The Tulsa National Weather Service TexNet Interface Project

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Abstract

This paper details information concerning the interface to the NWS system in Tulsa by the TexNet network and how it can be replicated by other networking systems at other NWS sites. Several functions are provided from the TULSWX node including: automated severe weather alert broadcasts, emergency service broadcast, color weather radar images using the NexRad Doppler (the WSR=88D), and the dissemination of messages directly to various EOCs and spotting groups.

Introduction

The NWS TexNet Interface project began in 1992 and went on-line in 1993. It began with amateur radio Skywarn spotters in Tulsa working in conjunction with NWS forecasters to examine ways to add packet radio operations to the NWS location in a meaningful manner. The Tulsa Skywarn organization has for many years been very close to the national weather service personnel.

For the last several years, the NWS has undergone a program of consolidation where many of their forecast offices have been moved and closed. Some of the burden of communicating weather observations to and from the public is falling to amateur volunteers. Packet is providing an important link between the NWS and the amateur volunteers. Voice reports from spotters are still as necessary as they ever were, even with the newer radars, because neither is capable of observing the same information set. Packet finds its place in communicating directly to various emergency nets and local EOCs that are spread out over ever increasing distances, as NWS sites are consolidated. These new distances make voice communications, once the mainstay of communications, nearly impossible for the NWS to use to communicate directly over these larger geographic areas.

TexNet, since its inception, was designed with emergency weather net operation in mind, partly because of its geographical location within Tornado Alley. When the Tulsa Skywarn organization made their wishes known for a packet system, TPRS was asked to provide information on its capabilities. A few of the Tulsa amateurs were familiar with the DFW area weather PMS (Packet Message System), and even at a distance of some 300 miles had used it a few times and knew what it was capable of providing.

This led to the creation of the TULWX node. A standard TexNet node is equipped with harddrive and a weather feed provided by the NWS. The NWS allowed the

equipment to be located on site, which provides secure facilities and has AC power backup. The only site drawback is there is no 2m user port; thus, users have to connect to the Tulsa weather node using nodes elsewhere on the network. The NWS 1.72 personnel, including their manager, have told us they are almost as proud of the capabilities of the PMS to distribute vital weather information to EOCs and spotters in a non-time consuming manner as they are of their brand new WSR-88D Doppler radar, and of course, the weather node is a whole lot cheaper.

The PMS, it should be noted, is a 10 user Packet Message Server, which is implemented on a TexNet node which contains a disk controller and drive. It has been included in TexNet almost since 1986, as has some form of weather server on the TexNet network. The original TexNet weather server was interfaced to a 5-bit baudot coded landline teletype circuit, which is now a thing of the past. A weather server is a standard PMS which includes an async serial capture port and. a search database that relates product codes to a fixed set of message numbers. It is usable as any PMS to save and read messages and also to read messages stored from the NWS input. Messages are available within seconds from the time the message is released by the forecaster.

Several functions are provided from the TULSWX node. These include: automated severe weather alert broadcasts, emergency service broadcasts, color weather radar images using the NexRad Doppler (the WSR=88D), and the dissemination of messages directly to various EOCs and spotting groups.

Automated Severe Weather Alert Broadcasts

This function is the newest showpiece of the weather server application of the TexNet revision, according to the beta-testers in Eastern Oklahoma, where it is running on TULWX and two Muskogee nodes. When any type I'S" (Severe) weather message is stored to the disk of the PMS, the message heading and the first 148 characters (following the NWS Product ID Code) are broadcast all over the 1.72 portion of the TexNet network -- to all ports of these nodes. The broadcast to the intended users is from an alias of "ARES" to another alias of "WX" as a UI frame. ARES stations, EOCs and the like set their TNCs to include "ARES" in their budlist and they enable the terminal bell. The message rings the terminal bell, sends the whole heading of the message, and enough of the first part of the message to display the NWS county warning data and expiration data. This can enable users, possibly by automated means! to log onto the PMS and read the message of interest, and know beforehand whether or not they are interested in it, thereby reducing the PMS user loading while speeding up delivery. This theory is of course contingent on proper administration to discriminate against reading unwanted messages so they don't overload the PMS all at once. Some of the users around Tulsa have written applications which scan monitored UI frames, and when they see one of these, connect to the PMS and automatically retrieve the whole message, and are then capable of taking further action on it. This opens up some interesting possibilities for alerting individuals.

