EASTNET
AN EAST COAST PACKET RADIO NETWORK

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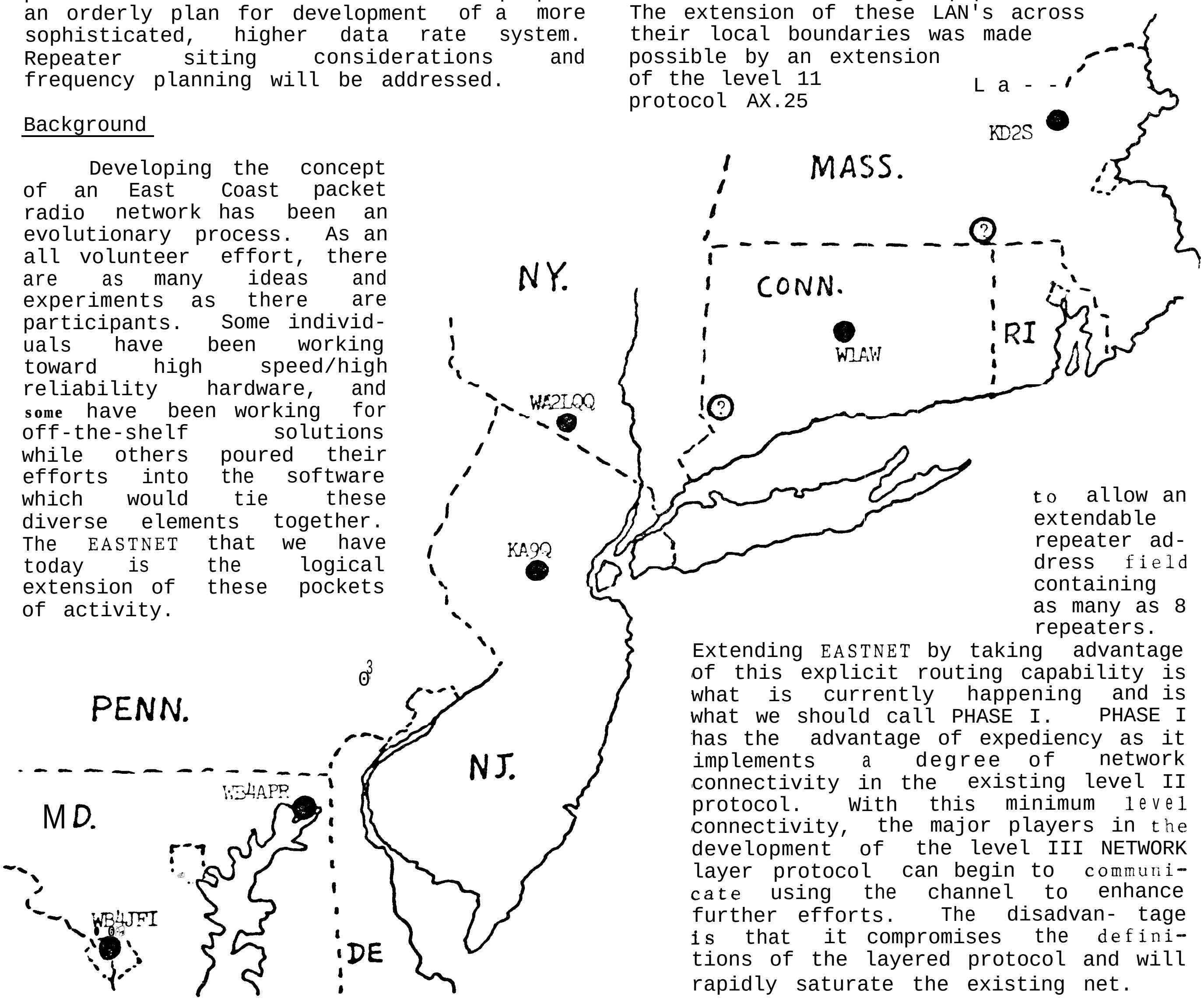
The idea of a digital packet radio network linking the East Coast was envisioned in the late 1970's when the Department of Communications in Canada and later the Federal Communications Commission in the US authorized the transmission of digital data over amateur radio frequencies. Today, EASTNET is a reality with relay sites becoming operational in Washington DC, Maryland, New Jersey, New York, Connecticut, and Boston. By 1985, connectivity from Boston to Norfolk will be established. This paper will discuss the present status of EASTNET and will propose an orderly plan for development of a more sophisticated, higher data rate system. Repeater siting considerations and frequency planning will be addressed.

