Evaluation of Collins WXR-700C-G Radar Performance During the MIST Project

July 24, 28 and 31, 1986, Huntsville, Alabama

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1.0 SUMMARY OF RESULTS

This report summarizes comparisons of the Collins WXR-700C-G and the Massachusetts Institute of Technology (MIT) Lincoln Laboratories FL2 Doppler radars. The intent of these comparisons is to evaluate the performance of the Collins radar as compared with the research quality MIT-FL2 ground based Doppler radar. The data used for the comparison were collected during the summer of 1986 in the Huntsville, Alabama area (Reinhart et.al., 1987).

There were substantial design differences between the two radars. The MIT radar (Reinhart et.al., 1987) is a S-band Doppler radar which has a peak transmitted power of 1.1 mega-watts, a beam width of 0.96°, and a pulse length of 0.65 μs (312 feet). The Collins radar (Rockwell, 1986) is a C-band Doppler radar with a peak transmitted power of 200 watts, a beam width of 5.5°, a Doppler measurement pulse length of 5.76 μs (2833 feet) and reflectivity measurement pulse lengths of 8.16 μs (3917 feet) and 19.68 μs (9678 feet) on the 25 and 50 Nmi selected ranges, respectively.

These design differences give the two radars quite different measurement capabilities. In general, the MIT radar should be a substantially more sensitive radar and it should have much higher measurement resolution than the Collins system. The effect of the lower sensitivity and resolution of the Collins system is to reduce the area of coverage (range) within which the Collins radar makes
measurements and to average the measurements over a larger pulse volume (azimuth, range and elevation) than does the MIT radar.

In spite of the substantial differences between the two radars, their measurements of convective weather systems compared quite favorably. The measurements of reflectivity factor, Doppler velocity and areas of turbulence generally compared quite well, particularly considering the inherent limitations of the extremely light weight, low power, and small size of the Collins design. Only three of the storm events studied (events 29, 30 and 31) showed clear signs of attenuation in the Collins C-band signal. This does not appear to be a problem except in the largest of storms.

The major limitations of the Collins system, as compared with the MIT radar, were the reduced sensitivity and the smearing effect of the larger Collins beam width and pulse length. The Collins reflectivity channel is designed only to display returns at reflectivities of about 20 dBZ and higher, and therefore is designed to be less sensitive than the MIT-FL2 radar. Based on the comparisons of this report, the velocity channel seems slightly less sensitive, with most velocity and turbulence returns being within about the 30 dBZ reflectivity contour at 20 Nmi ranges. The effects of the wide beam width and long pulse length of the Collins system were noted throughout the comparisons of data from the two radars. These effects can be clearly seen in the reflectivity, velocity and turbulence data.
The major areas which could be considered for simple improvement of the Collins system would be improving the resolution and increasing the total system sensitivity. For ground based operation, addition of a larger antenna would clearly help. However, for both ground and airborne operation, either a larger antenna or a shorter wavelength (X-band) could be an advantage for Doppler work (Hildebrand, 1981). Since the intent of the Doppler measurements is generally directed toward small, intense and dangerous events, the trade-off of improved resolution for increased attenuation may be an acceptable choice.

2.0 RADAR CHARACTERISTICS

2.1 COLLINS WXR-700C-G RADAR

2.1.1 SPECIFICATIONS

The Collins WXR-700C-G (Rockwell, 1986) is a ground based version of the Collins WXR-700C, C-band airborne Doppler radar. For ground operation the pulse length and PRF of the radar have been changed from the airborne configuration. The technical specifications are given in Table 1. The radar is a low power, solid state, Doppler weather radar. It has multi-mode operation with a mean Doppler mode (mean radial velocity), a Doppler variance mode (turbulence), a reflectivity mode and a combined reflectivity-variance mode. The discussions in this paper will relate to the Doppler mode. When operating in the Doppler mode, the radar makes use of a 5.76 μs or 2765 ft pulse depth. The radar beam width is
5.5°. At ranges of 10, 20, 30 or 40 Nmi, this produces a physical beam width of about 5800, 11600, 17500 and 23300 feet.

