Amateur Radio: The original social media

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This paper provides an overview of the amateur service with respect to:

1. the contemporary context of the amateur radio,
2. typical operational activities,
3. its regulatory and legislative background,
4. the Australian preparatory process for each ITU World Radiocommunication Conference,
5. the role amateur radio societies in the operational and regulatory governance of the amateur service,
6. emerging issues,
7. STEM and the future.

1. The contemporary context of the amateur service

The history of radiocommunications is complicated and fascinating; in 1901 Marconi made the first one-way transatlantic transmission and the first transmission of voice and music occurred in 1906, Public imagination was spurred on by the public announcements of these achievements and by the developments in the new science of 'wireless'.

Figure 1: Marconi with early radio apparatus.

Amateur radio was born very early days of radio as interested private citizens built their own receivers and transmitters, a number of Australians were active in amateur radio before the First World War. Soon after WW1 amateur experimentation recommenced along with rapid commercial development of wireless technology. The aim of amateur radio then, as it is now, was for interested people to undertake technical experiments and to communicate using their creations with other like-minded individuals. These people had to be active participants in making their communication happen because there was little commercial equipment or components available, so even basic components had to be home-made.

Today the amateur service has nearly 4 million licensed operators across the world. Most countries permit amateur radio activities in some form and amateur operators are still using their own equipment to communicate locally and across the world with similarly inclined people. Sometimes modern amateurs use techniques that would be instantly recognisable to the amateurs of 1910, while other techniques would appear to be magic. The internet, and inexpensive and powerful computing has influenced amateur radio activities just as it has had similar impacts on many other aspects of modern life. But despite the modern technology and different applications, the same driver still exists: to experiment with wireless technology and communicate with similarly inclined individuals, often using devices they have built or modified in some way.

The definition of the amateur and amateur-satellite services is given in Article 1 of the ITU Radio Regulations:

> **1.56** *amateur service:* A *radiocommunication service* for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.
>
> **1.57** *amateur-satellite service:* A *radiocommunication service* using *space stations* on earth *satellites* for the same purposes as those of the *amateur service*.

Within that broad definition there are a diverse and wide range of technical and communications activities that cover almost the whole range of the radiofrequency spectrum and which use a wide of technologies. The following section provides some details of these activities and applications. Note the text about … *authorized persons interested in radio technique solely with a personal aim and without pecuniary interest*; this is a fundamental feature of amateur radio; it's the personal pursuit of knowledge and training with no financial return.

2. Typical amateur radio activities

"… there is nothing - absolutely nothing - half so much worth doing as simply messing about with radios …" with apologies to Kenneth Grahame (The Wind in the Willows)

Amateur bands range in wavelength from approximately 2200 m to 1 mm; that is a frequency range from 137 kHz to 250 GHz. The significance of the wavelength is that is correlates more-or-less directly to the size of the components and antenna systems that might be used by amateur operators to communicate with other operators. Another factor to consider is that the available bandwidth on the various bands more-or-less scales with the band frequency so different applications are used on various bands, however in many cases communications is successfully achieved at the very threshold of possibility either because of the technology used or because of the communications path length. Also, even on bands above 100 MHz, the noise floor is rising due to increasing man-made noise, hence increasing use digital signal processing technology, highly structured coding methods and forward error correction is occurring. These techniques allow 'weak signal' communications to occur in circumstances that often render conventional analog applications inoperable.

Amateur frequency allocations between 1 MHz and 30 MHZ are the traditional 'ham radio' or 'short wave bands' and Morse code, moderate speed data, voice and Slow Scan TV (SSTV) applications are typically used, with most applications needed 3 kHz or less of spectrum. In this frequency range communications between stations can be achieved over distances of a few kilometres to many thousands of kilometres; depending on the ionospheric propagation mode, time of day and frequency of operation. Multi-hop ionospheric propagation allows global communications.