Background

Developing the concept of an East Coast packet radio network has been an evolutionary process. As an all volunteer effort, there are as many ideas and experiments as there are participants. Some individuals have been working toward high speed/high reliability hardware, and some have been working for off-the-shelf solutions while others poured their efforts into the software which would tie these diverse elements together. The EASTNET that we have today is the logical extension of these pockets of activity.



BY proper orientation of these interests, the growth of packet radio can proceed smoothly to faster data rates and more sophisticated network capability while retaining lower level gateways to casual users. This appeal to the entry level user must be maintained in order for packet radio to flourish.

PHASE I

Using the level II protocol AX.25, local area networks (LAN's) have flourished in several of the major population centers. The extension of these LAN's across their local boundaries was made possible by an extension of the level 11 protocol AX.25 to allow an extendable repeater address field containing as many as 8 repeaters. Extending EASTNET by taking advantage of this explicit routing capability is what is currently happening and is what we should call PHASE I. PHASE I has the advantage of expediency as it implements a degree of network connectivity in the existing level II protocol. With this minimum level connectivity, the major players in the development of the level III NETWORK layer protocol can begin to communicate using the channel to enhance further efforts. The disadvan- tage is that it compromises the definitions of the layered protocol and will rapidly saturate the existing net.

PHASE II

The amount of time that will be required to define and develop a level III NETWORK layer protocol will be significant but will allow a PHASE II improvement in the EASTNET link hardware. The goal under PHASE II will be to move packet radio activity to a significantly higher baudrate in preparation for the eventual implementation of the level III NETWORK protocol under PHASE III. Also under PHASE II, integration of gateways to other channels such as HF and satellite longhaul links will be developed. The hardware will be improved, frequencies established, and permanent repeater sites located.

PHASE III

In PHASE III, the level III NETWORK layer protocol will be implemented within the PHASE II high reliability link hardware, with gateways as necessary to match the topology of the network.

Frequency Considerations

The majority of packet activity is currently centered on two meters because of the overwhelming popularity of this VHF frequency band. The early use of this band for packet radio has had the advantage of attracting new users because of the availability of equipment and ease of integration into existing operation. The explosive growth of packet radio, however, will quickly saturate the available frequencies in this very active band and require new frequencies to be identified.

The 220 Mhz Band

The ideal area for expansion of packet radio is on the 220 Mhz band. This band is relatively under used because historically there has not been as much commercial equipment available as there has been for two meters and 450 Mhz. In fact, the under utilization of 220 Mhz has made it a target for several attempts by commercial interests to obtain the spectrum space from the FCC. Not only is the spectrum space presently available for wideband packet radio expansion, but if the present rate of packet radio expansion continues and a specific band segment on 220 Mhz can be dedicated to packet radio use, the amateur radio community might finally be able to prove conclusively to the FCC the tremendous utility of this band.

Discussions with Paul Rinaldo W4RI at ARRL and the local repeater coordinating committee have suggested the following band plan for packet radio which would be compatible with the existing ARRL plan.