Table 1
Features of the MIT-FL2 and Collins WXR-700C-G Radars.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>FL2</th>
<th>WXR-700C-G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter</td>
<td>ft</td>
<td>28</td>
<td>2.5</td>
</tr>
<tr>
<td>Beam width</td>
<td>deg</td>
<td>0.96</td>
<td>5.5</td>
</tr>
<tr>
<td>Polarization</td>
<td></td>
<td>horizontal</td>
<td>horizontal</td>
</tr>
<tr>
<td>Rotation rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max.</td>
<td>deg/s</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>Typical</td>
<td>deg/s</td>
<td>5 to 8</td>
<td>22.5</td>
</tr>
<tr>
<td>Adaptive scans</td>
<td></td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>(PPI, sector scan, RHI)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmitter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplifier</td>
<td></td>
<td>klystron</td>
<td>solid state</td>
</tr>
<tr>
<td>Frequency</td>
<td>MHz</td>
<td>2880</td>
<td>5440</td>
</tr>
<tr>
<td>Band</td>
<td>S</td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Peak power</td>
<td>MW</td>
<td>1.1</td>
<td>0.0002</td>
</tr>
<tr>
<td>Signal wave form</td>
<td></td>
<td>uncoded pulse</td>
<td>uncoded pulse</td>
</tr>
<tr>
<td>Pulse length</td>
<td>μs</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>Pulse repetition rate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reflectivity</td>
<td>1/s</td>
<td>700-1200</td>
<td>360</td>
</tr>
<tr>
<td>Velocity</td>
<td>1/s</td>
<td>700-1200</td>
<td>1446</td>
</tr>
<tr>
<td>Receiver</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Band width</td>
<td>MHz</td>
<td>1.3</td>
<td>--</td>
</tr>
<tr>
<td>Sensitivity time control</td>
<td></td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>Min. detectable signal</td>
<td>dBm</td>
<td>-107</td>
<td>-124</td>
</tr>
<tr>
<td>Min. detectable reflect-dB</td>
<td></td>
<td>-5.5</td>
<td>13 (refl,50Nmi)</td>
</tr>
<tr>
<td>ivity (at 50 km range)</td>
<td></td>
<td></td>
<td>21 (Doppler)</td>
</tr>
<tr>
<td>Noise figure</td>
<td>dB</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Signal Processor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A/D converter bits</td>
<td></td>
<td>12</td>
<td>8</td>
</tr>
<tr>
<td>Clutter filtering</td>
<td></td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Number of range gates</td>
<td></td>
<td>800</td>
<td>256 (refl)</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td></td>
<td>128 (Doppler)</td>
</tr>
<tr>
<td>Range-gate spacing</td>
<td></td>
<td>120,240</td>
<td>determined by selected range</td>
</tr>
</tbody>
</table>
2.1.2 DATA

The Collins radar data consist of measurements of radar reflectivity factor, radial velocity and the turbulence indicator. The Collins radar (I & Q) data were recorded by Collins and later displayed on a scope and photographed. The photo slides were used as the primary data set for this study.

In the photo slides, the reflectivities are displayed with a color table as in Table 2.

Table 2
The reflectivity color table for the Collins WXR-700C radar.

<table>
<thead>
<tr>
<th>color</th>
<th>reflectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>black</td>
<td>below 20 dBZ</td>
</tr>
<tr>
<td>light green</td>
<td>20 - 30 dBZ</td>
</tr>
<tr>
<td>dark green</td>
<td>30 - 40 dBZ</td>
</tr>
<tr>
<td>yellow</td>
<td>40 - 45 dBZ</td>
</tr>
<tr>
<td>red</td>
<td>&gt;45 dBZ</td>
</tr>
</tbody>
</table>

The velocities are color-coded in 2.5 m/s increments with receding velocities indicated as positive using violet through brown, and approaching velocities as negative using green through blue tones. The velocities are shown within the range -20 m/s to +20 m/s. The zero velocity area of the Collins color table covers the range ±2.5 m/s. The turbulence signal, a magenta color on the display, is illuminated when the standard deviation of the velocities within the radar pulse volume exceeds a selected preset threshold of 5 m/s for receiver signal-to-noise ≥15 dB and is
gradually reduced to 4 m/s as the receiver signal-to-noise approaches 0 dB.

2.1.3 SCANNING

The Collins radar data used in this report were obtained by scanning at a roughly constant elevation, which typically was at 1-3° elevation. These elevations corresponded closely with some of the MIT radar scans.

Table 3 lists the scans of the Collins and MIT radar which were used in this report.

2.1.4 RADAR PHOTOS

The Collins radar photos were made at Collins using a color table which approximates the color table used at the NCAR Research Data Support System (RDSS). This allows for increased ease in comparison of the Collins and MIT radar scans.

2.2 MIT-FL2 RADAR

2.2.1 SPECIFICATIONS

The MIT-FL2 radar is an S-band Doppler radar assembled by the Lincoln Laboratories using components from a variety of sources (Rinehart, et al., 1987). The transmitter and basic components of the receiver are from a standard air-traffic surveillance ASR-8 radar. The antenna pedestal came from an earlier FAA project and the antenna reflector was built to Lincoln Laboratory's
specifications by Hayes and Walsh. The antenna was modified to have the same diameter as the Next Generation Radar (NEXRAD) systems. The signal processor, clutter filter, display and recording systems were largely designed and built in-house by the Lincoln Laboratories. Table 1 lists the main features of the FL2 radar system.