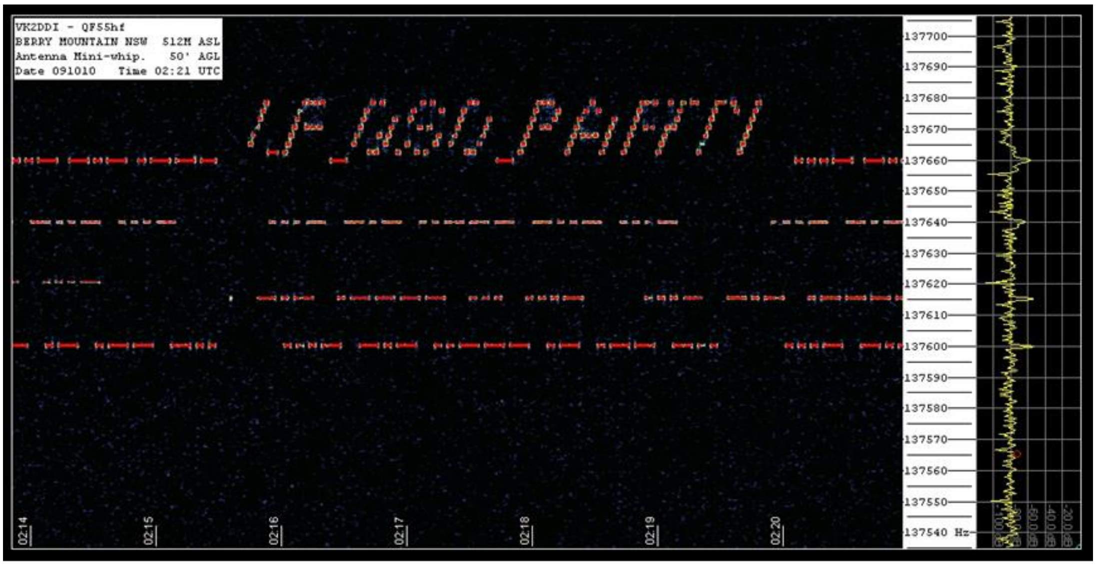


Figure 2: Four stations operating in 80 Hz between 137.600 and 137.680 kHz, the text is multi-frequency sequential Hellschreiber. (photo author)

Because the amateur frequency allocations below 1 MHz are only a few kilohertz wide, they can only sustain a few simultaneous Morse code or narrow-band data modes (see figure 2). Also, because of the low radiated power on these bands, communication is mostly restricted to distances of a few thousand kilometres, but developments in specialised data coding and error correction have enabled global communications, albeit a very slow data rates or 1 or 2 bits per second or less. Most equipment used by amateurs on these bands is home-made because very little suitable commercial equipment exists.

Above 30 MHz, in addition to the applications already listed, relatively wide-band voice and data modes may be used and conventional Fast Scan TV is used on bands above about 440 MHz. Various forms of digital television (DVB-S and DVB-T) are replacing analog TV standards because of the improved performance of digital modulation schemes. Experiments using DVB-S adapted for terrestrial use and using reduced bandwidth (as low as 300 kHz) are showing great promise. In general, VHF and UHF frequency ranges are limited to line-of-sight distances though the use of aircraft & meteor scattering, satellites, internet linking and certain ionospheric conditions can extend the distance to regional and global scales.

Above 1 GHz virtually any mode of communications can and is being used, including data and mesh networks using re-purposed RLAN equipment. A popular activity on the microwave bands is extending the communications range and some astonishing distances records have been achieved. For example, two-way communication between the east coast of Australia and New Zealand has been achieved on the 10 GHz frequency band and other records being established on frequency bands up to 245 GHz. Because there is very little commercially made equipment for most microwave bands above about 2 GHz Virtually all equipment used on the amateur bands above 2 GHz is home-made or modified/re-purposed commercial equipment.

