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Radiocommunication Sector

Handbook on Amateur and amateur-satellite services

Edition of 2026

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Radiocommunication Bureau

Foreword

This Handbook provides general information about the amateur and amateur-satellite services. It also includes a list of existing ITU texts of relevance to the amateur and amateur-satellite services.

The amateur service is one of the oldest radio services and pre-dates regulation of radiocommunication. The amateur service was first defined in the 1927 edition of the International Radiotelegraph Convention. Today, the amateur service operates in relatively small allocations throughout the spectrum from 135.7 kHz to 250 GHz.

The 1963 World Administrative Radio Conference (WARC) created Footnote 284A, which states: "In the band 144-146 MHz, artificial satellites may be used by the amateur service". The amateur-satellite service was created and given frequency allocations at the 1971 Space WARC. Since then, scores of amateur satellites have been designed, constructed and operated by amateurs. In addition, amateur radio has been used aboard manned space stations including MIR and the International Space Station. Most astronauts and cosmonauts are licenced amateur radio operators.

Self-training is an important purpose of the amateur services, as articulated in the definition of the amateur service in No. **1.56** of the Radio Regulations (RR).

Radio amateurs have made significant technical contributions to the fields of radio propagation, high frequency single sideband radiotelephony, HF data communications, packet radio protocols and communication satellite design.

Radio Regulations No. **25.9A** encourages administrations to allow amateur stations to support disaster relief. Amateur radio continues to provide basic radiocommunications especially in the early moments of a disaster causing the loss or overloading of normal telecommunications networks.

This Handbook is intended to present, in one publication, information about the amateur services for administrations and amateur radio organizations.

This work would not have been possible without the efforts of many volunteers and delegates over a number of years and their efforts should be recognised.

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CHAPTER 1

THE AMATEUR SERVICES

1.1 Historical context

The amateur service is one of the oldest radio service and pre-dates regulation of radiocommunication. Today, the amateur service retains relatively narrow bands throughout the entire radio spectrum. These bands provide the whole range of radio wave propagation mechanisms and, through experimentation, amateurs continue to contribute to the understanding of propagation.

1.2 The amateur services today

Over the years, radio amateurs have made significant technical contributions to the field of radio propagation and antenna design over a wide range of frequencies from 135.7 kHz to beyond 250 GHz. Equipment developments have progressed from continuous wave telegraphy, amplitude modulation, analogue single-sideband telephony, and frequency modulation into digital voice modes, data communication systems, digital radio protocols, image and video transmission, communications-satellites and software-defined radio techniques.

New communication protocols using structured data with strong forward error correction together with sophisticated correlation processes have been developed that ensure reliable communication at very poor signal to noise ratios and these systems have enabled the use of communications paths when they would otherwise not be usable.

Amateur radio continues to play an important role in disaster communications. It has the unique ability to provide radiocommunication independent of the telephone network, the internet, other radio services and independent of national power grids, particularly in the first few days before relief agencies are at the scene and have set up emergency telecommunication systems.

1.3 Regulatory interactions

As the amateur and amateur-satellite services are defined in the Radio Regulations and operate under national licensing arrangements, it is common for representatives of the amateur and amateur-satellite services to interact with regulatory bodies at global, regional and national levels.

The International Amateur Radio Union (IARU), founded in Paris in 1925, is the federation of the national amateur radio associations existing in most countries. It represents the amateur and amateur-satellite services in the ITU and regional telecommunications organizations.

As a global organization, the IARU is a member of the ITU Radiocommunication (ITU-R) and Telecommunication Development (ITU-D) Sectors. Through this membership the IARU participates in various ITU-R Working Party meetings, Radiocommunication Assemblies and World Radiocommunication Conferences.

At a regional level, a number of amateur representative organizations have Memorandums of Understanding with relevant Regional Telecommunication Organizations and participate in discussions relevant to the amateur and amateur-satellite services:

– ITU Region 1:
  - IARU Region 1 participates in ASMG, ATU, CEPT, RCC discussions;
  - European Radio Amateurs' Organization (EURAO) is an observer at CEPT (and are an ITU-R Sector Member);

– ITU Region 2: IARU Region 2 participates in CITEL discussions;

– ITU Region 3: IARU Region 3 participates in APT discussions.

At a national level there are many national amateur radio societies that participate in discussions covering regulatory and operational issues that are relevant to the amateur services in their country. Many countries permit representatives of national amateur societies to participate in ITU-R discussions through membership of national delegations to ITU-R meetings.

1.4 Training

The amateur services include self-training as an important objective and all amateur radio operators are licensed having demonstrated a level of technical and regulatory competence through a national examination process as described in Recommendation ITU-R M.1544.

Some national amateur radio societies have one or more training courses and publications designed for individuals preparing to take amateur licence examinations. The training material usually covers the technical and regulatory aspects of radiocommunication so that the operator can use their station to communicate effectively without causing interference to other services. Some national societies also have continuing education courses in a variety of subjects including courses on preparedness for emergencies.

Radio amateurs have the opportunity of planning, designing, building, operating, and maintaining a complete radio station, which contributes to the telecommunication human resources development of a country.

Training young people in radiocommunications technology and applying the technologies and techniques of amateur radio is an ideal way to promote scientific, technical, engineering and math (STEM) education experiences in the classroom.

1.5 Mutual recognition of amateur radio licences

As for all other radiocommunication services, the operation of an amateur station requires authorization from the administration of the country of operation. Such an authorization is frequently referred to as a licence. According to RR No. **25.6**, any person wishing to obtain such an authorization must prove their operational and technical qualifications.

RR No. **25.9B** allows an administration to determine whether to permit a person who has been granted a licence to operate an amateur station by another administration to operate an amateur station while that person is temporarily in its territory.

There are various types of operating authorizations:

– visitor licences issued by an administration based on presentation of a valid licence from the operator's country of origin;

– reciprocal agreements between national administrations and regional groups; e.g. CEPT Recommendations T/R 61-01, T/R 61-02 and ECC/REC/(05)06;

– OAS/CITEL International Amateur Radio Permit (IARP).

1.5.1 CEPT

Based on standardized licensing rules, CEPT members established a system of mutual recognition of amateur radio licences.

The following table lists the different licensing schemes and the relevant CEPT documents.

Licence class	Exam qualifications / Syllabus	Reciprocal/temporary licence recognition
Full	Recommendation T/R 61-02 (HAREC)	Recommendation T/R 61-01
Novice (intermediate)	ERC Report 32	ECC Recommendation (05)06
Entry level	ECC Report 89	–

These documents can be found on the CEPT Deliverables website.

CEPT Recommendation T/R 61-02 establishes a mutually recognised Harmonized Amateur Radio Examination Certificate (HAREC). The HAREC document shows proof of successfully passing an amateur radio examination which complies with the examination syllabus for the HAREC. It facilitates the issuing of an individual licence to radio amateurs in their home country as well as for of other countries for stays longer term than that mentioned in CEPT Recommendation T/R 61-01 (as the latter is limited to temporary visits). It also facilitates the issuing of an individual licence to a radio amateur returning to his native country showing the HAREC certificate issued by a foreign Administration.

ERC Report 32 provides the amateur radio novice examination syllabus in support of ECC Recommendation (05)06 on the CEPT Novice Radio Amateur Licence which also rules the mutual recognition of CEPT Novices licences.

Any non-CEPT administration wishing to join the mutual recognition of either CEPT Recommendation T/R 61-01, T/R 61-02 or ECC/REC(05)06 can apply by providing a 'Statement of Conformity' (SOC). The final approval for applications by non-CEPT administrations is subject to the agreement of CEPT administrations.