220.55 220.65 220.75 220.85 220.95	100 Khz	221.01 221.03 221.05 ... 221.19	20 Khz

The key elements of this proposal are the allocation of 220.5 to 221 Mhz for experimental use and the overlap of US and Canadian privileges which allow 100 Khz bandwidths in that segment. Five 100 Khz channels would be established, Narrow-band 20 Khz activity could go immediately above 221 Mhz where wideband modulation is not permitted for the Canadians. Since the current allocation of the 221.0 to 222.0 Mhz segment of the band is for link and control frequencies, application for narrow-band packet radio use must be made through the local frequency coordinating bodies. If enough applications are filed for narrow-band 20 Khz packet radio frequencies on the low end immediately above 221.0 Mhz, eventually maybe a 200 Khz segment for ten 20 Khz channels could be standardized. Packet radio groups contemplating experimenting with 9600 baud on 220 Mhz should request coordination of these frequencies not currently in use beginning at 221.0 Mhz and up in their local area. Allocation of the 5 wideband channels should be addressed at a national level, recognizing that hardware will take longer to develop,

Backbone and Gateways

As level III NETWORK layer software becomes available, a single network controller will be defined for each community. This controller will be the Data Communication Equipment (DCE) to all Data Terminal Equipment (DTE) in the Local Area Network (LAN). Any number of links or gateways to other networks, can be logically connected as DTE's or the controller can have transparent connectivity to nearby noc'es or long haul backbores. The details of this connectivity will be addressed in the level III standard, The EASTNET repeater sites during PHASE II will be upgraded to 220 Mhz 9600 baud capability while retaining the two meter gateway frequencies of 145,010 Mhz for local use and access. By the time level III is ready, 56 Kbaud wideband channels will be implemented which can handle the backbone traffic of both the two meter low speed and 220 Mhz high speed local channels.

Repeater Site Selection

The goal of PHASE I is to locate good, permanent link sites with optimum spacing to minimize the number of repeaters required in the backbone system. With thousands of two meter repeaters across the country there is a wealth of experience with the reliable communications range of two meter voice operation, This experience, however, is based on the usual mobile/fixed station-to-repeater path and does not include the more advantageous repeater-to-repeater path to be used in optimum backbone repeater siting. For the Elk Neck repeater site, the Washington DC repeater is barely detectable at ground level using a good mobile antenna, whereas

100 feet up the tower the repeater is well received on a walkie-talkie. The following paragraphs help quantify the expected performance of a repeater site from data obtained using the Washington DC repeater and a portable packet station consisting of an ICOM IC-2AT, VADCG TNC, and VADIC 202 modem.

Path Loss

Figure I shows the typical microwave line of sight plot using an equivalent earth radius factor of 4/3 for the Washington to Elk Neck path. Clearly, an absolute line of site path is not necessary at 145 Mhz for reliable reception.

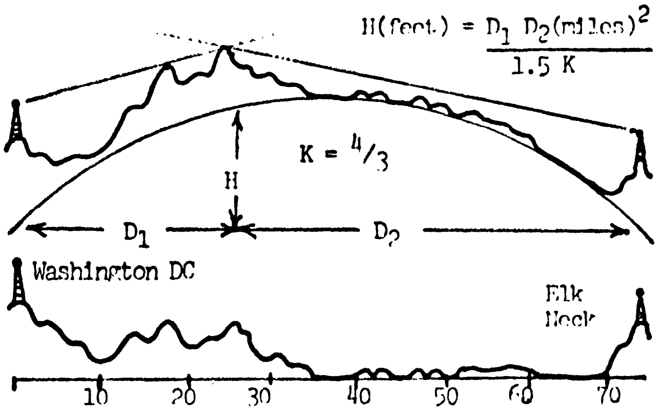


Figure 1. Line-of-site path over flat earth and 4/3 equivalent earth curvature. Total path length of 75 miles.

A plot of tropospheric path loss vs. distance from the ARRL VHF Manual is reproduced as figure 2 and shows a definate flattening of the curve at 200 db from a range of 120 to 200 miles. Although these ranges can be easily operated with weak signal equipment such as CW and SSB, they cannot give the 20db signal-to-noise (S/N) ratio necessary for the relatively wideband AFSK FM modulation techniques currently employed using the typical omni-directional medium gain antenna of a packet repeater.

