APPLIED DIGITAL COMMUNICATIONS VIA HF RADIO

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INTRODUCTION

This paper discusses a number of applications of microcomputers using automated transfers of messages between radio stations, mainly by means of packet radio techniques in the radio amateur environment. The reason for this is that the world of Amateur Radio encompasses all the aspects of radio communications in a condensed form. Many radio amateurs get involved in several of these aspects by virtue of having to do the job on their own. To set up and gain the most use from their station, the individual operator must know something about transmitters, receivers, antennas and propagation. In fact, in many instances radio amateurs use hf radio the hard way. The majority of radio amateurs use limited powers and compromise antennas. This, in the main, is due to the constraints of having to purchase their equipment out of their own funds and having their station set up in their own homes. Yet in spite of, or perhaps because of, their limitations, radio amateurs are steadily advancing the state of the art in applied digital communications. This paper concludes by describing some of the features implemented in LAN-LINK, a software package developed for the MS-DOS Personal Computer family, to automate digital message handling via radio links with military and commercial as well applications in the amateur radio environment.

DIGITAL COMMUNICATIONS MODES

Before going into the subject of applied digital communications via hf radio, this section provides a quick look at the development and capabilities of the different technologies.

Morse Code

Morse code was the earliest form of digital communications. Morse code is still used, can be generated and received by both men and machines.

Radio Teletypewriter

When Radio Teletypewriter (RTTY) equipment using the BAUDOT code became readily available on the surplus market in the years following World War 2, radio amateurs experimented with using that equipment for communications. RTTY modems convert the digital waveforms to and from two audio tones which are transmitted on the radio link. As long as the radio frequency (rf) signal strength is high and interference is not present the signals are received error free. Fading in the ionosphere or interfering signals cause hits in the received data which show up as random characters. There is no way for the sending station to know that the signal has not been received perfectly until the end of the message. In many applications of point to multi-point (one transmitter to many receivers) the sending station never gets that acknowledgement in a timely manner. RTTY is a half duplex communications mode. One station is transmitting at any time. RTTY is also a character communications mode in that each character is transmitted as soon as it is typed.

AMTOR

Amateur Teleprinting Over Radio (AMTOR) (1) is an improvement over RTTY in that it is derived from the Simplex Telex Over Radio (SITOR) protocols (2), and in its point-to-point mode of use provides error correction in real time, and guarantees error free delivery. Like RTTY, AMTOR uses a limited alphabet. AMTOR is a half duplex communications mode with some of the attributes of a full duplex mode. In this mode, software controls which station is talking and only one station can send data at a time. Operators can type characters into a keyboard buffer which will be transmitted automatically when the other station turns the control over.

Packet Radio

Radio amateurs took the X.25 packet radio protocols and modified them for use on radio links (3) which utilize a single frequency channel time-shared by a number of amateur radio stations. Packet Radio communications is a full duplex mode of communications. Character typed by an operator at the keyboard are stored and sent out as a burst or packet. Packet Radio is a multiple access or distributed situation in which many of the stations in the network can, in real time, see information passing between other stations in that network(4)(5). Packet Radio is an ideal message medium. While there is place for keyboard operation, Packet Radio 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.

Packet radio is used both at vhf and at hf. It takes the form of many stations time sharing a single radio channel using a somewhat modified random access Aloha approach (6). 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 both messages and bulletins to be uploaded and stored for later retrieval. These BBSs also serve as gateways from the LAN to the international message handling network. Many of these BBS stations operate on more than one frequency, as well as providing for multiple user access on each access frequency.

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 twenty four 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. I have sent myself (G3ZCZ) test messages that travelled around the world automatically. A typical message which was deposited on the N4QQ BBS in suburban Washington DC (with routing instructions) was forwarded to WB6GFJ in California on an hf channel. There it was uplinked to the University of Surrey's Orbiting Satellite Carrying Amateur Radio (UoSAT-OSCAR 11). Several orbits later, as the spacecraft passed over Europe the message was downlinked to GB3UP, a station at the University of Surrey, in England. The message then travelled across England passing through several nodes on vhf and uhf and was forwarded by GB7LDI on hf to 4X1RU, a station in Israel who subsequently forwarded the message to N4QQ-1 in a suburb of Washington DC in Northern Virginia, which in turn forwarded it back to my local BBS (N4QQ). The whole process took about a week, only because the satellite uplink station in California was off-line for a few days. I also claim to have originated the first non real time amateur packet radio communications between the USA and the USSR when a message I left on my local BBS (N4QQ) was forwarded to 4X1RU in Israel, and then on to UA3CR in Moscow in November 1988.