As with all UI transmissions on packet, RECEPTION IS NOT GUARANTEED. Use of this capability is to enhance emergency operating procedures. Users know NOT to solely depend on this feature.

Emergen.cy Service Broad.cas ts

The Weather Alert broadcast may also be initiated manually by an Emergency Net Control station who has TexNet Sysop privileges. The sysop can then issue an Emergency Service Alert broadcast directly from their keyboard. The same broadcast mechanism is used as found in the Weather Alert broadcast. It is used to alert the ARES packet community of emergency operations or nets being initiated.

A manual command (admin permission required) has been added to the admin command list of the TexNet node to initiate a broadcast. A fixed 228 byte line is retransmitted. Syntax is as follows:

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A :Enter the text string to be broadcast,
   up to 227 characters and c/r.
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This is a variation of the admin A -ON -OFF TexNet command. The colon indicates that any text following the colon will be broadcast all over the place. The local outputs are preceded by a bell and a c/r, to ring a terminal bell and turn up a fresh line on the crt of any station monitoring UI frames. The UI frame address is from ARES to WX, the same as with the PMS alerts. The remote output mechanism does not exist on V1.71 and prior nodes. This command does NOT toggle the alert status of the network.

This function was discussed at a spring 94 meeting at Tulsa, needed by severe weather spotters. The anticipated downside of this will be that there is a possibility that many users might connect to the same PMS at once and try to read the same message at once, which has been known to lock it up because of lack of memory

Color Weather Radar Distribution over Packet

One of the products that the NWS NexRad Doppler (the WSR-88D) system makes available is the' Radar Coded Message (RCM). It is an ASCII "text" file, no more than 4K, which is sent by the NWS as a normal weather product that is automatically generated by the WSR-88D (NexRad) systems. Figure 1 shows a black and white print of the color screen image (the image does lose some of its effectiveness in black and white). The text output, shown in Figure 2, can be decoded by software written by Larry Hinson, of the Tulsa NWS office. This program was in fact written to take advantage of the connection that TexNet has with the Tulsa NWS office. The software can be run on any PC and allows the RCM file to be displayed as a lower resolution version of what they see on their own radar user terminal (called a Pup). The RCM output was, up until then, thought of as a low resolution and useless product that happened to exist in the software support of the WSR=88D, until it was discovered it would easily fit on a PMS message track. Since the spring of 1994, these files have been available on the Tulsa weather PMS, and are popular items for storm spotting weather nets and emergency operations centers in cities and counties within range of the radar. This software is described later in the paper.

