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# Radio refractivity observations over the oceans using airborne microwave refractometer in tropics

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**सार** - भारतीय उपमहाद्वीप के समुद्र तट पर रेडियों अपवर्तन की सूक्ष्म संरचना (fine structure) के विश्वसनीय मापन का अभाव है। विशेष रूप से संचार तथा युद्ध के दौरान पनडुब्बियों को नष्ट करने आदि के क्षेत्र में असंगत संचार के प्रभाव का शमन करने में वास्तविक समय के आधार की आवश्यकता होती है। इस कार्यक्रम का उद्देश्य ऊष्णकटिबन्धीय (tropical) भारतीय सागर के ऊपर रेडियों अपवर्तक सतह की रचना तथा सागर की सतह में होने वाले परिवर्तनों को प्रलेख रूप में तैयार करना था। इस पत्र में लेखक ने राष्ट्रीय भौतिक प्रयोगशाला, नई दिल्ली में अपने द्वारा विकसित वायुवाहित सूक्ष्मतरंग अपवर्तनमापी द्वारा लिए गए उपर्युक्त प्रेक्षणों का वर्णन किया है। इस पत्र में (भारत में पहली बार) सामान्य तथा असंगत संचार परिस्थितियों में लिए गए आंकड़े प्रस्तुत किए गए हैं तथा भारत के समुद्र तटीय क्षेत्र में पानी के जहाज पर लिए गए प्रेक्षणों से उनकी तुलना की गई है।

ABSTRACT. The coastal waters of Indian sub-continent do not have reliable measurements of fine structure of radio refractivity especially in near real-time basis needed to mitigate the effects of anomalous propagation for the defence communications as well as for antisubmarine warfare. This programme was designed to document the radio refractive layer structure and variations of the marine layer in tropical waters of India. The paper describes the above observations taken using the airborne microwave refractometer developed by the author at National Physical Laboratory, New Delhi. Typical observations taken (for the first time in India) under normal and anomalous propagation conditions are presented and the results are compared with the special shipborne observations made under MONEX operation over the coastal waters of India.

**Key words** — Refractivity, fine structure, marine boundary layer, tropical waters, anomalous propagation, atmospheric anomalies and super refraction.

## 1. Introduction

In the coastal waters of Indian sub-continent (a typical tropical country) high resolution (both horizontal & vertical) radio refractive index information is non-existent. Throughout the world the impotatnce of refractive phenomena in fleet operations is well recognised. Thus from the Indian Navy's point of view there is an urgent need to collect good high resolution data on radio refractive index using aircraft and parameterization of this data on a top priority basis has to be done over the oceans. Radio refractive index profile information derived from meteorological sensor data is not so useful for the studies of day to day variability in characteristics or of the variations which may affect the radiowave propagation conditions for specific paths and times. This is mainly due to several factors especially the poor spectral resolution and large response time of the sensors used in meteorological data collection. However, compromise has to be made between the collection of scientific data and the need for real-time data for operation purposes. The main advantage of aircraft measurements is that a good horizontal and vertical resolution in radio refractive index can be obtained. This type of data collection gives an opportunity for the development of internally consistent data sets for tropical numerical prediction models near the equator especially at and below cloud base within and in the vicinity of cloud clusters. The best height resolution that can be obtained from a standard (best) radiosonde instrument is only about 150 metres (at the most) which is not at all sufficient for use in communications. Precise data, with good resolution, on radio refractive index gradients is needed for the studies of anomalous propagation, an important requirement for defence communications. It is a well established fact that the water vapour distribution (especially in tropics) assumes great significance because of its role in modifying turbulence related radio refractive index fluctuations in causing attenuation at frequencies in the UHF/SHF range and in producing large radio refractive index gradients (to form ducts) leading to anomalous propagation conditions. Unfortunately most of the sharp gradients are smoothed out in the profiles, obtained by the conventional meteorological sensors, giving highly erroneous data on radio refractive index which can not be used in designing high reliability radio and radar systems for tactical applications.