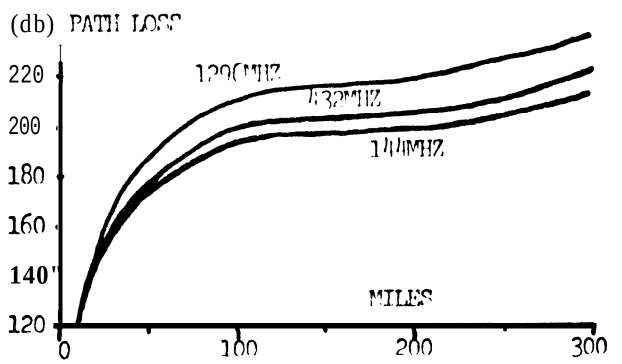


Figure 2. Tropospheric path loss vs. distance for VHF amateur frequencies for 99 percent reliability. (reprinted from the Radio Amateur's VHF Manual)

Receive Margins

Using the portable packet station at several distances from the Washington repeater, packet receive margins were taken with a step attenuator and normalized to a zero db gain receive system consisting of the IC-2AT receiver. These receive margins plotted in figure 3, can be used to predict packet performance at a particular site relative to the 40 watt ERP transmitted signal at an antenna height of 200 feet. To use the plot, simply subtract feedline loss, and add antenna gain and antenna height gain from the nomogram in the VHF Manual. Antenna height gain on paths of about 55 miles is roughly Odb at 30 feet and increases by 4 db for each doubling in height. Although these measurements are only accurate to 3 db or so, they do show that repeater separations on the order of 50 to 60 miles are achievable with nominal sites and equipment.

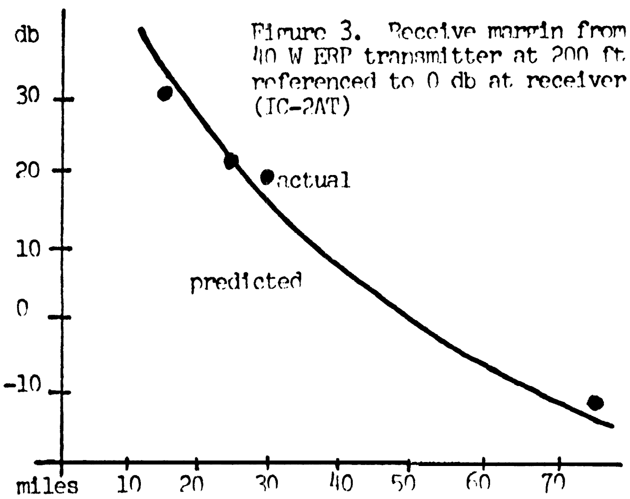


Figure 3. Receive margin from 40 W ERP transmitter at 200 ft. referenced to 0 db at receiver (IC-2AT)

The plot can be used for any other transmitter height and ERP by appropriate corrections. The reliable path between two 40 Watt ERP repeaters at 100 feet with 6 db gain antennas, 2 db line loss, and 7 db receive margins should be about 50 miles. The same stations at 60 feet should be no further than 40 miles apart. Mountain top sites have an additional advantage which can add as much as 35 miles per 1000 feet of altitude over average intermediate terrain. A direct comparison of this data to the calculations illustrated in the VHF Manual suggests using 1 db for the noise figure, 12 Khz bandwidth for the receiver, and a signal to noise requirement of 11 db. Because of the FM improvement factor, an 11 db carrier to noise ratio results in approximately an 18 db signal to noise ratio for the 202 modem. Using these assumptions, calculated path margins using the VHF Manual procedures support the empirical data.

EASTNET Site Summaries

Each of the following summaries is the best information available at the time of this writing (mid March 84). The order is roughly south to north.

