GPS and GLONASS. On May 2024, the Author was nominated to serve as Rapporteur of the Chapter 'Specific monitoring systems and procedures' including the Section 'Monitoring of spacecraft emissions'.

determine the position of the receiving earth site. The constellation provides the user with eight satellites visible from any point on the Earth. Navigation in three dimensions is the primary function of GPS. The differential global positioning system (DGPS) enables more precise positioning, by using GPS receivers at reference locations, to provide corrections and relative positioning data for remote receivers. In case of the **best** implementations, the improvement is from the 15-meter nominal GPS accuracy to about 10 cm; see more general numbers in Table 2.6: Accuracies of GPS, GLONASS and GPS+GLONASS . Time and frequency dissemination, based on the precise clocks on board of satellites and controlled by the monitor stations, is another use for GPS. Telecommunications facilities and laboratory standards can be set to precise time signals or controlled to accurate frequencies by special purpose GPS receivers.
The GPS receiver calculates its position by precisely timing the signals sent by GPS satellites. Each satellite continually transmits messages that include the time the message was transmitted and the satellite position. At least four satellites (i = 1,2,3,4…) should be visible, in order to solve four unknowns: three receiver coordinates (x,y,z) and user clock bias (b)[10]. SAT HB p. 321 specifies: in distribution networks, the central earth station (sometimes called the "hub") is, in principle, a transmit-only station (although receive facilities are usually provided for control and network supervision) and the remote earth stations are receive-only (RO) stations (often called terminals). There are many applications of satellite information distribution to RO terminals; as mentioned, the GPS is the best example: as it is based on the reception, by small, handheld terminals, of reference signals broadcasted by several orbiting satellites. Another example is offered by paging systems where dedicated signals are addressed to the users.
The band 5,010-5,030 MHz is allocated on a primary basis to the RNSS (space-to-Earth and space-to-space) in all three ITU Regions.
Regulators should protect carefully the RNSS frequencies, to provide continuous coverage of the Earth by many satellites. Under RR footnote No. 5.328B, “the use of the bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz and 5 010-5 030 MHz by systems and networks in the RNSS…is subject to the application of the provisions of RR Nos. 9.12, 9.12A and 9.13 …”.
The locus of points having a constant difference in distance to two points (two RNSS satellites) is a hyperboloid. In order to identify the *x*, *y*, *z* and *time* of the RNSS receiver, four or more measured reception are needed; the receiver can be placed at the intersection of the surfaces of three or more hyperboloids.
of ITU-2011[11] *Handbook on Spectrum Monitoring* compares the American and Russian networks’ satellites; see the following two Tables.

Table 2.5: Comparison of GNSS systems

Parameter	GLONASS	GPS
Ephemeris information presentation method	Earth centred fixed coordinates + its derivatives of first and second order	Modified Kepler elements of orbit
Geodesic coordinate system	Parametry Zemli 1990; PZ-90.11	Geodetic Datum; WGS-84
Time corrections relative to the Universal Time Coordinated (UTC)	UTC (SU) SU is the Russian UTC	UTC (USNO); US Naval Observatory master clock
Number of satellites (fully operational)	GLONASS-M: 24 + 2 spares, + 2 GLONASS-K test	30 + 1 spare + 1 test
Number of orbital planes	3	6
Orbital inclination	64.8°	55°
Orbit altitude	19,100 km	20,180 km
Orbital period	11 h 15 min	12 h
Satellite signal division method	FDMA	CDMA
Frequency band L1 (MHz) (civilian)	**1,598.0625 –1,605.375; center 1,602**	**1,575.42 ±1.023**
Frequency band L2 (MHz) (+military)	**1,242.9375–1,248.625; center 1,246**	**1,227.6 ±1.023**
Duration of almanac transmission	2.5 min	12.5 min
Super frame capacity	7,500 bits (5 frames)	37,500 bits (25 frames)
Frame length	30 seconds	
Synchro-code repetition period	2 s	6 s
Cross-talk between neighboring channels	–48 dB	–21 dB
Coarse/Acquisition (C/A); chips per sec	511 kHz	1,023 kHz
C/A-code length (symbols)	511	1,023

[10] Given $c\equiv$ light velocity, the i-th satellite messages its time t_i, position (x_i, y_i, z_i) and pseudo-range (c multiplied by time difference) $r_i = c^*\Delta t_i$. The receiver position (x, y, z) and clock bias time b are found by solving these four (i= 1 to 4) equations: $(x_i-x)^2+(y_i-y)^2+(z_i-z)^2=(r_i-c^*b)^2$.
[11] The author developed the original Table 49 p. 404 at the Monitoring Handbook in 1995.