Due to the time required for individuals to attain the high-level technical knowledge of the theory required for the HAREC licence (see T/R 61-02 and T/R 61-01) and NOVICE licence (see Report ERC Report 32 and ECC/REC/(05)06), it has been suggested by the International Amateur Radio Union (IARU) that a lower-level examination suitable for an amateur radio 'Entry Level' class licence be introduced. Several administrations wish to establish or are establishing such a licence class.

ECC Report 89 describes such a third level European amateur radio licence, the ENTRY-CLASS, an examination syllabus, its application, and administrative process. Administrations are not required to implement all the licence levels. Depending on national circumstances administrations may decide to make use of one, two or all three licence levels. The entry level licence is currently not subject to mutual recognition of licences.

1.5.2 OAS International Amateur Radio Permit (IARP)

The IARP is an inter-American treaty established by the Organization of American States (OAS) for the Member States of the Inter-American Telecommunication Commission (CITEL). It was first signed in 1987 as the Inter-American Amateur Radio Service Convention ("Lima Convention") and last revised in 2018. It permits amateurs from treaty signatory countries of the Americas to operate in other signatory countries of the Americas without seeking a special licence or permit other than the IARP.

1.6 Standardized operator qualifications

Recommendation ITU-R M.1544 establishes minimum qualifications of radio amateurs. This Recommendation defines minimum levels of operational and technical knowledge required by amateur radio operators. The information is useful for administrations when verifying the qualifications of a person wishing to operate a station in the amateur services.

Some countries have developed their own syllabi and pools of examination questions. National amateur radio societies are aware of the systems used in other countries, and there is a trend toward uniformity of approaches; these are activities outside of ITU-R.

1.7 Types of amateur radio licences

All amateur radio operators are authorized by a national licence to transmit in bands allocated to the amateur and amateur-satellite services according to their national regulations. Although there is variation by country, there are at least two kinds of licencing procedures:

– once the operator is qualified by national examination, he/she is granted a licence to transmit; this is known as the operator or class licence; and

– the operator is qualified by national examination to acquire an operator certificate, then he/she can apply for the station or apparatus licence to transmit.

The operator or class licence is a permit for a person to operate an amateur station, and this licence may be valid for a specified number of years but there are some administrations issuing lifetime operator licences. Station or apparatus licences are typically issued for a certain number of years to enable the administration to maintain a current database of amateur stations.

The situation in some administrations is slightly different in that there is no amateur radio licence per se. Rather, an applicant must obtain, by examination, a Certificate of Proficiency in Amateur Radio. A call sign may then be assigned and attached to this certificate. The authorisation is good for some years or the lifetime of the holder.

1.7.1 Individual amateur licence

Amateur radio licences are issued to individual operators after successfully passing a licence examination. The privileges of a licence may not be transferred to other persons, but a licensee may, depending on national regulations, permit another person to operate the amateur station under supervision provided that a licensee is in direct control of the transmissions.

1.7.2 Club stations

Administrations may issue club station licences to an amateur radio organization. Normally, the licence is issued to a “trustee” who is a licenced operator and is responsible for the proper operation of the club station. Club stations are particularly valuable for educational purposes.

The premier example of a radio club station is the International Amateur Radio Club (IARC) using the call sign 4U1ITU operating in the ITU premises. It is available for use by ITU delegates who are licenced radio amateurs upon issuance of a visitor’s licence.

1.7.3 Special event stations

Some administrations issue temporary licences, or otherwise authorize stations for special events, such as to commemorate a national anniversary. These licences may be issued to an individual or a club.

1.7.4 Repeaters and beacons

Repeaters and beacons are devices set up to assist the community of amateur operators in many countries. The usual purpose is to extend the communication range within a geographic area. Voice repeaters re-transmit narrow-band analogue and digital voice traffic when activated with a signal on the input frequency. Some voice repeaters can replay the input signal to allow an operator to check their signal quality. Data and Amateur Television (ATV) repeater stations transmit wider bandwidth amateur signals and ATV repeater stations may transmit test signals when not being accessed by a

user station on the input channel. All repeater stations regularly transmit callsign and sometimes other information.

Repeaters operate on nearly all bands above 29 MHz allocated to the amateur service. Some repeaters are ‘cross-band’; that is, the input frequency band is different to the output frequency band.

It is becoming increasingly common for individual repeaters to be linked into a network of repeaters. In some cases, the network can offer national coverage or even international coverage. Some repeater networks also provide the facility of protocol conversion (often known as ‘transcoding’) so that different modes of communications can intercommunicate; for example, some systems convert analogue FM voice to digital voice and vice-versa. This expands the user base and allows otherwise incompatible technologies to seamlessly communicate.

If the repeater is permanently installed, it would be licenced for its designated location, operating frequency, and output power by the national authority. The licence and responsibility of the station operation are usually associated with a licenced radio amateur operator known as the ‘keeper’ of the installation. Portable repeater systems also exist, and they may be deployed for temporary use at community events or to support disaster and emergency relief operations.

Propagation beacons are usually intended to operate continuously and are required to transmit a short repeating message using on/off keying or a narrow-band FSK signal with call sign ID and location information. The beacons indicate when propagation paths exist which may be suitable for longer distance communications. The beacons may be standalone or be part of a time synchronized network which may assist in providing an advance warning of enhanced propagation conditions. All beacons are licenced under national regulations by the relevant national authority.

1.8 Technical characteristics of stations

RR No. **25.7** provides that “The maximum power of amateur stations shall be fixed by the administrations concerned”. While the manner of regulating transmitter power varies among administrations, it is typically specified as peak envelope power output (also called PX or pX). The maximum power typically is set at between 26 and 33 dBW for the most qualified operators, with lower limits for certain frequency bands and classes of operator licence. The most recent version of Recommendation ITU-R M.1732 provides information on typical characteristics of amateur stations across the range of frequency bands allocated to the amateur and amateur-satellite services.

CHAPTER 2

AMATEUR SERVICE

2.1 Applications of bands allocated to the amateur service

The following tables describe typical applications of frequency bands available to the amateur service. Refer to Radio Regulations Article **5** for the specific allocation status of each band. Refer to national regulations for specific allocations, as they may vary by country.

Nominal wavelength	**Frequency band (kHz) (R = Region)**	**Application**
2 200 m	135.7-137.8 (secondary) Geographical constraints are given is RR Nos. **5.67A** and **5.67B**	Propagation in this band permits short-range communications during daytime hours and longer-range communications via ionospheric refraction at night, when D layer absorption weakens. Power output is limited to 1 W e.i.r.p. which is sufficient for transcontinental and transoceanic transmissions at night.
630 m	472-479 (secondary) Geographical and technical constraints are given in RR Nos. **5.82**, **5.80A** and **5.80B**	Propagation in this band permits short-range communications during daytime hours and longer-range communications via ionospheric refraction at night, when D layer absorption weakens. Power output is limited to either 1 W or 5 W e.i.r.p., depending on the location of the station (see RR Nos. **5.80A** and **5.80B**)
160 m	1 810-1 850 R1 (co-primary use with other services) RR Nos. **5.98**, **5.99**, **5.100**, **5.101** and **5.103**	The propagation characteristics of this band allows short-range communications during daytime hours, and medium and long-range communications during night-time hours. This band is particularly useful during sunspot minima, when the maximum usable frequency (MUF) is below 3 500 kHz.
	1 800-1 850 R2	
	1 800-2 000 R2, R3 (co-primary use with other services) RR Nos. **5.96** and **5.102**	

