551.551

An unusual case of abnormal propagation of micro-wave caused by Nor'wester

A. C. DE

Meteorological Office, Calcutta

(Received 29 August 1957)

ABSTRACT. An unusual type of radar echo was noticed on the PPI-scope of a 3-cm meteorological radar at Dum Dum airport on 3 April 1957 after the passage of a nor'wester squall. It has been shown that conditions were favourable for the formation of a radio duct at that time and this echo was probably due to existence of this duct.

1. Introduction

The paper reports and discusses a case of occurrence of anomalous propagation at 3-cm wavelength at the Dum Dum airport (Calcutta), following a nor'wester on 3 April 1957. The case reported is not covered by the usual super-refraction conditions as generally prevail in this area and as have been discussed in a recent communication (De *et al.* 1957).

On this date the radar was in operation for detection of the first nor'wester of the season. After the squall had passed over the station from northwest, a line type of echo was noticed on the PPI-scope towards south. This at first sight appeared to be due to receding thunderstorm cells. Subsequent observations, however, revealed that the echo gradually approached the station from the south. This coupled with the fact that no clouds capable of producing any precipitation echoes were present, could only be interpreted as a case of super-standard radar propagation caused probably by the downdrafts from the thunderstorm cells.

2. Description and analysis of the observations

The first radar echo consisting of three small cells appeared at 1230 IST towards northwest. These cells subsequently formed into a line and passed over the station at 1345 IST from northnorthwest. At 1500 IST the retreating squall line was located towards southeast (Fig. 1a). At 1600 IST the line lost its identity and only isolated cells appeared on the scope. These cells were of diffused type (Fig. 1 b) and the estimated height was less than 20,000 ft a.s.l.

The line type of echoes referred to in Section 1 appeared at 1700 IST (Fig. 1c). The lie of the line was from 080°/40 miles, through 125°/18 miles, 160°/25 miles, 185°/15 miles to 250°/40 miles. The appearance of this echo was interesting as no vertical development of clouds could be seen from the station, nor the existence of any such clouds reported by any aircrafts flying at that time in that region. On careful examination, the nature of the echoes was also seen to be different from that of usual precipitation echoes, these being more diffused. By 1725 IST, the line instead of receding—as it would have normally done if it was due to precipitation cells associated with the nor'wester—appeared to be nearer the station. This can be seen from Fig. 1 (d), the line extending from 90° to 230° with its centre at a distance of about 20 miles from station. At 1800 IST the line appeared still nearer (Fig. 1 e). At 1900 IST this line almost encircled the station. Unfortunately the photograph of the PPI presentation at 1900 IST is not available.

3. Synoptic situations

At 0830 IST of 3 April 1957 there was a surface "low" over West Bengal (north of Calcutta) and the associated cyclonic circulation extended up to 5000 ft. a.s.l. and conditions were favourable for the occurrence