The first amateur satellite (OSCAR-1) (OSCAR = Orbiting Satellite Carrying Amateur Radio) was launched in December 1961 (see figure 3) and amateur operators have had access to a wide range of amateur satellites since then. An Australian amateur satellite (OSCAR-5) was launched in 1970 and was the first amateur satellite able to be controlled from the ground. Amateur satellites most commonly use the VHF and UHF bands allocated to the amateur-satellite service; however there has also been some limited satellite operations on the upper HF bands and recent focus has been on using the amateur microwave allocations because of the wider bandwidths available. At present there are about 20 operational amateur satellites carrying communications transponders, and many more with various educational payloads. Typical amateur satellites operate at altitudes of between 400 km and 1200 km, though there is a geostationary satellite in operation over the middle East which carries a transponder which is available to suitably equipped amateur stations in Europe, the Middle East and Africa, at present there are no other geostationary satellites available for amateur usage. In general, amateur satellites carry transponders that allow several simultaneous two-way voice conversations, though some satellites operate as simple single-channel FM repeaters. Reception of images and telemetry transmitted from amateur satellites is a popular activity and increasing use is being made of Software Defined Radio (SDR) techniques. At least one global group of amateur exists which provides world-wide reception of satellite telemetry (see SatNOGS which is an Open-Source global network of satellite ground stations). The International Space Station (ISS) also carries an amateur service payload and that equipment is available globally for all amateur operators to use. The ISS crew undertake STEM activities via ARISS using amateur service bands and applications when time permits (see figures 14 and 15).

Figure 3: OSCAR 1 launched in 1961.

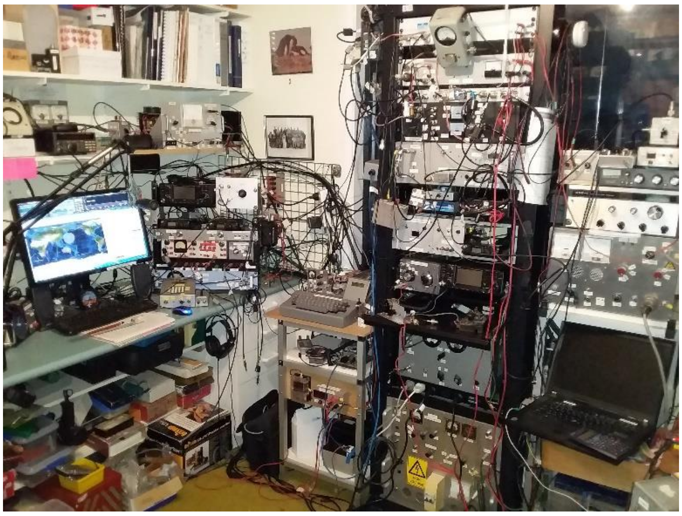


Figure 4: My satellite ground station, probably more complex than most (photo author).

An amateur activity that takes considerable skill and dedication is known as 'Moon bounce' where the Moon is used as a passive reflector for signals transmitted from Earth to another location on Earth. Intercontinental communications on VHF, UHF and microwave frequencies are a regular occurrence.

Not all amateur radio activities take place indoors, there are outdoor radio pursuits that many enjoy. Amateur Radio Direction Finding (ARDF) is a very popular radiosport activity that combines orienteering and hunting for hidden radio transmitters. There are world championship competitions which are widely supported. Summits Of The Air (SOTA) is another outdoor activity where people get to a mountain peak and make contacts with other stations on other peaks or with other station generally (see figures 5 and 6). Points are awarded depending the degree of difficulty in getting to the peak etc. SOTA activity takes place in nearly 100 countries and is very popular in Australia.

Figure 5: SOTA activation on microwave bands; 1.3 and 2.4 GHz (photo author).

Figure 6: Nothing beats Switzerland for SOTA! (photo author)

Portable operation (often to get away from radio interference in urban environments) more generally is popular and many people take radios camping and enjoy nature and radiocommunication at the same time (see figures 7 and 8). The are several field day contests during the year which are very popular.

Figures 7 and 8: Radio in the field (photo author).