Nominal wavelength	Frequency band (kHz) (R = Region)	Application
80 m	3 500-3 800 R1 (co-primary use with other services) RR No. **5.92**	This band is used for contacts over distances of up to 500 km during the day, and for distances of 2 000 km and more at night. It is heavily used during communications emergencies.
80 m	3 500-3 750 R2 (primary) RR No. **5.119**	
	3 500-3 900 R3 (co-primary use with other services)	
	3 750-4 000 R2 (co-primary use with other services) RR Nos. **5.122** and **5.125**	
60 m	5 351.5-5 366.5 (secondary) RR No. **5.133B**	Amateur e.i.r.p is limited to 15 W or 25 W in accordance with RR No. **5.133B** while some countries allow higher powers. This band displays very good Near Vertical Incidence Sky wave propagation characteristics.
40 m	7 000-7 200 R1, R3 (primary) RR Nos. **5.40**, **5.141**, **5.141A**, **5.142**	The 7 MHz band is heavily used 24 hours each day. During daylight hours, the band carries the bulk of amateur sky wave communication over distances of less than 1 300 km.
	7 000-7 300 R2 (primary) RR No. **5.142**	
30 m	10 100-10 150 (secondary)	This band is in use 24 hours each day, as a bridge between the 7 MHz and 14 MHz bands.
20 m	14 000-14 250 (primary)	This is the most popular band for international communications.
	14 250-14 350 (Conditions of co-primary use with other services in a number of countries are given in RR No. **5.152**)	
17 m	18 068-18 168 (conditions of co-primary use with other services in a number of countries are given in RR No. **5.154**)	The band is used as an alternative to 14 MHz which is often congested with traffic.
15 m	21 000-21 450 (primary)	These bands are used particularly during the daytime and when sunspot activity is high.
12 m	24 890-24 990 (primary)	
10 m	28 000-29 700 (primary)	

Nominal wavelength	**Frequency band (MHz) (R = Region)**	**Application**
6 m	50-52 R1 RR Nos. **5.166A**, **5.166B**, **5.166C**, **5.166D**, **5.166E**, **5.169**, **5.169A** and **5.169B**	This band is used for local communication at all times including via repeaters. The band may also be used on occasion for word wide communication by sky wave, tropospheric scatter, Earth-Moon-Earth (EME), sporadic reflection from the E layer of the ionosphere (Es) and scattering by the ionized trails of meteors (MS). In some countries, part of the 50-52 MHz frequency band may also include telecommand of objects such as models by radio amateurs.
	50-54 (primary) R2, R3 (geographical constraints are given in RR Nos. **5.162A**, **5.167**, **5.167A**, **5.158** and **5.170**)	
2 m	144-146 (primary) RR No. **5.216**	This band is heavily used throughout the world for short-range communications, including the use of repeaters. This band is actively used for EME communications using analogue and digital modulation techniques, for different types of radio waves propagation – tropospheric scattering and super refraction (TROPO), scattering by Field Aligned Irregularities (FAI) in the lower ionosphere, scattering by the ionized trails of meteors as well as ionospheric scattering in the circumpolar regions during polar storms, making it possible to contact, using analogue and digital modulation techniques, over distances of up to 2 000-3 000 km. This band is actively used for local communications in times of disasters. It is also used for contacts with the use of repeaters on board amateur satellites.
	144-148 R2, R3 (conditions of co-primary use with other services in a number of countries are given in RR No**. 5.217**)	
1.25 m	220-225 R2 (primary)	Where allocated, this band serves as an alternative to the 144 MHz band for short-range communications.
70 cm	430-440 (R1 and some countries in R2 co-primary use with other services, R3 secondary) RR Nos. **5.138**, **5.271**, **5.272**, **5.273**, **5.274**, **5.275**, **5.276**, **5.277**, **5.278**, **5.279A**, **5.280**, **5.281**, **5.282** and **5.283**	This band is used for short-range communications including repeaters and amateur analogue and digital television. It is also used for EME communications using analogue and digital modulation techniques. Tropospheric scattering and TROPO makes it possible to contact over distances of up to 2 000 km. It is also used for contacts with the repeaters on board amateur satellites.
	420-430 and 440-450 in several countries. R2, R3 on a secondary basis RR No. **5.270**	
33 cm	902-928 R2 (secondary) RR No. **5.150**	This band is allocated to the amateur service only in Region 2.

Nominal wavelength	Frequency band (MHz) (R = Region)	Application
23 cm	1 240-1 300 (secondary) RR Nos. **5.282** and **5.332A**	This band is used for communications using analogue and digital modulation techniques, as well as for digital television and repeater networks. Tropospheric scattering and TROPO makes is possible to contact over distances of over 1 000 km. This band is the most popular for EME communications using analogue and digital modulation techniques. Also, this band is used for contacts on board amateur satellites (Earth-to-space direction only). In some countries there are e.i.r.p. and transmitted bandwidth limitations.
13 cm	2 300-2 450 (secondary)	This band is used for narrowband, data and television communications and for experimentation. It is also used for EME communications and for contacts with the use of repeaters on board amateur satellites.
9 cm	3 300-3 500 R2, R3 (secondary)	These bands are used for narrowband communications, data links and for EME communications using analogue and digital modulation techniques.
5 cm	5 650-5 850 R1, R3 5 650-5 925 R2 (secondary in all three regions)	

Nominal wavelength	Frequency band (GHz)	Application
3 cm	10-10.5 (secondary)	This band is used for narrowband communications, short range wideband communications, television (including repeaters), and for EME communications using analogue and digital modulation techniques. The band is also used in the amateur-satellite service for contacts with the use of transponders on board amateur satellites. Certain propagation conditions such as TROPO or RAINSCATTER can result in communications ranges in excess of 1 000 km. It is the most popular band above 1.3 GHz.
1.2 cm	24-24.05 (primary)	These bands (at 24 GHz, 47 GHz and 76 GHz) are largely used for narrowband communications, short range wideband communications (digital television) and for experimentation, and also for Earth-Moon-Earth (EME) communications. Parts of this band is also available for the amateur-satellite service.
	24.05-24.25 (secondary) RR No. **5.150**	
6 mm	47-47.2 (primary)	This band is also available for the amateur-satellite service.
4 mm	76-77.5 (secondary) 77.5-78 (primary) 78-81 (secondary)	These bands are also available for the amateur-satellite service.
2.5 mm	122.25-123 (secondary)	Bands at 122 GHz and above are largely used for communications and experimentation.
2 mm	134-136 (primary)	This band is also available for the amateur-satellite service.
1 mm	136-141 (secondary)	These bands are also available for the amateur-satellite service.
	241-248 (secondary)	
	248-250 (primary)	

NOTE – Some administrations permit amateur experimentation at frequencies above 275 GHz, consistent with RR No. **5.565** (WRC-12).

2.2 Amateur radio band plans

The allocations of frequency bands for the amateur and amateur-satellite services are made by the ITU and are reflected in national regulations. The specific applications for parts of these allocations are recommended by "band plans" established by the IARU. Because of differences in allocation and usage, each IARU region develops a regional band plan on the usage of frequencies which are harmonised across the regions wherever possible and necessary for inter-regional communications. These band plans are general guidance and may need to be tailored to take into account the variations of regulations of each country within the region. For this reason, some national societies develop national band plans complying with national regulations and being compatible to the extent possible with the regional band plan. However, these band plans are not in all cases binding as they are not part of national regulations, but radio amateurs voluntarily respect these plans since they identify segments of the bands used for different applications which enables communications and minimizes mutual interference.

2.3 Amateur service operations and operator training

2.3.1 Typical operations

Typical operations within the amateur service consist of contacts between two, or among more, amateur stations as stated in RR No. **1.56**, that is "for the purpose of self-training, intercommunication and technical investigations carried out by amateurs".

Operations include dialogue between operators on a variety of subjects including technical discussions. Competition between stations is encouraged and many contests are carried out to demonstrate the level of proficiency, to challenge and raise the level of operator skills, demonstrate and test amateur station capabilities and commemorate special events.