The FL2 radar commenced operations during August, 1984. During 1986, the FL2 radar started meteorological data collection on 4 March and continued until 27 November, collecting a total of 963 tapes during the season. The radar results which follow are based on data collected during the 1986 field season.

2.2.2 DATA

The MIT-FL2 radar data consist of digitized values of radar reflectivity, radial velocity, spectral width, and signal to noise ratio. These data were used at NCAR to produce the displays. The MIT radar displays consist of reflectivity, radial velocity, spectral width and, in some cases, the radial shear. The radial shear was calculated as the change in radial velocity measured over a depth comparable to the Collins radar pulse volume.

2.2.3 SCANNING

The MIT-FL2 radar generally scanned in PPI or sector scans in which the elevation angle was held fixed and the azimuth angle was changed smoothly. The elevation angles were changed after every sector or full 360° sweep. The elevation angle was generally
stepped to cover a 12° elevation height above ground in the following way: 0, 4, 8, 12, 0, 3, 7, 11, 0, 2, 6, 10, 0, 1, 5, 9. This full scan required 3-4 min and one sub-cycle of elevation steps (e.g., 0,4,8,12) took about 1 minute. This provided relatively quick coverage of the full 12° elevation range at about 4° steps, and the ability to fill in the gaps through time. The MIT-FL2 radar also made occasional use of RHI scans which were generally made with 1° azimuth steps.

Table 3 lists the Collins and MIT radar data which were used in this report.

2.2.4 RADAR PHOTOS

The radar photos for the MIT radar were made on the NCAR Research Data Support System (RDSS). The MIT radar data were displayed, and some derived data fields were developed and displayed. The derived data fields are described in section 4.1.

3.0 DATA COLLECTION

Both radars were operated in the field during the MIST project by radar crews from their home organization. The MIT FL2 radar scans were performed according to a prescribed scanning strategy which was designed to evaluate capabilities of a ground based Doppler radar to detect and measure microbursts. In addition, the FL2 scans were designed to provide data which could subsequently be used in the development of operational radar scanning techniques.
for microburst detection and warning. The Collins WXR-700C-G radar scans were coordinated to match the MIT-FL2 radar scan strategy so that the data from the two radars were collected at approximately the same elevation angles and azimuth sectors during the same time periods (Appendix A).

4.0 DATA ANALYSIS TECHNIQUE

4.1 DATA PROCESSING TECHNIQUE

There were a number of differences between the Collins and MIT radars which should be accounted for in analyzing the data. These differences relate to the differing sizes of the radar pulse volumes for the two radars.

When operating in the Doppler mode, the Collins radar makes use of a 5.76 $\mu$s or 0.47 Nmi pulse depth. The radar beam width is 5.5$^\circ$. At ranges of 10, 20, 30 or 40 Nmi, this produces a physical beam width of 5800, 11600, 17500 or 23300 feet. In contrast, the MIT radar uses a 1 $\mu$s pulse and has a 1$^\circ$ radar beam width. The physical pulse length is thus about 0.08 Nmi. At ranges of 10, 20, 30 or 40 Nmi, this produces a physical beam width of 1060, 2100, 3200, or 4200 feet.

Comparison of data from the two radars requires performing some smoothing of the MIT radar data to make them more comparable with the Collins radar data. For the most part, this smoothing is
performed by eye in the course of comparing the data sets.

A radial shear indicator was derived from the MIT radar data by calculating the velocity change over 9 gates; a radial depth comparable to the Collins radar pulse volume. This was done to evaluate the effects of larger-than-MIT scale turbulence and shears on the illumination of the Collins turbulence indicator.

While well suited for observing cloud precipitation features, the MIT radar scan technique was not optimal for comparisons with another radar, particularly considering the need for comparisons of data from adjacent radar beams gathered over a short interval. Thus, in many cases where there may be questions concerning the comparison between the two radars, it would have been helpful to have additional scans from the MIT radar which were immediately adjacent in both time and space (i.e., elevation). Unfortunately, due to the MIT scanning strategy, this was generally not possible and use of the physically adjacent MIT radar scans often required delays of about 1 minute. For quickly developing phenomena, this can be a problem.

4.2 TECHNIQUE OF COMPARISON OF DATA FROM THE COLLINS AND MIT RADARS

The case studies consist of comparisons between the Collins radar photos and the MIT radar photos. Based on the radar display photos provided by Collins, the MIT radar data were displayed and the radar data displays (photos) closest in time to the Collins
data obtained. A visual comparison between the Collins and MIT radar data was then performed in which the data fields presented by the Collins radar were compared and verified against the MIT radar data.

