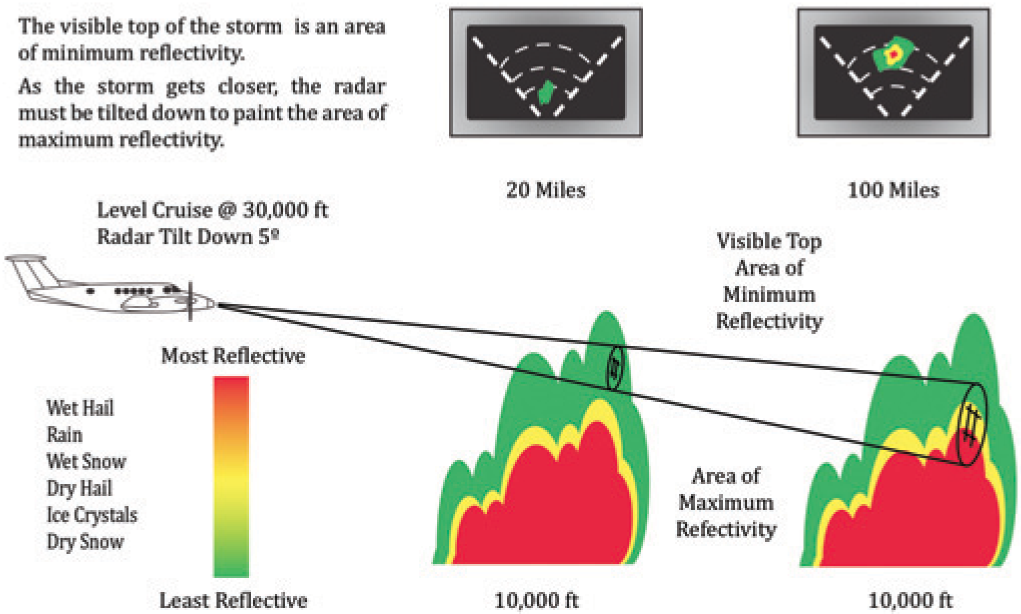

-- Figure 4-1: Reflectivity --

Airborne Weather Radar

PART III: Theory & Operation for More Effective Troubleshooting

STORY BY DAVID W. MANSEN, TEXASGYRO

EDITOR'S NOTE:
Avionics News *will present this white paper, authored by TexasGYRO, in multiple parts. This white paper presentation is for training purposes only. Its sole intent is to improve the maintenance technician's knowledge and understanding of airborne weather radar systems. Refer to manufacturer's most current technical data, maintenance and/or installation manuals or pilot's guides whenever performing maintenance on aircraft or aircraft components.*

PILOT'S PERSPECTIVE

Understanding a pilot's perspective as to the radar's operation is critical to understanding the complaint and repairing the system.

▸ *Weather Observation/Reflectivity*

Radar reflectivity (return levels) is calibrated as rainfall rates, inches per hour. The manufacturer will design the system with three or four levels of returns. These will be divided equally between the minimum and maximum. A typical three-color system will be green, yellow and red, with red being the most severe. A typical four-color system will be green, yellow, red and magenta, with magenta being the most severe.

• ***Thunderstorms:*** When thunderstorms develop, they build up, and cell height is an indication of storm intensity. Rain showers that develop low and stay low are typically not hazardous to aviation. Hazards to aviation will build in the 18,000 to 25,000 feet range. FAA Advisory Circular 00-24B (Thunderstorms) should be consulted for detailed information on thunderstorms.

Never regard any thunderstorm as light, small or inconsequential. All thunderstorms must be avoided by at least 20 nautical miles.

• ***Tornados:*** Tornados cannot be distinguished from thunderstorms by radar, but the shape of the thunderstorm return can indicate the possibility of tornado activity. Sharp-edged thunderstorms, or those that show projections or crescent-shaped indentions, should be given additional separation.

• ***Hail:*** Hail is generally associated with large thunderstorms. Wet hail is an excellent reflector of radar energy. It is common for some hail shafts to be quite narrow and difficult to detect.