Many radio clubs provide communication services for other community activities like sporting and outdoor events where the usual communication facilities don't exist or don't support the needs of the participants. These community events are also an important part of having equipment and procedures ready for emergency and natural disaster relief communications which is an important aspect of the amateur service, and which is recognised by the ITU and national administrations. Teams of properly trained and equipped amateur operators are able to quickly setup temporary communication links in communities that have lost the usual communication facilities, such amateur service links allow necessary supplies to flow early and for families to know what has happened to other family members. Recently, during COVID-19 some amateur satellites have been used in part of Asia for communication between remote communities to facilitate communications for health and humanitarian purposes. Australian amateur operators perform similar services through organisations like WICEN, and after appropriate training some amateur operators are embedded in government emergency response activities.

In all cases above, the individual amateur operator are active participants in some aspect of radiocommunication and often make some or all of the equipment they use. This is important aspect of 'self-training' and 'technical investigation' which is fundamental to the amateur service.

3. The international regulatory and national legislative background of the amateur service

When wireless technology first started there was little control and no regulations; though that changed quickly when it became apparent:

- that wireless technology could compete with established wireline communications,
- wireless communication had significant defence and military applications,
- that wireless communication was a potentially powerful medium for spreading information,
- interference between wireless users could severely limit the utility of wireless communications and may have safety of life impact.

These factors, and possibly others, led governments to regulate most aspects of wireless communication technology and usage. In some case the national military or postal administrations wanted to have control of the emerging wireless applications and exclude, or at least limit, other potential users or applications which might intrude upon their sphere of interest. It was soon realised that wireless communication had a global reach and that some international cooperation and agreements were necessary if radiocommunication was to fulfil its promise.

The international regulatory lead is taken by the International Telecommunication Union (ITU) which became a specialist agency of the United Nations in 1949. The origins of the ITU go back to 1865 when the first international telegraph networks were being built and it was realised that global cooperation was necessary for the success of such systems. ITU's global membership includes 193 Member States as well as some 900 companies, universities, and international and regional organisations. The ITU has three sectors covering radio and satellite communication (ITU-R), ICT standards (ITU-T) and global telecommunications development (ITU-D) and the focus of this paper is on ITU-R.

The first driver for radio technology development, international cooperation and regulation was the use of wireless communication by ships at sea; previously when ships were away from land there were very few options for communications between a ship, other ships and the ship's owner or controller. Reliable radiocommunication allowed for much greater control and safety leading to reduced cost, increased operational flexibility and reduced loss of life. The first conference to discuss cooperation and regulation of wireless communication was held in Berlin in 1903. The first International Radiotelegraph Convention (of 15 pages…) was published following the 1906 International Radiotelegraph Conference. Disasters like the sinking of the Titanic in 1912 really pushed along the development of regulations, standardised operating frequencies and operating procedures, most notably cementing the use of the SOS signal for disaster situations. At the 1927 Washington conference there were delegates from 80 countries (including Australia) and the first allocations of frequency bands for the various types of radio applications (what we call services) were made; including the amateur service.

The first definition of the amateur service was given as "*a station used by an "amateur", that is to say a duly authorised. person. interested in radioelectric practice with a purely personal aim and without pecuniary interest;*" It's interesting to note that the complete frequency range covered by the table of frequency allocations was from 10 kHz through to 60 MHz and that amateurs had access to five frequency bands within that range, four of which remain where amateur operators still have some or all of the original allocations. A number of the provisions of the 1927 regulations are very close to those that still exist today in the International Radio Regulations and our Australian Amateur Licence Conditions. Note that the 2020 Radio Regulations extend from 8.3 kHz to 275 GHz and cover many more services!

In Australia, the Wireless Telegraphy Act was first enacted in 1905 and its successor (to date and now subject to significant review), the Radiocommunication Act, continues to be amended and applied to our current usage of wireless technology. Operation of individual amateur stations by licensed amateur operators is regulated through the Radiocommunications Licence Conditions (Amateur Licence) Determination 2015 (Made under paragraph 107(1)(f) of the Radiocommunications Act 1992) Amateur operators are individually licenced by the ACMA and there are presently three classes of operators with different operating privileges according to qualification level.

