FROM RTTY TO PACKETS

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Introduction

Putting a microprocessor into an RTTY station can improve the usefulness of the station by orders magnitude. RTTY comes in various aspects: there is the old fashioned Baudot network chugging along at 45.5 bauds; the new ASCII links are running at 300 bauds and exchanging computer data; and, up and coming are the packet radio networks. This article discusses the whole arena of digital communications and shows how each is a step in the whole picture; and how as computers are added,, a digital network can be developed that can accommodate users with almost any equipment so that radio amateurs having incompatible equipment (e.g., a Model 15 Baudot machine and an ASCII terminal) can communicate via microprocessor based repeaters,

Digital Communications

Digital communications at this time refer to Morse code or RTTY communications. Morse code is a digital communications medium in which the presence or absence of a signal and the spacing of the signals define the content of the data. RTTY communications use either Baudot or ASCII codes to relay written information which is displayed by a radio teletypewriter or, as is becoming more evident, a cathode ray tube terminal. 'This section deals with RTTY communications at vhf/uhf.

Vhf/uhf RTTY is usually transmitted using audio frequency shift keying (afsk) on fm equipment.

Transmissions can be asynchronous random length using ASCII or Baudot codes, or fixed--format packets of data using ASCII or some other 8-bit word code, Putting microcomputers into the communications link can allow anybody equipped with digital communications hardware to communicate with anybody else also equipped with digital communications hardware, even if their equipment cannot communicate directly. Thus, G3ZCZ/W3 who has ASCII NO-baud equipment could communicate with WA3LOS who is equipped with a Baudot Model 15 teletypewriter. This is an ideal way to provide for low-cost, low-speed communications at advanced levels. This paper examines various aspects of digital communications.

RTTY Repeaters

The usual RTTY repeater usually provides coverage of a large metropolitan area. The frequencies of 146.10 MHz (input) - 146.70 MHz (output) have been assigned to such repeaters in the USA, although often other frequencies are used. Simple repeaters receive the afsk tones and reradiate them directly just as if they were audio signals in a conventional repeater, More advanced repeaters demodulate and then regenerate the signals.

RTTY repeaters first came into operation for the same reasons that audio repeaters were utilized, They can provide an extended coverage area as shown in Fig 1. Thus in the coverage area, anyone having suitable equipment can copy signals on the frequency.

RTTY, however, is a slow mode of communicating. Most people cannot even type at 45.5 bauds, and even when sending pre-stored messages at full machine speed, messages still take a long time to send. A two-way RTTY contact can take an hour or so to pass information that can be passed in minutes by voice. RTTY does have one major advantage over voice communications, however, and that is unattended operation or autostart capability.

RTTY Network

The RTTY network works as follows. All stations monitor the same frequency, either at hf or vhf., Messages are sent blind: that is, when a message is originated into the network, the sender does not know for certain if the destination station is monitoring the frequency, unless contact is first established. In the evening, or at weekends, this may not pose much of a problem because the probability of someone being at home is great. However, by day, that probability decreases, Thus, if contact cannot be established directly, the message can still be sent, but there is the probability that the destination will not be on line, and it will be lost,

If the message can be stored in a central computer by the sender, and then retrieved later by the receiver, the probability of successful transmission of the message from sender to receiver becomes a certainty. The addition of a computer thus becomes an asset to the network,

If several stations in the network have computers capable of answer back, the utilization of the computer may be reduced, A sender can put out a direct call, If an answer is not received (indicating that the destination is not on line or monitoring at the time), the message can either be transmitted to the computer for storage or held and transmission retried at a later time, It is also possible for the network computer performing the store-and-forward operation to rotate among the various member station computers on an as *available* basis as long as the network computer has a **distinctive** identification.

Some repeaters allow ASCII signals at data rates of 300-1200 bauds to be carried. Stations with Baudot equipment cannot directly communicate with stations having ASCII equipment. The network computer can contain a **conversion** capability wherein messages received on one mode would be converted to and retransmitted using the other mode.

In use, ASCII messages would be relayed directly. The ***high-speed*** ASCII message being input would be stored in a memory buffer and an output program would transmit the contents of the buffer at **45.5** bauds even while the buffer is filling up at the ASCII data rate. Incoming Baudot messages can either be transmitted directly in ASCII at the higher baud rate (but still at a real character spacing of **45.5** bauds) or can be stored and then transmitted later as a single message at full speed. In the latter **case,** some sort of tone or signal would have to be placed on the output frequency to notify all users that an incoming signal is present and is being stored but not transmitted. It would probably be better in this case to retransmit the Baudot message as it is received and then follow it with the ASCII message upon completion of the reception.

In use, the operator at his station types up and transmits a message. The message is transmitted directly to the target station or is stored in the computer. Some time later, the operator will check to see if a reply has been received. Depending on the degree of sophistication of the network, he may even be able to interrogate the network computer to see if the message has been forwarded. **Thus,** the concept of store ***and*** forward in the network computer is really a logical extension of autostart techniques,

These techniques for Baudot/ASCII conversions allow amateurs equipped for different modes of operation to communicate. The scheme presented above does suffer from the limitation that only one message can be transmitted at any one time,

The Baudot network can **be** classified in the ***dumb*** range, The users of this network are usually operating in the manual mode, possibly using paper or audio tape to facilitate operations, Incoming messages are printed out and possibly punched on tape, Very little selectivity exists to separate messages addressed to a station from others on the frequency, (A few hard-wired selective calling units do exist.) Error detection and correction techniques are minimal,

The ASCII network can be classified as a semi-***smart*** network. **Most** users have some kind of microcomputer-based system. Communications are at **300-**9600 bauds, but again have a minimal amount of error-correction facilities. This network can be used to transfer files between computers and in fact is being used as such.

The packet network can be classified as a ***smart*** network since *error* detecting and correcting techniques *can be* used. Thus, if the receiving station detects an error in the message, it can automatically request a retransmission of the bad message to ensure that the traffic is correct.

Burst Mode **Communications**

Consider a digital repeater operating at 1200-9600 baud ASCII. Each user has a small **microprocessor-**based terminal that contains a minimal amount of hardware and software to perform the following operations:

1) store a few lines of **text;**
2) remember who the message is going to;
3) remember the call sign o:f the station; and,
4) display incoming and outgoing message.

These capabilities are not too advanced on current smart dedicated microprocessor-based **RTTY** terminals.