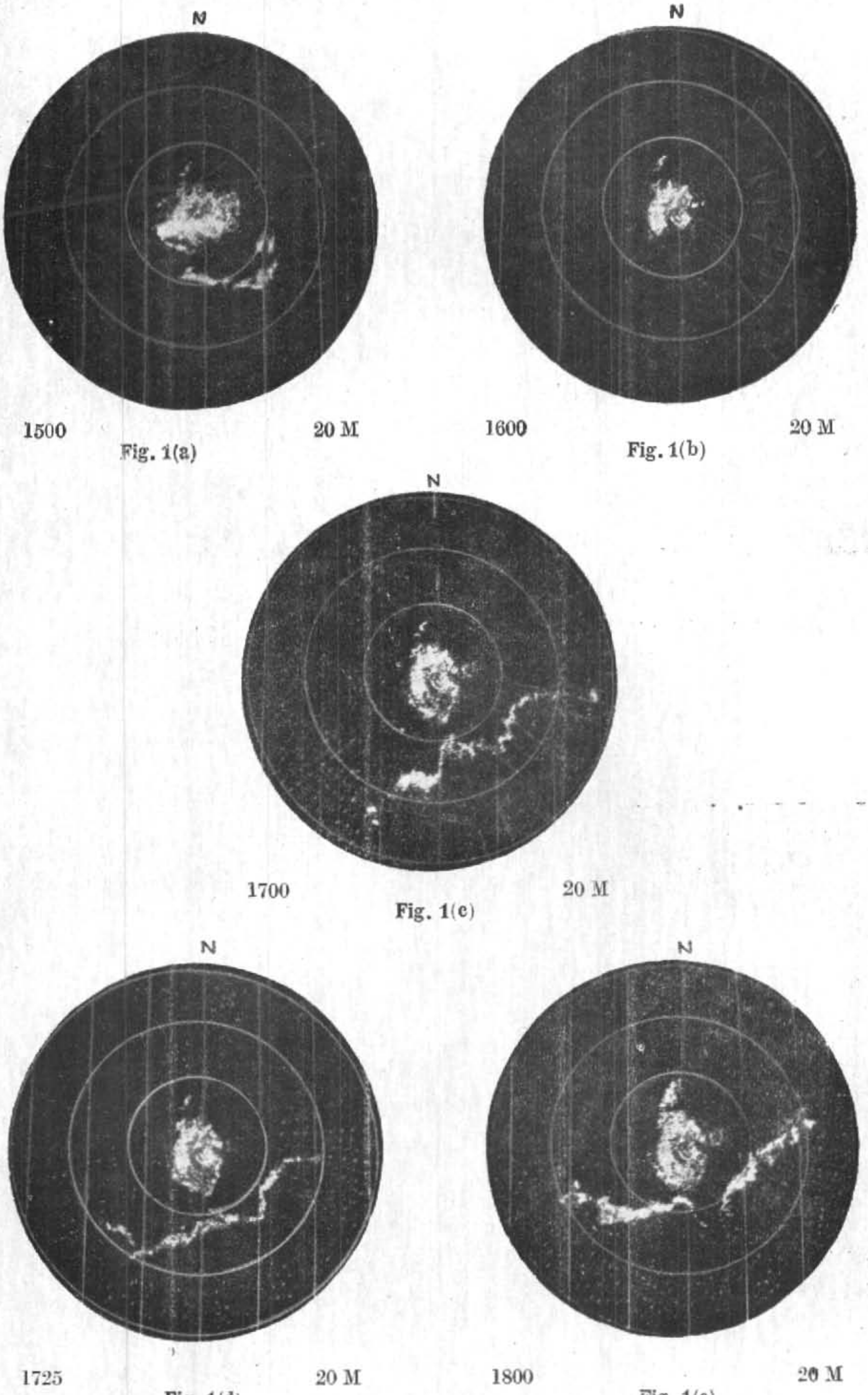
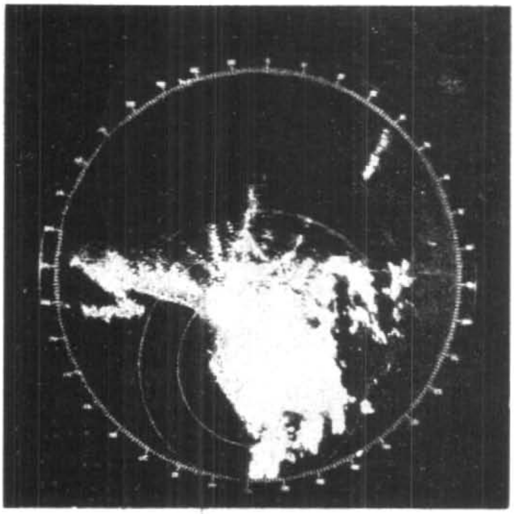


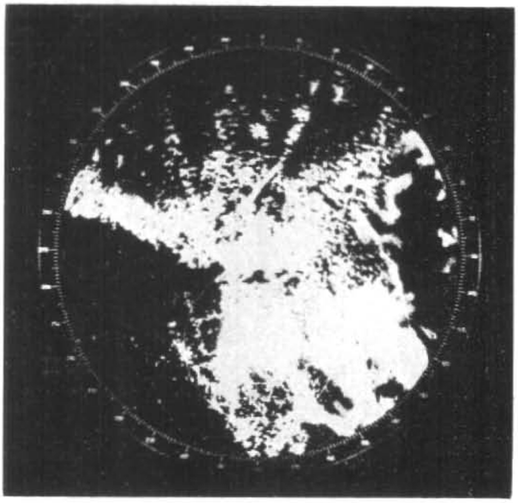
Fig. 1. PPI presentations of the storm detecting radar at Dum Dum airport on 3 April 1957

The figures in the left and right hand bottom corners indicate time in IST and range rings in miles respectively



