

**PRESENT AND EXPECTED USE OF THE BAND 9320-9500 MHz
BY MOBILE RADARS OF THE RADIONAVIGATION SERVICE**

(Question 63/8)

(1986)

1. Introduction

1.1 CONSIDERING (g) of Question 63/8 draws attention to the increase in harmful interference occurring in the frequency band 9300-9500 MHz due to the increasing number of shipborne radars, the increasing need for navigational aids working with primary radars and the increasing number of stations of the aeronautical radionavigation service.

1.2 This Report is the result of studies and measurement by the United Kingdom and the United States of America on present and expected use of the band 9320-9500 MHz by mobile radars of the radionavigation service.

2. Present use of the band 9320-9500 MHz

2.1 The band 9320-9500 MHz is allocated world-wide on a primary basis to the radionavigation service and is used particularly heavily by shipborne primary radar. It is also used extensively by aeronautical ground and airborne radar. The use of primary radar by shipping is a valuable aid to navigation in open and confined waters and is recognized as such by the International Maritime Organization which is amending the International Convention on the Safety of Life at Sea, 1974, to include additional requirements concerning the carriage of radar.

* The Director, CCIR, is requested to bring this Report to the attention of the International Civil Aviation Organization (ICAO), the International Maritime Organization (IMO), the International Association of Lighthouse Authorities (IALA).

2.2 Economic and technical considerations have led to much greater use being made of the band 9320-9500 MHz by radar than is made of other bands allocated to the radionavigation service which are suitable for this purpose.

2.3 In many countries magnetrons for radar use in the band 9320-9500 MHz are manufactured to four "spot" frequencies:

<i>Frequency (MHz)</i>	<i>Service</i>
9345	Aeronautical
9375	Aeronautical and marine
9410	Marine
9445	Marine

A spot frequency is the nominal frequency of manufacture and is a median value for all magnetrons made to that value. In practice, the centre frequencies of individual magnetrons are of approximately Gaussian distribution about the "spot" frequency, with a 95% probability of variation within ± 30 MHz.

3. Operational effect of radar-to-radar interference

3.1 Interference from a single source will be observed typically on a radar display first as one striation. Then as the interference becomes more severe, an increasing series of interrupted striations in arc-shaped form radiating from the centre of the display will be observed.

3.2 If the interference continues to increase due to decreasing range, the number of striations also increases and the arc of the display over which they appear will get larger until finally the display will be totally covered by strong returns around the whole of the display.

3.3 The effect of such interference on the radar observer is related to both the number of striations and to the corresponding area of the display which is rendered useless for normal tasks. This area varies with the pulse widths of the interfering radars.

3.4 Subjective assessment suggests that more than about 15 simultaneous striations or 5% of the display area obliterated would be unacceptable.

4. Measurements of potential interference

4.1 Initial studies of the problem indicated that when two radars are within detection range of each other it is possible to relate the degree of potential interference with the form of the radar antenna azimuth polar pattern (see Fig. 1). The degree of potential interference is largely range related and the three most serious cases are:

4.1.1 at longer ranges when one radar antenna main lobe is looking at the back of another radar antenna, and *vice versa*;

4.1.2 at medium ranges when the first major side lobe of one radar antenna is looking at the back lobe of another radar antenna, and *vice versa*;

4.1.3 at shorter ranges when the radiation from the back lobe of one radar antenna is being picked up through the back lobe of another radar antenna.

4.2 More detailed study of these three cases indicated that the first two represent situations in which the possibility of unacceptable interference is minimal because:

4.2.1 the main lobe is likely to be not greater than about 2° and it would therefore require many other ships equally spaced around one's own ship within the range and frequency criteria before interference became unacceptable; and

4.2.2 similar cases apply to the first major lobe which is unlikely to exceed about 20° .

4.3 The most serious case therefore is the one described in § 4.1.3. This situation was examined in detail by trials carried out in the high traffic density area of the Straits of Dover. Subsequent analysis of the results obtained is given below.

5. Analysis of trials data

5.1 There are many interrelated factors which determine, in practice, whether a radar display has been rendered useless due to interference from other radars. Some of these are:

5.1.1 the training of radar observers;

5.1.2 the electronic processing methods used in the radar receiver;

5.1.3 the ranges, frequencies and PRFs of the interfering radars;

5.1.4 the density of possible interfering radars.

For the purpose of this analysis only § 5.1.3 and § 5.1.4 were considered.