In these comparisons we have taken into account, as best possible, the effects of the difference in radar pulse volumes. While the radars have different beam widths and pulse depths, the primary differences between the sampling for the two radars was due to the differences in beam width. These differences have a significant effect on the comparisons of the two radars. This is because the Collins radar, with its wider beam (5.5° vs 1° for the MIT radar) averages measurements from above and below the nominal radar beam level as well as averaging horizontally. Due to the normal vertical stratification of the atmosphere, these effects can be large, particularly in the vicinity of convective storms, such as were observed during data collection for this experiment. Due to the somewhat irregular scanning strategy of the MIT-FL2 radar (see section 2.2.2), it is not always possible to evaluate the effects of the differences in the Collins and MIT radar beam widths.

In the displays of data from the two systems, care has been taken to make the displays as similar as practical. Thus, the color table for displays from the two radars are similar and the range rings for the two radars are nearly equal. One significant difference between the color tables for the two radars is that the
Collins velocity color table depicts "zero" velocity as in the range ± 2.5 m/s, whereas the MIT color scale only uses ± 1.5 m/s. The Collins range rings are in Nmi. The MIT range rings are in km, with the rings selected to be equivalent to every 5 or 10 Nmi range.

4.3 DATA USED IN THE ANALYSIS

The data reviewed as a part of this analysis are listed in Table 3 which indicates the event number, date, time (GMT and CDT), approximate azimuth and range of the event, and comments on the event.

These data consist of observations of five storms, as indicated by the breaks in Table 3. For purposes of comparison between the WXR-700C and the FL2 radars, these five storms will each be discussed together. This is convenient because of the meteorological continuity of the observations within each storm.
Table 3

Event log for the WXR-700C - FL2 data comparison. The storm number, event number, date, time (GMT and CDT), the elevation for the WXR-700C-G radar, the azimuths and range of the storms observed, and comments on the event are shown.

<table>
<thead>
<tr>
<th>SN</th>
<th>EV</th>
<th>DAY</th>
<th>TIME</th>
<th>ELEV</th>
<th>AZIM</th>
<th>RANGE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>##</td>
<td>(July)</td>
<td>(GMT)</td>
<td>(CDT)</td>
<td>(deg)</td>
<td>(deg)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>28</td>
<td>2330</td>
<td>1830</td>
<td>1</td>
<td>010-040</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>13</td>
<td>28</td>
<td>2340</td>
<td>1840</td>
<td>2</td>
<td>010-045</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>28</td>
<td>0006</td>
<td>1906</td>
<td>1</td>
<td>015-060</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>28</td>
<td>0012</td>
<td>1912</td>
<td>1</td>
<td>000-070</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>28</td>
<td>0120</td>
<td>2020</td>
<td>1</td>
<td>045-120</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>21</td>
<td>28</td>
<td>0129</td>
<td>2029</td>
<td>1</td>
<td>050-140</td>
<td>15</td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>31</td>
<td>1811</td>
<td>1311</td>
<td>2</td>
<td>315-015</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>31</td>
<td>1823</td>
<td>1323</td>
<td>2</td>
<td>315-030</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>31</td>
<td>31</td>
<td>1827</td>
<td>1327</td>
<td>2</td>
<td>315-030</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>34</td>
<td>31</td>
<td>1855</td>
<td>1355</td>
<td>5</td>
<td>315-040</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>36</td>
<td>31</td>
<td>1917</td>
<td>1417</td>
<td>2</td>
<td>010-080</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>37</td>
<td>31</td>
<td>1922</td>
<td>1422</td>
<td>2</td>
<td>010-090</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>42</td>
<td>31</td>
<td>0226</td>
<td>2126</td>
<td>6</td>
<td>260-040</td>
<td>15</td>
</tr>
<tr>
<td>7</td>
<td>47</td>
<td>31</td>
<td>0251</td>
<td>2152</td>
<td>8</td>
<td>250-060</td>
<td>10</td>
</tr>
</tbody>
</table>
5.0 DATA ANALYSIS RESULTS

5.1 STORM 2

On 28 July 1986, two E-W oriented lines of convection were observed to the north of the radars. Each line consisted of several cells having reflectivities of >40 dBZ. Areas of turbulence were present in each of the scans of these cells. At the beginning of the observations (event 12), the line closer to the radars contained 3 closely spaced convective cells, plus a fourth cell further to the east along the same line of convection. A second line of convection was located about 12-15 Nmi to the north of the first line. As time progressed, the lines moved slightly to the east-southeast, the southern line dissipated, and the cells in the northern line intensified. During events 12, 13 and 16, fairly good matches between the Collins radar scans and the MIT radar scans were achieved.