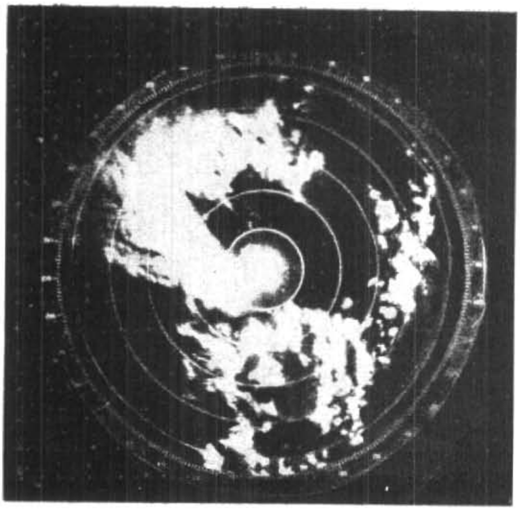
1904 20 km

Fig. 3(a). 9 June 1958



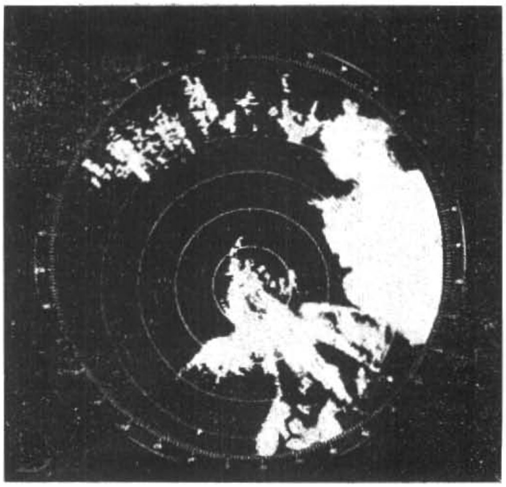
1907 10 km

Fig. 3(b). 9 June 1958



1915 20 km

Fig. 3(c). 13 June 1958



1622 20 km

Fig. 3(d). 18 June 1958

Fig. 3. PPI presentations of the storm detecting radar at Dum Dum airport

Figures in the left and right hand bottom corners indicate time in IST and range rings in km respectively

TABLE 1

Meteorological data from the radiosonde sounding on 3 April 1957 at 1730 IST at Dum Dum

Pressure (mb)	Height (ft)	D. B. temp. (°K)	Vap. pressure (mb)
1008	0	299·0	21·18
1000	230	300·0	18·92
994	570	301·2	22·20
930	2340	300·0	7·10

of nor'westers in the afternoon. Upper winds were mainly westerly and the thundersquall was expected at the station from west or northwest. The squall actually struck the Dum Dum airport at 1345 IST from north-northwesterly direction with 46 mph. The barograph showed a rise in pressure by 1·5 mb and the dry bulb thermograph showed a fall of temperature by 20°F. The humidity rose by 47 per cent and 0·52 inch of rainfall was recorded. The maximum rate of precipitation was 3 mm/hr.

4. Discussion

The possibility of the echoes being due either to precipitation or to the presence of suspended water droplets would be discussed in the following paras. As has already been pointed out, the nature and the type of the echo were quite different from usual precipitation cells.

At 1700 IST it was observed that only 1/8 *Cu* clouds at 3000 ft asl and 2/8 *Ac* clouds at 12,000 ft asl were present. At 1730 IST only 2/8 *Ac* clouds at 12,000 ft asl, and at 1800 to 1900 IST only 1/8 *Ac* at 12,000 ft were present. If we consider the small dropsize and the low distribution of liquid water content in *Ac* clouds, the possibility of such clouds being able to reflect detectable energy becomes insignificant. It can therefore be inferred that the echoes as seen on the radarscope at 1700 IST and afterwards could not have been due to reflection from *Ac* clouds.

The main objection to the possibility of occurrence of radar echoes due to suspended water droplets without the presence of cloud cells is not physically possible. As there was no cloud formation, the existence of such droplets becomes extremely doubtful. Further, water droplets, if present, would have been drifted away by the wind currents blowing at 10-12 mph towards NW-SE direction and such a movement away from the airfield would also have been detected on the PPI-scope. On the contrary the echoes were seen approaching the station.

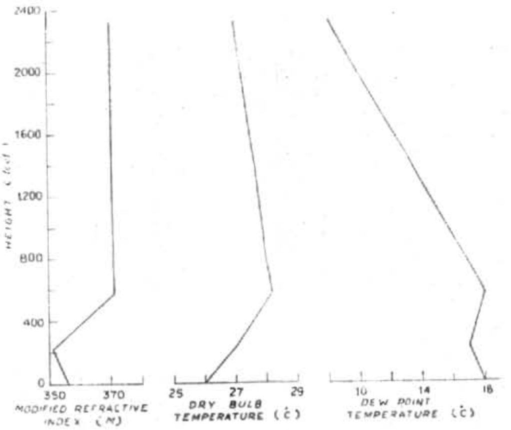


Fig. 2. Distribution of Modified Refractive Index (*M*), D.B. and Dew point temperatures up to 2340 ft asl at Dum Dum airport on 3 April 1957 at 1730 IST

