AMATEUR RADIO: PAST, PRESENT AND FUTURE

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Amateur radio is a hobby that encompasses the whole range of communications technology. It has existed since the time Marconi, Hertz and others began their experiments. It is the only hobby that is regulated by the government of every country in the world. To obtain their operating licenses, amateurs are required to pass a written examination in radio regulations and fundamentals of radio technology. More than a 1.5 million persons worldwide are licensed amateurs. Now, after 100 years, amateur radio is at a critical turning point. After a brief summary of how radio amateurs advanced the communication state-of-the art in the past, this paper discusses current problems facing amateur radio in the present and the potential for amateur radio in the future.

THE PAST

Most early commercial and professional experimental transmissions in wireless telegraphy before World War I were carried out on the "long" wavelengths. Amateurs were banished to the "useless short waves" around and below 200 meters (1.5 MHz). The enthusiastic young people who built their own items of electrical and wireless apparatus were first known as "Wireless Experimenters". Many of them were later granted licenses for the use of "Wireless Telegraphy for experimental purposes" (in the United Kingdom (UK)) by the Postmaster General (PMG) under the terms of the 1904 Wireless Telegraphy Act. In his report to Parliament for the years 1905-1906 the PMG stated that it was his wish "to promote experimental investigations in this promising field" - Joly 1990 (1).

Amateurs in other countries were not so fortunate and had difficulty obtaining licenses. For example, Bob Avigdor (4X4CJ) had to petition the King of England in 1936 before he was issued with the first Palestinian call sign ZC6AA. In other countries, amateur radio was an unlicensed activity even as late as the 1950's. For example, Joly (G3FNJ) 1990 (1) wrote that "although there was no official recognition of amateur radio in Greece in the 1930's, the existence and identity of the handful of 'under cover' operators was known to the Head of the Wireless Telegraph section at the Greek Ministry of Posts & Telegraphs, Stefanos Eleftheriou, who did more than anyone else to encourage and promote the development of our hobby".

These early amateurs were experimenters who built and used their own equipment. One of them, Alan Campbell Swinton introduced Guglielmo Marconi to William Preece, then Engineer-in-Chief of the British Post Office. Alan Campbell Swinton later became the first president of the London Wireless Club (LWC) when it was formed in 1913 one year before the American Radio Relay League (ARRL) was founded. The LWC has since grown into the leading organization of radio amateurs in the UK, currently known as the Radio Society of Great Britain (RSGB). As the technology improved and commercial equipment became available, the applications amateurs came into existence. These were amateurs who used the medium to communicate rather than experiment with equipment and frequencies. They provided the other end of the link for the experimenters, and developed communications capabilities. consequently, they were able to provide emergency communications as and when needed. These communicators occupy the frequency allocations and keep them in the amateur service for use by the experimenters who now form a tiny but important minority of the amateur radio population. The technical educational and training role of amateurs is also well known in the amateur radio community.

The value of the radio amateur experimenter was recognized by the professionals as early as 1919. Clarricoats (2) provided the following extracts from 1919 issues of *Wireless World* (WW) in support of an early resumption of their activities following the end of World War I.

A leading article in the March issue began with a quotation attributed to Marconi:

> "I consider that the existence of a body of independent and often enthusiastic amateurs constitutes a valuable asset towards the further development of wireless telegraphy."

In a subsequent letter to the editor Marconi wrote:

> "In my opinion it would be a mistaken policy to introduce legislation to prevent amateurs experimenting with wireless telegraphy (which the authorities were then contemplating). Had it not been for amateurs, wireless telegraphy as a great world-fact might not have existed at all. A great deal of the development and progress of wireless telegraphy is due to the efforts of amateurs."

John Ambrose Fleming, the inventor of the diode valve, also wrote to the Editor of WW as follows:

> "It is a matter of common knowledge that a large part of the important inventions in connec-

tion with wireless telegraphy have been the work of amateurs and private research and not the outcome of official brains or the handiwork of military or naval organizations. In fact we may say that wireless telegraphy itself in its inception was an amateur product. Numerous important inventions such as the crystal detector, the oscillating valve, the triode valve - have been due to private or amateur work. If full opportunities for such non-official research work are not restored, the progress of the art of radio telegraphy and radio telephony will be greatly hindered."