In use, any amateur would start typing a message at the terminal, When a line of text has been input, the microcomputer would check the frequency to see that it was clear and then transmit that line of text at the high-speed rate (verifying it on the repeater output frequency to ensure that it was reradiated properly), The amateur typing away at the terminal need not even know when the transmission burst is sent. Since most people type slowly compared to 1200-9600 bauds, the terminal will spend most of its time in the non-transmitting state, **Thus,** a number of amateurs could be using it at ***the*** same time, Anyone monitoring the channel would pick up all the signals, Each line of text could belong to differing messages and thus would appear **to** be garbled, If, however, each line of text was prefixed by the call sign of the target station (and suffixed by the call sign of the sending station) and the microprocessor in each terminal was programmed to respond to and display messages only addressed to its call sign, the traffic on frequency would become invisible and this ***time*** sharing of the repeater would be unnoticed by the users, in that incoming messages would be displayed a line at a time instead of a character at a time as in the conventional network. These lines of text that are transmitted in a. burst mode can be called packets of data.

Once a microprocessor is put into use **in** storing the input characters and then bursting them out as a packet, it can also be used to provide some error-detection capabilities.

Packets

A packet of data can be considered as a **high-**speed burst of information. The typical RTTY frequency can be **occupied** only by one QSO at a time, and data is sent at the rate that it is typed. Thus, although a Baudot network can pass data at 60 words per minute **(wpm)** using conventional mechanical teletypewriters, a real data throughput of 60 wpm is only achieved when running at machine speed. Since the actual typing speed in a contact varies as a function of the digital dexterity of the operator, the data throughput is slow. Computers can be used to speed up the flow of information and improve the channel occupancy.

Suppose the data being typed is buffered by the computer. The contents of the buffer can then be output at high speed (say 1200-9600 bauds) as a burst. If the computer checks that the channel is unoccupied before transmitting,, there will be a minimal amount of loss of data due to interference (two stations transmitting simultaneous bursts are the only practical cause of such interference). If each packet or burst was prefixed by the call sign of the destination station, it would be uniquely identified, The computer at the receiving station would ignore all bursts addressed to other stations. Thus, many QSOs could take place timesharing the channel, An example of such a scheme is shown in Fig. 2, Any station could display all information relayed or just the messages addressed to itself. Thus, the addition of a minimal amount of software would improve the use of the basic RTTY repeater network,

Once computers are used for high-speed data burst communication links, advantage may be taken of the capabilities of the computer to provide error checking and correction capacity, Thus, protocols can be defined and adopted with those ends in mind,

The main problem here is that new stations joining the network can *bomb* it if their equipment (hardware or software) is not working correctly, If an average of one new station per week joins the network and bombs it for two evenings each time, the network will suffer a lot of down time.

Several techniques can be used to minimize this problem. The station software can be tested out on a simplex or different channel, or a cheap special-purpose microprocessor-based circuit card could be developed that would act as a front-end processor fitting between the computer and terminal unit. It would contain the buffers and network communication algorithm. Anyone wishing to access the network would be required to obtain the unit in a similar manner to the way that a tone burst or sub-audible tone is required for access to a large number of two meter (audio) fm repeaters. The front-end processor card could be mass produced at low cost once protocols are established. If designed properly, the protocols could be PROM-based and the same unit could be used for a number of different protocols by plugging in a different PROM for each protocol in the likely event that different protocols be established in different networks.

The actual protocol provides a means for ensuring error free transmission of a message and is transparent as far as the message itself is concerned.

The analogy in conventional amateur radio is that the sounds emerging from a loudspeaker at the receiving station are the same as those entering the microphone at the transmitting station, In an interference free situation it does not matter to those sounds if the modulation technique was am, fm, ssb, or dsb.

The Packet Network

The packet network is set up for stations who can communicate directly using packet techniques. The advantages of packet communications are many and include the timesharing of the channel, relatively high speeds and error detection and correction,

The block diagram of a packet network would be identical to an RTTY Baudot or ASCII network, but packet transmissions offer one big advantage in that a packet repeater can operate in the simplex or single-frequency mode. In this network, all stations monitor the same frequency. All stations can transmit to and receive from the central store-and-forward station (repeater). In use, a station would store the message as received. It would then transmit the message on the same frequency so that the intended recipient would be able to receive it, If the intended recipient was not able to copy the original message, it would be able to detect that it had received the same message twice because the repeater would have set a flag byte in the message header indicating that the packet was a relayed version.

The conventional repeater requirement for two frequencies (input and output) at one time has now been replaced by the requirement for two time frames (original (input) and retransmitted (output)) on one frequency,

Network Communications Language

The Baudot and ASCII RTTY networks require some routing signals to ensure that messages are routed to their intended destinations. A suitable source for these signals is the Q Code commonly used by radio amateurs., The use of slightly modified Q Code signals will make the messages easily readable by both man and machine,

For example, a message such as

WR3ABU :QSP: WA3VXE :QSO: ALAN

PLEASE CALL ME ON THE TELEPHONE AFTER NINE TONIGHT : QSL: DE G3ZCZ/W3

is almost already understandable even without explaining that

:QSP: means (please) relay to call sign following

:QSO: the message following

:QSL: end of message/confirm reception,

In other words, the store-and-forward computer at WR3ABU was asked to forward (QSP) a message to WA3VXE and confirm its reception by G3ZCZ/W3. Later on when WA3VXE signs in to the network, he would send

WR3ABU :QRU: DE WA3VXE

which means WR3ABU do you have any messages for me.

WR3ABU would reply

WA3VXE :QRU: G3ZCZ/W3, WB2YUX/3, DE WR3ABU meaning that there are messages from G3ZCZ/W3 and WB2YUX/3.

WA3VXE would then send either

WR3ABU :QUA: DE WA3VXE

or

WR3ABU :QBM: G3ZCZ/W3 DE WA3VXE.

If you know the Q Code, you will know that QUA means *send me* all new messages, and QBM means *send me the message from "----".*

Other examples are:

WR3ABU :QRT: DE G3ZCZ/W3

which signs G3ZCZ/W3 off the network.

WA3VXE :QRL: DE G3ZCZ/W3

which asks WA3VXE if he is busy, No response within a short period of time means that he is not there. If he is, the replay would be

G3ZCZ/W3 :QRU: DE WA3VXE

i.e., an automatic answer back.