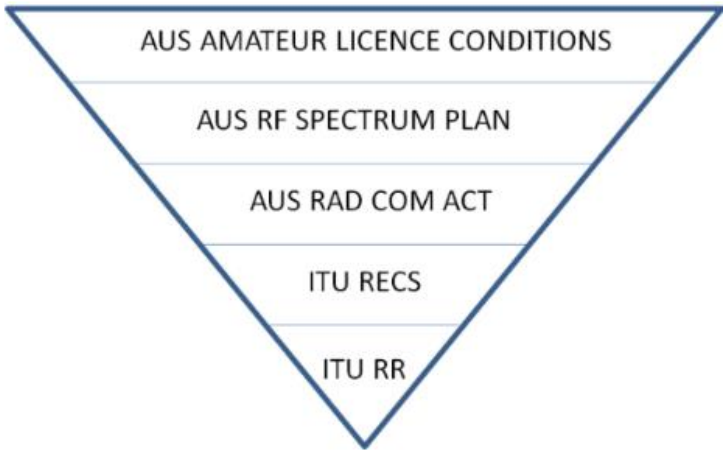


Figure 9: The hierarchy of regulations which underpin the amateur service.

As technology, and the level and types of personal freedoms have changed, so has the legislative regime and the process of obtaining an amateur licence is now very much simpler that it was in the past. Many of the previous restrictions about content and technical aspects (bandwidths etc.) of communications have been lifted and the ‘regulatory burden’ is now much reduced. Change in this respect is incremental and driven by both changes in the International Radio Regulations and national legislation. Changes to the Radio Regulations are made at ITU World Radiocommunication Conferences and Australia participates in the conferences and preparatory meetings.

4. The Australian preparatory process for each ITU World Radiocommunication Conference

The Radio Regulations are a global treaty re-negotiated every three of four years at a World Radiocommunication Conference. The most recent WRC (WRC-19) was held in late 2019 at Sharm el-Sheikh in Egypt and it was a vast and complex affair with over 3000 delegates and hundreds of separate meetings (see figure 10). The negotiations take into account the changing spectrum need of the various radiocommunication services and global events that may impact spectrum usage. While technology changes rapidly, that alone is not necessarily a direct factor because the Radio Regulations attempt to be technology neutral, focusing only on the needs of various radiocommunication services and applications within those services. However, technology does impact the applications within services which may change spectrum requirements. Global events may also be a contributing factor; the mysterious loss of flight MH370 in 2014 resulted in lengthy discussions at WRC-15 regarding the need for global flight tracking and how it might be implemented via satellite. Another global need is the dissemination of time signals and whether, or not, leap-seconds are still required.

Figure 10: A plenary session of WRC-19 (ITU photo).

Figure 11: Chairing one session of many at WRC-19. One of the most personally challenging things I have ever done… (ITU photo)

Many countries, including Australia, prepare for each WRC by engaging with representatives of the various radiocommunication services to determine the national spectrum needs and to identify issues related to WRC agenda items. In the Australia representatives of the defence department, maritime users, aviation users, broadcasters, satellite operators, teleco's, science and amateurs meet together with officers of the Commonwealth Department of Infrastructure, Transport, Regional Development and Communications (DITRDC) and the ACMA in different but inter-related groups. Through the WRC cycle the WRC Preparatory Group develops and refines Australian views on WRC agenda items and Australian Radio Study Groups participate in the technical studies at ITU-R for particular WRC agenda items. Both groups try to reach consensus-based decisions on WRC agenda items which aligns with Government policy and is in Australia's best interest.

The Australian preliminary positions on WRC agenda items are used as the basis of Australian input into the ITU and WRC preparatory group meetings of the Asia-Pacific Telecommunity. The Australian preliminary positions are refined and revised as necessary through discussions at all these various local and international preparatory meetings and finally become the formal Australian positions going into WRC and being a national position on changes to a global treaty, they are approved by the Government prior to WRC. Like all discussions during the WRC cycle most decisions at the conference are consensus based which can result in a very arduous process. This approach often results in what is (half-jokingly) referred to as 'everyone being equally unhappy…'. The final acts of the WRC are the changes to the articles of the Radio Regulations and during the WRC closing ceremony a representative of each ITU member state signs off on the revised Radio Regulations which come into force some time after each conference.

