

# Choosing a Radar Reflector

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Several years ago I decided to purchase a radar reflector to improve my sailboat's radar image. I learned that no one had satisfactorily analyzed these devices, properly called Radar Target Enhancers, or RTE, in the marine environment and I discovered that there are a number of misconceptions about how the units work and what characteristics are desirable. After a lot of research and analysis I did choose one (and write a book and several magazine articles dealing with radar reflectors). The process I followed should be helpful to anyone looking for an RTE for their own boat. My choice was strongly influenced by the fact that most of my sailing is in a 42-foot monohull sloop on Chesapeake Bay. Your selection will depend on your boat, where you sail, and your budget.

## Radar Target Enhancer vs. Radar Reflector

A comment on terminology is in order. Some devices for improving the radar signature of sailboats are strictly passive; that is they simply reflect radar waves. Others are active; that is they are electronic devices that receive the radar wave, amplify the signal, and retransmit it. I use the term *radar target enhancer*, or RTE, to include both passive and active devices, usually distinguishing between *active* RTE and *passive* RTE. I also use the term *radar reflector* to apply to strictly passive RTE. Unfortunately the generic term "radar target enhancer" is commonly used to mean only active units. Context should resolve any ambiguity.

The relevant performance factors need to be described before discussing specific designs. These are the effective "size" of the RTE, i.e. the strength of the reflected signal, how the effective size changes as the orientation between radar and RTE changes, and cost. Cost is obvious but the other two factors need some discussion.

## Reflected signal

The effective size of an RTE is a measure of the strength of the reflected signal. It is referred to as the radar cross section (RCS) and is traditionally measured in square meters ( $m^2$ ). Multiply the strength of the radar pulse hitting the RTE by the RCS to get the strength of the reflected pulse. Large RCS makes the target easier to detect and a target with larger RCS will be detected at greater range and in worse weather. If you often sail in reduced visibility, as I do, you should carry a unit with the largest available RCS;  $10 m^2$  is a good number to aim for. If you do most of your sailing in good

visibility you can probably get by with a unit having a smaller RCS. Note that the RCS may be quite different from the physical size.

## Azimuth and elevation coverage

RCS depends on the device's orientation relative to the radar beam and how the RCS varies as orientation changes is just as important as the magnitude at any particular orientation. For example if you have a unit mounted on the mast of your boat and a radar on a nearby vessel

is observing you, the azimuth, or relative bearing, of the radar relative to your boat changes as the vessel steams around you (see the diagrams). If your boat heels, your mast tilts off vertical, either toward or away from the radar, and the relative elevation angle between the radar beam and the base plane of the RTE changes. The RCS depends on the aspect, i.e. the azimuth and elevation, or relative bearing and angle of heel, at the instant a radar pulse hits the unit. You need a complete tabulation of the radar cross-section at all angles of azimuth and elevation to understand the unit's performance.

Some angles will produce a small cross section while others will produce a large cross section. The important point is that the unit provides large radar cross section over the most important ranges of azimuth and elevation. The tradeoff is determined by the application. For example, if the RTE is mounted on a catamaran, the unit should produce strong reflections at low elevation angles and at all azimuth angles. If mounted on a monohull sailboat the range of good elevation coverage should be much larger so that the unit is effective when the boat is heeled. If you anticipate using the enhancer for search and rescue applications the best units will also provide strong reflection at high elevation angles to be picked up by a search aircraft.

### **Coverage gaps**

If you want to maximize the potential for collision avoidance there should be no coverage gaps, or ranges of azimuth and elevation for which the RCS is close to zero, and the variation in RCS with bearing and angle of heel should be small. For example if seas are calm, a single azimuth/elevation aspect could be presented to the radar during the entire constant-bearing-decreasing-range collision encounter. If that aspect corresponds to a gap in RCS, your vessel could be invisible to radar right up to collision. In other conditions, when your boat is rolling and pitching, the RCS seen by radar may change significantly from sweep to sweep of the antenna. If the RCS varies a lot as your vessel rolls and pitches, some sweeps will get a reflection and some might not. Intermittent detection makes it harder for a human radar operator to track you and it might keep automatic radar plotting assistant (ARPA) software from detecting you at all.

Generally speaking, you want large RCS over all azimuth angles and all elevation angles up to the expected angle of heel of your boat, no significant gaps in RCS, and little variation of RCS with aspect. Such complete information is generally lacking in product literature. My research focused on detailed mathematical analysis of all the common RTE, resulting in complete descriptions of how the RCS of each device varies with azimuth and elevation angles.

### **Active vs. passive**

Before analyzing specific designs, I examined the differences between the two types of RTE: active and passive. Passive units are made of flat metal plates and lenses that passively reflect the incoming radar pulse. The strength of the reflected signal is just the strength of the incoming radar pulse multiplied by the RCS. Eliminating gaps in coverage and providing smooth variation of RCS with aspect is difficult using passive reflector plates and many passive units are prone to spotty coverage, but they are inexpensive and reliable and can provide good RCS at extreme angles of heel. Active units are electronic systems consisting of a receiving


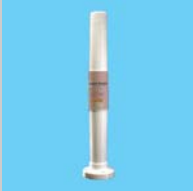

antenna, electronic amplifier, and transmitting antenna. They work by receiving a radar pulse, actively amplifying it, and transmitting the amplified pulse back toward the radar. Electronic amplification can provide much larger RCS than passive units, little variation of RCS with aspect, and no isolated coverage gaps. However, like all electronic devices they are subject to failure and they consume power. Purchase price and installation costs are much higher for active RTE than for passive units. Also, the amplifier may be overloaded if the unit is close to the radar transmitter. Overloading reduces the RCS of an active unit as the range to the radar decreases once the “critical saturation range” is passed. Much of the RCS advantage of active units is lost at ranges less than about 3 nautical miles (6,000 yards).

