AMATEUR PACKET RADIO IN IARU REGION 3*

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INTRODUCTION

About 6000 radio amateurs throughout the world are now equipped for packet radio, and the number is more than doubling each year. Amateur packet radio was made possible by the introduction of the personal computer around 1975 and experimentation by radio amateurs since 1978. The common goal of these experimenters is to build a global network that will enable personal computers to exchange data rapidly and without errors. The network not only will handle conversational QSOs but will support many new services such as transfer of record messages, access to electronic data bases, transmission of videotex and facsimile images, and digitized speech. Packet radio is not simply a high-tech replacement for radioteletype; it is an automatic and reliable method of transmitting any digital information in short bursts.

While amateur packet radio had its start in the North America, it has now taken root in many countries throughout the world. In the Asia and Pacific areas, there is notable amateur packet-radio development in Australia, Japan and New Zealand. There are early signs that the Japanese Amateur Radio industry is looking very seriously at new products involving packet radio. Not only can they sell packet-radio products to amateurs worldwide, but there are many commercial and governmental applications for a full product line. In the United States, there already has been some spinoff of amateur packet radio into other radio services. Some current examples are: (a) U.S. Forestry Service use between personal computers in National Parks, (b) data communications with military severe-weather-surveillance aircraft, and (c) mobile communications with a large fleet of over-night courier vehicles.

Without a doubt, amateur packet radio is here and is here to stay. As in any new technology, it is not possible to predict its future twists and turns, or even its ultimate shape. Military or commercial projects can be organized in a top-down manner with clear objectives, financial control and technical direction. We amateurs do not have the benefit of a well-funded central authority to develop a network. Instead, we have individuals and groups with a great freedom of action and diversity operating with funds of piggy-bank proportions. The Amateur Satellite program was perhaps the first example of how amateurs learned cooperation and division of labor in a complex technical program that would serve all radio amateurs. Building a global packet-radio network will require the same synergism -- and more. We need the specialists to devise new protocols, software and hardware. We also need the organizers, facilitators and entrepreneurs to apply their efforts to the main stream without stifling innovation.

National Societies have a large stake in the outcome of packet-radio development in Region 3. Societies can help create an environment in which creative amateurs can flourish. Finding precious human and material resources is another role. Clearing away obstacles to packet radio in radio regulations is an important goal for National Societies and the IARU. Cooperation in international amateur packet-radio standards is another essential task for National Societies to ensure that the network is interoperable.

CREATING AN ENVIRONMENT FOR PACKET RADIO EXPERIMENTATION

Many countries in Region 3 already have centers of excellence -- areas with Amateur Radio clubs with technical interests, radio amateurs in the science and engineering professions, computers, laboratories, and universities. Chances are that amateur packet radio will sprout on its own in these areas. But for that to happen, there has to be some knowledge that packet radio exists and an individual who will be a spark plug or initiator. National Society membership journals, commercial magazines and newsletters can spread the word of packet radio's existence. In our experience, however, it takes a personal presentation by a packet-radio enthusiast to plant the seed. A demonstration of a working packet-radio system is needed by most amateurs for them to comprehend how it works and what it can do. A knowledgeable person can answer questions and clear up any misconceptions. Our experience is that this is sufficient to generate interest in these centers of excellence. Actually making packet radio happen in such areas usually depends on putting a packet-radio repeater (digipea-

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ter) on the air and getting at least two amateurs to start using it. From there, packet radio seems to be established and capable of further growth.

For packet radio to get started in high-tech areas, there must be continual access to equipment, software, and other system support. These things are readily available in the United States and are becomming available in other countries. In some countries, importing is a problem, and developing domestic sources may be possible. For example, you may wish to investigate local production of packet-radio equipment printed-circuit boards under license of a U.S. manufacturer. Some countries have the resources to developtheir own equipment; however, this is not a trivial task.