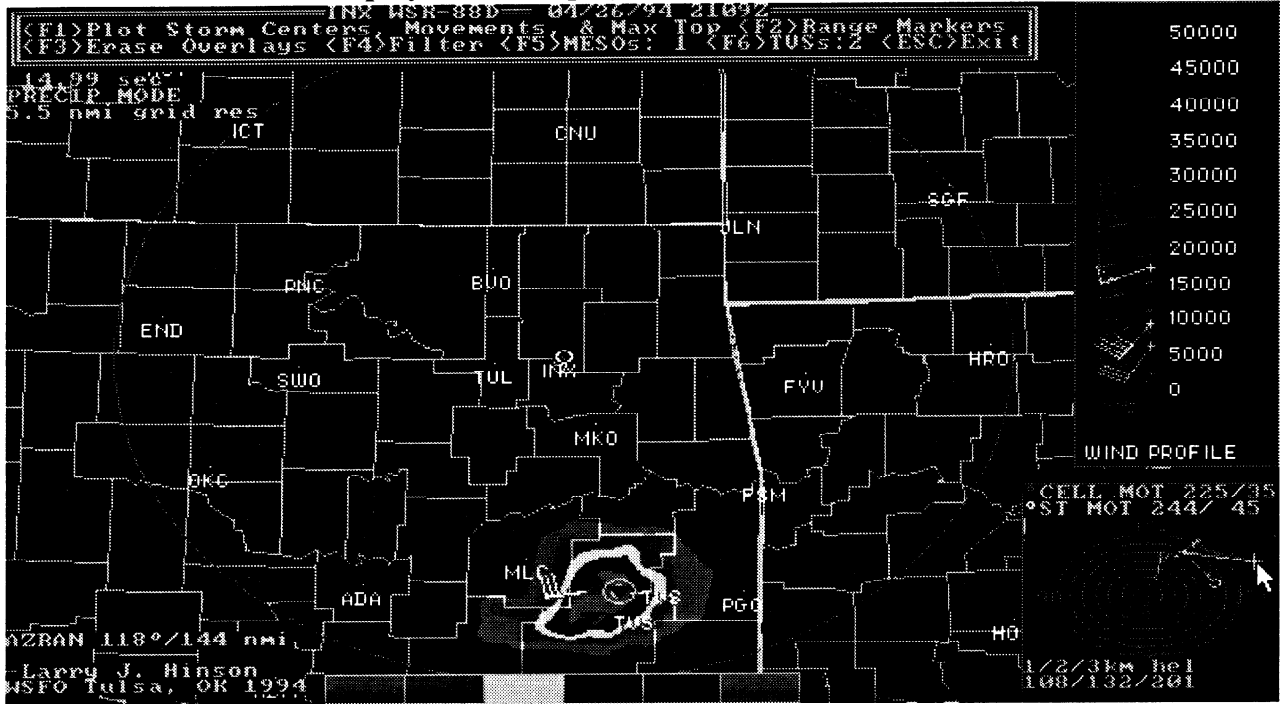**FIGURE 1 - Weather Display (B&W display of color screen)**

Figure 2 - Example NexRad file sent to the PMS which the user could download and display (as seen in Figure 1)

ZCZC OKCRCMTUL LOC
TTAAOO KTUL 010307
/NEXRAA05570109940307UNEDITED.
/MDPCPN/SC0906/NI1507: .
HLPl 10B10110Bl IIM11O1E01D001J IRA8 IIF801C221E221N IIGl 2Fl D2l M2l B
 IIL1B221E2122i 101C2B1F JH1800iE21D~21C2D1210B1,J1N18213343233101B
 'JJG12E3D210101E JR01 JjLlB2Bll JND1B2211,JRP10B8,KJElC322l12lE221
B KJFl G221CZl BZBi B KRkl 08E KJd22112BlB KRGlC8G,KJPlJ22112BlB KRD
l b78B788 LHA8 LKAl k2Cl l 2Bl' LQIl F7D88 LHB81BCl LKBl HZCl l 2B1, LQJi DZZ
7D8C LHKi 0Bl D00l G2343112Bl b0Bl D337C8C LGP880l E01101H24521D4422001 F
227Di D ~~~~~~
l E2233fC8D MHD10C1D01121D32B32B12101E2B337E8C MHPl 0Cl D011224454310
l F233227ESt NHIl BBBl NKM H224B32101E2233237F88 NHNl NJFl0Bl01101C2
34C321001D23C227F88 kHG1 NKG10C1011232552B00lE2B3B7F8B NMDl B224422
101F2B3B7F8C 0ME132i 5221H2D337F8C OJBl OLF10C3C2112E7188 0HC7 0MCl
42442B01FZE3fHBB008 OLP3443231221f2F7JbD PLE143321001JZEfI8F l3LF13
2B POBl E2Cl B7G87B8Efs808 PLGl P0Gl B2F187k808878C08B7 PHP78, POHl BZD
11787787G8G7B8B QIA8 LEi l Nfl E2E7788788778G08878778787 QLFl Zl BBC
l G2B788787F88008 "N&78 if12 QNGl E212B8E7E8 QVCSC MHl i 01D212127
B808007B8778 QWLh8 RHA88&8 RMfl I7C80C78E RXAh RHBSd8B RMFl D2127E
8080C8C RIG8' RMCl 8718E RJPsf87B80087HBC0B8 SJI87B87788787HB8 SIJ8B
08778C77887D87788 SIK880887808G7C8E SKHBFBk787E TKI8E008E78788, TL
B8B0C8G08 TN08808' TJP88, TMD8, TOD8, Ui I8, ULF88, UOB~, UJL8C, VJI8D, VKJ8
 VKG88 VKHB8, WKA88.
7MT330: NSC.
/NCEN04: C22NNMD00000, C0SOMD000000, C980NC000000, C74JLK000000.
/ENDAA.
/NEXRBB05570109940307.
010C010015, 820B045034, 030B067036, 040B097024, 050B124020, 060A135016,
070A145012, 080A146012, 090A169011, 100A189011, 120A226012, 140A243012,
160A271013, 180A290015, 200A265017, 358A234044.
/ENDBB.
/NEXRCC05570109940307.
/NCEN04: C22NNMS010HN, C050MDS010HN, C980NCS010HN, C74JLKS010HN.
NNNN