Professor W.H. Eccles wrote:

"Improvements and invention must be stimulated to the utmost. It is not impossible to devise laws to impose restrictions upon the emission of wireless waves as will preclude interference with the public radio service of the future and yet allow liberal opportunities for the experimental study of wireless telegraphy."

Radio amateurs lived up to their reputation and have made many important contributions to the state-of-the-art in telecommunications. For example, they:

- Discovered and pioneered the long distance communications potential of short waves.
- Used the knowledge acquired for their hobby to pursue successful careers in communications and engineering.
- Perfected the single sideband (SSB) communications mode.
- Made considerable contributions during World War II - Clarricoats (2).
- Pioneered the techniques for the vhf/uhf personal communications services.

Short wave communications When the first radio amateur attempt to span the Atlantic was made in February of 1921, about 25 stations in the USA, who were permitted to use a DC input power of 1000 watts to the anode of the final stage of their transmitters, did the transmitting. The Europeans did the listening and were unable to hear anything that could be considered as a trans-atlantic transmission.

The Americans decided the failure of the tests was due to the "inferior equipment used in Europe" and decided to apply technology and money to solve the problem. They sent a prominent US radio amateur, Paul Godley (2ZE), to Europe to take part in a second series of tests planned for December. He brought a standard American regenerative circuit using variometer tuning, and an Armstrong superheterodyne receiver.

Paul Godley eventually set up his receiving equipment at Ardrossan a coast town near Glasgow, Scotland. 1,300 feet of phosphor-bronze wire was stretched 12 feet above the ground on ten poles spaced equally along the full length of the wire which was earthed at the far end through a non-inductive resistor. This was the first Beverage type receiving array ever erected in the UK. However, the length of the wire was reduced to 850 feet before the actual tests took place.

At 0050 GMT on December 9th 1921, Godley received and identified fragments of signals transmitted by the Radio Club of America station (1BCG) located at Greenwich, CT. Six club members were present at the time, including E. Howard Armstrong, the inventor of the regenerative detector, super-regeneration and the supersonic heterodyne receiver. Two days later Godley copied the first complete transatlantic message from 1BCG. Eight British amateurs also copied the same message correctly. One of them was W. E. "Bill" Corsham (2UV) of Willesden, London, who used a simple three valve receiver and an inverted-L wire 100 feet long. British ingenuity seems to have been the equal of American technology and funding. Corsham has also been credited by the RSGB and the ARRL as being the inventor of the QSL card.

The amateur's role in pioneering the use of short waves culminated in 1924 when the first two-way radio link between the UK (G2SZ) and New Zealand (ZL4AA) (about a far as one could go) was made by the Mill Hill School in North West London at the UK end of the link. The school station, operated by a former schoolboy, Cecil Goyder, who later assisted another pioneer, Gerald Marcuse, G2NM, to build the hf transmitter on which the first UK hf "Empire" broadcasts were made. Goyder became a professional broadcast engineer and was a one time Chief Engineer of All India Radio, and later in charge of United Nations Radio. One of the many notable examples of how early participation in the hobby led to many successful careers. Other experimenters, also licensed radio amateurs were Beverage and Krause, known for their antenna work.

After showing what the short wave frequencies were capable of, their reward was the loss of most of their shared frequencies in the 1927 Washington (DC) Radio conference. As the years went by, more of their frequencies were lost. More were lost in Atlantic City in 1947, although a new allocation at 21 MHz was received, while in 1979 the radio amateur service received new small allocations at 10 MHz, 18 MHz and 24 MHz. The representatives of organized amateur radio found in each conference that many of the delegates had no idea what amateur radio was about. Amateur radio does not seem to have done a good job in publicizing itself among the decision makers around the world.

Radio amateurs continue to experiment and discover new properties in the hf spectrum, such as:

- Albrecht's theory of *chordal hop* hf propagation which was based on the reception of amateur signals from England, in Australia in the 1940s.

