# TROUBLESHOOTING AIRBORNE WEATHER RADAR

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Radar, **RA**dio **D**etection **A**nd **R**anging, has become much more common on a wide variety of aircraft and has proven itself as an indispensable tool for high performance aircraft flying in the IFR environment. This discussion will be kept fairly simple and I will try to give the newer technician a sense of the big picture when it comes to troubleshooting airborne weather radar.

In order to provide the protection necessary for the aircraft, it must be operating at peak performance or it will become an unreliable indicator of what is ahead. Even when operating properly, pilots have gotten into trouble by misinterpreting what the radar is telling them. What may look like a large area of no precipitation behind a strong cell of rain can be an even stronger cell whose return is attenuated by the storm between the "clear" area and the radar.

When you add degraded performance on top of an already hard to interpret return, the pilot could easily be misled. I have always encouraged pilots and aircraft owners to have their radars checked on an annual basis in the spring. Radar performance can drop off gradually with time making it hard for a pilot to identify problems until the performance is really poor.

On April 4, 1977, a Southern Airways DC-9 crash landed killing 62 people onboard and eight people on the ground. The crew misinterpreted a radar shadow (attenuation of farther targets caused by nearer targets) as a hole in a line of thunderstorms. They flew the aircraft into the maw of the storm and encountered such heavy water and hail that both engines stalled causing the crash landing. The shadowing effect occurred on a radar system with much higher peak pulse power and a much larger antenna than the typical GA radar system.

When I first entered the avionics field, radar capability was a rare rating for the typical avionics shop. Those shops that did have a radar rating usually had an odd-duck technician that worked on the noisiest bench in the shop—the radar bench—with its clattering antennas, whining equipment fans and popping pulse forming networks. Now the rating is common and the noise is a little bit less however, a good radar man is hard to find.

A good understanding of the basics is a necessity for troubleshooting so let's have a review, shall we? Design factors that affect the performance of radar systems include transmitter power, receiver sensitivity and noise factor, frequency of operation, the shape of the radar beam, pulse repetition frequency, and pulse width.

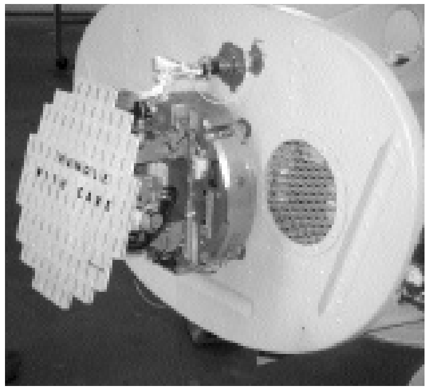
Transmitter power is important since even with the most concentrated beam, only a fraction of the power will reach the target. Much of the energy that hits the target will be scattered and only a fraction of the incident energy is reflected back to the radar

*EFIS Flight Deck with RADAR test pattern on EHSI and MFD* antenna. In general, the higher the radiated power, the more reflected energy will be received and the greater the possible range of the system. However, doubling the peak power of a radar system will only increase the range by a factor of about 1.2. Many newer radar designs trade peak power for average power and improved receiver sensitivity. The engineers insist the result is the same. The Collins WXR-84X and TWR-85X have a solid-state transmitter design and a peak power of only 25 watts.

The input signal-to-noise ratio is determined by atmospheric noise and other external factors and is the ultimate limit on the sensitivity of a radar receiver. As the signal and noise travel through the receiver, additional internal noise is added caused by thermal agitation within the receiver itself or by magnetron noise. At the output of the receiver, the signal-to-noise ratio (SNR) will be less than at the input. This ratio of input SNR to output SNR is known as the noise factor and the lower the noise factor, the better. This is hard to achieve since the received pulses are very narrow requiring a wide receiver bandwidth. As we all know, the wider the receiver bandwidth, the more noise the receiver will pick up. The receiver sensitivity of radar systems is often referred to as MDS or minimum discernable signal.

The frequency of operation is important and is selected by the manufacturer to give the best performance relative to the use of the radar system. For a proper echo, the quarter wavelength of the radar signal must be less than the size of the target. This means airborne weather radar is typically X-band, pulse modulated and operating in the 8-12 Ghz range. Most radars that I have worked with operate on a frequency of 9,345 Mhz ± 30 Mhz.