The NexRad output is updated several times an hour as a weather product saved on the PMS. It has wind and other information embedded in it, in addition to the basic radar image, such as any Mesocyclones (meso) or Tornadic Vortex Signatures (tvs) which the radar system has analyzed. If you live in Texas and Oklahoma, and have a thunderstorm with a TVS in it, you want to know about it, I guarantee you. That's the tornadic vortex inside a thunderstorm which is one of the signatures that the storm is spawning, or may spawn a tornado. Hail can also be shown. The software for the user's pc includes the geographic background or the static part of the radar image, usually the county map lines and city names. The standard distribution is set up for most of the NexRad sites in the nation. It can operate more than one site, and can merge two sites together to subtract ground clutter. It contains wind information which the user can interact with.

The radar site (INX), shown in Figure 1, is located near Inola, Oklahoma, which is east of Tulsa by approximately thirty miles. The Doppler range of NexRad is 124 miles, and that is also the radius of the RCM display, so it reaches into western Arkansas. Its coverage roughly happens to coincide with the TexNet/HogNet network in NE Oklahoma and NW Arkansas and SW Missouri.

To receive the file, the user connects to the network and then makes a connection to the weather server. Then they can initiate a text capture to a disk file, and read the message from the PMS, close the file, exit the terminal comm program, and bring up GDRCM, and display it. The RCM program will remove the overhead of the disk capture and the PMS heading and normally no ASCII file editing is required. Any reliable terminal packet or modem program with a terminal emulator and capture to disk files should do.

Procomm and Yapp both work, and I am sure that there are others which will work equally well.

The following are excerpts from the GDRCM software. These are only excerpts, and the program is continually being improved. Please refer to the program for current and complete information. [l]

GDRCM Introduction
The WSR-88D Radar Coded Message Display Software was designed to decode and graphically display the contents of the RCM message for any WSR-88D radar.

Once the RCM software is installed, reflectivity data, storm information, and wind data within the RCM can be extracted and graphically displayed. The reflectivity data, when color contoured and animated by this software, offers an excellent radar display and pinpoints areas of developing storms. Storm movement and maximum tops are also superimposed on the reflectivity data.

In addition, an interactive hodograph is constructed using the wind data in the RCM. Storm relative helicity values are automatically computed for a storm moving 30 degrees to the right and 75 percent of the mean winds from the surface to 25000 feet MSL. Storm relative helicity values can also be computed using individual storm movements as given within the RCM.