C/A-code type; pseudorandom noise (PRN)	pseudo-random ranging code	binary sequence: gold code
Modulation	BPSK	
Navigational message data rate	50 bit/s	

Table 2.6: Accuracies of GPS, GLONASS and GPS+GLONASS

Accuracy Parameters (Standards, 95%)*	GLONASS	GPS	GPS+GLONASS
Horizontal	28 m	22 m	20 m
Vertical	40 m	33 m	30 m
Velocity	15 cm/s	50 cm/s	5 cm/s
Timing (ns)	700	200	<200 µs

* civilian accuracy:
- GLONASS accuracy based on open standard-precision;
- GPS accuracy based on standard positioning service (SPS) without selective availability (SA).

2.1.3 Satellite Equipment

The space and earth satellites' equipment should comply with the relevant provisions of the ITU Radio Regulations, ITU-R Recommendations and any relevant domestic regulation requirements. As the space segment does not comply with national borders, no domestic regulation can contradict international regulation.

2.1.3.1 Space Segment

A satellite (which we also can refer to it as "spacecraft") is made up of many sub-systems, such as the:
- Solar arrays to collect energy from the sun and stored in batteries or used real-time;
- Thermal subsystem which controls and manages heat creating and transfer in the satellite;
- Propulsion sub-system for the station keeping of the satellite; and
- Radiocommunication payload which collects signals from the Earth and retransmits these back down, or uses some of them to control and monitor the spacecraft.

Using a space vehicle to capture a signal from Earth and reflect it back requires a specific communication system, the payload:
- Active repeaters- one that demodulates the communication received and re-modulates it before its transmission back to Earth; or
- Passive reflectors- one that acts as a pure bend-pipe system, where the signal spectral components are reflected back to Earth at a different carrier frequency.

The general subsystems of a communication satellite include the:
- Space platform or enclosure;
- Power generating system;
- Environmental;
- Orbital control components; and
- Communication payload.

Those are the main GSO problems:
- Launching and positioning in orbit;
- Fuel up to 10-15 years;
- Stability: solar panels and antennas;
- Power: solar power is used to generate electricity, operation during solar eclipse (in the earth's shadow);
- Communications: satellite to satellite communication by microwave or by optical laser;
- Harsh environment: components need to be specially "hardened'', not only for temperature;
- Effective thermal control of electrical and other components;
- High degree of station-keeping accuracy and attitude control; and

- High antenna pointing accuracy.

For LEOs, batteries are needed as about half the time LEOs are behind the earth. In the case of non-GSO systems, station-keeping is not usually required; lifetimes are usually shorter, because low orbital altitudes introduce drag forces which accelerate orbit decay; and launch vehicle requirements are considerably less for low-altitude orbits.

2.1.3.2 Earth Stations

2.1.3.2.1 GSO and MSS Earth Stations

The earth station is the transmission, reception, relay and control terminal of a telecommunication link via satellite. The general configuration of an earth station is not substantially different from that of a radio-relay terminal, but the very large free-space attenuation (about 200 dB) undergone by the carrier radio waves, on their path between the station and satellite (approximately 36,000 km) usually requires the main subsystems of an earth station to have a much higher performance level, than those of a radio relay terminal see (SAT HB pp. 471-3):

- High-gain (i.e. large diameter, high performance) antenna[12]. Due to its narrow beam, the receiver is less susceptible to noise and to interference;
- High-sensitivity receiver (i.e. with a very low internal noise); and
- powerful transmitter.

The earth station consists of the following main subsystems:

- Antenna, receiver amplifiers (low-noise), transmitter amplifiers (power);
- Telecommunication equipment- frequency converters and modems;
- Multiplexers and demultiplexers;
- Connection with the terrestrial network; and
- Auxiliary equipment, power-supply equipment and general infrastructure.

2.1.3.2.2 Small Earth Stations

Earth stations are often classified by the dimension of their antenna. The antenna diameters of earth stations are less than 7 m (and generally less than 5 m), 2.5 m and 1 m respectively in the 6/4[13] GHz, 14/10-12 GHz and 30/20 GHz frequency bands. Small earth station includes a wide variety of earth stations implemented in the FSS (at 6/4 GHz, 14/10-12 GHz, 30/20 GHz) in the framework of GSO or non-GSO satellite systems. The small earth stations are characterized by their applications. Small stations serve as remote area communications systems (rural telecommunications and services to isolated sites such as off-shore platforms, pipelines, mines, etc.) and business communications (corporate networks), generally in the framework of closed users communities. Some important applications are listed below: telephony and data transmission; TV reception for local distribution (e.g. cable TV: CATV) or re-broadcasting etc.