5.1.1 EVENT 12

The data for event 12 consists of Collins radar data from 1° elevation at 183157 EDT (233157Z) (Fig. 1), MIT data from 2° elevation at 233052Z (Fig. 2), and 1° elevation at 233146Z (Fig. 3). Collins 1° elevation data from 183049 EDT are also available and are not shown for they are substantially the same as the data in Fig. 1.
Reflectivity:

The same basic reflectivity returns are seen in both the Collins and the MIT displays, with 3 closely spaced convective cells at about 30 Nmi and 355-020°. A fourth cell lies further to the east along the same line of convection at about 35 Nmi and 050°. The reflectivity features from the Collins system appear to lie at about 3 Nmi greater range than the returns from the MIT radar.

Both radars depict the same basic convective cell shapes. The peak reflectivities on the Collins radar appear to be somewhat lower in value than those from the MIT radar. The peak reflectivities from the Collins radar are in the 40-45 dBZ range for the group of three cells, and >45 dBZ for the eastern cell. The MIT radar shows peak reflectivities in the 45 - 50 dBz range for the group of three cells, and a peak of 55 - 60 dBZ for the eastern cell. These differences can possibly be attributed to differences in the pulse length and beam width between the two radars, with the Collins radar's longer pulse and wider beam filtering the reflectivity values thus lowering the peak reflectivity values measured by the radar. The locations of the peaks within the storms correspond well between the two radars. Due to the wider radar beam width, the Collins radar connects two storms that are shown as separate on the MIT radar.

Velocity:

The Collins velocity channel is less sensitive than the reflectivity channel due to pulse width and receiver sensitivity
differences. In the data from event 12, the displayed velocity values appear at locations corresponding to a reflectivity of about 30 dBZ at a range of 40 Nmi.

The Collins and MIT radar displays from 1° elevation (Fig. 2, upper right) show similar velocities. The major difference is that the Collins display shows larger areas of "zero" velocity between the positive and negative velocities than does the MIT radar. These differences are primarily due to the differences in the displays: The Collins display depicts the range ± 2.5 m/s as "zero", whereas the MIT radar display depicts the range ± 1.5 m/s as "zero". Some additional portion of the difference may be due to the combined effects of the large beam width for the Collins radar coupled with ground clutter.

Nevertheless, both radars show velocities between 5 and 10 m/s in the same areas. This comparison is good when the velocities from the Collins radar at 1° elevation are compared with the 2° MIT velocities in Fig. 2. The comparison is poorer for the 1° elevation MIT scan. The Collins display embodies the effects of beam and range filtering. This averages the data over the different elevation angles.

Turbulence:

The Collins and MIT displays both show areas of turbulence in the cell at 20° azimuth from the radars. The Collins radar shows a large area of turbulence in the center of the three cells
(Fig. 1) and a smaller area in the eastern cell. In the cell at about 40° azimuth, the Collins radar shows a small area of turbulence on the north side of the 40 dBZ contour. The MIT radar 2° scan shows a spectral width of greater than 4.5 m/s for the center cell and the 40° cell, and an area of shear in the eastern of the three cells (at about 25°) and in other areas. The MIT 1° scan also shows good comparison with the Collins data. It therefore appears that the Collins radar was accurately responding to areas of turbulence which were detected by the MIT radar.
Figure 1.
5.1.2 EVENT 13

The data for event 13 consists of Collins radar data from 2° elevation at 184140 EDT (234140Z) (Fig. 4), and MIT data from 2° elevation at 234143Z (Fig. 5).

Reflectivity:

The reflectivity fields have the same basic shape on both radars. As was the case in Event 12, the Collins maximum reflectivities were 5-10 dBZ lower than the MIT values, e.g., in the 3 cells north of the radars, MIT has peak reflectivities of 45-55 dBZ, whereas the Collins radar shows 40-45 dBZ.

Velocity:

The Collins velocity depictions are in good agreement with the MIT velocities. The areas of approaching and receding velocities are in good agreement, and the values agree well. As was the case for Event 12, the velocity display for the Collins radar appears to begin at about 30 dBZ reflectivity.

Turbulence:

The Collins radar shows a scattered area of turbulence in the storm at 20°, 30 Nmi, and an additional area of turbulence in the cell at about 005°, 40 Nmi. No area of turbulence is shown in the cell at 40°, 30 Nmi.

The MIT radar indicates turbulence in the 005°, 40 Nmi cell. The cell at 020°, 30 Nmi has scattered areas of turbulence on the
MIT radar, and additionally some areas of moderately large shear which are associated with the storm circulations. The Collins turbulence indications are therefore well supported in those cells. In the cell at 040°, 30 Nmi, the MIT radar indicated areas of spectral width >4 m/s. The value of 4 m/s falls below the 5 m/s threshold of the Collins radar turbulence display.
5.1.3 EVENT 15

The data for event 15 consists of Collins radar data from 1° elevation at 190633 EDT (000633Z) (Fig. 6), and MIT data from 0° elevation at 000620Z (Fig. 7). The 0° elevation angle data from the MIT radar in Fig. 7 are heavily contaminated by the effects of the earth's surface (ground clutter and atmospheric stratification); hence, this comparison is of lower quality than the others. Therefore, only brief comments are offered.