This version offers the following additional features:
1) Handles binary and text formatted RCMs. Text formatted RCMs are necessary for transmission through Ham Packet Radio. See Appendix I for further details on the text formatted RCMs.
2) Handles 9 and 6-letter RCM file IDs. (Refer to installation instructions for the handling of 6-letter file IDs.)
3) County and state maps for the 48 contiguous states.
4) Looping capabilities.
5) Ground-clutter suppression capabilities.

Instructions to loop through stored RCMs and draw a ground track.

3.2 Analyze/Loop through Previously Stored RCMs

Press the F2 key from the main menu to bring up a sub-menu of RRR files in the RCM subdirectory. It will resemble the following, with its own set of function key assignments:

<F I >DISPLAY RCM
<F2>LOOP THROUGH LAST 5 RCMS OR FLAGGED RCMS
<F3>ARCHIVE FLAGGED
<F4>DELETE FLAGGED
<F5>RETURN to MENU

The arrow keys move the cursor across the filenames which are ready for display. The display screen will show up to 40 filenames at once, sorted in descending sequence by month, day, and time. If there are more than 40 files, and you want to get to a file not shown, simply continue to move the cursor to the right or down and the display will automatically scroll to the right.

A file can be selected for display by either pressing the <FI> or <enter> key. Files may be looped by flagging the appropriate files using the space bar or <F3>. A diamond will appear to the right of each selected file. Pressing <Fz> will process each of the flagged RCMs and loop through the resulting pictures. If no RCMs have been flagged with a diamond, the latest 5 RCMs (or the number of RCMs specified in the RRR.IN I file) in the data base will automatically be looped. Striking the space bar on a flagged file will unflag that file. <F5> will return the main menu.

While the RCMs are being looped, a number of options exist in what is being displayed. Most of these options are the same as those described under section 3.3. Other options include:

I) The ability to filter out different intensity levels from the screen while the RCM pictures are being animated. This is accomplished by pressing the numeric digits I through 6 on the keyboard for the particular intensities you want to filter. Pressing "0" restores the screen back to the original colors.
2) The ability to track a storm's history of locations. This is done by pressing the "T" key on the keyboard. All storm centroids within the RCMs are given a unique 2-digit ID consisting of numbers

or letters of the alphabet. These are labeled in blue. Those storm centroids that maintain continuity will consistently be reported within the RCM at 30 minute intervals. The RCM looping program will then find all of these storm centroids that are consistently reported and will draw red line segments representing the trajectory of each storm centroid.The storm centroid locations along the line segments will be denoted with white "+" signs.

Description of the Display

After pressing <F I > from the main menu, or after an RCM message is decoded, a contoured color analysis of the reflectivity is displayed within the left two-thirds of the screen. Superimposed on this data is a county and state map. If a city file has been created for the radar (see section 6, part A, subsection I. IO), these cities will also be displayed.

The vertical wind profile (knots) will then be displayed on the right side of the screen. Winds within the RCM message are coded at intervals of 1,000 feet up to 10,000 feet, 2,000 feet from 10,000 to 20,000 feet, and 5,000 feet above 20,000 feet (Federal Meteorological Handbook No. I I). Because of the data density at the lower levels, winds below 10,000 feet are plotted at 2,000 foot intervals. This results in a more readable vertical profile of the winds.

The hodograph is in the lower right side of the display. All available winds from the surface to 9000 feet are used to create the hodograph. Each wind is represented by a white circle with line segments (shear vectors) connecting each circle. Cell movement and storm movement,as described earlier, are printed at the top of the hodograph and are depicted within the hodograph by blue and yellow circles, respectively. Rings on the hodograph are 5 knot isotachs.

A summary of the options is shown below. These options are displayed at the top of the screen.