Note that WR3ABU would not respond to the QRU because its call sign was not recognized, G3ZCZ/W3 would then send his message as follows:

WA3VXE :QSO: ALAN, IT LOOKS LIKE WR3ABU IS DOWN, SO I TRIED YOU DIRECT :QSL: DE G3ZCZ/W3.

The response would come in a flash (or at least at 60 wpm)

G3ZCZ/W3 :QSL: DE WA3VXE

Hence, even if WR3ABU was monitoring the transmission and recognized its call in the text, since the call sign was not immediately followed by the :Q sequence, it would forget that it had just recognized its call and go back to sleep.

A message in the form:

WR3ABU :QSP: GB3LO :QSP: G8BTB :QSO: PAT ARRIVING ON THURSDAY 22 JUNE :QSL: DE G3ZCZ/W3.

Would instruct WR3ABU that a message is to be sent to GB3LO who will then forward it to G8BTB. This extension assumes that GB3LO is the store-and-forward computer in a second network in which G8BTB is operating.

The ":" placed before and after the three letter group of the Q Code makes recognition and decoding easier since all control language statements begin with :Q and a : is the fifth character in the sequence. An example of some of the Q codes suitable for use in the dumb and semi-smart networks are shown in Fig. 3.

Amateurs using Baudot equipment would have to type the control language statements in full. Those having microcomputers could type ASCII control characters which would be software converted to the equivalent S-letter control group,,

Network Control Language

The Network Control Language (NCL) provides the computers with information as to what is to be done with the data in a message. Numerous languages exist to provide computers with instructions, but few exist for communications purposes. NCL is written in some other language and is not a true language as such, but is an implementation of an NCL Program in which the man-machine (or machine-machine) dialog is in specific format. Most radio amateurs are familiar with the Q code. Words such as QRM, QSL or QSO are understood by them all. Others, such as QRA or QSP, may not be understood unless the radio amateur is used to traffic handling; but, since they already have some knowledge of the Q code and--better still--an idea of the concept behind it, the Q code is an ideal *language* f'or telling the computer how to route or process data.

The NCL based on the Q code can be used at all levels of digital networking, starting with a lowly Baudot circuit all the way up to a packet network carrying video as well as audio packets of data. Of course, the packet network with its fixed length packets can simplify the actual transfer of data by using positions in the packet to convey information, Thus, the call sign of the sending or receiving station could always be placed in a certain position in the packet, rather than--as in the random length RTTY message--use the Q code to specify originator or destination.

NCL is used to communicate with the communications software in the computer ox in a stand-alone packet terminal interface. Apart from the use of the : as prefix and suffix for the control word (example; :QRM:) the Q code can be used pretty much in the conventional meanings. Thus, the Q code shown in Fig. 3 can be converted to NCL as shown in Fig. 4, The call signs can also be expanded upon, drawing upon the usage of *wild card* characters used in several microcomputer operating systems.

Theme wild card characters are known as general call characters and allow the sender to send a message to a category of stations.

The "?" character may be used to match any single character, or number, For example, G3Z?? matches any call sign in the G3ZAA-G3ZZZ series. W1??? matches any W1 call with a three letter suffix. The "*" character matches any section of a call sign (including a null character) as follows:

- **G3*** matches anybody with the G3 prefix
- **G**** matches anybody with the G prefix
- **GM3*** matches all calls with the GM3 prefix
- ***3*** matches any call with the three digit in it
- ***** matches any call in the world

'The two general call characters can be mixed at will, For example, G*3A?? will match any call in the United Kingdom in the G3AAA-G3AZZ series, including those with the GM, GW, GC, GJ, GU, and GB prefixes. Thus, GB3AAA, GM3ART and GW3AAA would be matched. Note that G3AA would not match because three ? characters were used.

Network Implementation

RTTY, packets, ASCII, how do they interconnect? How does an amateur who only has a Model 15 RTTY machine communicate with an amateur who has a packet terminal? Should he? In the conventional communication modes an amateur who only has a Morse Code (cw) station can communicate with another amateur who is using voice (ssb), but neither of these can communicate with someone else using the teletypewriter (RTTY). There are many Baudot stations in existence; newer amateurs may come on the air with ASCII using microcomputers and advanced amateurs can use packet techniques. In general or random communications, in which one amateur calls CQ and wants to see who (what?) comes back, all modes usually work other stations equipped with the same mode, Thus, Baudot RTTY stations have established frequencies within the amateur bands where they have the greatest probability of finding others suitably equipped. It is conceivable that ASCII and packet stations could do the same. The big advantage of packets and computers in the RTTY area is that delivery of messages can be guaranteed, and by using a hierarchy of rf links, messages can be relayed between amateurs having different digital equipment. Thus, a Baudot station could send a message to an ASCII station.

Consider the hierarchy involved: many local area nets exist using Baudot equipment. These nets may be on vhf or on hf. Each mode has its advantages and disadvantages. Fig, 5 shows a potential situation for interconnecting such a network with a new ASCII network in the same local area. In its simplest implementation, two repeaters are co-sited, One is a conventional Baudot RTTY repeater, the second an ASCII repeater, In the normal mode the two are separate; ASCII stations talk to ASCII stations at 300 bauds or even at 1200 bauds and Baudot stations talk to Baudot stations at 45.5 bauds,

However, by using a translator, Baudot stations can communicate with ASCII stations, since the translator will perform the code/speed conversions from one to the other, The translator can in a sense be thought of as a third repeater,

Each network can operate independently, When somebody on one network wishes to send a message to someone on the other, he can use the network control language based on the Q code to instruct the translator accordingly. The translator should thus be able to store the message for later forwarding in case the other network is carrying traffic at the time that the message is originated, The translator will transmit the message later when the other network is free, or can hold it until the intended recipient signs in (on either network) and requests his message.