• ***Icing:*** Radar will not warn the operator of icing conditions, either super-cooled water droplets or ice crystals, unless it is associated with active precipitation.

• ***Snow:*** Dry snow cannot be reliably detected with radar. Heavy, wet snow can often be difficult to detect and identify.

• ***Lightning:*** Lightning is static discharge created by the massive vertical movements of air in a thunderstorm. These massive vertical movements of air make thunderstorms so extremely dangerous to aviation.

• ***Visible Top:*** The top of a thunderstorm provides little reflectivity for the radar. The radar must be tilted down to paint the meat of the storm, the area of maximum reflectivity.

► *Tilt Management*

Tilt management is the single most important factor for effective use of an airborne weather radar system. Failure to properly manage tilt is the most misused function of weather radar systems. Too low of a tilt setting results in excessive ground returns and the inability to distinguish weather from ground clutter. With tilt set too high, the beam will scan over the top of weather. Either way the pilot will not distinguish crucial weather data. Correct tilt angle is directly dependant on the storm's distance from the aircraft and upon height and intensity.

At 10 nm, one degree of tilt motion will move the center of the beam up or down 1,000 feet. At 80 nm this one degree of motion will move the center of the beam 8,000 feet. Think about it, five degrees of tilt at 80 nm will move the center of the beam 40,000 feet.

It must be remembered that when thunderstorms develop, they build up; cell height is an indication of storm intensity. Rain showers that develop low and stay low are typically not hazardous to aviation. Hazards to aviation will build in the 18,000 to 25,000 feet range. This is where the radar must search for activity.

At high altitude cruise the tilt must be adjusted down as the storm gets closer to the aircraft or the radar will scan over the top and miss the weather.

► *Stabilization*

The purpose of radar stabilization is to maintain a constant radar scan at desired tilt angle, level with the Earth's horizon during normal aircraft operations and maneuvers.

During turns, aircraft bank will roll one wing down. As the radar scans to the wing down side it will paint excessive ground clutter. On the wing high side, the radar will scan above storms and fail to display accurate weather data to the pilot. Stabilization will adjust the tilt angle to maintain a level scan with the horizon.

During climb or decent, stabilization will adjust the tilt angle up or down as appropriate to maintain a level scan with the horizon.

If not for stabilization, the radar would scan above or below possible targets, thus missing potentially dangerous weather.

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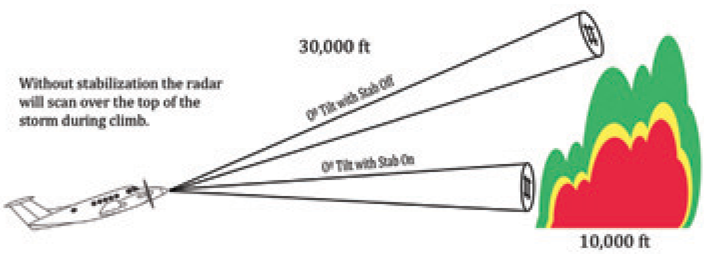


-- Figure 4-2: Stabilization On/Off --

A reference (typically this is 26Vac or 115Vac at 400Hz) is established by the aircraft's vertical gyro. Stabilization accuracy is dependent on the aircraft's vertical gyro and 400Hz inverter. Most vertical gyros and radar systems require 400Hz AC.

Two degrees of stabilization errors is considered acceptable. To diagnose tilt calibration, establish level flight at 10,000 feet with radar stabilization on. Tilt the radar antenna down until ground returns begin to show on one side or the other and take note of the tilt setting. Continue to tilt down until ground returns show on both sides. If the difference is less than two degrees, this is considered acceptable. If the difference is greater than two degrees, there might be a stabilization problem.