Reflectivity:

As was the case for Events 12 and 13, the reflectivity fields look very similar. The major differences relate to the aforementioned differences in reflectivity values.

Velocity:

The velocity values do not correspond well, except for the storm at 010°, 35 Nmi. This is probably due to the effects of ground clutter and atmospheric stratification, combined with the large differences in beam width for the two radars. At the longer range of the storm at 010°, 35 Nmi, these effects are somewhat mitigated and the velocity depictions from the two radars are similar.

Turbulence:

The Collins radar shows a small area of turbulence in the storm at 010°, 35 Nmi. This is in qualitative agreement with the MIT 0° scan data (Fig. 7) and the meteorology of the storm.
5.1.4 EVENT 16

The data for event 16 consist of Collins radar data from 4° elevation at 191158 EDT (001158Z) (Fig. 8) and MIT data from 4° elevation at 001153Z (Fig. 9).

Reflectivity:

The reflectivity fields correspond quite well. As noted previously, the Collins reflectivities are somewhat lower, and the ranges are about 3 Nmi longer than the MIT radar.

Velocity:

The Collins and MIT mean velocity values correspond well, considering the large differences in the beam width between the two radars. The values and locations of the velocity maxima correspond between the two radars.

Turbulence:

The Collins radar shows several turbulent areas in the storm at 000-030°, 35 Nmi. These areas correspond well to areas of turbulence measured by the MIT radar. However, in the storm at 040°, 22 Nmi, the MIT radar measured a turbulent area of spectral width >5.5 m/s. This area was just on the inner edge of the Collins radar data processing/display and may have therefore been missed.
Figure 8a.
Figure 8b.
5.2 Storm 3

This storm is a continuation of storm 2, but with observations taken a little more than an hour later. At this time the storm had formed into a disorganized mass having several reflectivity centers. Strong low altitude outflow can be noted.

5.2.1 EVENT 20

The data for event 20 consists of Collins radar data from 1° elevation at 202000 EDT (012000Z) (Fig. 10), and MIT data from 1° elevation at 012008Z (Fig. 11).

Reflectivity:

The reflectivity displays are very similar and the values correspond well if the offset in range and maximum reflectivity between the two radars is taken into account. The Collins radar shows multiple reflectivity peaks of >45 dBZ. The MIT radar has a large area of 45-50 dBZ with a few peak values in the 50-55 dBZ range. The Collins radar area of reflectivities of >45 dBZ is smaller than the MIT radar area of >50 dBZ reflectivities.

Velocity:

The two radars show similar velocity features. The major area of interest in this event is a dissipating microburst which is located at about 080° 12-17 Nmi. The MIT radar clearly shows the area of storm flow toward the radar as -18 m/s at 11 Nmi, and the flow away from the radar as +7.5 m/s at 17 Nmi. The Collins radar
velocity display depicts the velocities as -11 to -14 m/s towards the radar, and +9 m/s away from the radar. The microburst shear is thus depicted as 25 m/s over about 5 Nmi for the MIT radar, and 20-25 m/s over about 5 Nmi for the Collins radar. At the average range of these microburst observations (15 Nmi), the MIT radar pulse volume was about 1350 feet wide and 310 feet deep. The Collins radar pulse was about 7600 feet wide and 2760 feet deep. The differences in measured shear is not surprising, considering the different sampling characteristics of the two radars.

Turbulence:

The only turbulence display is a small area noted by both the radars at about 70°, 13 Nmi. This very small area probably corresponds to the location of the microburst. In the Collins radar this is seen as a turbulence area; in the MIT radar several speckles are seen in the turbulence display.
5.2.2 EVENT 21

The data for event 21 consists of Collins radar data from 1° elevation at 203001 EDT (013001Z) (Fig. 12), and MIT data from 1° elevation at 012956Z (Fig. 13).

Reflectivity:

The reflectivity fields from the two radars are very similar. The Collins radar shows multiple reflectivity peaks of >45 dBZ. The MIT radar has a large area of 45-50 dBZ with a few peak values in the 50-55 dBZ range.

Velocity:

The velocity values appear to correspond well between the two radars. The Collins radar (Fig. 14) shows the microburst to be at about 085°, 12-17 Nmi, and the velocities to be -8 m/s and +8 m/s for a shear of about 16.5 m/s over about 3-4 Nmi. The MIT radar shows velocities of about -15 and +12 m/s for a shear of 27 m/s over the same distance. As was the case in Event 20, the differences in the velocity values are very likely attributable to the different beam filtering effects of the radars.