TVRO is television receive-only: an antenna and associated equipment for reception from a broadcasting-satellite. The TVROs needed for BSS reception are smaller than the ones needed for operation in the FSS; for example, 0.6 m to 0.8 m diameter antennas are commonly used to receive digital TV bouquets broadcast at 11 GHz[14]; See SAT HB pp. 488-9.

VSAT is a very small aperture terminal, serving business communications. VSAT earth stations operate on the FSS; their most commonly used FSS bands are 14/11-12 GHz and 6/4 GHz bands; see Recommendation ITU-R S.725.

[12] The antenna of the earth station is used for both reception and transmission.

[13] The first number in the left stands for uplink and the second number on the right of the slash stands for downlink. The downlink transmits at the lower RF, due to reduced propagation loss; see Chapter 5 of this book, Section 5.2.5.2 'Full Duplex Techniques'.

[14] The reduction of the antenna diameter may be limited by the need to avoid interference from nearby satellites. This should not be the case in the BSS, where the satellites are significantly spaced apart.

At higher frequencies, the antenna diameter is smaller for a given antenna gain and bandwidth (see Chapter 5 of this book – antennas, equation 5.17[15]). The sizes[16] of typical antennas are for the:

- C Band (4 GHz to 8 GHz) 1.4m to 2.4m;
- Ku Band (12 to 18 GHz) 0.45m to 1.2m;
- Ka Band (18 to 40 GHz) 0.2m to 0.6m.

The following Table is based on ITU (2023) Handbook on Small Satellites Section 1.1 and Recommendation ITU-R V.431-8 (08/2015)[17]:

Table 2.7: Vocabulary and designations of Satellites' RF bands

	RF (GHz)			RF (GHz)
L-Band	1 - 2		**Ku** -Band	12 - 18
S Band	2 - 4		**K** -Band	18 - 26.5
C Band	4 - 8		**Ka** -Band	26.5 - 40
X-Band	8 - 12		**Q** -Band	40 - 50

2.1.3.2.3 and Portable earth station

Transportable earth stations are used in the following applications:

- satellite news gathering (SNG),
- emergency communications in cases of natural disasters,
- temporary communications,
- additional communications capacity for special events (such as sports, musical and live broadcasting).

These earth stations are transportable via a van, truck, vessel or aircraft and provide voice, data and video transmission through international, regional and domestic satellite systems. Various transportable earth stations are used in the 6/4 GHz, 14/12 GHz and 30/20 GHz frequency bands; see SAT HB p. 494.

In the framework of the MSS or personal satellite communications, such as Iridium, Globalstar and others, very compact handheld earth stations (often called simply "terminal") are currently in use. These terminals are designed under the same technological principles as those used in the cellular mobile terrestrial systems.

A gain of −5 dBi is typical to portable receivers from satellites visible above 5° elevation using hemispherical coverage antennas. The antenna gain of Galileo receivers varies from –5 dBi to +4 dBi for elevation angles between 5° and 90°; SAT HB p. 496.

2.1.4 Monitoring and Regulating Satellite Communications

2.1.4.1 Monitoring of Satellite Communications

ITU Monitoring handbook 2011 Section 5.1 describes professionally the Monitoring of spacecraft emissions[18].

2.1.4.2 Regulatory considerations and system planning

One GEO satellite covers large areas and may interfere with various radio services in many countries; moreover, the frequency can be reused; therefore a global regulation is needed. The ITU Member States have established a legal regime which is codified through the ITU Constitution / Convention, including the Radio Regulations (RR). These instruments contain the main principles and lay down the specific regulations governing the following major elements:

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[15] When using the same units for λ wavelength and l antenna length or diameter, the antenna gain G_0 (dBi) equals 7.9 - 20log(λ / l).

[16] To get the same gain, the ratio λ / l should stay: so, at 10 GHz should be twice the diameter at 20 GHz antenna; see this book Section 5.5.1.2 "Antenna gain", and Recommendation ITU-R F.699-8 *recommends* 3 and 4.