Operations are usually made from a station located at the home of the amateur operator but can also be made from a temporary portable location or in a vehicle, boat or airplane. They may also include the use of remote transmitting and receiving stations, accessed via the internet, which assist amateur operators residing in urban and residential areas who may have restrictions or technical limitations, particularly on antennas. The technical challenges of setting up and operating a remotely-controlled station are significant, and there are regulatory issues on a national basis such as the level of licence needed to operate a remote station, and how to deal with a remote station in one country which is operated by an amateur in a different country.

2.3.2 Operating activities

Radio amateurs use their stations in a wide variety of operating modes. Generally amateurs spend much of their time listening to other amateur stations making a two-way contact (known as a "QSO" – a Q code meaning "I can communicate with…", see Recommendation ITU-R M.1172). They may join the contact and contribute to the ongoing conversation. The contacts may be lengthy lasting as much as an hour but are often very brief, simply the exchange of call signs, signal reports, names and locations. Brief contacts are common for amateur stations operating from locations (countries and call sign prefixes) which are rarely on the air.

The basis of many contacts is to call "CQ" (meaning "General call to all stations") to invite any other station to respond. If more than two stations are involved in a contact, it may be called a "roundtable" or a "net". The participating stations often have a common interest to share. A group contact made regularly (same day of the week, same time, and frequency) is called a "net". Nets can exist for more formal purposes, such as an exchange of messages related to emergencies, health and welfare information, weather conditions, and others.

2.3.3 Radiosport

Radiosport is the term for a variety of amateur radio competitive activities. Some are sponsored by the IARU, others by national amateur radio societies or amateur radio magazines, and a few have their origins in state-sponsored sport programmes. These activities have formal rules published by the sponsors, have measures of performance or achievement, and normally involve publication of results and issuance of awards and trophies. The various aspects of Radiosport are explained in the following sections.

2.3.3.1 Contesting

Contesting is a competitive activity usually involving an attempt to reach a goal, perhaps to contact as many amateur stations as possible during a given time period, on certain frequency bands and within specified geographical areas. There are contests scheduled throughout the year, particularly on weekends.

2.3.3.2 Awards programmes

There are many awards programmes for amateur operators, and these activities often encourage physical and travel activities. The following are some of the more popular awards available to amateur operators.

In recognition of international two-way amateur radio communication, the IARU issues Worked-All-Continents" (WAC) certificates to amateur radio stations of the world. Qualification for the WAC award is based on an examination by the IARU International Secretariat, or a member-society of the IARU, of QSL cards that the applicant has received from other amateur stations to confirm a radio contact in each of the six continents. QSL cards may be in either a physical or electronic format.

DXCC is an award issued by the American Radio Relay League (ARRL) for proof of a station contacting stations in at least 100 different countries.

"Islands on the Air" (IOTA), sponsored by the Radio Society of Great Britain (RSGB), is intended to encourage contacts with amateur stations on islands throughout the world.

An increasing popular activity is "Summits on the air" (SOTA), which is an activity that combines outdoor activity and the operation of portable stations at identified elevated locations. "Parks on the Air" (POTA) encourages amateur radio operators who enjoy the outdoors to combine interests by operating from local, state, or national parks around the world.

Many national amateur radio societies issue certificates or diplomas for contacting a certain number of amateur stations in their territories under specified conditions.

Awards are also attainable for special interest activities such as two-way television communication or communications in microwave and millimetre wave bands. Often these are administered by the specific national special interest groups.

2.3.3.3 DXpeditions

DX (meaning "long distance") expeditions, (DXpeditions), are organized to countries or remote places with few or no regularly operated amateur stations. They provide amateur stations the opportunity to make contact with these rare locations and exchange physical or electronic QSL cards as proof of contact.

2.3.3.4 Amateur radio direction finding

Amateur radio direction finding (ARDF), sometimes called "orienteering", "rabbit hunting" or "fox hunting" is a time limited race to demonstrate skills in searching for radio transmitters. Amateur service bands at 3.5 MHz and 144 MHz are normally used. Annual ARDF activities are conducted in a number of countries operating under IARU rules. The IARU sponsors Regional and World Championships.

2.3.3.5 High speed telegraphy

High speed telegraphy (HST) challenges operators to correctly send and receive Morse code at the highest possible speeds. International competitions are organised by the IARU.

2.3.3.6 Youth activities

Various events exist to encourage interest in, and to develop skills in the technical aspects of radiocommunications through the amateur and amateur-satellite services. "Jamboree On The Air" (JOTA) is an activity of the international Scouting movement where member scouts receive basic electronics and communications training with a view to developing skills in radio communications. During JOTA events scouts can experience amateur radio by visiting amateur stations and communicating with other JOTA stations. JOTA events are held annually in many countries and these raise awareness of amateur radio as a recreational activity and provide basic understanding of how the technology and skills can be used to assist the community in times of need.

Another youth activity is the "Youngsters On The Air" (YOTA) initiative. YOTA is a quickly growing group of young radio amateurs from ITU Region 1. Their goal is to get more young people interested in amateur radio and grow the amateur radio community. Every summer many youngsters meet in a different ITU Region 1 country for a week of exchanging ideas and experiences. At these summer camps youngsters learn how to organize youth activities in their own countries, for example presentations at schools, smaller camps for youngsters and more. There are also young contest teams, special callsigns, and lots of other activities. YOTA initiatives have spread to ITU Regions 2 and 3.

The activities may also stimulate a future career interest leading to training and employment in professional radiocommunications.

2.4 Role of the amateur service in emergency telecommunications

Its wide scope of activities, and the skills of amateur radio operators make the amateur service a valuable asset in emergency telecommunications. There are a large number of operational amateur stations in almost all countries of the world, providing a robust network independent from any other. In many cases, it has provided the first, and sometimes the only, link outside the area affected by disaster. The amateur service has training programmes and emergency simulation exercises developed by some of the national amateur radio societies.

Typical situations for which the amateur service can supplement emergency communications include:

– *Initial emergency alerts* may originate from individual amateur stations to bring an incident to the attention of competent institutional emergency services.

– In *search and rescue* operations, amateur stations can reinforce the professional teams by increasing their communication capabilities and reporting observations.

– *Hospitals* and similar establishments might in the aftermath of a disaster be without communications. Local amateur radio emergency groups prepare in advance for such assistance.

– *Hazardous materials (HAZMAT)* and other incidents may require the evacuation of residents, and coordination between the disaster site and the evacuation sites or shelters. Amateur emergency stations may be asked to establish communications with such institutions.

– *Additional resource to emergency services* to assist at large public events such as sporting or entertainment events.

2.4.1 Amateur networks available for emergency telecommunications

2.4.1.1 Short-range networks

Amateur short-range networks provide operational or tactical communications at the site of a disaster and with the surrounding areas. They can include fixed, mobile and nomadic equipment typically using frequencies in the bands 50-54 MHz, 144-148 MHz and 420-450 MHz, noting that there are regional and national differences in these frequency ranges, including other VHF/UHF frequency bands like 220-225 MHz, 902-928 MHz (both only in Region 2) and above.

Repeater stations are used to extend the communication range. Positioned in elevated locations, they allow communication between fixed or mobile amateur stations separated by obstructions such as mountains, or tall buildings when operating in an urban environment. A repeater station receives on one channel and transmits on a different frequency, usually within the same frequency band.

There is increasing use of amateur operated multi-media systems based on modified commercial equipment for emergency use as this allows wider bandwidth applications which are useful for disaster relief activities. See for example Amateur Radio Emergency Data Network (AREDN) and Highspeed Amateur Radio Multimedia NETwork (HAMNET).

AREDN is a meshed radio network that operates in amateur radio frequency allocations (usually above 1 GHz) with data rates up to 54 Mbit/s. Its main purpose is to provide TCP/IP connectivity even if other network infrastructure has failed.

