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Radar Limitations

By Frank Mummert

It's a classic scene from World War II movies. The captain and his executive officer are hunched over the radar operator, the three of them staring intently at a glowing screen. A radar beam circles the blank screen once, twice, a third time. Then, suddenly, the screen lights up. "There he is," the captain exclaims. The captain turns and, with fire in his eyes, shouts, "we've got him this time! Battle stations!"

It's an exciting scene that pumps the adrenaline every time. It is also completely wrong.

Anyone who has spent any time staring into with a radar screen quickly discovers that there is a lot of information being presented – some of it useful, most of it not. According to the Rules of the Road, a mariner has to consider the limitations of his radar unit when making decisions, but most radar units don't include a list of these limitations in the owner's manual. A radar class will cover these limits, but there is no requirement for recreational boat owners to take such a class.

The limitations are sea and air clutter, minimum and maximum range resolutions, beam width and beam height. Although these may sound technical, the basic concepts are fairly simple – even intuitive.

SEA AND AIR CLUTTER

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Radar reflects best off of hard vertical surfaces and slanting beaches may be overshadowed by trees or hills further inshore.

Radar was originally billed as a way "to see in the fog" and a significant amount of its application deals with its use in restricted visibility. However, radar is not the all-seeing eye that Hollywood portrays. The best example of what radar really is can be seen on the nightly news.

As part of the local news broadcast, a weather forecaster stands in front of a map of the area as rain clouds, shown in green and yellow, march across the screen. This precipitation, your forecaster explains, is being tracked by the super maximum Doppler radars mounted throughout your viewing area. Obviously, if the radar is picking up the movement of rain and snow showers, it is going to have difficulty picking up the fiberglass yacht that is moving in that rain shower.

Water is actually an excellent radar reflector. Both rain and waves can reflect radar energy back and create images on the screen, blanking out entire regions. Most recreational radar installations are less than 15 feet off the water's surface and wave heights of five to seven feet can often be seen on the radar screen. This becomes especially true if the boat is rolling or pitching as it moves through bad weather.

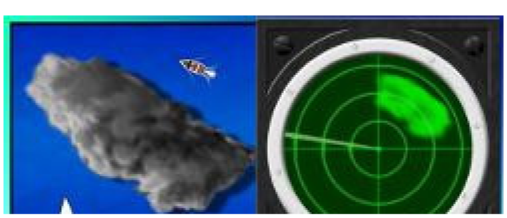
Additionally, the direction of the waves can affect the radar return, since breaking waves have one side that is steeper and more vertical than the other. Because of this, the waves on one side of the boat may be much better reflectors.

ATC (Air Traffic Control) and STC (Sensitivity Time Control) on high end units can reduce the effects of air and sea clutter, but most units rely on automatic controls. Unfortunately, without having control over these functions, the operator may not be able to determine how much of the return is being blanked out. Knowing the size and shape of a squall can allow the captain to decide how best to avoid it, along with anything that might be hidden with in the return.

MINIMUM AND MAXIMUM RESOLUTION

The basic concept of radar is that a radio signal is transmitted in a specific direction, and then the radar unit switches over to a receiving mode and measures the amount of energy returned and the amount of time it takes for the signal to return.

Because this takes place over a period of time, the radar beam moves a certain distance from the antenna before it can start to receive. Depending on the specifications of the radar unit and the range for which it is set, that distance may be anything from several feet to a significant part of a mile. Anything inside that distance will not be "seen" by the radar.



In general, this is not a problem since anything that is close was probably far away at some point and the radar operator should have been tracking it before it got close enough to disappear. But there are situations cases where this is not the case. A small contact with poor reflective characteristics might not reflect enough energy, until it gets close. A target may emerge from the water within the minimum range. Most often the radar may have been off or in radar watch mode, allowing a contact to get close without detection.

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Radar reflections off of heavy rain or snow can obscure vessels or other hazards.

The best technique for dealing with minimum range issues is to switch ranges. If the boat is operating in open waters with the radar at the maximum range, the operator should check the closer ranges on a regular basis. If the horizon is cluttered with other vessels and contacts, the operator may need to continuously move between short and long range scanning, while still maintaining plots of other vessels. Use of a separate paper plot becomes important in this situation, since it becomes impossible to keep the plot on the screen.

Maximum resolution becomes an issue in two cases. The first is the maximum distance the radar can "see" because of height. Radar energy is sent out in "line-of-sight," meaning it does not bend much at the physical horizon. Radar beams can only travel about 15 percent further than light waves, meaning that the radar is limited to just beyond the horizon for effective scanning. Because of the curvature of the earth, a contact can be hidden below the effective scan of the radar. A radar antenna mounted fifteen feet off the water has an effective horizon of about five nautical miles. Doubling the height of the antenna moves the horizon out to slightly more than seven nautical miles.