There will also be a continual need for the latest information about packet radio because it is rapidly developing. ARRL Headquarters keeps fully informed about packet-radio activities in North America and elsewhere, and is willing to share this information on a timely basis with other National Societies. ARRL publications (Gateway, QST, QEX and the Handbook) are the vehicles we regularly use to disseminate information about packet radio. In addition, we offer the proceedings of past ARRL Amateur Radio Computer Networking Conferences -- some 76 technical papers written by amateurs.

So far, I have covered only the simpler problem of how to get packet radio started in an area with essentially the right conditions. What can be done where the environment is not particularly conducive? It may be a long process and might have to waituntilthe day of mass availability of packet-radio systems. Perhaps the major manufacturers will eventually reduce the packet-radio controller to a single integrated circuit and make it an organic part of all-mode transceivers. Butwhatcan we do in the short term? The answer could lie in the centers-of-excellence concepts outlined above and encouraging such centers to set up networks between them, both nationally and internationally. Maybe that will attract others. "Packeteers" in the United States wishing to link from one city to another have been able to recruit another breed of ham -- the fellow who sees his role in life as putting VHF repeaters on the air. Newsletter editors, club officers and other amateurs initially not the least interested in packet radio similarly can be enticed to help. We haven't gotten the attention of many contesters, but that too will come in time. My point is that by division of labor and recruiting people with varied backgrounds, packet radio can get started with only a few "high-teckies."

Another possibility is to take advantage of the fact, as the saying goes, that necessity is the mother of invention. In those parts of the world where radio amateurs play a role in disaster communications, there already has been considerable interest expressed in packet radio -- and some significant use of the method, particularly in California. A marriage of technically inclined amateurs with those having a need or desire to improve Amateur Radio disaster communications can yield enormous benefits.

RADIO REGULATIONS

Radio amateurs in North America should consider themselves fortunate that their regulatory agencies (Department of Communications in Canada, and Federal Communications Commission in the United States) led the way by writing packet radio provisions in the rules. In the Canadian instance, in 1978, the DOC deliberately set out to foster packet radio, laid down specific rules for it, and created a Digital Amateur license class. In the U.S., the FCC took notice of the Canadian action and introduced both the ASCII code and packet radio into the regulations as the saving grace of an embattled inquiry already underway to control emissions by bandwidth rather than mode.

This is not to say that U.S. and Canadian radio rules are without problems with respect to packet radio. However, in both countries, the administrations took the initiative and have remained receptive to regulatory changes to encourage experimentation. If such receptivity to experimentation is lacking, the National Society should consider ways of working with regulatory officials to improve the climate. FCC officials have responded favorably to in-person briefings on, and demonstrations of, new technology. All regulatory officials having approving authority need to know what packet radio is, its potential, and its impact on others who share the spectrum. More fundamentally, they should understand how Amateur Radio experimentation benefits the general public and the communications industry.

Concerns

In addition to an appreciation of amateur experimentation and the benefits of packet radio, there are several concerns that need to be satisfied.

A major concern is that the regulatory agency may not be able to monitor packet-radio transmissions if and when they wish to. In dealing with this issue, we have pointed out that it is impossible for the government to monitor all Amateur Radio transmissions anyway because of propagation. Thus the propriety of Amateur Radio transmissions depends largely upon a trust that licensed amateurs will act responsibly and obey the law. The

Amateur Service takes pride in its ability to police itself. Confirmation of this bond of trust between amateurs and the government should do much to address the concerns that packet radio would be misused in the Amateur Service. Nevertheless, the regulatory agency needs the technical tools to monitor when it needs to. This can be satisfied by a packet-radio controller and a low-cost personal computer. The National Society can help by specifying exactly what is needed, facilitating procurement, and assisting in the initial installation if needed. Perhaps this can be obviated by getting one licensed enforcement official personally interested in packet radio to the degree of getting on the air. In certain countries, it may suffice to ensure that amateurs having the necessary qualifications and the full trust of their government have the ability to monitor packet transmissions.*