Technically, AREDN is the evolution of firmware for LINUX-based WIFI and WISP (Wireless Internet Service Provider) devices and it replaces the manufacturers firmware of the devices. An important use case of AREDN is to develop standards and services for emergency communication use. AREDN enables a high data throughput combined with a simple setup using a standard TCP/IP structure. Therefore, it behaves like a wired local home network and common services like telephony, e-mail, cameras, and web servers, etc. are relatively easy to implement.

All AREDN nodes operate on the same frequency. Only in the case of several link routers at the same location may it be necessary to set individual point-to-point links to different frequencies. The network is designed as an ad-hoc network, which means that anyone can connect to anyone. A sophisticated logic finds connections between different nodes and evaluates the quality of the connection. If packets are transmitted, the best route is selected. If a part of the route fails, an alternative route will be chosen.

HAMNET is a radio and cable-based IP network developed and operated by radio amateurs. It serves as a powerful backbone for the already available infrastructure of the amateur radio service and enables IP connections between amateur stations. The network handles a number of other amateur radio services, including EchoLink, WinLink2000, instant messaging, VoIP, DATV, IP ATV and APRS. In some countries it also serves as a feeder for the Mesh radio network AREDN. HAMNET is a network separate from the Internet and interconnects amateur radio repeater stations primarily in the 5 GHz range and is used to exchange digital data (e.g. for Digital Voice repeaters). It is also intended to cover aspects of emergency radio operation (independence from the Internet and mains power supply) as well as experimental operating procedures. The transmission protocol is TCP/IP and commercially available hardware from various vendors is used at the specific nodes. HAMNET is designed as a closed network, access from the Internet is only possible via a gateway.

HAMNET has seen a tremendous growth in Europe, in particular in Germany where several hundred nodes are in operation. These nodes basically form the backbone for the various regional and local Digital Voice repeater stations, allowing radio amateurs to bridge large distances from fixed and mobile stations.

2.4.1.2 Medium-range networks

Amateur medium-range networks typically provide communication from a disaster site to organizational and administrative centres outside an affected area, or to headquarters of response providers in neighbouring countries. They also ensure communication with vehicles, vessels and aircraft operating outside the coverage of available VHF or UHF networks. Communication at medium distances of up to 500 km may be accomplished by Near Vertical Incidence Sky wave (NVIS) propagation in the following frequency bands 1 800-2 000 kHz, 3 500-4 000 kHz, 5 351.5-5 366.5 kHz and 7 000-7 300 kHz, noting that there are regional and national differences in these bands.

In addition, several national administrations have designated specific frequencies (channels) giving priority to amateur radio emergency traffic and related training. There are a number of specific frequencies in the various amateur bands designated for emergency communications by the IARU. This is a voluntary coordination process designed to reduce the potential for interference from other amateur stations using the bands. An example of this is The Hurricane Watch Net, a group of licenced Amateur Radio Operators, trained and organized to provide essential communications support to the National Hurricane Centre in Miami/FL during times of Hurricane emergencies. The primary mission of the Hurricane Watch Net is to disseminate tropical cyclone advisory information to island communities in the Caribbean, Central America, along the Atlantic seaboard of the United States of America, and throughout the Gulf of Mexico coastal areas. When activated, the network operates on 14 325 kHz (USB) by day and 7 268 kHz (LSB) by night, subject to propagation and interference conditions.

Nevertheless, all amateur radio spectrum is available to support amateur emergency communication.

2.4.1.3 Long-range networks

Amateur long-range networks provide communication with headquarters of international emergency and disaster response providers. They serve as backup connections between offices of such institutions in different countries or on different continents. Amateur stations routinely communicate over long distances typically beyond 500 km, using sky-wave propagation in bands from 3 500 kHz through 29 700 kHz.

Communications via satellite is also available in some cases, giving regional coverage and amateur satellites in low Earth orbit and geostationary orbits have been used for emergency communications by amateur stations. As above, there are suggested spot frequencies for emergency communications traffic.

2.5 Amateur systems

For the purpose of sharing studies, generic characteristics of typical amateur systems are documented in the latest edition of Recommendation ITU-R M.1732.

2.5.1 Telegraphy and data systems

Morse code – International Morse code in accordance with Recommendation ITU-R M.1677 continues to be used in the amateur service despite the removal of the mandatory requirement for demonstration of Morse proficiency from RR Article **25** at WRC-03. Some administrations have discontinued Morse testing while others have maintained an examination at five words per minute for certain classes of amateur licences. Morse code telegraphy does not require complex equipment and is a robust mode capable of operation with weak signals during poor propagation conditions.

Radioteletype – Known as RTTY in the amateur service, this mode involves teleprinters at each end of the radio circuit. There continues to be 45 Bd, start-stop, frequency-shift RTTY operation and narrow-band direct-printing (NBDP) using a variant of Recommendation ITU-R M.476 (known as AMTOR) in the amateur service HF bands. The trend is toward replacing these modes with narrow-band PSK systems such as PSK31 and various data communications modes.

PSK31 – PSK31 is a digital communications mode intended for interactive keyboard operation between personal computers using amateur single-sideband (SSB) transceiver. Its data rate is 31.25 Bd (about 30 words per minute) and its emission symbol is 60H0J2B. It is implemented using software written for personal computer sound cards. See Recommendation ITU-R M.2034 for more details.

PACTOR – PACTOR is an adaptive data communications system using different modulation and encoding methods depending on channel quality. Using DPSK and multi-level QAM, and data compression, its effective throughput can be as high as 10 kbit/s.

MFSK – This is a data communications system using multi-tone frequency-shift keying, affording a data rates of 3 kbit/s or more, depending on the number of tones used.

PR – Packet Radio (PR) is a digital communication method for amateur radio that sends data in packets. It involves dividing data into small packets, which are then transmitted using protocols like AX.25 which provides error detection and retransmission of corrupted data packets. These packets can be relayed through a network of stations called Digipeaters to extend the communication range. Packet radio can be used across the HF, VHF and UHF amateur frequency bands, with data rates ranging between 300 bit/s to at least 9.6 kbit/s depending upon the band being used.

APRS – An automatic position reporting system (APRS) is in operation in the amateur service. Individual mobile units derive their locations from global positioning satellites, and report tracking, mapping and related data to amateur stations via HF or VHF amateur packet radio.

FT8 and associated structured data modes – These are communications mode designed to operate at lower power and in channels with low signal to noise ratios. The mode minimises the amount of information transmitted to that necessary to complete a contact and applies strong Forward Error Correction so that the message can be correctly reconstructed despite significant data loss. This technology is replacing most other forms of low-speed data communication in the amateur service.

Other data communication modes and modulation techniques are regularly developed as new technology becomes available. For example, LoRa which uses chirped spread-spectrum technology, is showing particular promise in replacing AFSK based APRS systems and for satellite telemetry.

2.5.2 Linking amateur stations via the Internet

The Internet and Voice Over IP technologies are used as a method of interconnection between separate amateur service networks. This is done so that amateur radio repeater networks may be linked beyond the normal radio frequency propagation range used by the networks. In all cases access to the internet linking is restricted to licenced amateur operators. Several methods for implementing this type of interconnection have been developed and are in active use:

WinLink 2000 – This method permits automatic transfer of messages between the Internet and remote amateur stations.

IRLP – The Internet Radio Linking Project (IRLP) uses Voice over Internet Protocol (VoIP) for interconnection of amateur stations by means of the Internet.

EchoLink – EchoLink links a personal computer to an amateur station via the Internet. It is one of the more common examples of radio-internet gateways.

In addition to these networks there are IP-based amateur communications networks that are independent of the internet and these networks may facilitate emergency communications. See section 2.4.1.1 above.

2.5.3 Telephony systems

Typically, voice transmissions use an audio bandwidth of 3 kHz or less, though wider bandwidths maybe used where band usage permits. There are a wide range of national provisions to accommodate various usage, considering the experimental nature of this service.

