Note on the resolution of radar systems

by J. Ph. Poley *)

In various papers on the resolution of radar systems the influence of several parameters is discussed which play an important role in the design and performance of modern radars. During the radar development after the war a trend can be distinguished towards a larger resolving power for medium and short range radars, thus favouring accurate position-finding and piloting by means of radar. Generally most attention is paid to the decrease of beamwidth Θ and pulselength P, which are commonly taken to be the determining factors for azimuth and radial resolution respectively. An accompanying decrease in wavelength makes in addition a more compact design possible.

For instance, as far as high discrimination is concerned, the Decca harbour radarset 31 ($\lambda \sim 3.20$ cm, $\Theta \sim 30'$, $P = 0.06\ \mu s$, 4.2 m scanner), the Decca river radar 214 ($\lambda \sim 3.20$ cm, $\Theta = 1.2°$, $P = 0.05\ \mu s$, 2.1 m scanner), the 3 cm Cossor surveillance radar [4]) ($\lambda \sim 3.20$ cm, $\Theta = 30'$, $P = 0.05\ \mu s$, 3.6 m scanner) and the New York Airport radar [5]) ($\lambda \sim 1.25$ cm, $\Theta = 15'$, $P = 0.02\ \mu s$, 3.6 m scanner) have been followed by the new Decca Q-band radar [6]) ($\lambda \sim 0.86$ cm, $\Theta = 24'$, $P = 0.05\ \mu s$, 1.8 m scanner). The performance of this last 8 mm radar, as installed at London Airport for airtraffic control is shown in fig. 1.

Too little attention, however, is given in literature to the fact that in striving towards a higher resolution, the improvement of the presentation qualities should keep pace with the improvement in radar apparatus design **). Otherwise the scope performance will put a firm and inevitable limit to the radar resolution by its spot diameter, especially at short distances.

The individual influences of the above-mentioned parameters are easily compared by considering their equivalent surface distances.

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**) An exception is found in ref. 5) and 7).

The azimuth width B of a point reflector is dependent upon the range R of the target according to

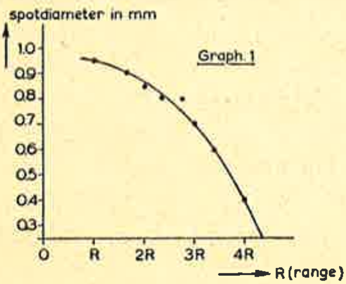
$$B \sim \frac{\Theta}{57.5} \times R \qquad (B \text{ in m}, \Theta \text{ in degrees}, R \text{ in m}),$$

while the actual azimuth resolution is about $1.25 \times B$[1]).

In radial direction the "depth" D, related to the pulselength, is obtained from

$$D = 150 \times P \qquad (D \text{ in m}, P \text{ in } \mu s)$$

The presentation quantity, which must compete with the radar parameters, i.e. the spot dimension, now requires some more discussion. For a certain presentation unit with maximum focussing a wide range of spot diameters is observed, dependent on the echo strength of the target. A curve showing the relation between spot diameter and distance of a groundbased target, as obtained empirically from the runway-edges of Fig.1, is given in Graph 1. However, for a full echo a minimum spot diameter between 0.7 and 1 mm will be found.



Graph 1.
Relation between spot diameter and relative target distance.

The equivalent width w corresponding with the spot diameter d for such an echo depends upon the rangescale S in use, and the sweep-range r of the radar, according to

$$w = \frac{d}{r} \times S$$

(w in m, S in m, d and r in cm f.i.).

The ratio d/r is the predominant factor of the presentation. Maximum discrimination will be obtained when the ratio d/r is as small as possible. This can be achieved for instance by increasing the screen dimensions as well as by offcentering[7]).

In Graph 2 the influence of B, D, and w are compared for a number of beamwidths and pulselengths using a short range radar ($S_1 = 500$ m, $S_2 = 1500$ m, $S_3 = 3000$ m). The scope parameters have been chosen as $d \sim 0.1$ cm, $r = 15$ cm.

It is easily seen that from a given presentation unit an optimum design for the attached radar can be deduced, whereas, on the contrary, certain radar parameters impose minimum requirements on the presentation unit to be used. Analyzing from