- Transequatorial Propagation, based on investigations by Ray Cracknell (ZE2JV) and Roland Whiting (5B4WR) in 1957. They noticed that vhf signals can travel 5,000 to 8,000 kilometers across the equator during the years of high sunspot activity. Contacts can be made by stations located approximately the same distance north and south of the magnetic (not geographic) equator shortly after sunset at both locations. The first such QSO took place on the 10th April 1978 between ZE2JV and 5B4WR and has been followed by many more. Late at nights, after the local TV station had shut down in the fall of 1982, I was able to view TV pictures from Harare in Jerusalem with nothing more than a TV and dipole aerial 2 meters above ground.

In terms of economics and trade, many famous companies producing communications equipment started by supplying the amateur radio market. The "communications receivers" widely used in military and professional circles during World War II are but one example. The advertisements in the amateur radio press portray this industrial growth over time.

Amateurs in space *Of all the amateur groups interested in space, amateur radio is the only one to have a real presence out there.* Project OSCAR Inc. put the first orbiting satellite carrying amateur radio (OSCAR) into space in December 1961. The Radio Amateur Satellite Corporation (AMSAT) was officially incorporated in 1969. AMSAT's first project, in conjunction with Project OSCAR Inc., was the refurbishment and launch of AUSTRALIS-OSCAR 5, originally built by students at the University of Melbourne, Australia.

OSCARs have provided many "firsts". For example, the:

- World's first multiple access communications satellite was OSCAR 3.
- First direct satellite communications link between the U.S.A. and the USSR was made by two radio amateurs using OSCAR 4.
- Emergency Locator Transmitter (ELT) System used to locate downed aircraft, currently credited with saving over 1000 lives was pioneered via AMSAT--OSCAR (AO) 6.

AO 7 was the first true example of international co--operation; component assemblies came from Canada, Japan (JAMSAT) and the Federal Republic of Germany (AMSAT-DL). Amateurs in Argentina, Brazil, France, Israel Italy, Mexico, Russia and the UK have built and launched about 40 satellites. Launches are usually only available on experimental rocket flights (high risk) and several launch vehicles carrying amateur radio payloads did not go as planned. Still, radio amateurs from those and other countries are continuing to build more spacecraft (mostly in conjunction with universities). An international team led by AMSAT-DL are building the most ambitious amateur communications satellite today (Phase 3D). In many countries, the first satellite earth station was assembled and operated by a radio amateur communicating through an OSCAR.

Amateur radio is an important part of MIR daily activities -Kasser and Kondratto (3). Its primary purpose there is to combat the boredom of long duration flights. American astronaut Dr. Norman Thaggart aboard MIR, was often heard talking to terrestrial amateur radio operators in the spring of 1995. Amateur radio has also flown several times on the National Aeronautical and Space Administration's (NASA) Space Shuttle as the Shuttle Radio Amateur Experiment (SAREX) including the historic first docking mission between the Shuttle 'Atlantis' and MIR in June 1995. In the future, amateur communications equipment may even be manifested as personal equipment belonging to the Shuttle astronauts. If that happens, any flight carrying an astronaut who is a radio amateur will have some amateur radio activity.

THE PRESENT

Amateur radio provides three main functions: communications, technical experimentation and technical training. Today, amateurs are perhaps best known for the emergency communications they provide during hurricanes, floods, earthquakes and other disasters until regular communications are restored. Other little known activities are discussed below.

Still advancing the state of the art Although few in number the experimenters continue at their work, some of which is well ahead of the professionals. For example, several presentations (by university graduates in the main) about over-the-horizon vhf/uhf propagation techniques at the 5th IEE hf radio conference in 1992, discussed work that was years behind the then current state of the art developed in over-the-horizon vhf/uhf radio amateur communications. It is really a shame that amateurs do not present papers at professional conferences. I am pleased to note that this conference expressly requested such participation. Let's hope the trend continues in the future.

Packet Radio Radio amateurs took the X.25 packet radio protocols and modified them for use on vhf and hf radio links - Fox (4) utilizing a single frequency channel time-shared by a number of amateur radio stations using a somewhat modified random access Aloha approach - Engle (5). Packet Radio is an ideal message medium and really shines when passing messages. Packet radio systems can be considered as part of a Local Area Network (LAN) in which messages can be left by one station in a computer belonging to a second station.