[17] Table 4 lists common RF bands; note that these RF bands are different than the IEEE designations

[18] On May 2024, the Author was nominated to serve as Rapporteur of the Chapter 'Specific monitoring systems and procedures' including the Section 'Monitoring of spacecraft emissions'.

- frequency spectrum allocations to different radiocommunication services (RR Article 5);
- international recognition of these rights by recording frequency assignments and, as appropriate, orbital positions used or intended to be used in the master international frequency register (MIFR) (see RR Article 11).

In general terms, the RR distinguish between non-GSO and GSO satellite networks, which are subject to different regulatory regimes. Any GSO satellite network in any frequency band has to coordinate its planned use of orbit and frequency spectrum with any other GSO system likely to be affected, for which notification was received at an earlier date by the ITU Radiocommunication Bureau (BR). Non-GSO networks are subject to coordination only in respect of certain specific space services in certain frequency bands, identified by footnotes to the international table of frequency allocations. The main regulatory procedures applicable to space systems are contained in RR Article 9 and in RR Appendix 5. In line with the normal practice in connection with space services, RR Article 9 contains a two-step procedure, consisting in the publication of simplified advance information on the planned network, followed by coordination with systems likely to be affected, observing an order of priority determined by the date of submission of the coordination data to ITU. The same Article envisages the need for coordination of a planned space system (space and earth station) vis-à-vis other non-GSO or GSO systems as well as with terrestrial services sharing the same frequency band. The procedure for notification and recording of space network frequency assignments in the MIFR is described in RR Article 11.

The MIFR provides 'usage right' to (mainly) geostationary earth orbit (GSO) networks. However, these rights are not absolute, as operators who have assignments in the MIFR must always do their utmost best to accommodate other newer systems -see ITU Radio Regulations (RR) No. 9.53 and the ITU Rules of Procedures-, as assignments can only be retained until a satellite come to its end of life or moved away from the orbital location and no other satellites replaces the old one. More on property and usage right, see in this Book, Section 4.2.3 "RF-spectrum and property rights".

The RR contain also provisions for sharing between space and terrestrial services. Above 1 GHz, RR Article 21, Sections I-III, aims to protect the GSO space services from the terrestrial emissions of fixed and mobile services, the transmitting stations of which must be pointed 2° away from the GSO and observe power level limits. With respect to the protection of terrestrial receiving stations vis-à-vis space stations, Sections IV and V respectively provide the minimum angle of elevation of earth stations and the limits of power flux density (pfd) from space stations. RR Article 22 indicates further the rules relating to space radiocommunications services.

2.1.4.3 Satellite Frequency bands

The following Table summarizes the main RF bands used for GSO. These RF bands are typical in ITU Region 1; similar bands with minor differences are used for GSO in ITU Regions 2 and 3. Typical utilizations are found in SAT HB p.12 (Table 1-2). The following Table specifies the allocation of frequencies to the FSS, BSS, MSS and inter-satellite service (ISS) services; see also Table 2.2: Space: RR Section IV– definition of radio stations, systems, networks or links.

Table 2.8: Main Frequency bands used in for GSO

Frequency bands (GHz)		
Current denomination	Up path/uplink (bandwidth)	Down path/downlink (bandwidth)
6/4 (C Band) (Unplanned FSS)	5.725-6. 725 (1,000 MHz)	3.4-4.2 (800 MHz)
6/4 (C Band) (Planned FSS)	6.725-7.025 (300 MHz)	4.5-4.8 (300 MHz)
8/7 (X-Band) (Unplanned FSS)	7.925-8.425 (500 MHz)	7.25-7.75 (500 MHz)
13/11 (Ku Band) Planned FSS	12.75-13.25 (500 MHz)	10.7-10.95;11.2-11.45 (500 MHz)
13-14/11-12 (Ku Band) Unplanned FSS	13.75-14.5 (750 MHz)	10.95-11.2;11.45-11.7; 12.5-12.75 (750 MHz)

18/12 (Ku Band) Planned BSS	17.3-18.1 (800 MHz)	11.7-12.5 (800 MHz)
30/20 (Ka Band)*	27.5-31.0 (3,500 MHz)	17.7-21.2 (3,500 MHz)
40/20 (Ka Band)	42.5-45.5 (3,000 MHz)	18.2-21.2 (3,000 MHz)

The RF bands 30.0-31.0 uplink and 20.2-21.2 GHz downlink, unnoticed at SAT HB Table 1-2, are mostly used for military purposes, but not mandatory.

As GSO/ GEO may cover more than one ITU Region, the RF bands are similar in different continents.