Hampton, Virginia

Bill Holmes W4UMC has operated his repeater in the Hampton Virginia area for over a year, Being 140 miles from the Washington DC repeater, he will probably be linked via Richmond and Fredricksburg.

Waynesboro, Virginia

Fred KF4DQ speaks for a group of operators interested in linking down the Shenandoah Valley from the Washington DC repeater. They have the Blue Ridge mountains to cross, but may be able to use that to advantage as altitudes of 3000 feet might be possible.

Washington DC

The AMRAD WB4JFI-5 repeater has been in operation since 1982 on the AMRAD voice repeater but was moved to its present site on the channel 9 TV tower in October 1983 replacing the WB5MMB simplex repeater in Vienna, The tower is on the highest ground in the District at 400 feet but suffers from a very high RF environment. It was moved to 145.010 Mhz in January 1984 coincident with the decision to burn-in that frequency for packet use on the east coast. It uses a VADCG board and runs 15 watts through a 10 inch cavity into an unknown abandoned VHF high band antenna about 200 feet up the tower.

Elk Neck, Maryland

The WB4APR-6 repeater has been in operation since February 84 but was moved to its present site on a 120 foot state f orrestry tower at 285 foot ground elevation on 8 March 84. The site has 40 miles of its 75 mile path to Washington over the Chesapeake Bay. It has good visibility into the Wilmington and possibly Philadelphia area with a slight shadow around Iron Mountain. The repeater is a good beacon, but suffers from poor receiver sensitivity and an undetermined transmit tone anomoly which degrades long packets. Replacement hardware is under construction which should allow connectivity with the Washington repeater.

Philadelphia, Pennsylvania

No optimum site has been identified although the TelCo. Pioneer Amateur Radio Club has expressed interest and has a downtown building top location. Steve Robinson W2FPY reports a possible site on the 125 foot Burlington municipal tower on a ground level of 85 feet; but this area is about 15 miles further away from Elk Neck and signal strength is low.

Warren Township, New Jersey

Phil Karnes KA9Q has been beaconing on 145.01 Mhz since February using his TAPR TNC. He is located on a very good hill with excellent southern visibility. He has possible access to the top of the hill (500 feet) and a tower which would improve his shot to the north. He reports good connectivity with W2LQQ in Warwick NY. A possible conflict is RFI to his satellite activities.

Warwick New York

Rip W2LQQ has also been beaconing on 145.01 Mhz using his TAPR TNC and reports favorable connectivity down to KA9Q. He is presently using his OSCAR array and would also have to solve the RFI problem with his satellite activity.

Stamford Connecticut

Ed Kalin K1IRT is interested in joining EASTNET and possibly serving as the link site towards Newington. His visibiliy over to Long Island is also favorable. Path lengths to Warwick and Newington are reasonable if a suitable high altitude site can be located.

Newington, Connecticut

As the national headquarters of the ARRL, the W1AW packet repeater is a key site in EASTNET. The repeater has been on the air since January 1984 using a VADCG board at the ARRL station. This site is not optimum and will hopefully be moved to a higher location possibly at 1000 feet to enhance EASTNET connectivity. Paul Rinaldo W4RI is the point of contact at the ARRL.

Rhode Island

A site located in northwest Rhode Island or south central Massachusetts would have reasonable 50 mile paths to link Newington to Boston. No activity reported.

Boston Massachusetts

The present packet repeater in the Boston area is KD2S in Lowell about 28 miles northwest of downtown. This repeater coupled with a good site southwest of the city would help in extending EASTNET down toward Newington. Efforts to obtain a good mountain top location could extend coverage throughout the state.

EASTNET Coordination NET

To facilitate inter-site communication for the further development of EASTNET, an AMRAD Packet Radio Users Group Net will be maintained at 2200 EST on 3855 Khz every Tuesday evening immediately after the regular AMSAT net. Participants in EASTNET are encouraged to check in for the regular dissimination of EASTNET and general packet radio information.