At vhf, packet radio is used in the form of LANs served by a central store and forward node, commonly called a Bulletin Board System (BBS). The fundamental problem within the amateur radio LAN, is that people can only send and receive messages to or from any specific station when that station is on-line. In the radio amateur environment, most stations are not active 24 hours a day but come and go. To compensate for this, Packet LAN development parallelled that of the centralized telephone network. BBSs were developed which allowed messages to be uploaded and stored for later retrieval. These BBSs also serve as connection nodes from the LAN to the international message handling network - Kasser (6).

Use of packet radio in amateur radio has grown from nothing starting in 1980 into today's integrated world wide network which makes use of hf, vhf and satellite communications. Volunteer radio amateur operators, have at their own expense, set up hf, vhf and satellite earth stations, with special permission from their national licensing authorities, that are on-line 24 hours a day each day automatically receiving and forwarding messages. Any suitable equipped radio amateur can leave a message on a local network node with the knowledge that within hours or days (depending on the destination), that message will be delivered anywhere in the world, via amateur radio. Packet radio is changing amateur radio. Communications no longer has to be in real time. Automated file servers are being installed that provide various types of information. Data banks contain modifications to equipment, and addresses of stations accessed by callsign.

While Transmission Control Protocol/Internet Protocol (TCP/IP) has been introduced in amateur radio, very few people use it. The current radio implementation of TCP/IP is difficult to set up and does not offer the user sufficient added value to make the effort worth while. Nodes are linked together via encapsulated packets through the Internet. These links known as wormholes, allow amateur packet nodes to link together irrespective of geographical location. A BBS in Australia is as accessible as one in London or Washington DC. Most Internet wormholes encapsulate the AX 2.5 packet data at each end of the link before transmitting them via TCP/IP on the Internet. Encapsulation also protects each side of the interface between amateur packet radio and the Internet. The state of the art in Internet wormholes is akin to that of the BBS ten years ago. As these links proliferate, this merger of packet radio and the Internet is going to change amateur radio in ways that we can only just get a glimpse of.

The Great Equalizer While radio amateurs are known by calls and names, they tend to speak as equals and develop reputations based on what they are, not who they are. So when amateur radio operators make a "first time" contact, they may not know the background of the other person. For example, the person at the other end of the link may be a factory worker, teacher, senator, star of stage or screen, or even the king of a country such as Spain or Jordan. Age has nothing to do with it either, teenagers converse with senior citizens as equals. Internet chat links follow in this tradition.

On the other hand, stations in rare countries tend to get called by many amateurs eager for a contact and a confirmation (QSL) card. This situation tends to cause interference to conversations in progress and keep operators from these countries off the air. Internet chat communications do not suffer from this effect. QSL cards are prized possessions and souvenirs of contacts and drive much experimentation to improve "state-of-the-art" equipment and techniques.

Low Earth Orbit Store and Forward Satellites Radio amateurs pioneered the use of LEO satellites for store and forward messages. The University of Surrey spun off Surrey Satellite Technologies to commercialize their use. However, the suitability of this technique while proven (by UoSAT-2 and Fuji-OSCAR 12) when being accessed by a small limited number of ground stations has yet to be proven when a large number of stations attempt the same. Indications that this concept will not work are already showing up in the operational use of follow-on satellites. Two negative characteristics of these satellites are the limited access on a daily basis due to being in LEO and the use of custom (incompatible with TCP/IP or AX 2.5) communications protocols. Internet wormholes provide compatible links with greater capacities and are available most if not all of the day. One such wormhole entrance in Florida has 25 wormholes to Australia, several european countries, Russia and a number of locations in Australia, Canada and the U.S.A. Not withstanding these limitations, the technology on these digital satellites is something exceptional. However, it seems that in this application, the degree of enhancement of the end product (packet radio as seen by a single user) by the additional technology and components required to make use of the innovation is unclear - White (7). As such there is little incentive for the average radio amateur to use these digital communications satellites.