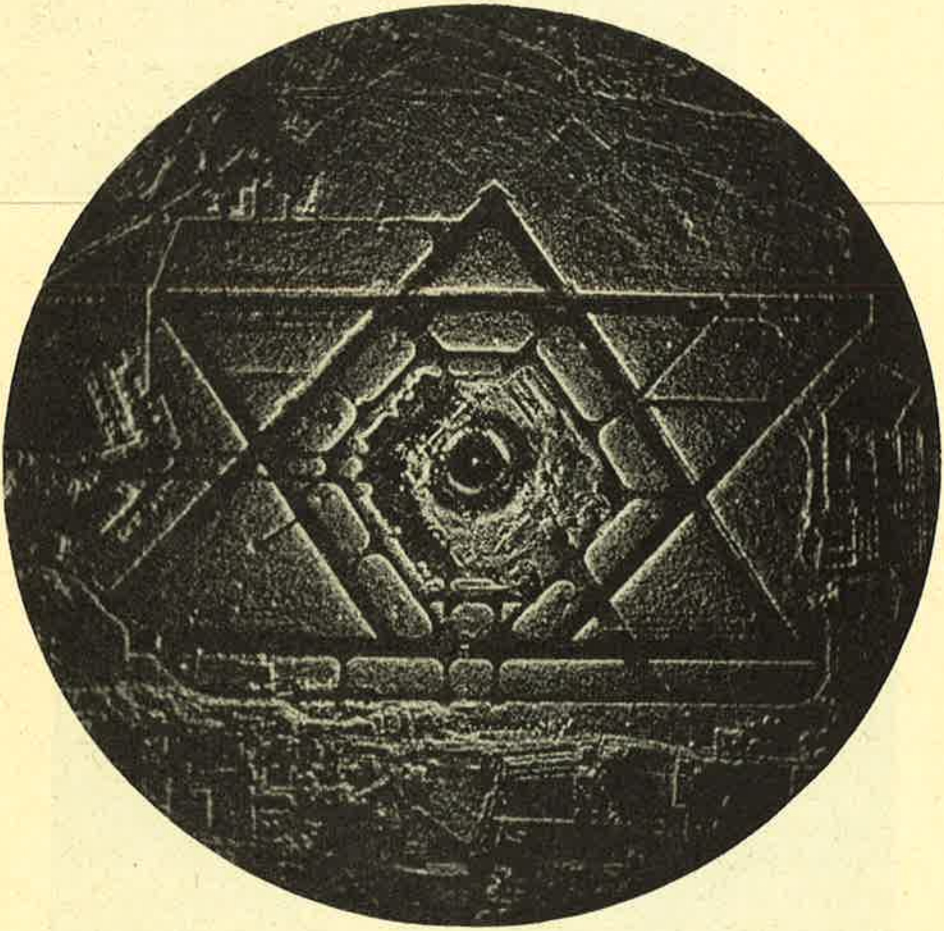


Fig. 1.
London Airport radar pattern 8.6 mm Decca radar (courtesy of Decca Ltd)

(Optical) picture of Bergen (Norway) fr

Fig. 3.
Radar picture of Bergen (Norway) 3.20 cm radar, $d/r \sim 1/50$, $S \sim 3000$ m.

2.
radar site (courtesy of Philips Telec. Ind. Ltd.)

Fig. 4.
Radar picture of Bergen (Norway) 0.86 mm radar, $d/r \sim 1/150$, $S \sim 1800$ m.