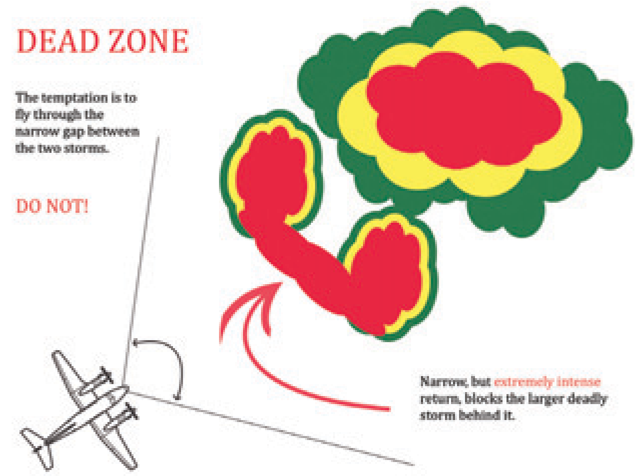
Stabilization errors are more pronounced in roll than in pitch. Roll trim is used to balance roll stabilization errors. This is adjusted in flight by the pilot, and procedures vary by system. Best means is to establish level flight at 10,000 feet, radar range at 100 nm. Tilt down until you just barely paint ground returns. Make a series of right and left turns, each with constant 20 degrees bank. Stabilization will keep the radar painting level with only minor ground returns on each side. Adjust the roll trim to balance out these minor ground returns on each side.

Radar stabilization is limited by the tilt range of the radar antenna, and this will vary from system to system. Stabilization limits may be exceeded during aircraft maneuvers, and these limits are typically +/-25 degrees.

Response time and accuracy also is limited by the type of gyro installed in the aircraft. A newer AHRS system will have better performance than an older iron core mechanical gyro. When the aircraft goes into a bank, it is not uncommon for the radar to paint some ground returns on the first sweep with an older iron core mechanical gyro. Newer AHRS systems will have considerable less ground returns from the first sweep upon entering a bank.

► *Dead Zone*

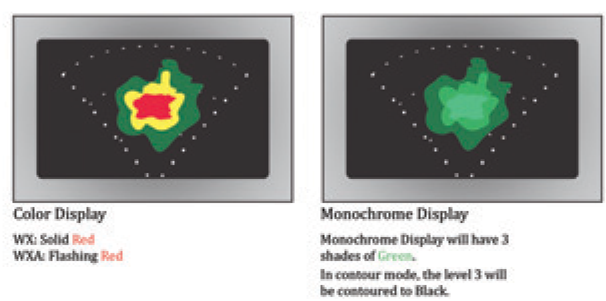
Often when flying in the spring, the pilot will be confronted with two large level-three returns separated by a narrow band of level three. The temptation will be to rapidly pass through this narrow band of rough weather to the large clear area behind it. Stop, do not fly through, and fly around. This narrow band is so intense that the radar pulses are unable to make it through to the severe storm behind. This is called the dead zone.



-- Figure 4-3: Dead Zone --

► *MODES: Wx/Wxa and Contour*

A color display will display level three as red in Wx (weather) mode. Wxa (weather alert) will flash the level three red. This is a hold-over from the older monochrome systems which had three different levels of green. It was often difficult to differentiate the three different levels, so they would flash the level three. Contour on a monochrome system will show the level three in black contoured by level-two and level-one greens.



-- Figure 4-4: Contour, Wx/WXa --

► *GAIN: Ground Map and Reflectivity from Land/Water*

Weather radar can be used for ground mapping. The main difference is in the use of the gain control.

The angle of incidence will determine the amount of reflected radar radiation. This is relative angle between the radar beam and the target surface. The greater the angle of incidence, the larger the reflected return.

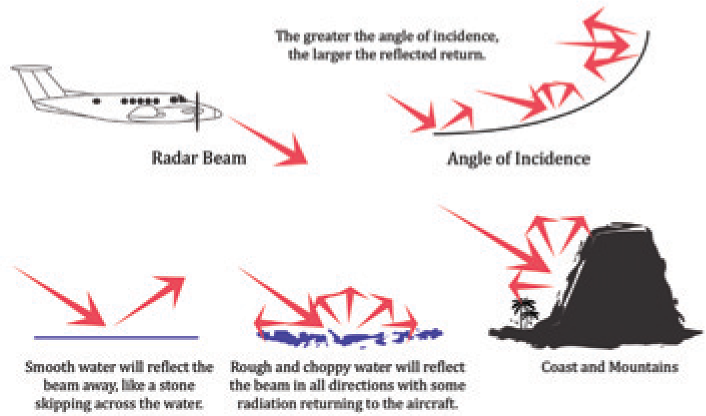
This is one of the fundamental principles of stealth technology; that radar waves will skip off of the flat surface of an object and away from the source radar. Look at the F-117's (the first stealth fighter) flat surfaces with very little curves, and almost nowhere will the aircraft give for a good radar return.