THE CHALLENGES

Amateur radio faces the following challenges at the present time:

- The communications capabilities offered by amateur radio are no longer unique.
- The vhf/uhf and microwave frequencies assigned to the amateur radio service are slowly being eroded.

The communications capabilities offered by amateur radio are no longer unique 30 years ago amateurs were the only civilians to have radio communications capabilities in their automobiles. 10 years ago, amateurs used hand held 2 m repeaters for personal communications. This personal communications capability provided by the amateur radio service is now become available to anyone at low cost by means of cellular phones, and the soon to be launched constellations of LEO communications satellites such as Motorola's Iridium. These days, cellular phones are proliferating almost as fast as a influenza epidemic.

The Internet provides news groups on almost any subject. These non real-time communications are available on almost any subject. With a modicum of knowledge of the 'net' one can locate a group of people with similar interests and communicate at your own convenience. You don't have to wait for propagation or have to stay up late until the person at the other end gets home from work. The store and forward capability makes such communications very convenient.

Communications capability will soon be ubiquitous, people will need not turn to amateur radio to provide communications.

The frequencies assigned to the amateur radio service are decreasing The Amateur Radio Service is facing the loss of sections of its vhf, uhf and microwave bands to commercial services. The amateur radio allocations on the uhf and microwave spectrum are secondary not primary, and other services have their eyes on the largely underpopulated amateur uhf and microwave bands. The perceived need for additional spectrum allocations in the microwave range for new services in the U.S.A. is putting pressure on the Federal Communications Commission (FCC) to reassign frequencies from the Radio Amateur Service to other services - Duncan (8). As another example, the FCC is also currently giving serious consideration to locating Doppler wind shear radars at 420-420 or 440-441 MHz with a need of perhaps as much as 5 MHz of spectrum. In many parts of the U.S.A., the 420-450 band is already shared with military radar. The frequencies amateur radio have lost since 1980 in the U.S.A. are 220-222 MHz, 420-430 MHz in some northern parts of the USA, 1215-1240 MHz, and 2310-2390 MHz. Other countries have snipped off sections of the vhf/uhf spectrum. For example, in the UK, 30 years ago the 70 cm band stretched from 420-450 MHz. These days it has shrunk to 430-440 MHz. A few years from now, the relative amount of spectrum space which will be lost will be greater than the loss that took place in 1927 when most of the shortwaves were reassigned and amateurs were left with a few harmonically related bands.

Making use of the microwave bands is extremely important to the future of amateur radio but few communicators are moving up from the 2 m and 70 cm bands. Equipment for 1.2 GHz equipment is available commercially, yet there is little incentive to move up to 23 cm. In general the higher the frequency, the more expensive the equipment that uses it. A new technology is rarely adopted unless it provides a new (and is or quickly becomes desired) capability - Burgelman (9). And, in 1995, the Amateur radio service is still using technology based on that developed in the 1970's, with the sole exception of packet radio. Recent advances in the state-of-the-art of computers and microwave technology have been ignored by the mainstream of radio amateurs. Radio amateurs need to find a way to use those bands that is matched to their characteristics and provide features that do not exist today. The RSGB is slightly ahead of the rest of the world, being the only national society which has published a band plan for the use of the amateur microwave assignments.

Amateur radio needs to develop a plan for the use of those vhf/uhf and microwave frequencies to safeguard them. The plan needs to cover:

- spectrum allocation;
- the incentives to use them;
- a vision of how the bands will be used;
- a pro forma implementation schedule.

The 10 GHz band holds the promise of becoming as popular in the future as the 20 m band is today, given the right incentives to use it.

THE FUTURE

Organized radio amateurs have to meet the challenges discussed above. Perhaps the way to do it is to evolve a little. Amateur radio has evolved over the last 100 years as shown in Figure 1. Apart from spark, all modes of communications are still in use. In the past, the spectrum has been split between amateurs and the rest on a frequency basis. With Internet interfaces and the new voice packet features, perhaps in the future we will timeshare communications resources. Consider some ways amateur radio may evolve.

Automated Operations Digital communications software can run in an automatic manner. BBSs are fully automatic. One user software package (LAN-LINK) contains an expert system based on a finite state machine concept. LAN-LINK can be programmed by a user with nothing more complicated than a pencil and paper and the built in text editor. The program is able to hold a conversation and may even be programmed to pass the Turing test for a first conversation (QSO).

