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FOR THE PILOTS OF OWNER-FLOWN, CABIN-CLASS AIRCRAFT

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Watching a New CJ3+ Come to Life

Radar Guidance: Understanding the Math

Flying by the Rule of 10's

Miller: Meet My New Plane

BEAM ME UP SCOTTY!

A discussion on radar beam geometry

by **Joe Ratterman**

Even though spring thunderstorms are behind us this year, keeping your radar skills sharp is important all year-round. You never know when convective activity might pop up around you. In last month's issue, I described a basic approach on how to use your onboard airborne radar system to look up, out, or down, depending on which phase of flight you are in. Without getting into too much of the science and geometry of radar systems, I wanted to simplify how to use your radar system to navigate tactically through and around dangerous weather.

The green line in the images above shows the original flight path, prior to deviating to the left-of-course. Using the NEXRAD display, a pilot would be tempted to only deviate a few degrees left of the indicated weather, but using the radar display suggested a much greater deviation.

This month, I would like to introduce a little bit of the math behind your radar system in order to build on the basic knowledge you now have. We'll focus on "dish size," and the corresponding radar beam angle (basic cone geometry) that goes along with different dish sizes.

Before getting into the specifics of dish size, I would advance the view that airborne radar should be your *primary* tool for tactical weather navigation and avoidance. Last month, I showed you side-by-side screen shots taken on approach to my home airport, one with NEXRAD weather and the other with on-board radar. The photos to the left highlight how different your NEXRAD display can be when looking at the weather immediately in front of you. Below is another example that shows, once again, why pilots should never count on NEXRAD (the left image) for tactical weather avoidance. Notice the location and the intensity of the storms depicted at two o'clock in front of the aircraft in both images. NEXRAD is great for seeing the big picture, but use your radar for maneuvering through the weather 10-60 miles in front of you.

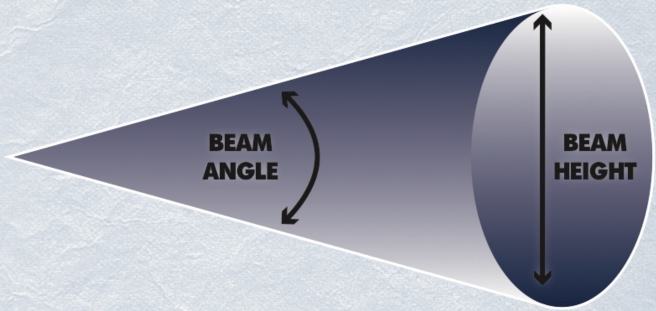
Understanding your radar beam's geometry starts with knowing the size of your radar dish. Since you are reading *Twin & Turbine* magazine, I'll assume you have a typical cabin-class airplane, and therefore you probably have either a 10-inch or 12-inch dish. Two very popular systems for airplanes in this class are the Bendix/King RDR 2000 and the Garmin GWX 68 (and the newer GWX 70). These are both excellent systems and can provide invaluable real-time weather information in the cockpit.

If you are wondering which system you have, refer to your AFM and any supplemental documentation that you received with your airplane. In my experience, most turboprop airplanes have a 10-inch dish (older Piper Meridians had the RDR 2000, newer Meridians have the Garmin GWX 68 or 70, newer TBM's have the Garmin GWX 68 or 70, and Pilatus PC-12's have the RDR 2000). Most small and medium-size twin-engine jets have a 12-inch dish, and late model Cessna Mustangs, M2s and C's have the Garmin GWX 68 or 70 installed.

In what will probably come as a surprise to most readers, the smaller the dish, the larger (or wider) the beam angle! If you have a 10-inch dish, then you have a 10-degree beam angle, and if you have a 12-inch dish, then you have an 8-degree beam angle (7.9 degrees to be precise). Larger jets may have a 24-inch dish with a corresponding narrow 4-degree beam angle. The smaller the angle, the more concentrated the area of radar coverage and the more precise you can be with scanning specific vertical regions of the sky in front of you.