Smooth water will skip most of the radar waves forward, with very little coming back to the aircraft. Rough and choppy water will reflect the radar waves in all directions with some of these returning to the aircraft. Rougher water will give a stronger reflection.

Ground from flatlands or coastal regions gives a good strong return. Mountains can saturate the radar with a solid level three; this is where "gain" control is useful.

Gain control is critical to consistent radar operation. When gain is set to auto, or automatic gain control, the system will consistently display weather as the correct level. When taken out of "auto" and placed in manual gain, all that can be determined from the display is a relative difference between two levels. Level one, two or three displayed in manual gain will not correlate to level one, two or three weather returns, just a relative difference between the levels.

Because mountainous terrain can saturate the radar, it is often useful to use map mode and variable gain to differentiate the different return levels of the terrain. Pilots should never use variable gain to depict weather.



-- Figure 4-5: Angle of Incidence --

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AIRBORNE WEATHER RADAR

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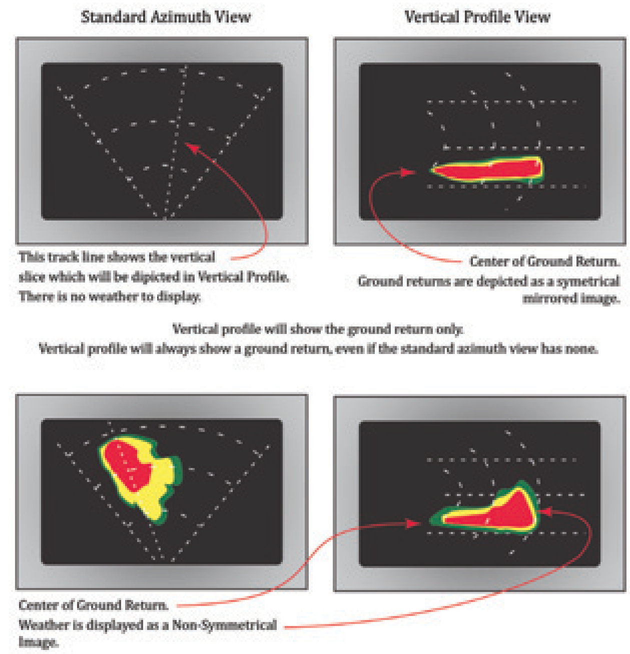
The curvature of the Earth limits ground mapping from high altitude. Weather radar will not normally paint ground returns from high altitude beyond 90 nautical miles, because the Earth's horizon at this distance and altitude will be almost parallel to the radar beam. Storms, hills, mountains, large buildings and cities will be painted.

► *Vertical Profile*

Thunderstorms build upwards with the height of the storm being an indication of its severity. Vertical profile was developed by Bendix/King , beginning with the RDS-82VP, as a means of easing the difficulties caused by improper tilt management, thus enabling pilots to readily determine storm height and intensity. The radar functions by parking the azimuth scan at the desired track position and scanning, utilizing tilt up and down.

The pilot will select an azimuth track line where he wishes to view the vertical slice. Vertical profile will then display a return image of the selected slice. VP works best in a wings-level scenario. Turns will obtain an angled and moving (azimuth) depiction of returns.

Ground returns are normally depicted by a symmetrical mirrored image both above and below the radar beam. A non-symmetrical image depicts weather. ❑



-- Figure 4-6: Vertical Profile Display --

Part IV of this white paper will appear in the June edition of Avionics News.