Even if it were technically possible to monitor every packet-radio transmission, there is the matter of volume. In the early stages of packet-radio development when volumes are low, it may be possible to closely monitor most or all transmissions within radio range. As volumes pick up, as they have in the U.S., human ability to physically read the transmissions is exceeded. It would be a full-time job for one person to scan traffic from one fully loaded packet-radio channel operating at 1200 bits per second. For an individual responsible for a digipeater, this poses a problem of how to prevent transmission of communications that are prohibited by the rules.

o An ultraconservative approach would be to have the digipeater trustee preview each and every packet prior to retransmission. That's obviously impractical and not considered necessary for voice repeaters; why burden a new technology with such a restriction?

o Another "cure" often suggested is to add a software "filter" that will screen out prohibited material. Some telephone-line bulletin-boards operators have gone so far as to develop a list of vulgar words. This has several pitfalls. There is a potential for embarrassment if the word list is revealed. Experience shows that it is impossible to think of every possible word or phrase that could be improper, especially if one is trying to rule out indecent language and other types of traffic (such as business messages). The "filter" ends up so all-encompassing that everyday communication between amateurs may not get through. Add to this the ability of individuals to outsmart the "filter" by using only words that are not on the list.

o The third approach is one based almost entirely on trust and peer pressure of the amateurs using the network. The trust aspect rests on the fact that amateurs are licensed, worked hard for it, and would not like to lose it by violating the rules. with a highly automated network, not too many amateurs will be monitoring each transmission, but those in range can do so.

Whether or not there is anyone monitoring, the packet still must be addressed to another amateur station; the addressee can be expected to advise the originator that a communication is improper. Operators of computer-based message systems (CBMSs), often called bulletin boards or mail boxes, can program their systems to prevent retransmission of messages not screened. Or, a more-liberal approach would be for the operator periodically to scan messages already stored, kill improper messages and advise the originator why the message was purged. This whole process can be backed up by a modest capability for volunteer monitors and governmental monitors to conduct spot checks and respond to complaints when they occur.

Signaling Rates and Spectrum Occupancy

About the only signaling rates in use at present are 300 and 1200 bauds. The lower speed is used on below 28 MHz; the higher one on VHF and UHF. If freedom to experiment were the only consideration, there should be no speed limit on transmission of data. But, of course, packet radio must share the spectrum with other users, so there should be some upper bound on the occupied bandwidth -- either by regulation or "gentlemen's agreement."

Unfortunately, it is not possible to equate data rate with bandwidth. Bandwidth is determined by several factors:

o data rate (in bits per second or bit/s)

o the modulation technique (e.g., FSR, BPSK)

o filtering and nonlinearities after filtering.

In the modulation systems used thus far, one bit is equal to one symbol transmitted (1 baud = 1 bit/s), thus bandwidth is proportional to data rate. However, as the spectrum becomes more occupied and

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* For many years ARRL has had Official Observers. In 1984 an agreement was reached between the ARRL and FCC to establish an Amateur Auxiliary or Volunteer Monitoring Program. The agreement covers two classes of volunteer monitoring stations: 1) the station-level monitor or individual Official Observer, and 2) a handful of Regional Monitoring Stations.

modems become more sophisticated, there will be a trend toward so-called m-ary modulation systems. In such systems, it is possible to encode 2, 4, 8, or more bits into a single transmitted symbol by using various phase and amplitude combinations. It is important that radio regulations provide for m-ary modulation systems, for both experimentation and future growth of packet radio.

In the regulatory proceeding that set speed limits for digital communication, the FCC proposed defining speed in bit/s. Commenting amateurs pointed out that this would have locked out the use of m-ary modulation and would have been counter to spectrum conservation. As a result, where speed is mentioned in the rules, it is specified in bauds (symbols per second). Thus there is a direct relationship between the modulation rate in bauds and bandwidth. The FCC used both modulation rate and bandwidth, as summarized below:

Frequencies	ITA2 AMTOR ASCII	Any digital codes, only above 50 MHz
<28 MHz	300 Bd	Not authorized
28-50 MHz	1200 Bd	Not authorized
50-220 MHz	19,600 Bd*	20-kHz bandwidth
220-902 MHz	56,000 Bd	100-kHz bandwidth
>902 MHz	56,000 Bd	Any bandwidth within given amateur band

*19,200 is the standard rate.