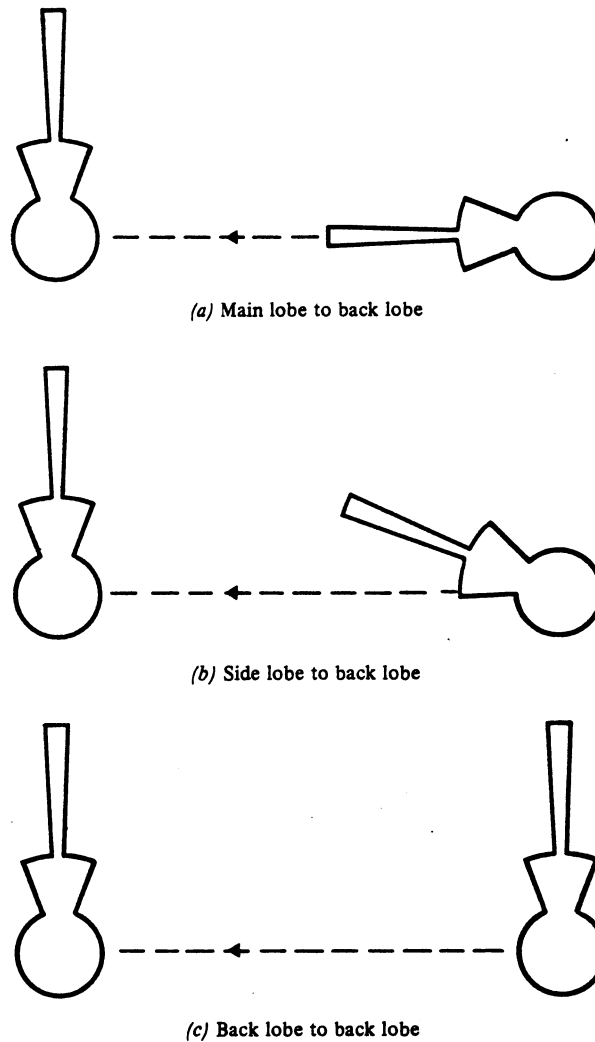


FIGURE 1 – Antenna pointing for different interference cases

5.2 An approximation of a fraction of the area, A , of a radar display suffering interference can be expressed as:

$$A = \frac{P_f \cdot k \cdot m \cdot W}{N}$$

where:

P_f : probability of a ship radar using frequency, f ;

m : number of ships within an interfering range;

W : pulse width, assumed to be 0.25 μ s;

N : average PRI (pulse repetition interval), typically 10^{-3} s;

k : empirical constant ≤ 1 , to take account of special receiver processing and bandwidth mismatch. (No information was available from the trials on the extent to which interference reduction circuitry was fitted on ships transiting the Straits of Dover.)

5.3 The major objective of the trials was to collect data that would allow P_f and m to be estimated.

6. Results of trials

6.1 The probability of a ship radar using frequency, f , can be estimated from the histogram chart (see Fig. 2) which shows the number of radars detected during the trials against the radar frequencies being used. The overall form of the histogram shows quite distinct peaks at the three nominal frequencies used by magnetrons fitted to shipborne radars. There were virtually no detections at the magnetron frequency used exclusively by the aeronautical service. However, the fact that the radar used for the trials had a relatively limited vertical aperture of only a few degrees might possibly have influenced this result, although this is considered unlikely.

