The Essentials in Radar Presentation

P. Hugon

In Captain Wylie's note on 'Radar as an anti-collision aid: the ultimate essentials in presentation'[1], masterly definition by an acknowledged expert aptly crowns the discussion which follows Commandant Oudet's paper on 'Collisions and the Courts'[2] in the same issue of the *Journal*. It is interesting and gratifying to find in that discussion a suggestion by E. S. Calvert on manœuvres in close-quarter situations which recalls a similar proposal made by the French Institute at our first joint meeting held in London in 1957. It is that the manœuvre should be a turn of $2x°$ to starboard if a threat, an echo for example, is perceived $x°$ forward of the port beam. This suggestion passed almost unnoticed at the time although it is mathematically sound if one assumes that the speed of the two vessels is the same[3].

Alarmed by the continuing frequency of collisions, the most able experts and the organizations most concerned have promoted or carried out detailed studies into a problem which radar, by itself, seems unable to solve quickly when the situation arises. They have examined it from every angle and in every possible mode of occurrence, in the light of special cases, statistics and mathematical treatments. The Institute of Navigation in England has been particularly active in this field.

There have been endless arguments about the interpretation to be put on some imprecise expressions in the Rules and often a lot of learned discussion between distinguished experts sometimes rivalling, as in the attempt to define 'existing circumstances and conditions', the famous controversy about the sex of angels.

But although these expositions have been invaluable in establishing first principles it must be said that they have not led to any clear and generally acceptable theory, based on well-defined rules and determining the course of action to be followed to avoid collisions in fog with conventional radar. Above all, it has not made such procedures practicable with a small bridge complement. Nor can such procedures be recommended for general adoption unless they require only the minimum technical equipment, allowing the information provided by conventional radar to be applied in a simple way.

This is why Captain Wylie has rightly tried to redress the balance by defining the essentials in presentation which would enable a single officer to detect a threat, distinguish between the priority of different hazards and work out the appropriate manœuvre. The problem of achieving this is formidable and the solutions that can be suggested are difficult and complicated. Nevertheless Captain Wylie has scrupulously tried to define these pressing needs in their final and most exacting terms and, in so doing, leaves us with little hope that they can be satisfactorily met with the equipment now available.

However, the fruitful discussions already mentioned have shown the methods, possible 'on paper', of attaining these ends. It is another matter to achieve them in practice without refined equipment or difficult mental exercises when there is only one man on the bridge, or even two, trained more for normal navigation duties than as specialists. Is there then no possibility, without resorting to sophisticated systems, of carrying out, within a reasonable time and with simple and easily manipulated instruments, the three necessary operations of detecting a threat, identifying the other vessel and judging her course, and making a prudent manœuvre?

In the light of the results of the studies already referred to, it is therefore proposed to consider the possibility of withdrawing to a position afforded by an approximate solution. The conditions are:

(*a*) Plotting is indispensable for as long as it can be kept up; it cannot be continued beyond a distance which depends on the time remaining before collision, that is to say it depends on the speed of approach. For example, 15 minutes corresponds to 10 miles at 40 knots and to about 6 miles at 25 knots. It may be remarked that radar is not an aid to close-quarter manœuvres.

(*b*) It would be ideal if a plot could be maintained simultaneously of all the echoes seen on the PPI, although this would lead to a confusion of lines on the screen. It is already sufficiently difficult to follow the movements of the most threatening targets, after a preliminary elimination by eye, even dealing with each echo separately.

(*c*) In smaller ships manual plotting is impracticable with only one officer on the bridge.

(*d*) Only a more or less automatic system requiring the minimum of displays could then maintain the plot, which might be on the radar screen or separate from it.

(*e*) The indicator should be large enough to allow plotting at a clear and convenient scale. Captain Wepster has wisely suggested a diameter of 40 cm.

(*f*) After three minutes run, and without further delay, the plotting must give the distance of closest approach and the time to go. It follows that the radar scope must have a memory of at least six minutes, or else the first echo must be marked on the face of the scope with a phosphorescent pencil; this would not be more troublesome than setting a marker on the echo in an automatic tracking device.

(*g*) In addition a simple vector system, operated automatically by not more than two or three settings, could show the range of admissible courses. This would obviously be based on the assumption that the target maintains her course and speed. Nobody can look into the future and it would be unreasonable to attempt to provide against indeterminate factors.

(*h*) A relative-motion presentation has been assumed; to prevent the blurring of the image, particularly with a memory tube, azimuth stabilization is to be desired and this may not be as difficult as it seems.

These modest requirements could be met by a very simple electronic or electromechanical system. One could if necessary find inexpensive and reliable components from among the array of rather crude mechanical devices available. The cost of a fairly simple system would no doubt be covered by the lightening of the task of a single non-specialist navigating officer; it would in any case be well worth the advantage of some reduction in the number of collisions in fog.

REFERENCES

1 Wylie, F. J. (1965). Radar as an anti-collision aid: the ultimate essentials in presentation. This *Journal*, 18, 232.

[2] Oudet, L. (1965). Collision and the courts. This *Journal*, 18, 188.
[3] Hugon, P. (1957). Les manoeuvres à faire à la mer en utilisant le radar pour eviter les abordages. *Navigation* (Paris) 5, 213.

A Probability Distribution for a Time-varying Quantity

D. A. Lloyd

In many practical situations in the field of navigation, it has been noticed that the probability distribution of measured errors has a shape which has considerable departures from that of the normal distribution. These departures are particularly noticeable in the 'tails' of the distribution of practical cases, which are often higher than those of the corresponding normal distributions (see, for example, 'Is the gaussian distribution normal', W/Cdr. E. W. Anderson. This *Journal*, 18, 65).

It can be shown that this phenomenon can arise from constant errors in the basic measuring device for a circuit or an apparatus containing a simple integrator. The integrator can be a real integrator or can arise from the kinematics of the situation. For example, in the case of a vehicle attempting to follow a fixed track with a heading indicator having a datum error, there is a 'kinematic integration' between heading and across-track error. In such a situation it can be shown that the error probability distribution for a large number of measurements of error is given by

$$p(y) = \frac{1}{7\cdot 2\sigma_y}\left[-Ei\left(-\frac{y^2}{16\cdot 5\sigma^2_y}\right]\right)$$

where $p(y)$ is the probability density function for the error y, and $-Ei(-z)$ is the exponential integral, given by

$$-Ei(-z) = \int_z^\infty \frac{e^{-q}}{q}\,dq$$

If this function is plotted on linear-logarithmic graph paper, it will be seen that it can be approximated by a straight line, and this line is not very different from the straight line given by an exponential probability distribution.

The distribution is plotted on Figs. 1 and 2 for the case of unit variance. The curves for the normal and exponential (one sided) distributions are given for comparison, and some experimental points arising from various practical situations are plotted on the graphs to show that the curve for $p(y)$ provides a reasonable fit to a number of different practical cases. The cases plotted represent doppler drift, Loran errors, and errors from the mean of vertical speed at the entry into the flare phase of an automatic landing.

It should be noted that the 'variance' in the above formula is the time average of the variance between 0 and T. The corresponding formula for $p(y)$ where σ^2_y is the true variance of y is

$$P(y) = \frac{1}{6\sigma_y}\left[-E_i\left(-\frac{y^2}{11\cdot 54\sigma^2_y}\right)\right]$$