2.2 References

The last version of any Delivery should be used.

ITU Radio Regulations and World Radio Conference (WRC) Resolutions **https://www.itu.int/dms_pub/itu-r/opb/reg/R-REG-RR-2024-ZPF-E.zip**
ITU Radio Regulations Edition of 2024*
Resolution 1 (REV.WRC-97) Notification of frequency assignments Resolution 2 (REV.WRC-03) Equitable use, by all countries, with equal rights, of the geostationary-satellite and other satellite orbits and of frequency bands for space radiocommunication services Resolution 4 (REV.WRC-03) Period of validity of frequency assignments to space stations using the geostationary-satellite and other satellite orbits Resolution 8 (WRC-23) Tolerances for certain orbital characteristics of space stations deployed as part of non-geostationary-satellite orbit systems in the fixed-satellite, broadcasting-satellite or mobile-satellite service Resolution 14 (WRC 23) Studies on development of regulatory measures, and implementability thereof, to limit the unauthorized operations of non-geostationary-satellite orbit (non-GSO) earth stations in the fixed-satellite service (FSS) and mobile-satellite service (MSS) and associated issues related to the service area of non-GSO FSS and MSS satellite systems Resolution 15 (REV.WRC-03) International cooperation and technical assistance in the field of space radiocommunications Resolution 22 (REV.WRC 23) Measures to limit unauthorized uplink transmissions from earth stations Resolution 25 (REV.WRC-23) Operation of global satellite systems for personal communications Resolution 32 (REV.WRC-23) Regulatory procedures for frequency assignments to non-geostationary-satellite networks or systems identified as short-duration mission not subject to the application of Section II of Article 9 Resolution 34 (REV.WRC 19) Establishment of the broadcasting-satellite service in Region 3 in the frequency band 12.5 12.75 GHz and sharing with space and terrestrial services in Regions 1, 2 Resolution 35 (REV.WRC-23) A milestone-based approach for the implementation of frequency assignments to space stations in a non-geostationary-satellite system in specific frequency bands and services Resolution 40 (REV.WRC-19) Use of one space station to bring frequency assignments to geostationary-satellite networks at different orbital locations into use within a short period of time Resolution 42 (REV.WRC-19) Use of interim systems in Region 2 in the broadcasting-satellite and fixed-satellite (feeder-link) services in Region 2 for the frequency bands covered by Appendices 30 and 30A Resolution 49 (REV.WRC-23) Administrative due diligence applicable to some satellite radiocommunication services Resolution 55 (REV.WRC-23) Electronic submission of, and communications on, notice forms for satellite networks, earth stations and radio astronomy stations and reports of harmful interference affecting space services Resolution 76 (REV.WRC-23) Protection of geostationary fixed-satellite service and geostationary broadcasting-satellite service networks from the maximum aggregate equivalent power flux density produced by multiple non geostationary fixed-satellite service systems in frequency bands where equivalent power flux-density limits have been adopted Resolution 85 (REV.WRC-23) Application of Article 22 of the Radio Regulations for the protection of geostationary fixed-satellite service and broadcasting-satellite service networks from non-geostationary fixed-satellite service systems Resolution 111 (ORB-88) Planning of the fixed-satellite service in the bands 18.1-18.3 GHz, 18.3-20.2 GHz and 27-30 GHz