Turbulence:

The Collins radar (Fig. 14) shows a small area of turbulence at about 90°, 13-14 Nmi. This area of turbulence coincides with a small area of turbulence observed by the MIT radar. The MIT radar also shows the same areas of enhanced spectral width and higher shear values in the vicinity of the microburst.
Figure 12.
Figure 13.
5.3 STORM 4

This storm occurred on 31 July 1986. This east-west line of storms was observed as it grew and moved to the east. As the storms developed, areas of turbulence developed during Events 30, 31, and 34.

5.3.1 EVENT 29

The data for event 29 consists of Collins radar data from 2° elevation at 131109 EDT (181109Z) (Fig. 14), and MIT data from 4° elevation at 181118Z (Fig. 15). Data from more closely comparable elevation angles were not available within a reasonable time period.

Reflectivity:

The reflectivity fields from the two radars are similar; however, the Collins radar exhibits some effects of attenuation at C-band on the far side of the storm. The Collins maximum reflectivity values are in the >45 dBZ range. The MIT radar has maximum reflectivity values of 60-65 dBZ and, due to the effects of attenuation, the area of reflectivity of >45 dBZ in the western storm cell is only partially depicted by the Collins radar.

Velocity:

Considering the differences in the elevation angle between the two radars (2° and 4°), the velocity fields agree fairly well. Both radars depict the same general pattern of velocities with
positive (receding) velocities on the close side of the storm and negative (approaching) velocities on the far side. The maximum approaching velocity is measured as -11 to -14 m/s, and -15 to -18 m/s for the Collins and MIT radars, respectively. The maximum approaching velocities are 9 m/s for the Collins radar, and 6-9 m/s for the MIT radar. (Note: the highest approaching velocities seen by the MIT radar fall outside of the area within which the Collins radar is sensitive enough to make velocity measurements.)

Turbulence:

No areas of turbulence are depicted on the Collins display. The MIT radar depicts an area at 325°, 23 Nmi which has moderate shear and spectral width. It appears this area might have been illuminated as a turbulent area had the Collins radar been observing at 4° elevation.
Figure 15.
5.3.2 EVENT 30

The data for event 30 consists of Collins radar data from 2° elevation at 132252 EDT (182252Z) (Fig. 16), and MIT data from 2° elevation at 182339Z (Fig. 17). The MIT radar data are from about 40 seconds later than the Collins data and relatively few changes can be assumed to have occurred.

Reflectivity:

The reflectivity fields correspond well. The Collins radar depicts two large areas with maximum values in the >45 dBZ range; the MIT maximum values are 55-60 dBZ. Some evidence of attenuation of the Collins C-band signal can be seen on the north side of the storm.

Velocity:

The velocity values correspond well in magnitude and location. The Collins radar shows a very high shear area at 345°, 17 Nmi, where a velocity of -14 m/s (towards the radar) directly opposes a velocity of +6 to +9 m/s away. The MIT radar depicts a cyclonic (counterclockwise) circulation at the same location with maximum corresponding velocities of -15 (towards on the left), and +7 m/s (away on the right). Thus, while there is agreement of the magnitudes of the velocities, the Collins display depicts the circulation as an area of convergence due to the effects of the wider beam width of the Collins radar (about 9100 feet at 18 Nmi versus about 1600 feet for the MIT radar).
Turbulence:

The Collins radar depicts two areas of turbulence. These areas are in good agreement with the MIT radar's measurements of spectral width. In addition, the MIT radar depicted an area of shear associated with the cyclonic circulation area which might have been contributing to the turbulence signal on the Collins radar.
Figure 16.
5.3.3 EVENT 31

The data for event 31 consists of Collins radar data from 2° elevation at 132905 EDT (182905Z) (Fig. 18), and MIT data from 2° elevation at 182903Z (Fig. 19).

Reflectivity:

The reflectivity patterns of the two radars generally agree well. The Collins radar again depicts two large areas with maximum values in the >45 dBZ range; the MIT maximum values are 55-60 dBZ. Some evidence of attenuation of the Collins C-band signal can be seen on the north side of the storm.

Velocity:

The velocity values from the two radars generally agree well, with the major features of the velocity fields and their magnitudes being quite similar. The main differences are the effects of the Collins radar's wider beam width. The wide Collins beam width obscures the two areas of positive (receding) velocities observable on the MIT radar at 340° and 355°, 18 Nmi. The velocity maxima and minima measured by the two radars are +9, and -14 m/s for the Collins radar, and 6 and -15 m/s for the MIT.

Turbulence:

The Collins radar shows four areas of turbulence at 330-345°, 18-22 Nmi. These areas correspond to similarly located areas of spectral width observed on the MIT radar. The Collins radar does not observe an area of turbulence at 355°, 18 Nmi which is observed
by the MIT radar; however, this area may be outside the area of adequate sensitivity for measurement for the Collins radar.
Figure 18.
5.3.4 EVENT 34

The data for event 34 consists of Collins radar data from 5° elevation at 135458 EDT (185458Z) (Fig. 20), and MIT data from 4° elevation at 185443Z (Fig. 21).