National radio amateur organizations such as the Radio Society of Great Britain and the American Radio Relay League (ARRL) are using packet radio to publish bulletins of interest to their members. Other groups publish bulletins containing information about various subjects as diversified as scouting, OSCAR applications, educational assistance or even requests for pen-pals. Individual amateurs post messages asking for help about particular points, or offering information that might be needed by others. If they are not careful, those messages can end up on every BBS in the world.

Packet message forwarding at hf is performed by closed groups of volunteer stations using specified frequencies on a number of different bands. The BBS forwarding software currently in use works on a timed basis to minimize interference. Each station in the network attempts to forward messages to designated stations at a specific number of minutes after the hour. Knowing this, and knowing the location of a BBS, anyone can determine if propagation exists to the geographical area a BBS is located in, just by listening for the forwarding. The quality of the link between that BBS and the one it is in contact with, can be determined by measuring the number of retries for each message.

Packet radio has started to change amateur radio. Communications no longer has to be in real time. Automated file servers are being installed that provide various types of information. Favorite data banks contain modifications to equipment, and addresses of stations accessed by callsign.

Distant transmission (DX) chasers are a group of radio amateurs who are interested in making a contact with as many different countries as possible and some amateurs add to that by trying to do it on as many bands as possible. These DX chasers have found an application for packet radio in a multiuser node capacity in the form of using a specialized network node server. When they are at home and doing something in their shack, they connect to their local DX node server. At any time of the day, in a large metropolitan area, there may be several radio amateurs scanning the bands looking for an opening while others are standing by doing something else. When they find one, they send a message to the node which relays it in turn to all stations connected to the node. DX stations have remarked on the effect, for no sooner do they establish a contact with a station in a new area (as a result of a change on propagation conditions), when they are called by several others from that area. This activity is gaining popularity very quickly. Let it be noted that at this time, Washington DC. has three 2m band packet radio channels dedicated to a linked set of nodes. This system has a coverage area ranging from at least north of Baltimore, Md. down to Richmond Va, and possibly further out.

DX stations get called by many amateurs eager for a contact and a confirmation (QSL) card. If the station is in a rare location, possibly only there for a short period of time, many amateurs try and make a contact at the same time. This effect known as a pile-up, results in a lot of interference and the communications rate drops. There are currently several techniques for overcoming that situation including list operations (one station takes a list and acts as a master of ceremonies to ensure that everyone gets a turn) and by spreading out the interference by asking stations to call on a range of frequencies rather than on a single one.

Future DX stations may be able to make use of packet radio and satellite links to cut out some of the pileups and increase their communications capacity. They will be able to connect into distant DX nodes directly via amateur digital satellite links and arrange a list of contacts (in real time) for the hf band and mode being operated on.

Propagation Research

There are a number of beacon transmitters on various bands for research into radio propagation at different frequencies. These beacons are currently either continuous wave (cw) or modulated frequency shift keying (FSK). Apart from one time shared system in the 20m band, each of these beacons has its own frequency. The current system works in an open loop manner. The beacon keepers may get reception reports, days or months after the fact. At the same time, the amateur bands are growing more crowded and there is pressure to move operations into the beacon sections of the bands. A shift from the present system to a packet radio based system would improve the service and reduce the amount of frequency spectrum needed. This could be done in several ways. In the simplest, all beacons in one band could be on the same frequency and transmit identification packets at periodic intervals. Any amateur wishing to monitor propagation conditions would just have to tune to that frequency, and leave the receiver there for a short period of time. A look at the screen would then show what beacons were heard.