The shape of the radar beam is very important in the design of a radar. For purposes of airborne weather radar, a narrow beam is the most desirable because it concentrates more energy on the target, which means more energy will come back in the echo. Flat Plate antennas are better than dish antennas and larger antennas are better than smaller antennas for concentrating the beam.



*Single Unit Design combining the R/T, waveguide and antenna*

The pulse repetition frequency (PRF) of a radar will determine its maximum range. The PRF must be long enough to allow the echo pulses to return from the maximum range target. The longer the required range, the lower the PRF Scanning speed comes into play with the PRF since a high scanning speed and low PRF would cause targets to be missed. At least one pulse should be transmitted per a beam width of scan.

Pulse width will determine the minimum range of the radar and also the resolution size of the target. If a target is close and the echo is reflected back to the radar while the transmitter pulse is still being transmitted, then obviously that target will be missed. Most radars I have worked with had a pulse width of less than 4 microseconds so this isn't a problem. Also, many radars will shorten their pulse width in map mode allowing a higher degree of resolution for ground targets such as shorelines or islands.

Typical airborne radar systems come in two basic configurations. The early systems and some of the bigger current models employ a separate receiver/transmitter (R/T). The major components of these systems are the R/T of course, the waveguide, the antenna, the radome and the indicator. Common systems with the remote R/T setup include the Sperry Primus 300/400, the Collins WXR-300 and the Bendix RDR-1100 or 1200. The other common configuration combines the waveguide, antenna, and R/T and seems to be the style of choice for most current general aviation systems. Typical models include the Bendix/King RDR-2000 or the Collins WXR-850.

As always, in troubleshooting any avionics problem, getting a good debrief from the pilot is the first step in fixing the problem. Radar problems can be classified into three major groups. Performance problems including poor range or weak returns, is one group. Display problems such as distortion of range rings, "spoking" returns, dim or no display, and improper colors are a second category. Stabilization, scan and tilt problems comprise the final group.

All technicians should familiarize themselves with FAA Advisory Circular AC 20-68B, *RECOMMENDED SAFETY PRECAUTIONS FOR GROUND OPERATION OF AIRBORNE WEATHER RADAR*. This Advisory Circular goes into some detail about the dangers associated with microwave radiation and how to calculate a recommended safe working distance from the antenna for a particular radar system. Even though peak power outputs of many newer radar models have dropped, all technicians involved with troubleshooting radar equipment should treat these precautions seriously. Besides, there are still plenty of high power units in the field.

When beginning the troubleshooting process in the aircraft, putting the

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radar in test mode is always the first order of business. When testing, always assume the radar is transmitting. The test feature on early Bendix radars such as the RDR-150, RDR-160 or the RDR-1100 does not turn on the transmitter in properly operating units. The reason I say "properly operating" is because I did have one of these units transmit in test due to a circuit failure. On older Sperry units, the test feature does turn on the transmitter. To be on the safe side, always assume that the transmitter will come on during test mode operation. If the test mode produces a correct display pattern, you can safely eliminate a display problem.

Performance problems, by far the most common problem group, can be caused by several components in the system. The waveguide, the R/T, the antenna and the radome could all cause or contribute to degraded performance. In combined systems, the troubleshooting is easier because the choices are fewer, the receiver/transmitter/antenna unit or the radome.

In any troubleshooting scenario, a good visual is always an excellent practice. Is the R/T securely mounted in the rack and is the waveguide properly attached? Does the waveguide make any sharp bends? Are the o-rings installed on the waveguide flange? Does the antenna have any signs of corrosion or moisture problems? Does the "dish" or Phased Array look OK? No dents or corrosion? Does the radome have any sign of moisture penetration into the honeycomb? Are there any holes, cracks or signs of improper repairs to the radome?