The translator can be used to perform the store-and-forward function for both networks at the same time, Once computers are put into the network, they can perform as many or as few tasks as their owners desire, The different functions can be split up between computers, or all the computers in the network can have the capability to perform all the tasks, thus providing a high degree of redundancy and reliability in operation,

Network Hierarchies

The lowest level is the 45.5-baud Baudot network, Baudot machines are usually available for less than $50 at local hamfests. They can be Large and noisy, but they work and can easily be interfaced to a computer. They can thus be used in basic or conventional RTTY stations and then when a computer is incorporated in the station, can be used as a hard-copy printout device or even as a system console. Since thousands are already in use, they should not be obsoleted just because newer and better things such as 1200-baud ASCII are now available. Their limitations will soon become apparent to the user; who will then upgrade to the newer and better devices, passing the Baudot equipment to someone else, allowing them to join in the fun. Thus, Baudot operators will still be able to enjoy simplex contacts at hf and uhf,

The next level is the ASCII user, Here the baud rates can go as high as 9600 baud and yet remain within a 3 kHz audio bandwidth. Common tone pairs used by amateurs in the USA are Bell 103 tones for 300/110 baud contacts and Bell 202 tones for 1200 bauds. It is thus possible to build a digital repeater that can monitor the incoming signal and perform conversion to a different code/tone pair for retransmission on the output. An example of such a device is shown in Fig 6. The incoming signals are demodulated and converted to

serial data by the different receive terminal units. These **are** fed to a microprocessor module **via** serial ports. The microprocessor is operating as a dedicated controller in this environment. Under normal conditions, the microprocessor retransmits the signals **in** the same format as they **were** received. Thus, if **45.5-baud** Baudot signals **were** received, that is what would be transmitted. If, however, the message is prefixed by a control code, the microprocessor would cause the signals to be transmitted using **a** different modulation technique. The microprocessor would also perform speed conversions as well as time conversions and provide first-in, first-out (FIFO) buffer **in** the event that the retransmitted signals were at a slower baud rate than the input signals. With this kind of arrangement, amateurs with **1200-**baud ASCII terminals will be able to communicate with **other** amateurs having Model 15s or similar Baudot equipment. The limitations of 45.5 bauds, as compared to the high speeds, will soon cause a decrease in the number of stations using Baudot and **a** corresponding increase in the number of ASCII operators. This approach, however, does allow the newcomer to join in with a minimal investment, encourages **upgrading** of equipment (by example), and does not penalize those with older **equipment.**

The basic data link allows errors to creep into the message. Errors **are** caused by noise or interference entering the communications path. In most of **today's** amateur digital communications the occurrence of errors are not too serious and can easily be detected by visually scanning or reading the received text, **When** computers are doing the communications, they also **have** to have a means to detect that errors have occurred in the transmission of the message.

Linking of Networks

The discussion so far has limited itself to single area networks serving a common set of users. The **requirement** to **interlink** networks exists. Being radio amateurs, the interlinking technology will of course be by radio. **An** example of interlinked area networks is shown in *Fig.* 7. In the figure, each network has at least two links to the outside world. The link may be through the central store-and-forward computer or it may be through one of the users. For example, if it is used to link two networks, the link may be either via the central computer or via the user, but if vhf/uhf is used, the link would probably be via **a** user who is located between the **two** networks and is able to access both directly (possibly only with the assistance of high power and directional antenna).

The communications on the interlinks use the packet mode. This is because the links will probably have lower signal-to-noise ratios than the vhf/uhf local network paths and the probability of interferences is greater.

Conventional vhf links also suffer from a **routing** problem. How does a message get from network G (in Fig. **7)** to network A?

Does the originator specify the routing, the final network store-and-forward call or nothing at all? **Which algorithm** is to be used **- fixed** path **-** random, etc? Professional networks have spent thousands of dollars on this problem. Radio amateurs **also** cannot guarantee that **all** the links will be operational with a reliability of 0.999. What happens when **a** network node goes down for **a** while **-** are messages going to get backed up, are they going to get lost?

Hf propogation also suffers from its own characteristics, The ionosphere that reflects back the hf radio signals is **a** dynamic medium. Its properties change from minute to minute, are different during the day and the night and are affected by solar activity which may enhance or detract from the reflecting properties of the **inonosphere** at any particular frequency. Thus, the situation shown in Fig. 8 is typical of the conditions under which radio amateurs operate. Stations A and B are in direct contact with each other. Station C can also hear A but cannot hear B. If station B is transmitting, Station A will be silent. When Station A is silent, Station C may try to send a packet to Station A and interfere with the packet that Station B is sending. Station **D,** who cannot hear any of them at this time, **may** transmit to someone else and as conditions change will interfere with A, B, or C. This situation is not impossible, it is just **difficult** to design around.

Several techniques have been developed to minimize the QRM situation, Each station in the network can transmit **at** random. If a collision between two packets **occurs,** i.e., one interferes with the other, the receiving station will not be able to send an acknowledgement to the sending stations so the sending station **will** try again later. If each station waits a different random amount of time before transmitting its packet, there is a good probability that the second time that **a** packet is transmitted it will get through.

Another alternative is to give each station **a** fixed time slot for transmission. Thus, Station A would always transmit during the first second of any minute, Station B during the second, and so on, If the stations are referenced to **WWV** or any other standard frequency and time transmission, a minimal amount of interference will occur, but the throughput will go down since **a** station may have no packets to send but that time slot will still be reserved for it.

Adding the interference problem to the routing problems, hf networks are in themselves a problem.

One solution could be to use a random transmission sequence based on the probability of **a** successful contact, This means that messages are only originated if there is a good probability that **there** will be propagation to the destination or target station at that time of day.

Given that a system in which everybody cannot hear everybody else, in which propagation is uncertain is a difficult system to operate, it follows that the converse is true - i.e., a system in which everybody can hear everybody else, in which propagation is 100% predictable is ideal. This situation occurs if a communications satellite can be utilized as the relaying medium.

Fig. **9a** shows the same four stations now using a communications satellite to relay messages, They can all hear each other, and since the orbit of the satellite is known, they can compute the time when propagation will be possible between any of them. If the **AMSAT** Phase III or Phase IV satellites are used, each covering large areas of the world, a global network takes on the shape of a local network as sketched in Fig, **9b.**

The satellite itself does not contain any **store-**and-forward equipment. The gateway stations on the ground each act as a local user to the satellite, They can all monitor the frequencies so can pick up any traffic targeted at themselves. Since the satellite operates in a duplex mode, they can all monitor the **downlink** when uplinking and can detect errors due to noise, or due to collisions and take appropriate steps. Since the orbit is known, they can determine mutual visibility and store messages until the target comes into a mutual visibility window.