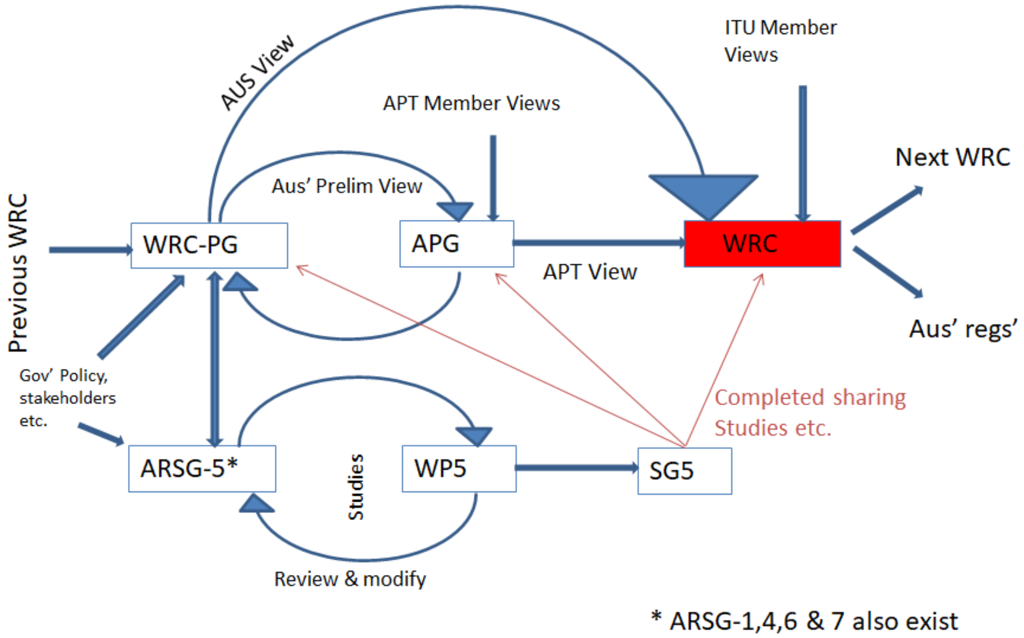


Figure 12: A schematic diagram of the overall Australian process of getting a result from WRC.

Sometime after each WRC the Joint Standing Committee on Treaties (JSCOT) reviews the revised treaty document (e.g. *World Radiocommunication Conference 2019 (WRC-19) Final Acts*) and national interest submissions from DITRDC and other interested parties, and a recommendation is made and tabled in the Parliament. The outcome of WRC-19 was examined by JSCOT in February 2021. Following the treaty ratification, the relevant Australian legislative instruments may need to be changed to reflect changes made in the Radio Regulations; this is done by the ACMA which revises the Australian Radiofrequency Spectrum Plan and any other related legislation or determinations like radiocommunication licence conditions.

5. The role of national and international amateur radio societies in operational, regulatory and governance aspects of the amateur service

National amateur radio societies were formed in many countries in the early 1900's to advance the interests of amateur radio enthusiasts. The role of the societies was to lobby governments and to act as a forum for likeminded people to exchange technical ideas and experimental details, along the way some societies also published books and technical journals. The Wireless Institute of Australia was formed in 1910 and is the earliest such group that is still in existence; the WIA journal 'Amateur Radio' is still published six times a year. Notable and successful national amateur societies in other countries are the Radio Society of Great Britain and the American Radio Relay League.

When it became apparent that global regulations were important and being applied to the amateur service, an international organisation was formed to represent the amateur service at international regulatory meetings; the International Amateur Radio Union was formed in 1925 and still exists. The IARU attends meetings of, or makes submissions to, the International Telecommunications Union (ITU), Regional Telecommunications Organisations, CISPR (International special committee on radio interference), ETSI (the European Telecommunications Standardisation Institute) and other organisations which are relevant to the amateur service.