The only alternative explanation left is the possibility of the echoes being due to superstandard refraction. The downdraft from the thundersquall had brought cold and moist air to the surface and had well mixed the air near the ground. After the squall had passed over the station, the surface wind became light southerly and the air close to the ground became semi-stable. The temperature and humidity distribution was thus favourable for the formation of a radio duct. The upper air soundings at Dum Dum airport at 1730 IST (as shown in Table 1) show a ground temperature inversion up to 600 ft and dew point temperature inversion from 230 to 600 ft. The modified refractive index (*M*) calculated according to the conventional formula using the data from this sounding at 1730 IST (Fig. 2) shows a ground *M*-inversion up to 230 ft and elevated S-shaped *M*-inversion (Burrows and Attwood 1949) from 600—2300 ft.

As the meteorological data at successive intervals close to the ground are not available an attempt has been made to utilise the radiosonde data in calculating the refractive index. The data from the sounding give an idea about the relative variation in the M-profile. For radio-wave propagation, this relative variation is considered more important than the absolute value of M at any particular height (Sheppard 1946). It may be seen from Fig. 1 that the ground clutters have increased which must be due to the presence of ground duct. The line type of echoes which appeared on the screen from 1700–1900 IST is indicative of an elevated S-shaped M-inversion between 600 and 2300 ft. Considering the topography of the area and also the fact that the echoes were from 20–40 miles to the southeast of Dum Dum it may be concluded that these echoes were from ground objects.

The most important factor determining the duct formation is the lapse rate of water vapour (Starr 1953). Near the ground the lapse rate of refractive index (β) is given roughly by the formula (Booker 1946)—

$$-\beta = (0 \cdot 2 + e' - t'/9)/a$$

where, e'=lapse rate of water vapour in mb per 100 ft, t'=lapse rate of temperature in °F/100 ft, $0 \cdot 2$ is due to gravitational lapse rate of density and a =earth's radius, $6 \cdot 4 \times 10^6$ metres.

The relative curvature of the ray with respect to earth's surface is $(1/a) - \beta$.

The condition that the ray bends round and moves in a duct is that the curvature of the ray is of the same order as that of the earth, that is, $\beta \doteqdot (1/a)$. Further, in order that the ray may reach back the earth β must be greater than $1/a$. In the present case, the values of β calculated from ground up to 230 ft and from 600 to 2300 ft were found to be $1 \cdot 28/a$ and $1 \cdot 1/a$ respectively. It can, therefore, be said that there were formation of radio duct at 1730 IST from ground up to 230 ft and also from 600—2300 ft.

The thundersquall associated with the nor'wester moved from northwest towards southeast. After a sufficient time, the lapse rate of water vapour must have become less steep due to the continuous in-flow of moisture in the lower layers. The duct heights therefore gradually decreased and ultimately disappeared. This may be the reason of gradual approach of the echoes towards the station from 1800 to 1900 IST.

The conditions favourable for duct formation are not present with each and every thunderstorm. Though this particular echo was observed after the passage of nor'wester on 3 April 1957, it was not noticed on any other day during the rest of the season. A high power (250 KW) 3-cm meteorological radar has recently been installed at Dum Dum airport. With this new radar similar phenomenon, *viz.*, anomalous propagation at 3-cm wavelength caused by thundersqualls was also noticed on a number of occasions. A few pictures of some selected occasions are shown in Fig. 3. On every occasion thundersquall had occurred over Dum Dum airport. Figs. 3a and 3b show the appearance of extended ground clutters upto 120 km in the NW-N-NE sectors while Figs. 3c and 3d show the presence of echoes up to 100 km in NE-E-SE and NW-N-NE sectors respectively. These echoes were not due to cloud or rain and might have been caused by downdrafts from the thunderstorm cells.

5. Acknowledgements

The author is greatly indebted to Professor S.K. Mitra, Emeritus Professor of Physics, University of Calcutta, at whose suggestion the work was undertaken. The author also wishes to acknowledge his grateful thanks to Dr. P. Koteswaram and Dr. S. N. Sen for valuable suggestions during the preparation of the manuscript.

REFERENCES

Booker, H. G. 1946 *J. Instn. elect. Engrs.*, **93**, Pt. 3A, 1, p. 69.
Burrows, C. R. and Attwood, S. S. 1949 *Radio wave propagation*, N.D.R.C. Rep., p. 12.
De, A. C. *et al.* 1957 *Indian J. Met. Geophys.*, **8**, 4, pp. 418-426.
Sheppard, P. A. 1946 *Phys. & R. met. Soc.*, pp. 37-79.
Starr, A. T. 1953 *Radar and Radar Technique*, Chap. 2, Sec. 7, pp. 79-81.