Each gateway station may act as the central store-and-forward station or as one of the regulars in its own network, and as long as the gateway is operational any station on the network has access to the network as a whole, Thus, it can truly be stated that ***the sky's the*** limit ***in amateur radio digital communications.***

Using the Networks

The **RTTY** networks can be used in an identical manner to existing RTTY channels, It does not matter if they are Baudot or **ASCII,** CQ random, or **point-to-**point (autostart). Communications **take** place in a conventional **manner.** The use of NCL only becomes necessary if a message is to be stored in or retrieved from a computer, The location of the computer also does not matter, The user of the packet network will usually have a dual processor system, as shown in Fig, **10.** The Terminal Interface Program (TIP) may or may not be part of the main computer. The TIP can operate in two modes; monitor or terminal, In the monitor mode, it can pass every packet it receives to the main computer. The destination of the packet does not matter) this mode is a good debug mode for testing the TIP, as well as providing a level of confidence in the early days. Since the packets may **or** may not be complete messages in themselves, the output of the TIP may or may not make **sense.** In the terminal mode, messages only addressed to the user will be output by the TIP,

If the **TIP** is a stand-alone board, having an RS-232-C interface, it can be connected to a terminal device and used as a dumb packet terminal, A dumb packet terminal is a terminal that can send and receive packets,, It contains the basic **low-**level software to format a packet for transmission, and acknowledges reception of, and unformats, a received packet, Such a stand-alone board, microprocessor based, is a low--cost introduction to packet techniques, There is, of course, no reason why the TIP function could not be performed in software by the host machine, apart from the obvious one that it may tend to prohibit the use of the computer for other purposes. An outline of a stand-alone TIP is shown in Fig. 11, The breakdown shown for the TIP comprises a standard microcomputer, The control program is in PROM, the data storage area is in **RAM.** The more RAM that is available, the greater the length of or number of packets that can be stored in the TIP.

It is **envisioned** that the user will graduate from the monitor **mode** to the terminal mode pretty quickly. After the novelty of receiving packet transmissions has worn off, the unit will be switched to the terminal mode, Of course, the user may temporarily revert to the monitor mode at any time to check that the TIP is still operating after a long period in which no messages have been received had occurred,, The user, via the terminal, or the host computer can communicate with the TIP by using **NCL.** In this way, the user does not really care about the mechanics of **getting** messages across. All he is interested in is the message, **i.e.,** the high level protocols, The low-level protocols of exactly how and when a TIP goes on the air can be left to the minority of technical hackers amidst the ranks,,

It is desirable that the same software be used in all the **TIPs. The** real world will, however, not be the same as the ideal world, The standard **PROMs** supplied with each TIP could be programmed with the station call sign as *******. These general call characters will respond to all call sign addresses which is the monitor mode situation, Thus, in use--at power up--the TIP would output a sign on message to the serial plot such as AMICOM TIP REV 3.6 QRA which would identify the network program protocol and the revision level, The TIP would then be in the monitor mode and the user would change to the terminal mode by entering :QRA: followed by the station call sign (including general call characters **(i.e., :QRA: G3ZCZ).** Note that a call sign such as **G3ZCZ/4X** would be recognized as having the 4X prefix--not the, or as well as the, G3 prefix,

One advantage of a separate TIP is that it tends to maintain the integrity of the network. Consider a network in which one new user a day joins in, Given the number of radio amateurs and the number **computers** in existence, that is not an unreasonable assumption, If each user has to bring up software and hardware at the same time in an area in which he has not worked in before, the probability of errors occurring, bombing or typing up the network, is high. The network could thus suffer from a lot of down time due to those newcomers not quite being able to access. If a standard board is available, the software can be provided to drive the integrated circuits on the TIP which will minimize the number of bad signals on the network frequency, If NCL is used to control the operation of the TIP, the TIP can be driven by any computer having a serial port, programmed in any language.

Once messages begin to flow into and out of the TIP, some high-level control is desired. This high-level control forms the user interface to the network, not at rf, as in the case of the simple RTTY network. Again, here a hierarchy is possible, The TIP can drive a simple terminal in the monitor mode or can interface a microcomputer with floppy disc capabilities for storing (and forwarding) messages.

In a simple RTTY network, only one contact is taking place at a time, irrespective of how many stations are taking part in the round table. In a packet network, only one packet is being transmitted at a time, but successive packets as received at one station need not be part of the same message. There is, thus, no reason why when two stations are in contact, packets originated by other stations could not start appearing in the network and some of those packets could be addressed to one or both of the stations already in contact.

Consider for a moment the working of the TIP in its receive mode. The program must monitor the frequency and read the leaders of all the packets on the channel. Messages intended for the TIP's own station will be output at the serial port. What happens if the TIP has received a packet from one station, but that the packet was not a complete message? While the TIP is waiting for the next packet that will contain more of the message, a packet arrives addressed to the TIP but originated from Station B. Does the TIP reject it because the new packet will garble the message currently being received?

If the TIP rejects it (by not acknowledging it), Station B may keep trying, thus slowing down the communications speed of the channel because its packets will be ignored by our TIP, yet are using up time that could be utilized by Station A to complete his message or by other stations to pass different traffic. If the TIP does not reject it, a computer (either the TIP or the host) has to have some way of recognizing the different origin of the packet and storing it in the relevant bit bucket. On the other hand, the TIP could send a busy packet to Station B and anybody else which means that they can either try again later, or wait until they are called back. The busy packet could contain a flag bit or byte or NCL word that instructs the calling station as to which of the choices to follow, The *call again later* technique requires minimal software in the receiving program, but can increase the amount of traffic, as the calling station keeps trying for a contact and keeps getting *try again later* responses. The *wait for me* to *call you* response requires some additional software in the receiving program to store a list of stations to call and notify that the TIP is ready for a new message, There the tradeoff is TIP software complexity against network traffic load,

Most disc-based BASICs (and other languages) have the capability to have more than one disc file open at a time. It is, thus, logical that a high-level protocol can be used when the TIP is used together with a host computer to allocate space on a disc for more than one incoming message at a time.