Relevant to the global recognition, governance and advancement of the amateur service, the IARU is recognised by the United Nations as a Non-Governmental Organisation (NGO) by virtue of its consultative status with other United Nations bodies. The ITU also recognises the IARU as an international organisation (CV/Art.19, No. 231). The IARU has worked with the ITU for nearly a century and is a member of the ITU radiocommunication sector (ITU-R), playing a significant part in the work of ITU-R as it affects amateur service spectrum, and also of the ITU development sector (ITU-D), relating to developing countries, emergency radiocommunication and technical education.

The IARU represents 160 national amateur radio organisations and consists of a global organisation and three regional organisations: IARU-R1, IARU-R2 and IARU-R3, with each organisation covering the same geographical area as the three ITU Regions. The main functions of the IARU are to coordinate the representation of the interests of amateur radio at international telecommunications conferences, to protect and enhance amateur service spectrum privileges, undertake long-range planning in close cooperation with the regional organisations to preserve the basic purposes of amateur radio and to serve as coordinator between the regional organisations on all matters of mutual interest. Together, the IARU and the regional groups play an important governance role through standardising the usage of amateur spectrum by developing non-binding but recommended operating and technical standards, emergency communication procedures, band plans which align application usage within individual amateur bands so that interference between incompatible applications is avoided, undertakes spectrum monitoring and supports a global HF beacon network. National radio societies may also develop local band plans for specific purposes to avoid interference with other services or circumstances peculiar to the national circumstances.

One important global IARU activity relates to amateur satellites which do not require the formal ITU coordination process under Article 9 of the Radio Regulations, however frequency coordination of amateur satellites is important so that they do not interfere with each other, or with terrestrial amateur applications and vice versa, so the IARU provides a free frequency coordination service for amateur and amateur-educational satellites that propose to use amateur-satellite service frequency bands. At the present time approximately 50 satellites are coordinated each year.

6. Emerging issues: spectrum pollution, changing technology, regulatory indifference

Spectrum pollution is becoming a serious issue and the amateur service is the ‘canary in the coalmine’. The radiofrequency environment in most cities and urban areas has almost reached ‘toxic waste dump’ status. A multitude of poorly designed and often non-conforming (to EMC requirements) consumer goods radiate significant amounts of broad and narrow band radiofrequency noise which can interfere with nearby radiocommunication receivers of all types. While it’s certainly very desirable to ensure high energy-use efficiency by using switch-mode power supplies, inverter motor-controllers (most commonly in air-conditioners) and LED lighting, they can be potent sources of radiofrequency interference. Similarly, domestic photo-voltaic installations are a growing source of day-time RFI because they operate at high power, are increasing in number and are located all urban areas. While photo-voltaic installations are a necessary step towards the reduction of our carbon footprint, all too frequently one form of pollution (CO_2) is replaced by another (RFI). Ideally consumer devices would comply with the relevant EMC standards and solar and other electrical installations would all and be installed in such a way to minimise conducted and radiated emissions. In addition to these spurious and unwanted emissions there are a variety of intentionally transmitted signals which are operating ‘out of band’ i.e., not in their allocations; typically, these are ‘Over the Horizon Radar’ systems and they cause widespread and wideband interference problems in many parts of the HF spectrum.

A further challenge of technological change is that of the physical hardware used to construct radio equipment. Many of the traditional components used to build equipment are now hard to get or expensive. Modern approaches tend towards very small, highly integrated and sophisticated devices which require significant skill to apply to designs, often they are more a software-engineering exercise which requires a fundamentally different skill set and tools (see figure 13). However, there are many new and useful devices available as ready built modules which can be assembled and integrated into a radio transceiver or some other useful device. In many ways technically oriented people have more options available than ever before, but using them often comes with a steep learning curve.