Is a 10-inch dish better than a 12-inch inch dish, or is the 12-inch inch dish better? The answer is "not really." At least not for what we are trying to use these systems for. It does mean that the math changes on what portion of the vertical region in front of you is covered by the radar, but as long as you know what your radar can "see" at different distances in front of your airplane, then you can use either one effectively.

The geometric formula for beam height may look a little intimidating at first:



Beam Height (ft)
2 x Distance x TAN (Beam Angle / 2)

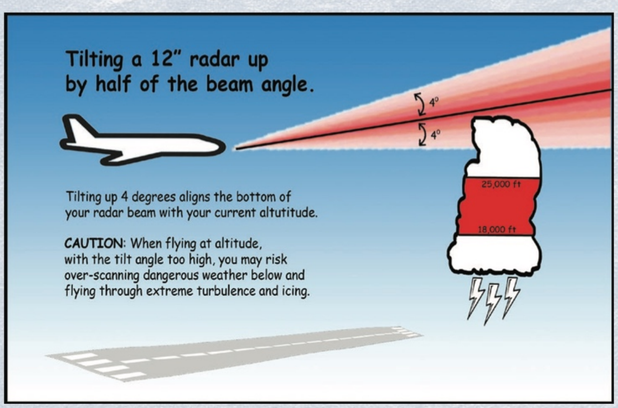
	Beam Angle	10 miles	15 miles	20 miles	40 miles	60 miles	80 miles
10-inch Dish	10-degree	10,600 ft	16,000 ft	21,300 ft	42,500 ft	63,800 ft	85,000 ft
12-inch Dish	8-degree	8,400 ft	12,600 ft	16,800 ft	33,500 ft	50,400 ft	67,100 ft

Following is a table that shows what the beam height is of radar coverage, for two different dish sizes, at different distances in front of an airplane. The resulting math will hopefully demystify the formula for you.

As your radar sweeps left and right, both the 10-inch and 12-inch dish sizes cover a large vertical area of the sky, even at just 40 miles out. At 80 miles out, your beam angle is encompassing an enormous vertical block of the sky.

It would be nice if this formula *precisely* defined the area covered by your radar's beam, but unfortunately these systems are prone to "scatter" on the edges of the beam, so you will likely pick up unwanted ground returns even when you have your tilt and range adjusted such that the radar beam should be scanning above the ground. That's ok, however, because most of our scanning should be done near the center of your radar beam anyway.

By understanding the shape and size of your radar beam's cone, you can begin to understand what's happening when you tilt your radar up and down. The first and simplest rule of thumb is that tilting your radar up by half of your dish's beam angle will essentially align the bottom of your radar beam straight out and level in front of the aircraft, with the top of the beam now angled up by the full beam angle. For example, titling a 12-inch dish up 4 degrees (8-degree beam angle divided by 2) will bring the bottom of the beam level with your altitude, and the top of the beam pointing up 8 degrees. At 40 miles out, this tilt angle is looking at the vertical slice of sky starting at your altitude and going up 33,500 ft from there. At FL200, you are looking at the portion of sky from your present altitude all the way up to 53,500 ft above sea level!



If you look back at the recommended tilt angles I presented last month, along with the math provided in this article, you can "do the math" yourself and see how your radar beam should be scanning, at a minimum, the 7,000 ft convective hotspot (18,000 ft to 25,000 ft) at each of the different phases of flight (takeoff, level en route, and approach).

Now it's time to go out and practice and put your new-found knowledge to the test. Do a bit of research to confirm which radar system you have, what your specific dish size and beam angle are, and then use the math from this article and have a little fun with your radar system in-between calls to ATC on your next flight. T&T

Joe Ratterman is an ATP pilot, type-rated in the Cessna Citation Mustang C510, with 2,500-plus hours in his logbook. Joe retired from a successful corporate executive career in 2015 and now flies as a professional charter pilot for Kansas City Aviation Company (KCAC) based in Overland Park, Kansas. He is also the current board chairman/president for Angel Flight Central.