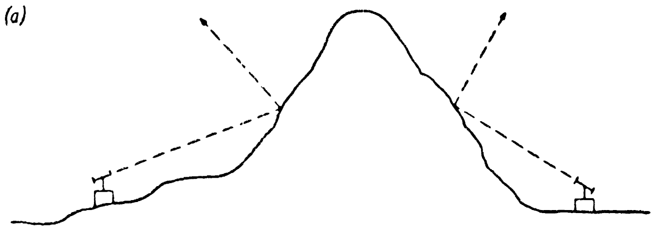
The user being interested only in the whole message does not care how many packets it took to receive the message. The network manager, on the other hand, may have different interests and a distinction should be drawn between the requirements of the network user and the network manager, Once a whole message has been received, the computer can signal its owner accordingly. The multi-message arrival problem is also significant in the situation in a store-and-forward mode, where the packets are assembled into complete messages for storage purposes.

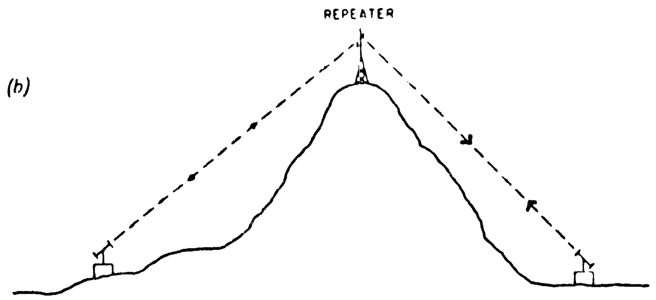
Another situation that has to be looked into is the CQ call or rather the response to the CQ call situation. One of the major advantages of packet communications is unattended operation, A terminal can thus be programmed to respond to a CQ call so that a newcomer joining the network will have a response to his initial call. What happens if 20 stations or so try and respond to the CQ call? If multiple simultaneous received messages are allowable, a station can end up having several simultaneous QSOs. An extreme example of this condition is the effect on the network due to the appearance of a rare DX station. Consider what could happen to the network if a rare DX station signs in or originates a message.

Avid DX chasers spend a lot of time and money on working new countries. It is thus very likely that these avid DX chasers could leave their TIPs in the monitor mode and have custom DX capture software in their host computer. Thus, the appearance of a DX station can be detected if it originates even one packet into the network. The result could be a pileup. Each of the DX chasers will originate packets aimed at the DX station. Collisions will occur, due to the QRM, calls will be tried over and over again and the network will be tied up for a long time even if the DX station has gone QRT (possibly due to front-end overloading of his TIP software?) as the DX chasers keep trying for a message acknowledgement. Thus, packet communications software deemed workable with few stations (initial net situation) may be less than optimum in a wide area established operational network.

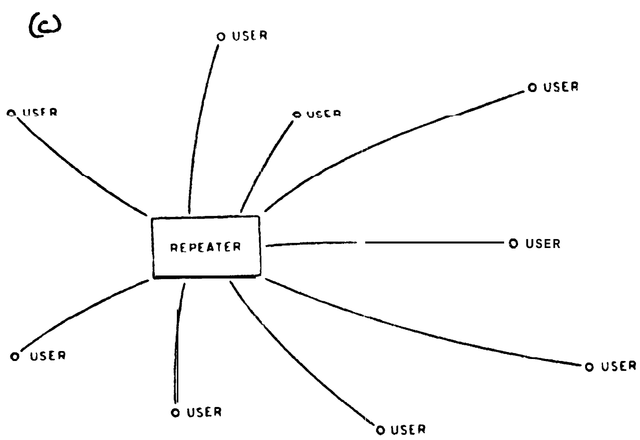
Packet communications offer a revolutionary new means of passing communications to amateur radio. For optimum results, it is very advisable that the low-level communication protocols and the high-level software be well thought out, flexible, and easily adaptable to changing circumstances.

Fig. 1. Extending Communications Range by Use of a Repeater



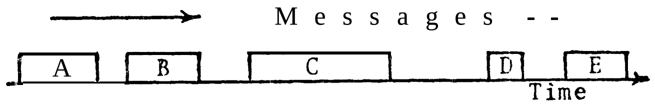


a shows that if there is a hill between two local stations, it is not possible for them to communicate by means of VHF. If a repeater station is positioned at the top of the hill as in b, communication becomes possible.



A city-wide radioteletypewriter VHF repeater link.

Fig, 2. Timesharing of a Communications Channel



Message A is sent by G3ZCZ/W3 to WA3LOS

B is sent by WB4JFI to W3ZM

C is sent by G3ZCZ/W3 to WA3LOS

D is sent by W3IWI to K1HTV/3

E is sent by WA3LOS to G3ZCZ/W3

With proper prefixes G3ZCZ/W3 and WA3LOS will not notice that the channel. is being shared by others during the times that they are not actually transmitting anything.

Fig. 3. Extracts from the Q Code.

Code	Question	Answer or Advice
QRA	What is your identification or call sign?	My call sign is . . . .
QRL	Are you busy?	Yes. I am in use by I . .
QRM	–	Your transmissions are being in terfered with.
QRQ	Shall I speed up to . . . . bauds?	Yes.
QRR	Are you equipped for automatic operation?	Yes.
QRS	Shall I slow down to. . . , bauds?	Yes.
QRT		Signing off (log off).
QRU	Have you any messages for me?	Yes, messages are from. . . .
QRV	Are you ready?	Yes.
QRX	Will you wait?	Yes.
QRY	What is my turn?	Your turn is number .
QSG		Send . . . . messages.
QSK	Can you operate full duplex?	Yes
QSL	Will you confirm?	Confirmed.
QSM		Repeat last message.
QSO	–	Message for . . . .
QSP		Relay via . .
QTA	Cancel message to	Cancelled
QTC		The message is . . .
QTH	What is your address?	My address is . . . .
QTR	What is the correct time?	It is . . . UTC.
QTX		Log on.
QUA	Send me all new messages.	
QUC	Who did the last message i sent: go to?	It went to . . . ,
QBM	Send me the message from	
QDB		The message to . . . , is for warded
Q/C	May I call . . . direct?	Yes
QJG		Revert to message mode (log off inter-active mode).
QNO	–	Negative response or action.