During program testing in 1987, my digital communications station made contact with other stations in nearly 50 countries. It even worked countries that I hadn't, usually because propagation was only present to those countries late at night or very early in the morning, my local time. It has operated in a contest, made more than 50 contacts and did not come last in its section. There is much scope for experimentation here. One that comes immediately to mind is language translation. The expert system can be programmed to hold a conversation in a foreign language not spoken by the operator. Another application is for an interactive on-line trainer or database.

Space Sciences and Engineering There is no substitute for the excitement of hands-on experience in awakening an interest in space. There are on-going programs in educational institutions - Allen (11) and Strieby (11) which bring signals from space into the classroom, providing students with first hand experience in receiving signals from outer space. The thrill of receiving a signal from space soon fades however if the data cannot be understood. Then even after the data has been decoded, the thrill soon fades. Watching the temperatures on-board a spacecraft as it passes overhead is also of little interest, but, what can be made interesting is receiving and capturing the data over many days or even months and looking for trends and relationships. The OSCAR satellites send back telemetry all the time. These data are downlinked on frequencies that can be received on regular vhf/uhf scanner radio receivers. Excluding the Personal Computer, a simple telemetry capturing ground station can be set up for less than $500.00 in equipment costs - Kasser (12). And for anyone who can't acquire the data in real-time, archives can be accessed via the Internet.

We are going to see increasing cooperation between amateur radio and universities and other educational institutions. This will result in:

- Mixed payloads containing science experiments and communications capabilities.
- New countries entering space.

Gateways Random contacts (QSO) on the microwave bands are few and far between. They seem to take place either as the result of a telephone call between the stations involved, or as the result of a scheduled expedition. In the latter case, the two stations involved drive out to different mountain tops, make a contact and write it up for the national magazine. All well and good, but hardly everyday use of the band. The microwave bands are not suited for random QSOs in the same way as the lower frequency bands. For example, consider a typical situation with three stations, each using highly directional antennas pointed away from each other. Their antennas are so directional that they cannot hear one another. On the other hand, if a repeater was employed at a central location they would be able to QSO easily enough. Repeaters are commonly used on 2 m and 70 cm, yet they are very rare on the microwave bands. Why? Perhaps it is because microwave users tend to be experimenters, not communicators. From the experimenter's point of view, there is no challenge in repeater QSOs. From the communicator's point of view, a microwave repeater, as a copy of a 2 m repeater, would not offer anything worthwhile building or purchasing the equipment to use it. However, change the repeater to a gateway providing new services suited to the characteristics of the microwave bands and a different scenario emerges.

The Gateway can be connected to a satellite communications station. Satellite Access Gateways were proposed and described in 1978 - Kasser (13). For any station accessing a satellite via a gateway, the gateway acts as a second transponder in series with the spacecraft and decouples the user interface to the spacecraft. Note that the gateway does not preclude individual access to the spacecraft or the microwave band by any station.

When wide band microwave gateways are established in urban areas, there is no reason why links should not be set up between gateways in neighboring areas, much in the same way that nodes link packet radio LANs. From the user's point of view, there is no difference if the gateways are linked by terrestrial or satellite nodes - Kasser (14). The actual inter-gateway links would also use a pair of microwave bands. One way of using linked gateways is by frequency division. The access frequency range would define local or distant access. This approach is similar in concept to the UK 2 m band geographical band-plan of the 1960-70 time frame - Hum (15).