Reflectivity:

The reflectivity patterns of the two radars generally agree well. The Collins C-band radar does a good job of portraying the reflectivity features on the back side of the storm beyond the large high reflectivity area. The targets to the south are ground returns.

Velocity:

The velocities from the Collins radar agree with the measurements from the MIT radar. The MIT radar has a peak velocity of -24 m/s at 355°, 10 Nmi. The Collins radar depicts a peak velocity of about -24 m/s in the same location. Both radars depict the maximum receding velocities to be about 3 m/s.

Turbulence:

The Collins radar shows a large area of turbulence at 340-355°, 20 Nmi. The MIT radar shows some small areas of spectral width in this area, but also some substantial areas of shear which could explain the Collins radar return.
Figure 21b.
Storm 5 was a continuation of storm 4 during which the observations centered on portions of the storms which were located to the north-east of the radars.

5.4.1 EVENT 36

The data for event 36 consists of Collins radar data from 2° elevation at 141706 EDT (192706Z) (Fig. 22), and MIT data from 2° elevation at 191707Z (Fig. 23).

Reflectivity:

The reflectivity patterns of the two radars agree very closely, with both radars depicting similarly located areas of >45 dBZ returns.

Velocity:

The velocity returns from the two radars agree quite well. The Collins and MIT radar velocity returns range from +10 m/s to -10 m/s at about 030°, with an apparent east-west line of divergence lying between the northward (positive) and southward (negative) flows.

Turbulence:

The Collins plot shows only a small area of turbulence at about 030°, 10 Nmi. The MIT radar shows only light turbulence in this area.
5.4.2 EVENT 37

The data for event 37 consists of Collins radar data from 2° elevation at 142205 EDT (192205Z) (Fig. 24) and, MIT data from 2° elevation data at 192206Z (Fig. 25).

Reflectivity:

The reflectivity patterns of the two radars agree very closely, with both radars depicting similarly located areas of >45 dBZ returns. The MIT radar shows maximum reflectivities of 55 dBZ which are located within the large >45dBZ area on the Collins radar display.

Velocity:

The velocity returns from the two radars agree quite well. The Collins and MIT radar velocity returns range from +12.5 m/s to -10 m/s at about 060°, with the east-west line of divergence lying between the northward (positive) and southward (negative) flows.

Turbulence:

Neither radar indicates any significant areas of turbulence. There is one small area of enhanced spectral width on the MIT radar; however, due to the small area and low magnitude of this turbulence it is not surprising that the Collins system did not depict this area.
5.5 STORM 7

Storm 7 consisted of observations of a large ENE-WSW band of storm cells which were passing over the radar sites. The observations therefore primarily consist of observations from the west through north-east of the site. Due to the timing of the scans from the two radars, only data from Event 47 provide an adequate correspondence in time and scanned elevation angle.

5.5.1 EVENT 47

The data for event 47 consists of Collins radar data from 8° elevation at 215111 ED T (025111Z) (Fig. 26), and MIT data from 8° elevation at 025034Z (Fig. 27).

Reflectivity:

The reflectivity patterns of the two radars agree fairly well, with both radars indicating comparable areas of >45 dBZ returns. In this case, the Collins system indicates slightly larger reflectivity areas. This may be due to the wide Collins beam width and the presence of higher reflectivities at lower altitudes in this dissipating storm.

Velocity:

The MIT and Collins radars indicate very similar velocity fields over the full azimuth scans shown in Figs. 26 and 27. To the north-east, the Collins system shows peak receding velocities
of 16-19 m/s with a large area of 14 m/s. In the same area the MIT radar system shows the same features. Both radars show similar transitions to approaching velocities toward the west with large areas of 10-15 m/s approaching velocities. While the details of the comparison are not in complete agreement, the comparison between the two radars is remarkable, considering the differences in pulse volume sampling. It is likely that the relatively uniform, dissipating conditions of this event assist this comparison through mitigating the effects of the sampling differences.

Turbulence:

The Collins radar depicts several small areas of turbulence at 010-025°, 13-14 Nmi. The MIT radar does not show any similar areas of turbulence. These turbulence indications from the Collins radar could possibly be the result of wind shear in the vertical, coupled with the wide beam width.
REFERENCES


Data available for comparisons between the Collins WXR-700C-G and the MIT-FL2 radars. The event numbers used in this report are underlined. The event numbers not fully identified as being on the tape in question are in parentheses.

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Data available for comparisons between the Collins WXR-700C-G and the MIT-FL2 radars.

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