Resolution 114 (REV.WRC-15) Compatibility between the aeronautical radionavigation service and the fixed-satellite service (Earth-to-space) (limited to feeder links of the non-geostationary mobile-satellite systems in the mobile-satellite service) in the frequency band 5 091-5 150 MHz
Resolution 121 (WRC-23) Use of the frequency band 12.75-13.25 GHz by earth stations in motion on aircraft and vessels communicating with geostationary space stations in the fixed-satellite service
Resolution 122 (REV.WRC 19) Use of the frequency bands 47.2-47.5 GHz and 47.9-48.2 GHz by high-altitude platform stations in the fixed service
Resolution 123 (WRC-23) Use of the frequency bands 17.7-18.6 GHz, 18.8 19.3 GHz and 19.7-20.2 GHz (space-to-Earth) and 27.5 29.1 GHz and 29.5-30 GHz (Earth-to-space) by aeronautical and maritime earth stations in motion communicating with non-geostationary space stations in the fixed-satellite serviceResolution 125 (REV.WRC-12) Frequency sharing in the bands 1 610.6 1 613.8 MHz and 1 660-1 660.5 MHz between the mobile-satellite service and the radio astronomy service
Resolution 126 (WRC-23) Temporary regulatory measures in Appendix 30B to improve the reference situation of severely impacted national allotments
Resolution 129 (WRC 23) Studies on possible revisions of sharing conditions in the frequency band 13.75-14 GHz to allow the use of uplink fixed-satellite service earth stations with smaller antenna sizes
Resolution 130 (WRC 23) Studies relating to the use of the frequency band 51.4-52.4 GHz to enable its use by gateway earth stations transmitting to non-geostationary-satellite orbit systems in the fixed-satellite service (Earth-to-space)
Resolution 131 (WRC 23) Consideration of technical and regulatory measures for fixed-satellite service satellite networks/systems in the frequency bands 37.5-42.5 GHz (space-to-Earth), 42.5 43.5 GHz (Earth-to-space), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space) for equitable access to these frequency bands
Resolution 133 (WRC-23) Study of the possible use of the frequency band 12.75-13.25 GHz by aeronautical and maritime earth stations in motion communicating with non-geostationary space stations in the fixed-satellite service (Earth-to-space)
Resolution 143 (REV.WRC 19) Guidelines for the implementation of high-density applications in the fixed-satellite service in frequency bands identified for these applications
Resolution 144 (REV.WRC-15) Special requirements of geographically small or narrow countries operating earth stations in the fixed-satellite service in the frequency band 13.75-14 GHz
Resolution 147 (WRC 07) Power flux-density limits for certain systems in the fixed-satellite service using highly-inclined orbits having an apogee altitude greater than 18 000 km and an orbital inclination between 35° and 145° in the band 17.7-19.7 GHz
Resolution 148 (REV.WRC-15) Satellite systems formerly listed in Part B of the Plan of Appendix 30B (WARC Orb-88)
Resolution 154 (REV.WRC 15) Consideration of technical and regulatory actions in order to support existing and future operation of fixed-satellite service earth stations within the frequency band 3 400-4 200 MHz, as an aid to the safe operation of aircraft and reliable distribution of meteorological information in some countries in Region 1
Resolution 155 (REV.WRC 19) Regulatory provisions related to earth stations on board unmanned aircraft which operate with geostationary-satellite networks in the fixed-satellite service in certain frequency bands not subject to a Plan of Appendices 30, 30A and 30B for the control and non-payload communications of unmanned aircraft systems in non-segregated airspaces
Resolution 156 (REV.WRC 23) Use of the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz by earth stations in motion communicating with geostationary space stations in the fixed-satellite service
Resolution 163 (WRC-15) Deployment of earth stations in some Regions 1 and 2 countries in the frequency band 14.5-14.75 GHz in the fixed-satellite service (Earth-to-space) not for feeder links for the broadcasting-satellite service
Resolution 169 (REV.WRC-23) Use of the frequency bands 17.7-19.7 GHz and 27.5-29.5 GHz by earth stations in motion communicating with geostationary space stations in the fixed-satellite service

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N^0	**Radio Assembly ITU-R Resolutions** https://www.itu.int/pub/R-RES/en
1.	Res.47 Future submission of satellite radio transmission technologies for IMT-2000
2.	Res.68 Improving the dissemination of knowledge concerning the applicable regulatory procedures for small satellites, including nanosatellites and picosatellites
3.	Res.69 Development and deployment of international public telecommunications via satellite in developing countries
4.	Res.74 Activities related to the sustainable use of radio-frequency spectrum and associated satellite-orbit resources used by space services

N^0	**ITU Handbooks** https://www.itu.int/pub/R-HDB
1.	ITU 2002 *Handbook on Satellite Communications*, third edition, West Sussex: John Wiley & Sons
2.	ITU 2011 *Monitoring handbook 2011*
3.	ITU 2023 Handbook on Small Satellites

N^0	**Recommendations ITU-R** https://www.itu.int/pub/R-REC/e
1.	F.699-8 Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to 86 GHz
2.	P.525 Calculation of free-space attenuation
3.	S.673 Terms and definitions relating to space radiocommunications
4.	S.725 Technical characteristics for very small aperture terminals (VSATs)
5.	S.1758 Characterization of HEO-type systems in the fixed-satellite service
6.	V.431-8 Nomenclature of the frequency and wavelength bands used in telecommunications

Bibliography
Mazar H. (2016) 'Radio Spectrum Management: Policies, Regulations and Techniques' appears at Wiley and Amazon; ISBN: 9781118511794; DOI:10.1002/9781118759639. Click- the link to this Section of the Book.

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