<FI >Plot Storm Centers, Movements, & Max Top
<FZ>Range Markers
<F3>Erase Overlays
<F4>Filter
cF5>MESOs:O
cF6>TVSs:O
<ESC>Exit

FI will plot the location of storm centers, movement in knots, and the maximum storm top in hundreds of feet (MSL). If the WSR-88D algorithms suggest hail is occurring with a given storm,that storm will be marked with a green triangle at the location where hail is suspected. Solid green triangles are used to denote storms that are considered producers of hail, while hollow green triangles denote storms that are probable producers of hail (Federal Meteorological Handbook No. I I).This option is automatically invoked after the precipitation is contoured. The top of the tallest storm (MT for max top in the RCM) is designated with a black square with white numbers and is specified just to the right of the location of the maximum echo top. To eliminate the wind barbs, maximum echo top, and hail from the screen, use F3.

F2 draws range markers.

F3 refreshes the screen with just the reflectivity pattern.

F4 will prompt the user for a level of precipitation to mask out. This can be a number from 0 to 6. I through 6 will filter out the blue,green,yellow, brown, red, and magenta colors, respectively. 0 will restore the screen to its original colors. In addition, precipitation can be masked out with the mouse cursor positioned on a desired color of reflectivity and by pressing the left button. It is easier to point and click the mouse cursor at one of the intensity squares at the bottom of the screen to filter out intensities.

F5 will display centers of 2-D uncorrelated shear, 3-D shear,and mesocyclones with 2 concentric yellow circles at each center.

F6 will display TornadoVortex Signatures with red triangles.

<ES0 returns you to the Main Menu.

In addition,the program can produce several products from the wind data
including:

I) A hodograph, if more than 3 levels of wind are available. The hodograph shows what the cell motion (degrees/knots) would be based on the mean winds from the surface to 25,000 feet. The storm motion (in knots) is indicated for a storm moving 30 degrees to the right and 75% of the mean wind. In addition, the storm relative inflow vectors are indicated, with each color coded to match the winds in theVAD profile (Jarboe, 1993).

2) Calculations of storm relative helicity in m*?/s*? up to 3 km at I km intervals. The helicity values are computed for a right-moving supercell thunderstorm with a motion vector 30 degrees to the right of, and with 75 percent of the magnitude of the mean wind vector, This motion vector is consistent with that used at the National Severe Storms Forecast Center (Leftwich, 1990) and by the SHARP Workstation (Hart & Korotky, 1990). The storm relative helicity values are indicated in the hodograph square at the lower right hand corner of the screen.

3) Moving the mouse cursor to a particular storm with a motion vector (wind barb) will cause the calculation of a new helicity based on the storm's actual motion. Please note, when you move the cursor to a storm, the wind barb associated with that storm will change to red, and the helicity in the vicinity of that storm will be highlighted in the hodograph box with a yellow cross indicating the storm's motion.

4) The winds in the VAD profile that may be more representative of a distant storm may be changed. This is done by moving the cursor into the VAD profiler box to any particular wind that you want to change.You will observe, by moving the cursor through the winds&at colored circles representing the individual wind vectors will appear on the hodograph. Because not all winds below 10,000 ft are displayed in the vertical wind profile, additional colored circles will appear in the hodograph at intermediate levels of the wind profile to which the mouse cursor is pointing. When you find the wind you want to change, press the left mouse button. The mouse cursor will move into the hodograph box. Modify the wind to whatever you want. As you are changing the wind,the wind barb in the VAD profiler box will change accordingly, and the direction and speed label of the wind will also change in the hodograph box. When you are satisfied with your change, press the right mouse button and the mouse cursor will move back into theVAD profiler box to the point where you left off. Other winds in the vertical wind profile can be changed in this manner.

5) Moving the cursor into the hodograph box will update the calculations of helicity based on the position of the cursor (yellow + sign). The position

of the cursor is converted into a polar coordinate and is assumed to be the motion of a storm. For example, a northeast moving storm (240 degrees 30 knots) would have the cursor positioned in the upper right corner of the hodograph on the 6th ring. (Each ring is plotted at 5 knot intervals.)