Gateways provide a training ground for developing new technical talent for the radio amateur space development program. Up to now, amateur spacecraft are built to order. A launch date is obtained, and the team strives mightily to meet that date. So far they have all succeeded in that the hardware has been aboard the rocket when it lifted off. This pressure is real because rocket payloads have to be balanced. If a date is missed, the launch agency might never allow amateurs another chance, and there are very few launch agencies. The project team have to allocate the work to people whose performance capabilities are known. They cannot take a chance on an untried person, and cannot take the time to give

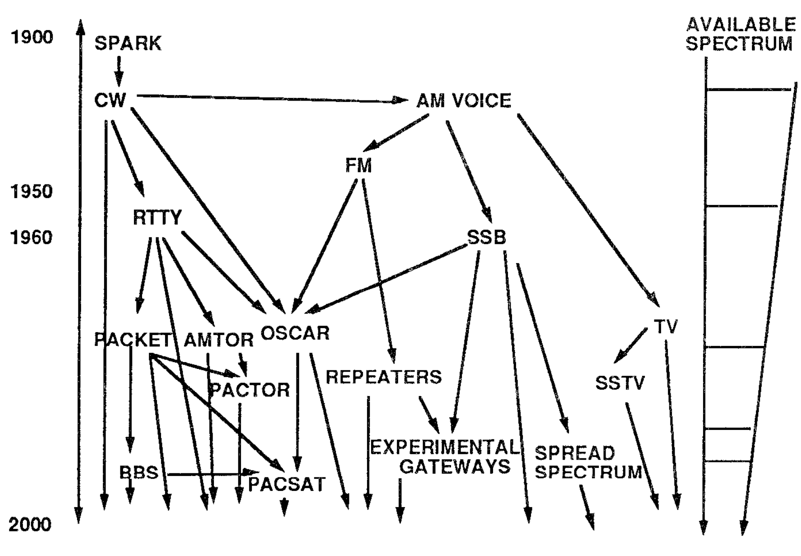

Figure 1 Evolution of Amateur Radio
(Reprinted with permission from *Software for Amateur Radio*)

that volunteer a chance. New volunteers are caught in a Catch-22 situation when trying to join existing teams. New groups on the other hand can develop their own spacecraft, but to form a group, a particular nucleus has to exist. Ground nodes on the other hand can be built by clubs, technical schools and other starting groups. They can take the time to do it right. They don't have a tight launch date to meet.

In the 1970's the technology to use gateways was not practical. Gateways of the future are feasible and can be built using even 1991 technology. A well equipped hf packet radio BBS contains about $5,000 of equipment, a packet radio node, about $500. Gateways should cost less than $5,000. As an example, consider a gateway that uses 1.2 GHz as the user transmit frequency and the 2.4 GHz band as the user receive frequency. This frequency pair has been chosen to be compatible with OSCAR uplinks and downlinks. A non rotatable microwave antenna is aimed at the gateway. This antenna may be placed on a mast, roof or balcony. Attached to it are the up/down converters which convert the gateway signals to those used by the 2 m and 70 cm equipment in the radio shack. This gives the user conventional 70 cm and 2 m capability and minimizes the radio frequency attenuation in the cables between the antennas and the radios. Contacts can be made without towers and beams. The equipment can provide digital or analog communications or a mixture. Real-time video is also a possibility. Suitable low cost equipment for users at these frequencies has already been described in the radio amateur literature - Krome (16) and de Guchteneire (17).

Path Attributes Consider the path loss and noise attributes of the microwave link. The goal of the transmitting station is to put a useable signal into the antenna socket of the distant receiver. For any given path between two stations. The received signal strength is a function of the gain of the antennas and the cable losses at each end of the link as well as the attenuation over the distance of the link. These factors have been worked out and the received signal levels at various frequencies for different link parameters can be readily predicted. The second major factor to impact microwave communications is noise. Atmospheric noise is both natural and man made. Most radio amateurs living in urban environments suffer from the effects of man made noise. Noise is also present in the front end of receivers. Any communications link design has to take noise into account. Adding transponders or gateways in series will add noise to the link, a phenomenon which will have to be accounted for. The limiting factor seems to be distance. A dish 1 m in diameter provides communications capabilities out to 450,000,000 km at 24 GHz. A 2 m diameter dish will provide QSOs out as far as 100,000,000 km at 1.2 GHz.