All of my concerns about the radome stem from the fact that the best performing radar in the world becomes rather useless when put behind a "dirty window." I have had great success in spotting damage by removing the radome and holding it up toward the light and looking at the unpainted inside surface for dark areas in the honeycomb or uneven light penetration. If moisture gets into the honeycomb structure, it will freeze at altitude and break into adjoining cells. This process will continue until a large area of the radome is compromised unless detected and repaired early. Repairs to radomes should only be performed by repair stations with the proper rating or by the manufacturer. In many cases, the repair consists of cutting away the radome from the base mounting ring and replacing it with a new radome attached to the old base mounting ring.

For more information on radome repair and inspection, refer to the article *Radome Refresher* by Dale Smith that appeared in the April 2003 issue of this magazine. FAA guidelines for the repair of radomes can be found in Advisory Circular AC 43-14, *Maintenance of Weather Radar Radomes.*

A flight test is sometimes necessary to determine overall performance and to check stabilization operation. As a general rule of thumb, if the radar has ground returns out 80 miles at 10,000 feet, the performance of the system is good.

Certain types of display group problems are becoming less of an issue as EFIS and multi-function displays are relegating many radar installations to the status of sensor. In newer aircraft, the MFD or EHSI serves as the radar display. The function is still there but the dedicated indicator is becoming a thing of the past. This makes troubleshooting simple because in these installations, the display function is totally separate. When an MFD goes bad, it will go bad for all functions, not just the radar. In EFIS systems, the ability to move the radar presentation to different displays will help diagnose display problems.

When no dedicated indicator is utilized, the controls are usually grouped on a separate control panel. These panels are typically very reliable and problems are usually the result of broken knobs, coffee spills, and failed switches; all easy to diagnose. Of course having said how easy it is, I am sure I will hear about some of your experiences with tough control panel problems.

In older dedicated systems, power for the indicator often was derived from the R/T. This made troubleshooting more difficult since a power supply problem in the R/T could cause a good display to be distorted or inoperative.

One type of display problem, "spoking," is almost always in the R/T. Spoking of the display is caused when the AFC circuit in the receiver/transmitter loses lock and sweeps the local oscillator through its entire frequency range. Whenever the local oscillator passes through the transmitter frequency, returns will appear briefly. This sweeping of the frequencies creates a spoke effect on the display that looks like the spokes of a wheel emanating from the apex of the display. When this symptom is present, a trip to the bench to replace the magnetron or repair the AFC circuitry is in order. This problem can be intermittent because as the radar warms up, the frequency of the R/T could move within range of the AFC circuit to lock on (or out of range). Resetting the "locked-on" frequency of the local oscillator to the center of the AFC control range fixes most of these problems.

Stabilization problems can come from the vertical gyro source, misalignment or failure of the stabilization circuits, antenna sweep circuitry problems and tilt circuitry problems. Hopefully the pilot will be able to tell you how the radar worked with stabilization turned off. With the stab off, the tilt control is the only external input to the radar sweep. If the radar worked fine with the tilt control only, then the stabilization problem is just that, a stabilization problem and probably not related to sweep or tilt problems. In this case, following the alignment procedure called out by the manufacturer will usually fix the stabilization problem or identify the culprit. Before proceeding, make sure you have inspected the antenna and radome for signs of water damage. The reason I mention the radome in relation to sweep or stabilization problems is because a really bad radome can bend the radar beam and give the appearance of a stabilization problem.

To check the tilt and scan operation, remove the radome and watch the antenna deflect as someone in the cockpit exercises the tilt control throughout its range. Turn the stabilization on and off with the tilt control at zero. Assuming the aircraft is level, this should produce no change in the tilt of the antenna. If the antenna tilt changes by more than a "twitch," then the stabilization input from the vertical gyro source is not correct or the stab circuitry is out of alignment.

Pilot problems are the final category. During the debrief, it is always a good idea to ask two very important questions listed in the AEA *Pilot's Avionics Troubleshooting Guide* (found under Pilot Resources at www.aea.net). They are, "Is the brightness turned down?" and "Is the gain turned down?" If either question causes the pilot to get a sheepish look, do not embarrass him or her with any more follow-up questions. Let the pilot steer the discussion in another direction and don't follow him or her out to the aircraft. If the pilot returns to confidently tell you that the answer to both questions is no, you can proceed with your debrief. If he or she does not return, you just fixed another problem without ever lifting a finger! ❑