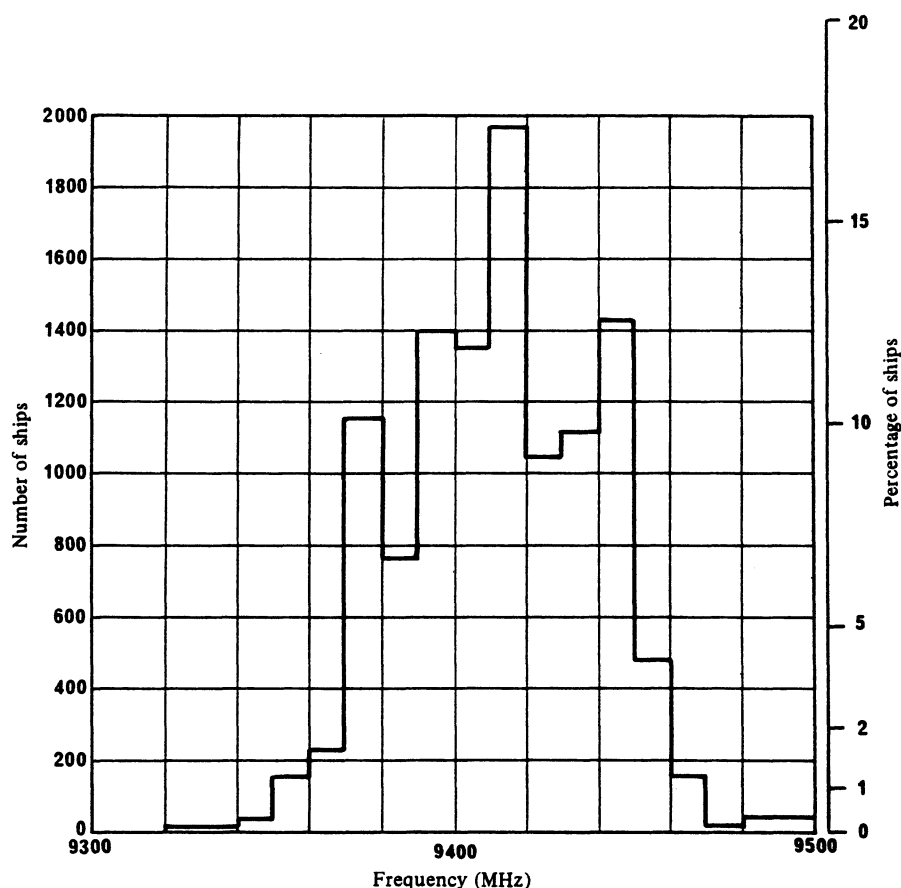


FIGURE 2 – Ship radar magnetron frequency distribution

6.2 To enable an estimation of the ships within interfering range, M , the ship population was divided into three classes, large ships of 10 000 gross tonnage and over, medium-sized ships of between 1600 and 10 000 gross tonnage and small ships of less than 1600 gross tonnage. The relevant characteristics of ships of these classes are given in Table I and the approximate class-to-class radar detection ranges are given in Table II.

TABLE I – *Ships' characteristics*

Size of ship	Large	Medium	Small
Radar height (m) ⁽¹⁾	30	15	7.5
Detection range (NM)	25	17	4
Traffic density (%) ⁽²⁾	20	35	45

⁽¹⁾ The detection ranges given were calculated using standard radar equations.

⁽²⁾ Derived from UK surveys of marine traffic in the Straits of Dover.

TABLE II – *Radar detection ranges (NM)*

Size of ship	Large	Medium	Small
Large	25	21	18
Medium	21	17	15
Small	18	15	12

Using Tables I and II and numbers/types of ships derived from recent shipping surveys, Table III has been constructed.

TABLE III – *Number of ships (m) within range (NM) for potential interference*

Size of ship	Range (NM)	4	12	15	17	18	21	25
Large		8	50	60	70	75	83	85
Medium		8	50	60	65	67	69	69
Small		8	31	36	38	39	39	39

6.3 Using the worst-case numbers from Table III, the values of P_f from Fig. 2 and the equation for the area, A , of the display suffering interference, Table IV was developed. This represents probably the worst condition of interference that a radar observer is likely to experience while transitting the Straits of Dover.

TABLE IV — *Probable maximum interference*

Size of ship	Number of striations	Display obscured (%)
Large	14	0.35
Medium	12	0.30
Small	7	0.17

6.4 Comparing the results given in Table IV with the subjective assessment of unacceptable interference given in § 3.4, it can be seen that at the present time in an area of high traffic density the probability of unacceptable interference is minimal.

7. Future use of the band 9320-9500 MHz by mobile radars of the radionavigation service

If the number of radars in use in the band increases, as seems very likely, radar-to-radar interference will also increase unless specific counter-measures are implemented. However, most modern radars make use of processing techniques some of which incorporate radar-to-radar suppression capabilities, and which may help to alleviate the problem.

8. Spectrum measurements

In the United States of America, mobile radionavigation radars have assignments to operate in the entire 9320-9500 MHz band rather than on specific frequencies within the band. Therefore, reviews of the frequency assignment records do not provide an understanding on how the band is being used. Sample measurements of the shipborne and airborne emissions in the band in the United States of America and surveys of radar and magnetron tube manufacturers will provide information on the present and expected future use of the band by mobile radionavigation radars.

8.1 Measurement system and techniques

The United States government operates a radio spectrum measurement system (RSMS) in support of frequency management processes. The RSMS is deployed in a mobile van and is a computer-controlled receiving system designed to make many different types of measurements between 100 kHz and 12 GHz. The RSMS has been used in measurement programs on communication and radar bands in many high spectrum usage areas in the United States of America. Descriptions of the RSMS have been presented in Matheson, [1977] and in Buss and Cutts, [1980].

One of the techniques used in the RSMS to obtain statistical data of a frequency band is a 24 or more hour observation of the band by the computer-controlled receiving system. During these periods, the system is incrementally tuned across the band, stopping for several seconds after each frequency step. While the receiver is sampling a frequency, a peak detector holds the amplitude of the maximum signal encountered and high speed counters count the number of radar pulses exceeding several preset amplitudes. The band is repeatedly scanned in this fashion, and the measured data is recorded on magnetic tape for later analysis. For the data presented here, the frequency bands were scanned 5 to 124 times. The recorded data was analysed to present:

- the maximum, average and minimum of the peak detected amplitudes at each frequency, and
- the maximum, average and minimum of the number of pulses counted at each frequency for each of several thresholds.