Analogue Voice – Analogue transmission of voice signals generally uses either amplitude modulation (AM), single sideband suppressed carrier (SSB) modulation or frequency/phase modulation (FM/PM).

SSB telephony has virtually replaced double sideband full carrier AM telephony in the amateur service. SSB is used on all amateur bands above 137 kHz.

FM or PM voice typically has a necessary bandwidth of up to 16 kHz, noting that in some countries lower bandwidth is used. These modes are generally used on bands upwards from 29 MHz. The use of FM repeaters for extension of range is common, particularly on VHF and UHF bands.

Digital Voice – Digital Voice (DV) has been used in the amateur service since the year 2000. This has experienced significant growth due to ongoing developments in both voice Codecs and RF digital modulation schemes.

A variety of CODECS are used, for example, the commercial AMBE family of codecs are utilised by C4FM, DMR, D-Star, NXDN, P25 and other commercial digital voice systems that have been adapted for use by the amateur service, particularly on the VHF and UHF amateur bands. An open-source system called CODEC2 has been developed for use by the amateur service, and this is commonly used on the HF bands. M17 is a digital voice system using CODEC2. M17 is also open source and is optimised for use on VHF and above.

A variety of frequency and phase modulated RF waveforms are used to convey digital voice including 4-FSK, GMSK, etc. Some repeaters and gateways are capable of auto-detecting digital voice standards and adapting to the input signals.

2.5.4 Image communications systems

SSTV – Amateurs use slow-scan television SSTV systems currently employing cameras and personal computers with special software for slow transmissions of colour images in voice-frequency bandwidths. There is a variety of analogue and digital systems in use offering a range of characteristics to suit particular needs. SSTV transmissions from amateur satellites are becoming more common.

FSTV – Most amateur analogue fast-scan television, using NTSC or PAL systems, involves the use of repeaters for extension of ranges. FSTV systems operate on frequencies above 420 MHz.

DATV – Radio amateurs have developed full-motion digital television using digital compression techniques in bandwidths from less than 300 kbit/s to 2 Mbit/s in frequency bands above 29 MHz. Both DVB-T and DVB-S standards are used. In many countries DATV is supplanting FSTV because it is more spectrally efficient.

2.5.5 Multimedia systems

Multimedia is where voice, data and imagery are combined and incorporated into a digital data stream and transmitted to a distant receiver. Some systems that provide this capability are:

D-Star – This is a digital voice and data system developed by the Japan Amateur Radio League (JARL) in cooperation with the Japanese administration and industry. It is designed for user access at VHF. Digitized voice/audio signals and short data messages are supported. In some bands its data transmission mode supports a rate of 128 kbit/s within a bandwidth of 150 kHz. Equipment can also use the 10 GHz amateur band or other means to link repeaters together.

C4FM – This is a digital modulation technology used primarily in modern VHF/UHF amateur radio communication systems. C4FM uses continuous 4-level frequency modulation and a Frequency Division Multiple Access scheme. It allows for a narrowband (with error correction) or a wideband voice communication mode and also features a 9.6 kbit/s data mode that can be used to transmit pictures. C4FM transceivers use the AMBE+ voice codec and feature a technology for interlinking repeaters via the internet, thus allowing worldwide digital communications.

There is continuing development of amateur systems capable of combining data, voice and image communications. There is some use of modified Wi-Fi equipment in the band 2 400-2 450 MHz and 5 650-5 850 MHz, in accordance with limitations of domestic amateur licences, to achieve extended ranges.

2.6 Experimentation in the amateur service

The amateur service is, at least in part, an experimental service offering the possibility of improving performance of new technologies and carrying out propagation experiments.

2.6.1 Communications system development

Experimentation by radio amateurs covers all aspects of the end-to-end transmission chain, with a focus on developing and evaluating new techniques for developing advanced digital transmission of data and multimedia information.

2.6.2 Antenna design

Typical amateur stations are located in residences or in private automobiles. Both installations present antenna installation constraints, and there is a continual need to develop innovative antenna system designs. The use of computer aided design and antenna modelling software is increasing, and this is assisting in the development of innovative and efficient amateur antenna systems.

2.6.3 Personal computers

Personal computers (PCs) are now part of virtually every amateur station. Amateur operators use PC applications for Digital Signal Processing, analysis of radio links, antenna design, propagation studies and forecasts, and digital communications applications amongst other.

PCs are increasingly being used to assume functions previously performed by hardware, for example Software Defined Radios (SDR) where the user interface is now a computer screen instead of traditional dials and meters. Software Defined Radios are now widely used in the amateur services to enable various transmission and reception modes, and software developed by amateurs is used on the SDR platforms to implement many amateur and amateur-satellite applications. Section 2.7.2 provides more details of SDR applications in the amateur and amateur-satellite services.

2.6.4 Propagation research and monitoring

In the early days of radio, radio amateurs were credited with the discovery and exploitation of new propagation modes, and this continues. While other communication services are primarily interested in reliable propagation to deliver a required signal, amateurs are also motivated to find unusual propagation openings.

To assist in identifying propagation paths, radio amateurs operate a global HF beacon system known as the IARU Beacon Project. This consists of a number of transmitting stations around the world which continuously transmit a time synchronised signal on a known frequency with a range of power levels. In addition, there are HF, VHF, UHF and SHF beacons in many countries which also provide real-time signals to indicate an available propagation path.

There is an alternative approach where, instead of beacons actively transmitting signals, amateur radio stations monitor the bands and manually or automatically report and upload stations they hear to a server or a website. This process often is referred to as “spotting” and the server or website that host and/or display these data are known as a “DX cluster”. The “spotting” data is used on a website or by a client application on a PC to display the real-time propagation environment. Such data may be used to change receiver and transmitter frequencies and also adjust the antenna pointing direction.

An early implementation of such functionality has been the Reverse Beacon Network (RBN) where a network of receiving stations around the world monitor Morse code transmissions and automatically upload this information to a website which can be accessed by amateurs. Most software clients for modern digital communication modes (PSK, MSK, WSPR, etc.) can automatically “spot” all received stations in a communication channel to a server that feeds a website for listing and displaying the communication paths PSK Reporter and WSPRnet. All these tools allow an amateur station operator to compare his received signal strength with other stations either in real-time or historically.

In addition, there are also various other servers and websites available where amateurs can upload the “spotted” stations. Which website or client application is used for propagation monitoring by the individual amateur station in daily operations depends on personal and operating preferences.

2.6.5 Digital signal processing

Digital signal processing (DSP) is playing an increasing role in amateur radio, particularly for the implementation of filters and modems. Radio amateurs have developed DSP algorithms for reduction or suppression of atmospheric noise (static), power-line noise and certain types of interfering signals. Some of these techniques have been implemented in commercial products and experimentation continues, especially using SDR platforms which have great flexibility to implement noise reduction algorithms.

Standalone DSP devices may be used for enhancing the reception of weak signals through modern signal averaging and correlation techniques which may significantly improve the Signal to Noise Ratio of received signals. This is especially useful for weak signal applications like Earth-Moon-Earth communications.

2.7 Amateur radio equipment

Consistent with the "self-training" objective and depending on national rules, radio amateurs operate either commercial radio equipment designed specifically to operate in the amateur service frequency ranges or modified and re-purposed commercial equipment or self-built homemade equipment. The same flexibility extends to the design and use of antennas. Amateur radio stations are not standardised, but operators are legally required to operate the radio equipment within the bounds of their national licence conditions. Most self-built equipment is designed to address a special interest such as amateur television or operation at microwave frequencies.

2.7.1 Typical commercial amateur radio equipment

Modern equipment is built around Digital Signal Processing technologies and often covers a wide range of frequencies for multi-band operation. Typical commercial HF radio equipment will have the capability to operate across all the amateur frequency bands from 1.8 MHz up to 50 MHz employing both analogue and digital modulation methods. Standardised interfaces for computer signal processing or remote operation are commonplace. Commercial equipment will comply with certain standards for EMC and spurious emissions.