Fig. 4. Basic NCL Dictionary

	Statement	Response (if any)
:QRA:	What is your call sign?	My call sign is ...
:QRG:	What is my exact frequency?	Your frequency is ... kHz
	What is the frequency of ...?	His frequency is . . . kHz
:QRH:	Does my frequency vary?	Yes
:QRK:		Your bit error rate is . . .
:QRL:		I am busy now, please call me later
:QRM:		Your signals were interfered with
:QRN:		There is noise on the frequency
:QRO:	Increase transmitter power	
:QRP:	Decrease transmitter power	
:QRQ:	Speed up to . . . bauds	OK
:QRS:	Slow down to ... bauds	OK
:QRT:		Signing off from the network
:QRU:	Have you any messages from me?	Yes, messages are from . . . .
:QRV:		Signing on to the network (includes QRU by implication)
:QRX:		I am busy now, I will call you later
:QRY:		It is your turn to send a message to ...
:QRZ:	Who is calling me?	
:QSA:		Your report is signal strength ...
:QSB:		Your signals are fading
:QSD:		Your signals were mutilated (negative acknowledgement or not received) try again
:QSG:		I cannot accept packets from ... stations concurrently
:QSK:	Can you operate full duplex?	I can operate full duplex
:QSL:		Acknowledging correct reception of packet
:QSM:		Repeat packet
:QSN:		I can copy you directly
:QSO:		The message follows
:QSP:		Please relay to ...
:QSU:		Send your reply via . . . (gateway or repeater station)
:QSW:	Which frequency/channel will you reply on?	I shall reply on ...
:QSX:	Can you copy . . . direct?	I can copy ... direct
:QSY:	Change to channel/frequency ...?	OK, I shall change to channel/frequency ...
:QSZ:		Repeat message or last packet
:QTA:		Cancel message
:QTB:		The character count is ... (used in RTTY messages only)
:QTC:	How many messages do you have for me?	I have . . . messages for you
:QTH:	What is your location?	My location is ...
:QTR:		Message was originated at (day, time)
:QUA:		Send me all the new messages
:QUC:	Has the last message I sent been forwarded?	Yes, it has been forwarded to ...
:QBM:		Send me the message from ...
:QDB:		The message to . . . has been forwarded
:QIC:		This is a direct call to ...
:QJG:		Reverting to automatic mode
:QNO:		Negative acknowledgement

NOTES: *:QSA: and :QRK: can form the basis for signal reports.*

:QSM: could be used to flag a message that has been passed via a store and forward repeater.

:QSU: can be used for routing control, whereas :QSP: defines final destination.

:QTA: is used by the operator to delete received messages from his system.

:QUA: can be used when transferring the function of network computer from one computer to another.

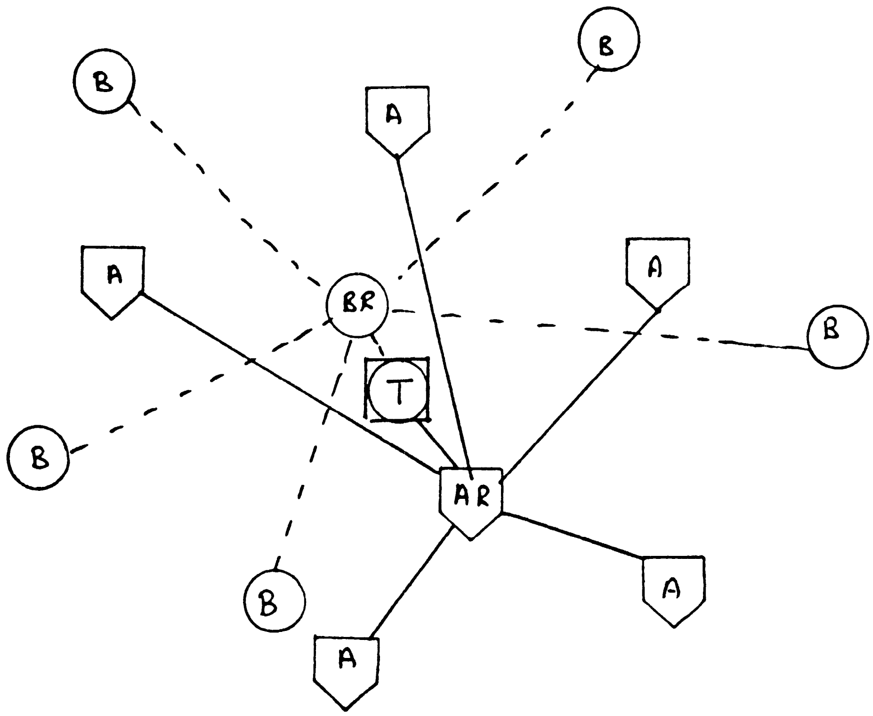
:QDB: could form an intermediate acknowledgement when tracking the routing of a message through the network.

:QIC: can be used to find out if a station is logged on at any particular time.

:QNO: is the standard negative acknowledgement to state that the receiving station cannot perform the desired operation; i.e., it cannot QSY or QRS.

This figure contains an initial proposal for the NCL dictionary which wfll, of course, be changed as NCL comes into use.