The above modulation-rate and bandwidth limitations have served us well up to now and perhaps sometime in the future. But one can anticipate the need to press the limits upward over time. In a country starting with a "clean slate," it may be possible to incorporate more liberal provisions from the outset.

The 300-baud limitation at HF may be overrestrictive in that higher rates are possible. There are experimental modems developed by industry for the military that operate at 9600 bauds (serial not parallel signaling) in a single-sideband speech bandwidth (3 kHz). They use sophisticated "learning" techniques, require computer processing, and are beyond Amateur Radio pocketbooks for now but not necessarily forever. A speed of 1200 bauds would appear to be a reasonable upper limit for amateurs. Through the use of m-ary modulation techniques, actual data rates of 2400 or 4800 could be accomplished with learning and computer processing. If specified in bandwidth, with a spectrally conservative modulation technique and proper filtering a 1200-baud signal could be kept well within a 1500-Hz bandwidth.

On frequencies between 220 and 902 MHz, the modulation rate permitted by the FCC (56,000 bauds) is a standard rate for North America but not for the rest of the world, which follows CCITT guidelines for speeds. The CCITT number being recommended for the Integrated Service Digital Network (ISDN) is 64,000 bit/s. Perhaps U.S. amateurs should follow that standard rather than North American telephone practices.

Eventually it may be necessary to ask the FCC to raise the speedlimitabove 902 MHz to either "no limit" or something in the megabit-per-second range. Here again, there are some differences between North American and CCITT recommended speeds for "first-order" pulse-code modulation (PCM) networks, which are 1.544 and 2.048 Mbit/s, respectively.

Emissions

The new emission symbols adopted in the World Administrative Radio Conference (WARC-79) are more specific than those used for so many previous years. Furthermore, they do not correspond, one for one, with the old ones. In addition to describing the signal as it appears on the air, the new symbols also are specific as to how the signal is generated. This makes it difficult to translate old symbols into new ones.

For packet radio, it is desirable to have a very broad description of permissible types of modulation in the rules. It might be possible simply to specify something like "data transmission, telemetry and telecommand by any amplitude modulation, angle modulation, or a combination thereof, using bandwidths in keeping with good engineering practice." Amplitude modulation and angle modulation cover everything except pulse modulation. For reasons probably needing reexamination today, pulse modulation is not permitted on the lower-frequency bands. Pulse modulation would be valuable for future higher-speed packet-radio applications.

The other alternative is to specify every possible modulation scheme by emission symbol. This becomes cumbersome. For example, the old symbol, F1 could be translated to F1D, but that covers only direct frequency shift of the main carrier. F1D does not include phase-shift keying (PSK), which would be G1D. To make things more complex, either frequency or phase shift of a subcarrier modulating a single-sideband transmitter would make the emission symbol J2D. Further, it is possible to suppress the sideband of a high-speed data transmission as commonly done for speech: that would be J1A. There could be other specific emission designators if two or more channels are multiplexed or if pulse modulation is used, both of which could occur at megabit-per-second speeds.

It appears that the better approach to emissions, particularly for packet radio, is to ask the administration to give amateurs only broad guidelines that will not stifle experimentation. That would also ensure that international packet-radio communications will not be hampered by incompatibility caused by overspecificity.

Station Identification

At one time, digital transmissions had to be identified by Morse code under FCC rules. It was liberalized to permit identification in any of the specified digital codes (ITA2, AMTGR and ASCII). Using the AX.25 link-layer protocol, the call signs of the addressed station and sending station are sent at the beginning of each packet transmission, in ASCII. This meets FCC identification requirements and lets any monitors know who is transmitting and who is intended to receive the packet. Where digipeaters are used, the AX.25 address field is extended to include the call signs of each digipeater along the way.