Equipment for use in the VHF and UHF ranges is also often multi-band and multi-mode and may be specifically aimed at base station use or mobile/portable use. Some equipment might target special interests such a satellite operation and include features to facilitate this type of operation. It is quite common for a station to be based around a high-performance HF radio and to be supplemented by a "transverter" (transmit and receive frequency converter) to shift operations up to VHF/UHF and microwave frequency bands or down to LF bands. This allows all the facilities of the high-performance HF radio to be available for alternative frequency operations. Commercially available transverters are commonplace.

2.7.2 Software defined radio systems

The advent of high-performance digital signal processing has encouraged the integration of radio equipment with computer processing. Analogue to digital converters are available which enable direct digitization of the incoming radio frequency signal in a receiver, bypassing traditional mixing and intermediate frequency stages, to enable further signal processing by DSP. Using this technology, standalone SDR systems are available today that can offer similar performance to that from a dedicated radio system and even small "USB Dongle" style receivers can be added to any computer. SDRs offer versatility to receive and transmit all manner of modulation types, display the receiver output in a graphic presentation format, process impairments in the received signals and again offer remote connection. SDRs may be connected and controlled via the internet to provide remote access.

CHAPTER 3

AMATEUR-SATELLITE SERVICE

3.1 Applications of bands allocated to the amateur-satellite service

The following tables describe typical applications of frequency bands available to the amateur-satellite service. Refer to RR Article **5** for the specific allocation status of each band.

Nominal wavelength	Frequency band (kHz)	Applications
40 m	7 000-7 100 (primary)	These bands are identified only for limited satellite application, such as ionospheric research, because of potential interference to and from terrestrial users.
20 m	14 000-14 250 (primary)	
17 m	18 068-18 168 (conditions of co-primary use with other services in a number of countries are given in RR No. **5.154**)	
15 m	21 000-21 450 (primary)	
12 m	24 890-24 990 (primary)	
10 m	28 000-29 700 (primary)	This band is used primarily in conjunction with a satellite input or output in the 144 MHz band.

Nominal wavelength	Frequency band (MHz)	Applications
2 m	144-146 (primary)	These bands are in heavy use by numerous amateur satellites for inputs and outputs.
70 cm	435-438 (secondary) RR No. **5.282**	
23 cm	1 260-1 270 (secondary) Earth-to-space only RR No. **5.282**	These bands are used as alternatives to the 144 MHz and 435 MHz bands because of congestion. Note: In some countries in Regions 1 and 3, use of the 23 cm band is subject to restriction to reduce the possibility of interference to RNSS receivers operating in the same frequency band. The 13 cm band is used for voice, data, DATV and experimental amateur satellite communications.
13 cm	2 400-2 450 (secondary) RR No. **5.282**	
9 cm	3 400-3 410 (secondary) Regions 2 and 3 only RR No. **5.282**	

Nominal wavelength	Frequency band (MHz)	Applications
5 cm	5 650-5 670 (secondary) Earth-to-space only RR No. **5.282**	These bands are used for experimental amateur satellites.
	5 830-5 850 (secondary) space-to-Earth only	

Nominal wavelength	Frequency band (GHz)	Applications
3 cm	10.45-10.5 (secondary)	These bands are used for voice, data, DATV and experimental amateur satellite communications.
1.2 cm	24-24.05 (primary)	
6 mm	47-47.2 (primary)	These bands are used for experimental amateur satellites.
4 mm	76-77.5 (secondary)	
	77.5-78 (primary)	
	78-81 (secondary)	
2 mm	134-136 (primary)	
2 mm	136-141 (secondary)	
1 mm	241-248 (secondary)	
1 mm	248-250 (primary)	

3.2 Background

The amateur-satellite programme began in 1961 with the design and launch of satellite OSCAR (Orbiting Satellite Carrying Amateur Radio). The original Project OSCAR group was responsible for the first four amateur satellites. In 1969 the Radio Amateur Satellite Corporation (AMSAT) was formed in the USA. This was followed by the establishment of similar organizations in many other countries. In general, most amateur satellites are built by radio amateurs and university students.

Most amateur satellites are of the low-Earth-orbiting (LEO) type and some have been designed for highly elliptical orbits (HEOs). As of 2024 one space-station in the amateur-satellite service operates in geostationary satellite orbit (GSO). Technology developed in the amateur-satellite service has been applied directly to commercial LEO satellite systems, and the amateur-satellite service has served as a training ground for design engineers.

Report ITU-R SA.2312 provides information on the characteristics of typical amateur satellites and missions.

3.3 Amateur earth stations

Amateur earth stations in the amateur-satellite service fall into two classes, telecommand and users:

– Telecommand stations located throughout the world are authorised to control the amateur satellites and to modify their operation in accordance with RR No. **25.11**.

– User stations are amateur stations with essentially the same equipment as used for terrestrial amateur operations. The primary differences are antennas and transmitter-receivers optimized for amateur-satellite operations.

An increasingly common practice is for multiple amateur stations to receive telemetry and automatically upload it to databases via the Internet to provide greater orbital coverage.

3.4 Challenges and experimentation in the amateur-satellite service

It was not certain at the beginning of the OSCAR programme whether small groups of amateurs could design satellites, arrange for their launch, develop sufficient financial resources, and manage orbiting satellites. However, these questions were answered positively in the early years of the programme. Each satellite offered new challenges that were successfully met by licenced amateurs.

Because resources were scarce and were scattered across different countries, it became necessary to use "distributed engineering" to accomplish design, construction and testing of amateur satellites. Internet e-mail, amateur-satellite conferences and amateur radio communications were instrumental in that coordination.

In addition to solving "radio" design challenges, many lessons were learned concerning the physical and thermal design of the spacecraft, attitude control, power system management, and orbital mechanics. The amateur-satellite service has proven to be a good training ground for satellite technologists.

3.5 Amateur-communication satellites

Most amateur-satellites are generally for communications use and provide either a single-channel cross-band FM repeater or a cross-band linear transponder which allows multiple simultaneous conversations between earth stations. These types of satellites are very popular and heavily used for routine communications between amateur stations. In some cases, amateur-satellite communication has been used to assist in times of natural disaster or national need through the provision of reliable voice communications by portable and low power stations.

There are also amateur-satellites which relay various forms of digital communications. These systems are often called "digipeaters" and they use the AX.25 packet radio protocol. Many current satellite missions operate using the format known as "Amateur Packet Reporting System" (APRS). This system is a real-time communications application which provides a one-to-many communications link with geolocation capability linked to a global communications backbone. The system is used for routine amateur communications and has supported emergency and disaster relief operations in some countries.

3.6 Amateur satellites combined with educational missions

Due to the significant decrease of costs associated with building and launching small satellites, many educational institutions are now using small satellites as part of their educational and research objectives. The reduction in mission costs for small satellites has been driven by the huge increase in industrial capacity supporting commercial space activities. The satellites often use a standardized construction format which specifies the general dimensions and mass of the satellite. In many cases the satellite lifetime is only a few years because of the orbits selected for the mission.

These educational amateur satellites missions do not always include a traditional transponder or repeater for communications between amateur stations, rather the mission is more focused on providing some educational, outreach or technology development outcome that is relevant to, and consistent with, the definition of the amateur and amateur-satellite services and the provisions of the Radio Regulations. These types of missions are usually operated by universities or other educational institutions and always under the supervision of a licenced amateur operator. In many cases the educational institutions also encourage students participating in the mission to obtain their amateur radio licence as this allows the students to take a more active role in the mission activities. It also develops skills in radiocommunications that may be applicable in the student's future career.