Fig. 5. Linking of Baudot and ASCII Networks



A ASCII Network User

B Baudot Network User

AR ASCII Network Repeater

BR Baudot Network Repeater

T ASCII/Baudot translator

Fig. 6. A Basic Digital Repeater

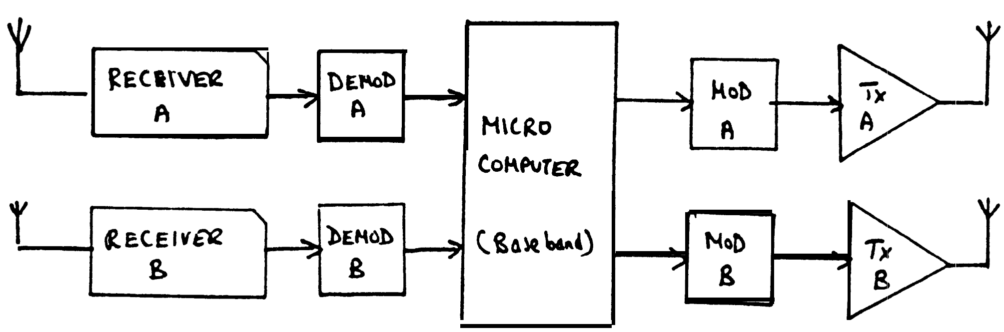


Fig. 7. Interlinking of Networks

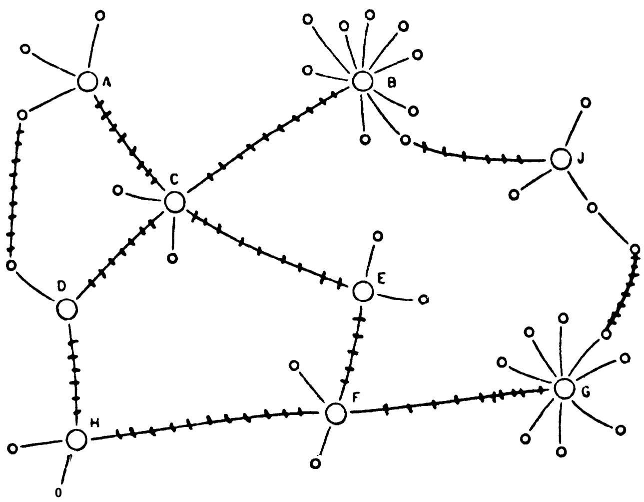


Fig. 8. Hf Propagation

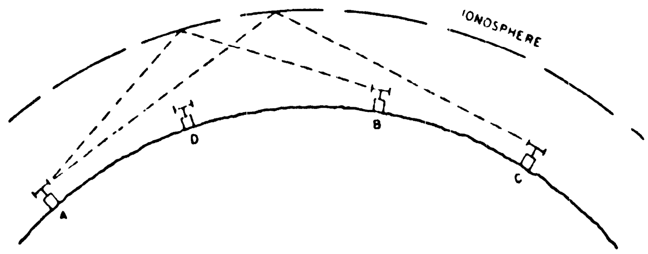
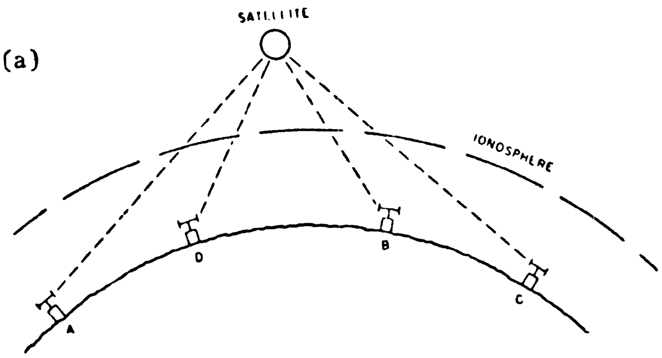
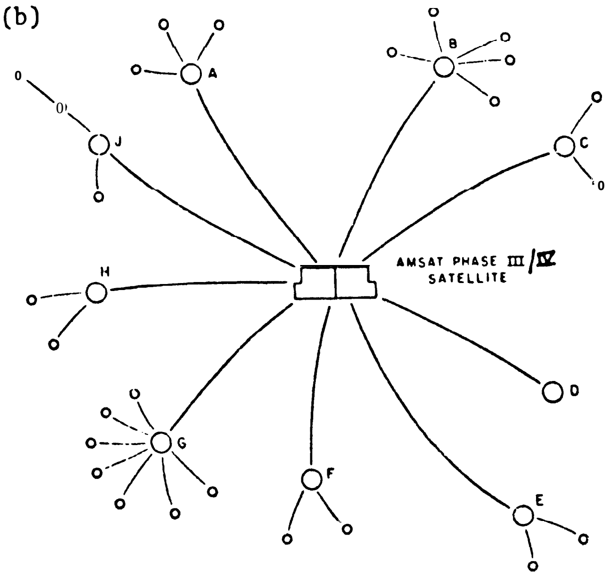


Fig. Fig. 9. .Satellite Based Network

(a)

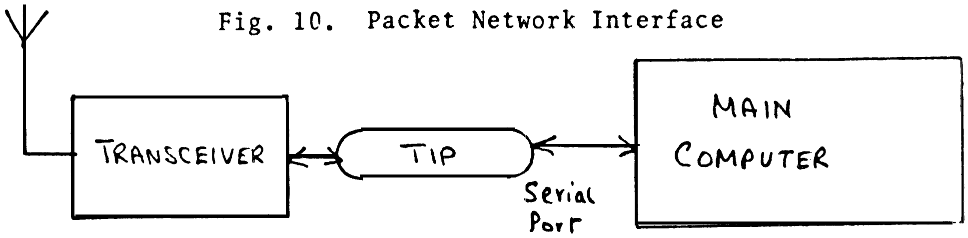


(b)



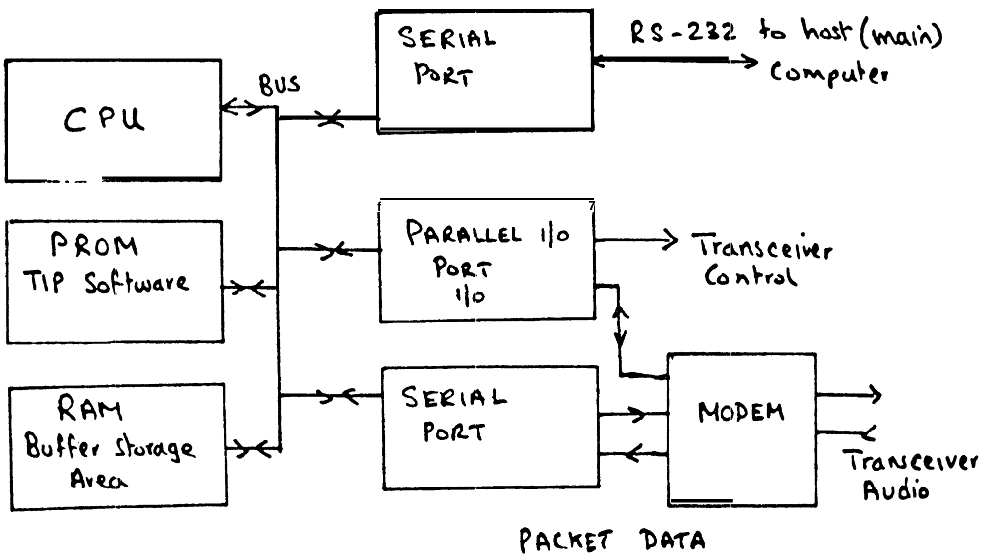
A distributed wide area network using a satellite. This approach would solve many of the message transmission problems. For a message to go from a station in network A to a station in network G it would hove to travel only through the satellite and hen be relayed to the other station.

Fig. 10. Packet Network Interface



Note: Similarity to RTTY TU.

Fig. 11. A Stand-alone TIP



Note: The block diagram is that of a typical micro processor module