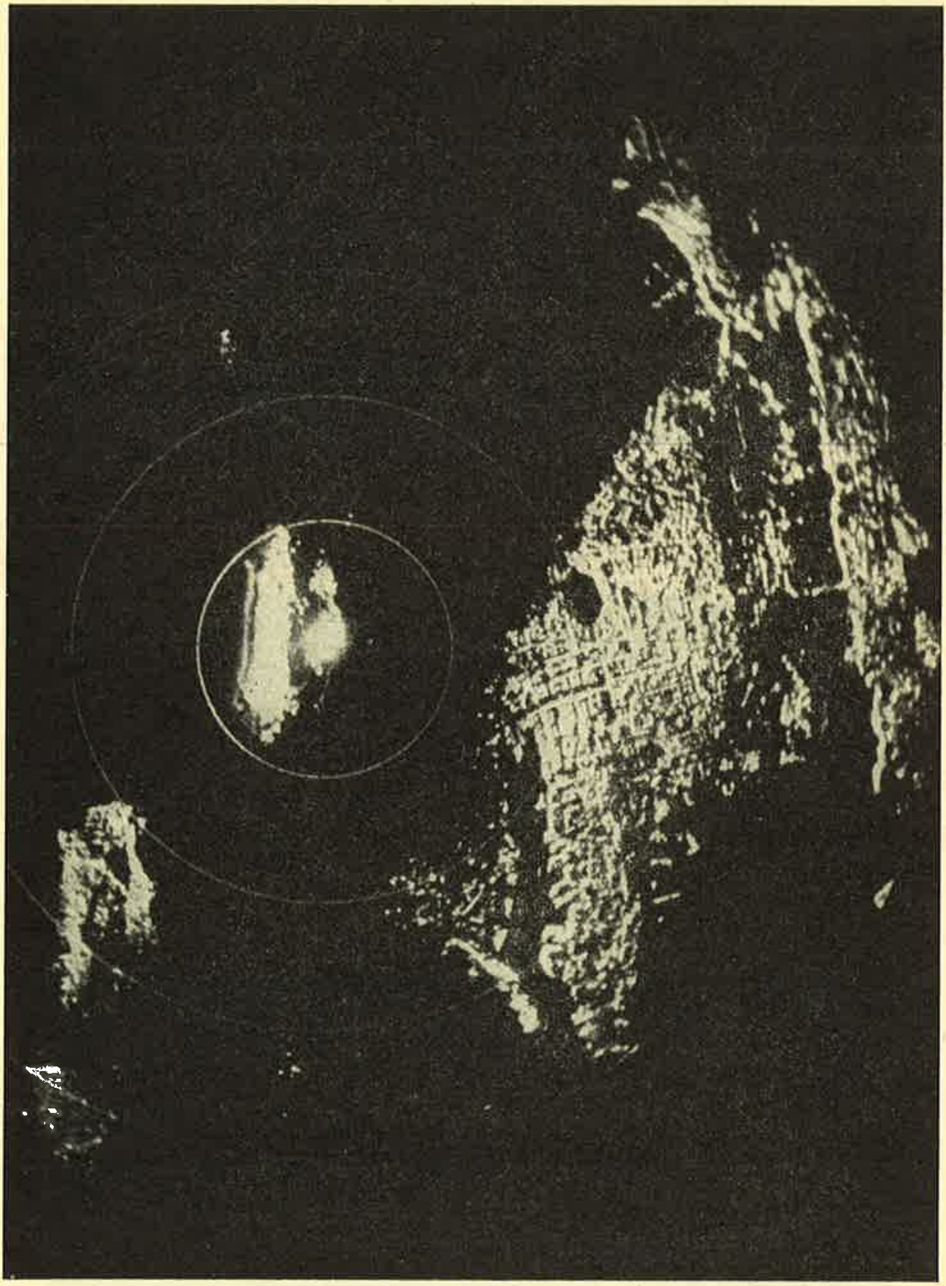
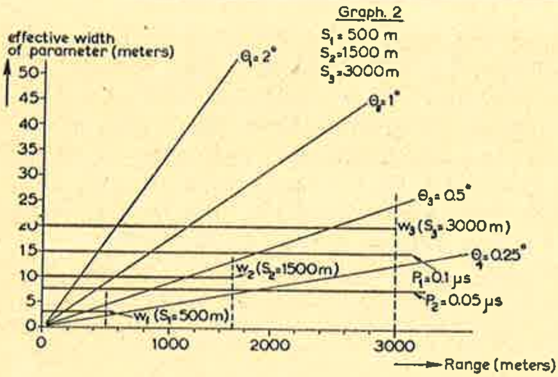


Fig. 5.
Radar picture of Bergen (Norway 0.86 mm radar, $d/r \sim 1/150$, $S \sim 2300$ m.



Graph 2.
Influence of beamwidth, pulselength and spot diameter on presentation.

this standpoint for instance is the above-mentioned London Airport radar, an excellent balance is found between radar parameters ($\Theta = 24'$, $P = 0.05\ \mu s$) and the qualities of the presentation unit in use ($d/r \sim 1/150$, $S_1 = 900$ m, $S_2 = 1800$ m).

Finally some illustrative material showing the limiting influence of the spot diameter can be given by recording here some results of recent radar work, done in cooperation with the Forsvarets Forsknings Institutt, Avd. for Radar, at Bergen (Norway).

From a hill mounted radar site (height about 330 m) overlooking the town of Bergen (fig. 2) at slant ranges between 800 and 2500 m, radar patterns were registered using a 3.20 cm Kelvin Hughes Marine radar ($\Theta = 1.2°$, $P = 0.2\ \mu s$, $d/r \approx 1/50$) and an experimental model of an 8.6 mm radar of Philips Telecommunication Industries Ltd ($\Theta = 15'$, $P = 0.02\ \mu s$, $d/r \approx 150$). In both cases the spot dimensions were the limiting factors for the discrimination, the equivalent distances being about 50 m and 18 m respectively (at rangescale $S = 2300$ m). Some results are given in Fig. 3 (3.20 cm radar, $d/r \sim 1/50$) and in Figs. 4 and 5 (8.6 mm radar, $d/r \sim 1/150$; $S_1 = 1800$ m and $S_2 = 2300$ m resp.). Although no optimum design had been pursued, the improvement in discrimination due to the decrease of the ratio d/r from 1/50 to 1/150 is already evident. In the last case the street patterns as well as single objects as trees, spires and lampposts show up clearly as individual targets.

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