A more advanced system, would allow the beacon stations to acknowledge an incoming connect request with a simple response and a serial number. Radio amateurs would attempt to connect to a distant beacon. If propagation is present, the connection would be made, and the amateur could leave a message describing the signal strength or any other fact to be noted. The beacon keeper would have near real time knowledge of band conditions, just by looking at the log of connections. The software to do this exists in the form of LAN-LINK. All that remains to be done is to implement it. It wouldn't take much effort to modify that software to provide the capability to change frequency at periodic times and either listen for or attempt a connection with a distant "beacon" to test for a path at that frequency. The same approach could be applied to meteor scatter communications at vhf and uhf. Many potential communications openings are missed these days, because nobody has the patience to try continuously or repetitively at periodic intervals. Computers however, have infinite patience and can do the job. The technology is there and can be used, it is obtaining the necessary licenses that poses the difficulty.

The Space Shuttle and MIR

In keeping with its integrated link philosophy, LAN-LINK provides both space-segment and ground segment capabilities for communications between the

American Space Shuttle and/or the Soviet MIR space station with radio amateurs on the ground. LAN-LINK has flown on the Space Shuttle as part of the Shuttle Amateur Radio Experiment (SAREX). One feature of the SAREX was a packet radio experiment. A robot packet station was flown on the STS-35 mission December 1990. Dr Ron Parise, WA4SIR, the payload specialist and radio amateur astronaut used LAN-LINK running on a laptop computer in the Shuttle's Mid deck to control the robot. Packet radio has also been activated by Musa Manarov, U2MIR, from the MIR space station in February 1991.

The flight path of STS-35 in 1991 due to the requirements of the primary astronomical payload mission constraints was such that the Space Shuttle passed over the USA, in the main, during late night or very early morning. The flight path of MIR brings it over different locations at various times of the day and night. At weekends staying up for a connect attempt may be fine, however during the week, that was a problem. LAN-LINK has features built in to it to allow radio amateurs to make a connect with the orbiting Robot, while they are at the office, or even fast asleep at home. When the feature is activated, LAN-LINK issues a connect request to the orbiting robot whenever a packet sent to or from it is heard. If the link is made, LAN-LINK deactivates the feature. If the connection does not go through, LAN-LINK tries again the next time it is triggered.

LAN-LINK

The packet radio medium has potential, but if the software is not there to allow the individual to apply that potential, the potential remains just that:- a potential. Packet Radio software to-date has in the main, been designed for a one-on-one connection ignoring the one-on-many capabilities available in a distributed LAN. Even the few applications that allow multiuser connections also require replication of each packet to each user. Applications software development in the field of packet radio has concentrated on message handling, and multiuser services. Apart from a few rudimentary software packages that interface the operator to the terminal most of the technical developers have assumed that messages get into the LAN and gone on from there. LAN-LINK, developed by this author is the only applications package that interacts with the LAN as opposed to the user's terminal. LAN-LINK takes advantages of the features inherent in digital computers to automate radio communications in a user friendly manner.

LAN-LINK contains too many features to be described in this paper. However, some of the major aspects are briefly outlined in the following paragraphs.

LAN-LINK allows stations to store messages in their computers so as to use it as an automatic answering machine. LAN-LINK also extends that concept to cover the eventuality of them wanting to take their computer off-line for some reason. Any station may load the message into any other computer they can connect with using elements of the Q code adapted to a proposed High Level Network Communications Language (NC/L) (5). NC/L is designed to be used by both people and machines. It is thus based on the 'Q Code' with which most radio amateurs are familiar to some extent. NC/L places a colon character ':' before and after the three letter Q code to inhibit recognition of the Q code in the middle of a message (and subsequent automatic operation).

LAN-LINK contains an AMTOR robot beacon and packet mode smart answering machine facility. When someone connects to a LAN-LINK station, if a message was left for him, he (or she or even it as the case may be, and only that station) will receive it automatically. No one else will normally be able to download that message. To ensure that people know that a message is waiting for them a 'MAIL for' list is loaded into each Packet Beacon and transmitted every 30 minutes as ':QTC:' followed by a list of calls. If no mail is pending, or the only message in a system is one addressed to that system, the beacon transmissions are inhibited. This conforms to good operating practice on crowded channels (at least inhibiting the beacon does).