It appears that the AX.25 addressing arrangement meets at least the spirit of identification requirements anywhere. However, the regulations of some administrations may require amendment or at least reinterpretation. For example, a national licensing authority may require that the call signs of the addressed and sending stations be transmitted at the beginning and the end of each transmission. It may be possible to successfully argue that the beginning and end of a packet lasting only one second are so close together that only one identification is needed per packet.

Conformity to Widely Recognized Standards

When AMTOR was new, FCC acceptance of this mode was easy, in part, because of the existence of CCIR Recommendation 476-2 specifying this mode for international maritime use. The FCC authorized AMTOR by simply incorporating by reference Rec. 476-2, and later 476-3, in the rules. It may be generalized that following industry and international standards strengthens a case in petitioning regulatory authorities for rules changes in the Amateur Service.

If rules changes are needed to permit packet radio, it can be stated that packet-switching techniques are now in widespread use throughout the world in other communications services. The AX.25 link-layer protocol follows a number of international standards, principally:

0 International Organization for Standardization (ISO) standard IS0 3309, Data communication--High-level data link control link procedures--Frame structure.

o International Telegraph and Telephone Consultative Committee (CCITT) Recommendation X.25, Interface between data terminal equipment and data circuit-terminating equipment for terminals operating in the packet mode on public data networks.

In development of packet-radio standards and practices, the ARRL approach has been to follow international (as distinguished from national) standards to the degree feasible. Amateurs in the U.S. are using modems that conform to North American Bell Telephone standards (not CCITT) for packet radio. This practice was brought about by the ready availability of Bell Telephone modems at surplus prices. Fortunately, Bell and CCITT modem incompatibilities are somewhat moot when used via Amateur Radio. On HF, for example, Bell 103 and CCITT V.21 can communicate through SSB transceivers because the frequency shift in both cases is 200 Hz; the difference in tones is easily compensated for by tuning of the transceiver. On VHF and UHF, there is little radio contact between North America and other continents except via satellite. The ARRL has not taken a position on packet-radio modems standards to date. However, any future recommendations will be developed with due consideration to international standards. The existence of integrated circuits capable of multiple Bell and CCITT modem protocols helps to diffuse modem standards as a serious issue. A modem using the AM7910 chip is shown in the current ARRL Handbook.

Third Party Traffic,

Perhaps the most sensitive issue is third-party traffic. Packet radio is technically suited to handle third-party traffic where permitted and may, in time, supplant manual transmission methods. Rules governing third-party traffic are quite liberal in the United States and certain other countries. There are certain restrictions to prohibit competition with common carriers and other commercial radio services. Yet, we are aware that other philosophies govern third-party traffic rules in other countries; many outlaw it entirely, while others have exceptions only for declared emergencies. In some cases, the regulatory language prohibiting third-party traffic was so broad as to rule out repeaters.

As the packet-radio network grows, there will be a "technical imperative" to have message traffic relayed from one country to another possibly through intermediary countries. If the third-party-traffic rules are nonuniform, routing requirements could become chaotic for international messages. Or, unfortunately, amateurs may simply choose to ignore provisions in the rules that seem inconvenient. Thus, the technical imperative takes over: It is **possible;** therefore do **it!**

It may be appropriate for the **IARU to** take the lead in developing **"model** regulations" pertaining to third-party traffic. If there is broad international agreement on a workable model based on a set of there is a good chance of favorable consideration by licensing authorities.

CONCLUSIONS

Packet radio is here now and is growing at a substantial rate. There is a sufficient technical base for its development throughout Region 3. National Societies can encourage its orderly growth by providing accurate and timely **information**, and by supporting their centers of excellence, as detailed above. Liaison with regulatory authorities is also a special role of National Societies; goals should be to a) assure that officials have a proper appreciation of this new technology and b) convince the authorities of the need to modernize regulations to accommodate new modes such as packet radio.

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