**My selection process**

The accompanying tables shows the ten designs I analyzed along with approximate cost. Additional details of my analysis are found in my book (available through this web site), succeeding articles in this series of articles, and in the magazine articles referenced at the end of this article.

I first looked at active units because they provide large RCS and smooth variation of RCS with azimuth and elevation, but decided against them because of the high cost and the decrease in RCS at short range. My sailing on Chesapeake Bay is almost exclusively what I would describe as close quarters and I am most interested in 2 to 3 mile detection for which the benefit of an active unit is not obvious.

**ACTIVE UNITS**

| Unit           | Image   | Approximate Cost |
|----------------|---|------------------|
| Sea-Me         |  | \$900            |
| Ocean Sentry   |  | \$1,300-\$2,000  |
| Seahawk TE-70X |  | \$4,600          |

That left the passive units. Collapsible octahedrals, such as the 12½" Davis Echomaster, provide very strong response at some ranges of aspect, particularly at large elevation angles, which makes them good for search and rescue applications. These units are the least expensive type of enhancer, which makes them an obvious choice for limited budgets. However the gaps in response at some ranges of aspect concerned me and my budget allowed me to consider other options. Should you decide on an octahedral I would recommend a rigid mount as the common practice of hanging an octahedral from the spreaders with a flag halyard allows the unit to flop around producing an undesired intermittent response.

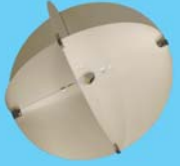




The Cyclops is designed for masthead mounting. The large Cyclops #3 provides good RCS over a respectable range of aspect, but masthead mounting adds almost a foot to required bridge clearance. It was not an option for me as my mast is already at the controlling height for getting under bridges on the Intracoastal Waterway and a cruise along the ICW is in my future. If bridge clearance is not an issue for you, the Cyclops should be considered because of its good RCS. However, you should take into consideration the installation cost as all masthead equipment has to be remounted with longer cables, windage and weight aloft (19 pounds), and blind zones resulting from the reflector being high above the water. Blind zones are intervals of range in which the reflector will not be detected regardless of radar power or reflector RCS. They become more significant as the height of the reflector increases and mounting an RTE on top of a tall mast is problematic.

For small angles of tilt the Mobri S-4 provides a very strong cross section, which is one reason why Mobri reflectors are being installed in new foam navigation buoys. The problem for sailors is that once the tilt goes beyond a couple degrees, there is virtually no response. I believe that the Mobri design is not acceptable for monohull sailboat use.

Both the Firdell Blipper 210-7 and Echomax 220 are similar in design and performance. The RCS is uneven; some regions produce a strong response while others produce a weak response. Even though the strong responses are quite good, the unevenness raises the possibility of coverage gaps and intermittent return. Also, the response decreases rapidly beyond an elevation of about 17 degrees, although the reduction in response is more gradual than the precipitous drop of the Lensref, and these units do provide some response at 20-25 degree angle of heel. I had some concern about the small gaps in coverage and the uneven response and I wanted better coverage at larger angles of heel, but the price is moderate and these designs cannot be rejected outright.

The Lensref provides a constant moderate RCS at all azimuths and elevations up to about 17 degrees. But when you exceed that angle the response drops to zero almost immediately. The 17 degree elevation was a little short of my projected 20-25 degree angle of heel and the cross section was too small for the conditions I sail in.

## PASSIVE UNITS

| Unit                                | Image   | Approximate Cost |
|-------------------------------------|---|------------------|
| Davis Echomaster 12 1/2" Octahedral |    | \$50-\$75        |
| Mobri S-4                           |    | \$150            |
| Firdell Blipper 210-7               |    | \$140-\$200      |
| Echomax 220                         |   | \$175-\$200      |
| Lensref DL-8A                       |  | \$475            |
| Cyclops #3                          |  | \$500            |
| Tri-Lens (large)                    |  | \$530            |

I finally selected the large Tri-Lens by Rozendal Associates. It met all my requirements, especially that of having a strong and consistent response at large elevation angles. It has a large constant 10 m<sup>2</sup> RCS over 360 degrees in relative bearing and at heel angles of 50 or 60 degrees. Only three small regions produce a small response. The large Tri-Lens is one of the more expensive passive reflectors but its solid performance fulfilled all of my requirements and made it the obvious choice.

## Limitations

A radar target enhancer is an essential piece of safety equipment that every boat should have. But whatever design you select you should be aware of the enhancer's two critical limitations. First, there will be weather conditions in which your boat is not detected, even by high-power commercial radar and with a good RTE. Second, even if your boat is detected by radar, the radar operator may not be paying attention and there is no guarantee that the other vessel can, or will, take action in time to avoid a collision. A radar target enhancer is a good safety aid but it doesn't relieve you of your responsibility to maintain a proper lookout.

## References

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