The mail beacon in the AMTOR Mode is transmitted as part of the beacon's automatic CQ message. It is automatically updated when a message is transmitted.

Any station using LAN-LINK can be configured to automatically attempt a connect when seeing their callsign in someone else's LAN-LINK beacon mail message list. LAN-LINK automates logbook entries for Packet and Mailbox/Beacon Mode AMTOR Connects, semiautomatic logbook entries for other modes. The logbook file is dBASE 3 compatible for automatic tracking of contacts for record keeping purposes.

LAN-LINK also provides for amateur contest operation, sends standard messages manually and automatically. Using AMTOR and a 100 Watts of rf feeding a simple vertical antenna, LAN-LINK made 50 contacts and placed 7th out of 8 entries in the Maryland low power section in the 1990 ARRL Digital Mode Contest.

The program allows automatic capture-to-disk of all packet radio connects. It has automatic indication of the number of Packet connects. It is capable of automatic connect attempts to download a message from another station in the LAN. It is capable of automatic connect attempts to a packet BBS to download incoming messages, when the relevant callsign appears on the BBS mail beacon annunciator. It is then capable of automatically requesting Bulletins on subjects of interest from a packet BBS.

It has a Conference Mode in multiconnect situations as well as a Bridge Mode.

It has an alert signal to let the operator know when a predetermined callsign shows up in a packet header on frequency. LAN-LINK also has an indicator that a specific station designated as the 'target' call connected in Packet Mode, or linked to AMTOR Beacon/Mailbox while the operator was away. There is an on-screen indication of connect by desired station (target call).

There is a automatic Beacon Mode CQ caller. It will call CQ repetitively and either work the connect and keep going after disconnect or signal when a reply is received.

Development Experiences

A major development, debugging and testing of LAN-LINK took place in Jerusalem, Israel, in the summer of 1987. There the Robot station G3ZCZ/4X using just 100 Watts of power output and a dipole antenna operated packet and AMTOR on an intermittent schedule mostly overnight and on weekends mainly on the 20m band until the power supply transformer in the transmitter smoked.
Amongst its achievements were:-

Worked all Continents (WAC) in both packet and AMTOR communications modes.

It worked nearly 50 countries each on both AMTOR and packet. The computer said that it made 663 packet connects with 371 different stations, and 526 AMTOR links with 330 different stations. It even worked countries that I still haven't, usually because propagation was only present to those countries late at night or very early in the morning, local time.

A 10 day long AMTOR QSO between G3ZCZ/4X and VU2IJ in which VU2IJ would link up, receive his message and leave a reply which would be answered the following day.

The first intra-Jerusalem (perhaps even intra-Israel) AMTOR QSO which took place between G3ZCZ/4X and 4X6AA. The unusual part of the QSO was that both G3ZCZ and 4X6AA were operating 4X6AA, while the Robot was operating at G3ZCZ/4X.

Pioneer Robot Propagation Beacon Experiment. The Robot put out a CQ every 2 to 4 minutes when active. This must have been the world's first HF Beacon station that could receive propagation reports from listeners in real time. This was not a mailbox. Whereas I (the beacon keeper) could leave messages for anyone and did, others could only leave them for me. Several stations contacted commented that they used the robot as an indicator of propagation, and I could tell by the log when propagation was present to DX areas.

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GLOSSARY

AMTOR	Amateur Teleprinting Over Radio.
ARRL	The American Radio Relay League.
BBS	Bulletin Board System.
CCIR	International Consultative Committee on Radio.
CQ	general call (seek you ?)
cw	continuous wave transmission
DX	Distant Transmission
FSK	Frequency Shift Keying
LAN	Local Area Network.
OSCAR	Orbiting Satellite Carrying Amateur Radio.
QSL	Confirmation
QSO	Communications
rf	radio frequency
RTTY	Radio Teletypewriter.
SAREX	Shuttle Amateur Radio Experiment.
SITOR	Simplex Telex Over Radio.
UoSAT	University of Surrey.