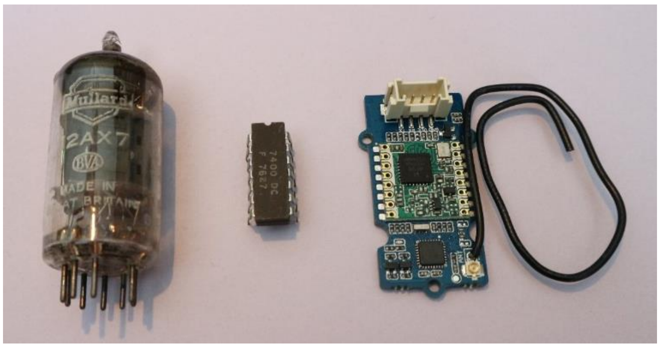


Figure 13: The change in scale: from a vacuum tube (1950's) with two active devices, to a TTL chip (1970's) with 10's of transistors to a complete radio transceiver and microcontroller (2020) with several hundred thousand active devices. (photo author)

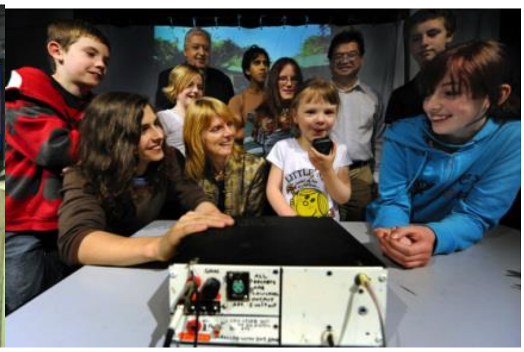
While the Radio Regulations are more-or-less technology neutral, the applications used by each radiocommunication service are very much subject to changes in technology. The changes may make new applications possible and render existing applications obsolete, or impact other users of the assigned spectrum, both of the same service and other services which may share a given frequency band. This is certainly true of the amateur service and amateur operators often take technology and use it in new ways, or adapt it for other purposes – they are the original makers and hackers!

An emerging issue is indifference about, or lack of understanding of the amateur service by national regulators. The general trend in many administrations appears to be a move away from a technical focus towards policy, legal and economic factors, with an overall reduction in technical skills. This leads to a different focus for the organisations and an understanding of technical issues frequently suffers. While it may be obvious what the broadcasting service is about, it may be far less obvious what the space operations service or amateur service etc. are about, and the problems which affect them. Even more so because it's hard to quantify the value of the amateur service in an economic way. This is one of the serious challenges of our time…

7. STEM opportunities – the future!

International telecommunication is now cheap and ubiquitous, no longer do you need your own personal radio station and antenna system to talk to someone on the other side of the world. So, this particular aspect of amateur radio is no longer the driving force it once was but the satisfaction of 'doing it yourself' and providing a service for the community remains for many; it's the journey rather than the ultimate destination that matters. The challenge is to get that message through to the next generation, and the movement to introduce young people to Science, Technology, Engineering and Mathematics (STEM) education is one possibility. People can be introduced to the challenges and joys of a career in science and/or engineering through an exposure to amateur radio activities. This a focus of activity in many amateur radio clubs and national societies throughout the world and some success is being achieved. In Australia the Victorian School Amateur Radio Club Network is a successful example of introducing children to technology through amateur radio.

Many students and teachers are fascinated by space and astronauts, and ARISS (Amateur Radio on the International Space Station) is program that allows students to speak with astronauts on the International Space Station. A recent ARISS event in South Australia was very successful with students at the Mawson Lakes School speaking with Shannon Walker aboard the ISS, the students were able to ask Shannon various questions about life on the ISS and other scientific topics. Amateur radio operators played a key role by providing the ground station through which the link was established and relaying the conversation to a much wider audience through the global IRLP network. Across the world similar events with school groups occur regularly.

Figures 14 and 15: An ISS crew member using amateur radio during an ARISS event, with school children asking questions.

8. Conclusion

Amateur radio is a fascinating, challenging and satisfying technical interest. Through a variety of amateur bands and applications, licenced amateurs can explore technology and communicate freely across the world with like minded individuals. Amateur operators and amateur service more generally can also play an important part in teaching the next generation of engineers, technologist and scientists; it also assists with the provision of emergency communications facilities in times of national need.

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