For further details, please see Report ITU-R SA.2312 – Characteristics, definitions and spectrum requirements of nanosatellites and picosatellites, as well as systems composed of such satellites.

3.7 Frequency co-ordination in the amateur-satellite service

The International Amateur Radio Union (IARU) provides advice and frequency coordination to assist amateur satellite builders and prospective builders. More information regarding this subject can be found at: https://www.iaru.org/on-the-air/satellites/

CHAPTER 4

WRC RESOLUTIONS THAT ARE RELEVANT TO THE AMATEUR AND AMATEUR-SATELLITE SERVICES

RESOLUTION 642

Relating to the bringing into use of earth stations in the amateur-satellite service

RESOLUTION 646 (Rev.WRC-19)

Public protection and disaster relief

Also see the ITU webpage Categorization of the W(A)RC Resolutions in force.

CHAPTER 5

ITU-R QUESTIONS RELEVANT TO THE AMATEUR SERVICES

QUESTION ITU-R 48-7/5

Techniques and frequency usage in the amateur service and amateur-satellite service

(2015)

http://www.itu.int/pub/R-QUE-SG05.48

QUESTION ITU-R 209-7/5

Use of the mobile, amateur and amateur satellite services in support of disaster radiocommunications

(2023)

http://www.itu.int/pub/R-QUE-SG05.209

CHAPTER 6

ITU-R RECOMMENDATIONS RELEVANT TO THE AMATEUR SERVICES

RECOMMENDATION ITU-R M.1041

Future amateur radio systems

(Question ITU-R 48/8)

Scope

This Recommendation provides the design objectives and characteristics that should be taken into account when developing future systems in the amateur and amateur-satellite services. It includes general, technical and operational considerations.

http://www.itu.int/rec/R-REC-M.1041/en

RECOMMENDATION ITU-R M.1042

Disaster communications in the amateur and amateur-satellite services

(Question ITU-R 48/8)

Scope

This Recommendation provides guidance on the development of amateur and amateur-satellite service networks supporting preparedness and radiocommunications during disaster and relief operations.

http://www.itu.int/rec/R-REC-M.1042/en

RECOMMENDATION ITU-R M.1043

Use of the amateur and amateur-satellite services in developing countries

(Question ITU-R 48/8)

Scope

This Recommendation encourages administrations to facilitate the amateur and amateur-satellite services to include developing operator skills, training of technicians, and deployment of amateur stations in rural areas and in emergency situations. It encourages the use of volunteers and to accommodate the particular needs of developing countries.

http://www.itu.int/rec/R-REC-M.1043/en

RECOMMENDATION ITU-R M.1044

Frequency sharing criteria in the amateur and amateur-satellite services

(Question ITU-R 48/8)

Scope

This Recommendation lists the radiocommunication services with which the amateur and amateur-satellite services may readily share, and those services with which sharing would be difficult. It states that the amateur services operate with relatively weak signals and provides mitigation procedures that facilitate sharing.

http://www.itu.int/rec/R-REC-M.1044/en

RECOMMENDATION ITU-R M.1172

Miscellaneous abbreviations and signals to be used for radiocommunications in the maritime mobile service

http://www.itu.int/rec/R-REC-M.1172/en

RECOMMENDATION ITU-R M.1544

Minimum qualifications of radio amateurs

(Question ITU-R 48/8)

Scope

This Recommendation defines minimum levels of operational and technical knowledge for use by administrations when verifying the qualifications of a person wishing to operate a station in the amateur services.

http://www.itu.int/rec/R-REC-M.1544/en

RECOMMENDATION ITU-R M.1677

International Morse code

Scope

This Recommendation confirms the International Morse code characters and the operational provisions applying to their use in radiocommunication services.

http://www.itu.int/rec/R-REC-M.1677/en

RECOMMENDATION ITU-R M.1732

Characteristics of systems operating in the amateur and amateur-satellite services for use in sharing studies

(Question ITU-R 48-6/5)

Scope

This Recommendation documents the technical and operational characteristics of systems used in the amateur service and amateur-satellite services for the purposes of carrying out sharing studies. The systems and their characteristics described in this Recommendation are considered representative of those operating in the frequency bands available to these services ranging from 135.7 kHz through 81.5 GHz.

http://www.itu.int/rec/R-REC-M.1732/en

RECOMMENDATION ITU-R M.2034

Telegraphic alphabet for data communication by phase shift keying at 31 Bd in the amateur and amateur-satellite services

(Question ITU-R 48-6/5)

Scope

This Recommendation establishes a telegraphic alphabet and transmission protocols for phase shift keying at 31 Bd in the amateur and amateur-satellite services.

http://www.itu.int/rec/R-REC-M.2034/en

RECOMMENDATION ITU-R M.2164

Guidance on technical and operational measures for the use of the frequency band 1 240-1 300 MHz by the amateur and amateur-satellite service in order to protect the radionavigation-satellite service (space-to-Earth)

Scope

This Recommendation provides guidance on technical and operational measures for administrations authorizing stations operating in the amateur and amateur-satellite services to protect the radionavigation-satellite service (space-to-Earth) in the frequency band 1 240-1 300 MHz. The relevant measures are contained in the Annex to this Recommendation.

https://www.itu.int/rec/R-REC-M.2164/en

CHAPTER 7

ITU-R REPORTS RELEVANT TO THE AMATEUR SERVICES

REPORT ITU-R M.2085

Role of the amateur and amateur-satellite services in support of disaster mitigation and relief

(Question ITU-R 209-3/5)

http://www.itu.int/pub/R-REP-M.2085

REPORT ITU-R M.2117

Software-defined radio in the land mobile, amateur and amateur-satellite services

http://www.itu.int/pub/R-REP-M.2117

REPORT ITU-R M.2200

Characteristics of amateur radio stations in the range 415-526.5 kHz for sharing studies

http://www.itu.int/pub/R-REP-M.2200

REPORT ITU-R M.2203

Compatibility of amateur service stations with existing services in the range 415-526.5 kHz

http://www.itu.int/pub/R-REP-M.2203

REPORT ITU-R M.2226

Description of amateur and experimental operation between 415 and 526.5 kHz in some countries

(Question ITU-R 48-6/5)

http://www.itu.int/pub/R-REP-M.2226

REPORT ITU-R M.2335

Sharing and compatibility analysis of possible amateur service stations with fixed, land mobile, and radiolocation services in the frequency band 5 250-5 450 kHz and the aeronautical mobile service in an adjacent band

https://www.itu.int/pub/R-REP-M.2335

REPORT ITU-R SA.2312

Characteristics, definitions and spectrum requirements of nanosatellites and picosatellites, as well as systems composed of such satellites

https://www.itu.int/pub/R-REP-SA.2312

REPORT ITU-R M.2478

Spectrum needs for the amateur service in the frequency band 50-54 MHz in Region 1 and sharing with mobile, fixed, radiolocation and broadcasting services

https://www.itu.int/pub/R-REP-M.2478

REPORT ITU-R M.2532

Amateur and amateur-satellite services characteristics and usage in the 1 240-1 300 MHz frequency band

https://www.itu.int/pub/R-REP-M.2532

CHAPTER 8

OTHER RECOMMENDATIONS AND HANDBOOKS RELEVANT TO THE AMATEUR SERVICES

ITU-R Handbook on Small Satellites

The ITU Handbook on Small Satellites was developed in response to Resolution ITU-R 68 on "Improving the dissemination of knowledge concerning the applicable regulatory procedures for small satellites, including nanosatellites and picosatellites". This stand-alone Handbook is intended to promote the development of small satellites effectively and better serve the needs of the membership and the entire satellite industry.

https://www.itu.int/pub/R-HDB-65-2023

ITU-D Recommendations and Handbooks

ITU-D Recommendations http://www.itu.int/rec/D-REC-D/e

ITU-D Handbooks http://www.itu.int/pub/D-HDB

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