Interplanetary Communications Radio amateurs bounce signals off the moon almost routinely. The moon is a mere mean distance of 384,399.1 km from the earth. An effective communications range of 100,000,000 km provides communications capabilities with future bases on the moon or Mars. The distance between the Earth and Mars ranges from about 80,000,000 to 230,000,000 km depending on the positions of the planets as they travel along their own orbits around the sun. Overcoming the path loss is only one problem that has to be faced by the radio amateur configuring for interplanetary communications. The major problem will be the time delay. The one way travel time for a signal between the Earth and Mars varies between about 4 minutes when Mars is only 80,000,000 km distant, and 20 minutes when Mars is 220,000,000 km. Inter-planetary amateur radio QSOs will not be real time voice links in the same format as intra-planetary QSOs. Nobody ever said that a QSO had to take place in real time. Apart from the path loss and the time delay, both planets are rotating, so there will be Doppler shift on the signals. For any amateur radio station located on the surface of the Earth (earth station), Mars will only be above the horizon for a few hours each day. There is no guarantee that when Mars is viewable by an earth station, Mars base will be able to see the Earth let alone the same earth station. These problems are not insurmountable, Personal computers (pcs) can handle all the math involved, but they do tend to make direct inter-planetary communications difficult. If suitable spacecraft were in orbit about both planets they could make inter-planetary communications much easier. However, getting these spacecraft built and into suitable orbits may be difficult.

Gateways of the future will be full duplex and provide new capabilities to attract the communicators. They can provide both intra-planetary and interplanetary communications capability. They can provide high speed audio, video and digital communications and a host of new services. *Best of all, they provide a plan for the use of the microwave bands in a manner for which the bands are best suited.* Such a plan may tend to safeguard those bands for the Amateur Radio Service. However, the gateways of the future need standards and imagination. They must be designed in a top down manner and implemented piecemeal - Kasser (18).

A Mission to Mars Not one, but two MARS missions carrying amateur radio have already been proposed. That's not so surprising as amateur space technology already exceeds that used for NASA's early Mariner missions to Mars. The World Space Foundation has proposed a solar sail flight to Mars carrying an amateur radio payload for the telemetry tracking and control functions - Garvey (19). During the preliminary planning for the Phase 3D spacecraft, Karl Meinzer (DJ4ZC) noted that the spacecraft frame contained space which could be filled by a secondary package which could be boosted out toward Mars. The Mars International Cooperative Hitch-hiker Amateur Educational Launch (MICHAEL) mission is more ambitious - Kasser (20). MICHAEL is proposed as follow on to Phase 3D. It would be an educational spacecraft carrying a communications transponder, telemetry and science instruments including a TV camera. This mission can easily be achieved using technology already developed by radio amateurs for the Phase 3D mission, all we need is the commitment to go ahead and the organization to do it.

SUMMARY

The world of amateur radio encompasses the whole range of communications technology. Amateur radio is a hobby that has existed since the time Marconi, Hertz and others began their experiments. It is the only hobby that is regulated by the government of every country in the world. There are more than a 1.5 million persons worldwide who are licensed amateurs.

Radio amateurs have made important contributions to the theory and application of communications technology in all areas of the genre. At this time, after 100 years, amateur radio is at a critical turning point. This paper briefly summarized of how radio amateurs advanced the communication state-of-the art in the past, discussed current problems facing amateur radio in the present and the potential for amateur radio in the future.

RECOMMENDATIONS

Until now, much of the technical contributions by radio amateurs have been a well kept secret. Yet, many papers published in the amateur radio journals, would make very good technical papers at professional conferences. It is recommended that the RSGB and the ARRL take the initiative to submit such papers to the appropriate conferences and subsidize the expenses of their presenters in the manner in which the ARRL subsidized the expenses of Paul Godley in 1921.

In the past amateurs have shared spectrum on a frequency basis. Let's look for further opportunities to share communications capacity on a time division basis such as we now see in the form of Internet wormholes.

CONCLUSION

If you think the ideas discussed in this paper are far fetched, look at Figure 1 and consider what Paul Godley might have thought of it as he strained his ears listening for a weak signal from the other side of the ocean back in 1921. Amateur Radio has and continues to evolve. The future may be even more exciting than we anticipate.

The conclusions of this paper are that amateur radio will exist 100 years from now, but its shape will be very different from amateur radio as we know it today. At the next Centennial Radio conference, 100 years from now, someone may even review this paper and comment at the limitations of my imagination.

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