Pressing <ES0 returns you to the Main Menu.

Notes on capabilities and resolution

There are a few things of which the user should be aware.

I) The RCM reflectivities are based on the **2.2** nm resolution composite reflectivity product. This means that reflectivities on the screen may or may not represent rain reaching the ground, since multiple elevation scans are combined to produce the RCM product. The image displayed is not necessarily occurring at the lowest elevation scan of 0.5 degrees. In many cases with severe thunderstorms, you will see a large area of level I reflectivity extending downwind of the strongest thunderstorm cells. This is indicative of the widespread cirrus cloud blowoff that is produced from these storms. Also, composite reflectivity products tend to make thunderstorms appear more severe than they may really be.

2) The RCM product is a 5.4 nm resolution product and echo "blooming" does occur That is, spotty showers with cores only a few miles across will appear larger than they really are.

3) Two reflectivity display modes are available with WSR-88D, Clear Air Mode and Precipitation Mode. This radar program will indicate whether the RCM data was obtained in either the Clear Air Mode or the Precipitation Mode.

4) Anomalous Propagation/Ground Clutter does occur with radars and may not always be suppressed successfully. The worst of this phenomena generally occurs at night and in the early morning.

Program Information
Program Information and Procedures for Installation and Execution.

RCM DISPLAY SOFWARE for IBM-compatibles

PROGRAM NAME: GDRCM

PURPOSE: Decodes/Displays/Manages WSR-88D reflectivity and wind data within RCM files. Includes an interactive hodograph, looping,and ground clutter suppression capabilities.

PROGRAM INFORMATION:
  Development & Maintenance programmer:
      Larry J. Hinson
      Location: NWSFO Tulsa, OK

Languages: Microsoft Quick Basic 4.5, Quick C 2.0, Borland Turbo C++ 3.0 Original Release/Rev 1.6 - December IO, 1994

RunningTime: Less than 30 seconds on a 486 DX2 to greater than 20 minutes on an 8088 XT An 8088 XT with a co-processor will be significantly faster with an estimated running time of 3 to 5 minutes.

SYSTEM REQUIREMENTS:
  IBM-compatible with DOS 3.3 or better, 5 I2K+ RAM, I .5 MB free disk space. EGA graphics capability monitor with 256K video memory. Co- processor and Microsoft-compatible mouse are recommended.

[Note: We are working on making this program available as part of the TAPR software library.]

Conclusion

In closing, I would like to add a few comments on data compression. When the RCM product and program appeared, the amateurs in the Tulsa area had been experimenting with ways to send pictures from the ATV system to the hams in Arkansas and other outlying areas who wanted access to the displays. We looked into ATV relays and packet. Both have their apparent problems. ATV links would cost a lot of money and the best we could do with compression of the ATV images was 50K using JPEG compression. These files would take from 15 to 30 minutes to send. Of course, the captured, compressed, and transmitted image was a raw reflectivity image and had no embedded wind data or storm and cyclone analysis. Thus the power of the RCM format became apparent. All of what we wanted and so much more could be delivered within a 2K to 4 K file and allow for multiple distribution.

While the approximate 6 mile resolution of the RCM sounds a little crude in some ways, it is usable, and I suspect that what we were digitizing on a field, or half-frame basis, with received noise, was no better, and perhaps would have been much older information when ultimately delivered. There is a lot of information packed into the small RCM data file and it appears to be used very well, and with the hardware that was already in place around the network. In some ways, the RCM files can be thought of as compression. It filters what is meteorologically significant, rather than trying to reduce just an image to a shorter form. A lot of the analysis is already done by the radar support system itself for the meteorologist.

The combination of the RCM message distribution across the network and the development of the GDRCM program has brought near real-time updates to EOCs and spotters of information that is required to fulfill their duties as amateur weather spotters. Combine the RCM capability with the weather alert functions and the network provides essential services to the day-to-day operations of weather related activities.

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