While a radar set for a range greater than this distance may produce a return, it will only do so if the contact is tall. The tops of a mountain range may be seen at the edge of the 48 mile maximum transmitter range, but even a large cargo carrier would be hidden until it got within the 20 mile range.

While placing the antenna higher in the rigging will extend the range the radar can see, the trade off is that the radome will be less stable as the vessel moves. As anyone who has ever been seasick knows, the further one gets from the center of the boat, the more movement is felt. Good radar plotting depends on having a stable platform, so the antenna should be mounted as close to the deck, consistent with crew safety, as possible.

BEAM WIDTH

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The more vertical shape of wind blown waves can increase the screen clutter on the windward side of the vessel.

The other issue related to maximum resolution is the width of the radar beam. Radar transmits for a period of time, usually microseconds, and then switches over to receiving, interpreting the signal both in terms of the time it took to receive it and the amount of energy received. It is similar to spraying water from a hose while turning in a circle. The water makes a horizontal spray.

Because of this radar beam width, the receiver may be getting energy from the beginning, the middle or the end of the pulse. The radar screen solves this by "painting" the screen with a bar that covers the entire width of the pulse.

The beam width of recreational radar is generally about 3 degrees of the entire sweep. At five miles, this means the beam is about 700 feet across. This width can affect the radar in two ways. The first is that a small target may not be able to reflect enough energy back to the system to create an effective display on the screen. The other way the beam is affected is if there are two separate contacts with a space of less than the beam width between them. These two contacts may show up on the screen as one large return.

Two vessels, traveling on similar courses, may give a single large return at times, then break in two and come back together. The opening to a small bay may be covered completely. Multiple channel markers may get clumped into a single mass. By relating the view on the radar with that on the chart and looking at the screen with different ranges, it is generally possible to separate fixed items into individual contacts.

BEAM HEIGHT

As the radar beam is created, it is manipulated electronically to be as flat as possible. If it were allowed to expand up and down, the return off of the water nearer the vessel would blank out anything further away. Because of this, the radar return is assumed to be a relatively flat dish of energy, expanding from the antenna. This works well to detect contacts that have a flat, vertical surface, like trees or hills. It does not work as well on sloping structures like beaches.

In a situation where there is a relatively flat and featureless beach leading up to a dense, vertical surface like a hillside or forest, the radar operator can be fooled into thinking that the land surface is several hundred feet further away than it is. In these cases, the radar image has to be coordinated with charts and dept sounder to determine the true location. While charts do have some contour lines that may indicate the height and grade of the land, trying to interpret this at night with limited visibility can be tricky. More information can often be determined by changing range scales or adjusting gain, if possible.

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RADAR TRAINING

Although there is no requirement for radar training for recreational boaters or even for entry-level master's license, operational training is available at a reasonable cost. The choices are online, classroom or home-schooling.

The Starpath School of Navigation is the premier recreational boating radar class. Its programs are available on-line or through their classroom courses in Seattle. In-class courses at Starpath are on hiatus throughout 2009 while the school focuses on its online curriculum, but should be up and running again thereafter.

If the trip to Seattle is not in your plans, the American Sailing Association has

The width of the radar beam can join contacts together on the screen, resulting in confusing or misleading images.

introduced a Radar Endorsement to their program. Taught by instructors using the Starpath course materials and software, the course does require that you have completed some prerequisite sailing courses, but for a power boater willing to forgo the benefits of ASA certification, some schools may make an exception.

The United States Power and Sail Squadrons also offer a course in radar, but the material is still fairly new and the course may be difficult to find. The organization offers a home study course that is available to the public, but neither of these courses is designed to have live or simulated radar.

Finally, there are the radar operator classes offered by professional mariner schools. While these may be seen as overkill and are usually more expensive than the recreational boater classes, they are an alternative if you learn better with a live instructor. Generally speaking, radar operator classes will require about three days for a "rivers only" class, designed for towboat operators, or five days for an ocean course.

Whatever program you choose, the most important goal is to become familiar with the radar system's limitations. The results will improve your boat handling, increase your safety and maybe even keep you out of court.

Frank Mummert spent 15 years in the Navy where he taught nuclear engineering. He is a licensed captain. Currently he teaches sailing, and for the last two years has served as an instructor for sailors trying to obtain their captain's licenses through the Mariner's School, which is headquartered in Princeton, NJ.