## 2. Principle of airborne microwave refractometer

Comparison of the resonant frequency of an exposed (to the atmosphere) microwave sampling cavity with that of a sealed reference cavity gives a measure of the variation of radio refractive index of the atmosphere at microwave frequencies since a linear inverse relationship between the cavity resonance frequency and the radio refractive index is a valid assumption. Thus

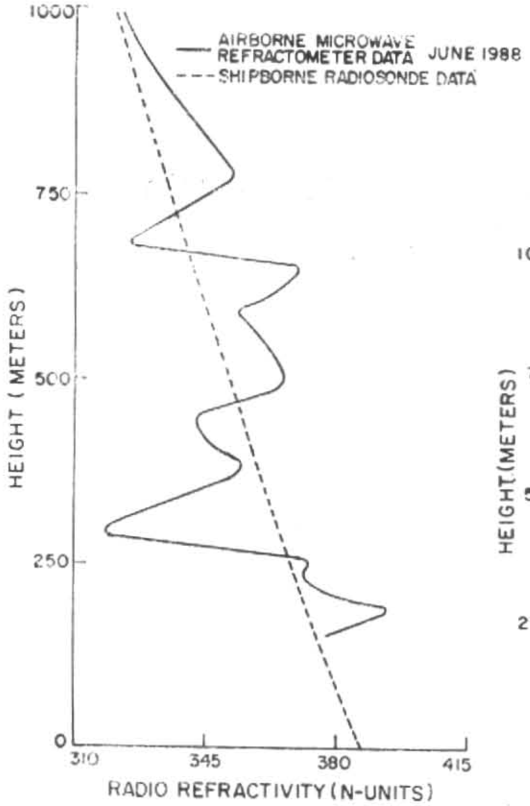


Fig. 1. Marine boundary layer radio refractivity over Bay of Bengal under normal propagation condition off Madras coast

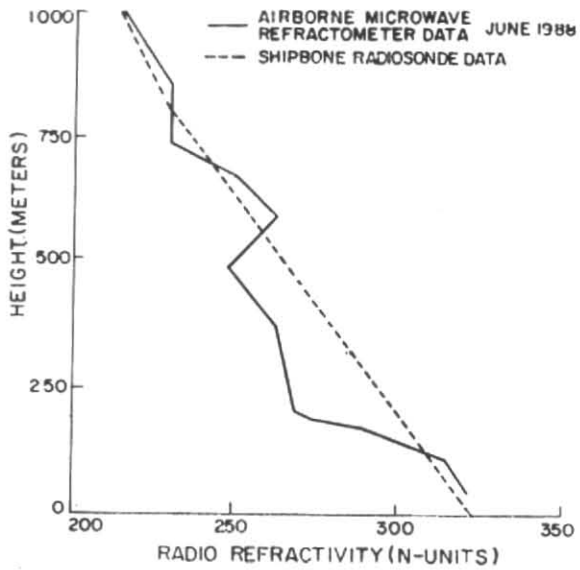


Fig. 2. Marine boundary layer radio refractivity over the Arabian Sea under anomalous propagation condition off Bombay coast

the microwave refractometer can be made to read directly the radio refractive index variations by proper use of electronic circuits. The present instrument operating at 9.341 GHz has a stability of $10^{-7}/^{\circ}C$ and a sensitivity better than 1N unit with a dynamic range of 0 – 400 N units. The expected frequency change is about 9.341 KHz per 1N unit. Figs. 3 and 4 indicate the system layout in the aircraft.

Airborne microwave refractometer is the only instrument of its kind which can provide data on the fine structure of radio refractive index (on a real-time basis) having a very good resolution to meet the operational requirements for assessment on atmospheric anomalies and development of techniques to mitigate these effects. During the past airborne microwave refractometers have been developed by several investigator (Birnbaum 1950, Crain 1950, Thompson and Vetter 1958, Lane *et al.* 1961, Vetter and Thompson 1962, 67 and 70, Fowler *et al.* 1966, Barton 1970, Kelly 1972, Chan 1974, Sarma *et al.* 1975 and 1989). The radio refractive index is normally described by its short term mean and variance, both of which are highly dependent of geographic location, season and the time of the day. Thus the variance in radio refractive index is the main source of variability in the received signal levels and

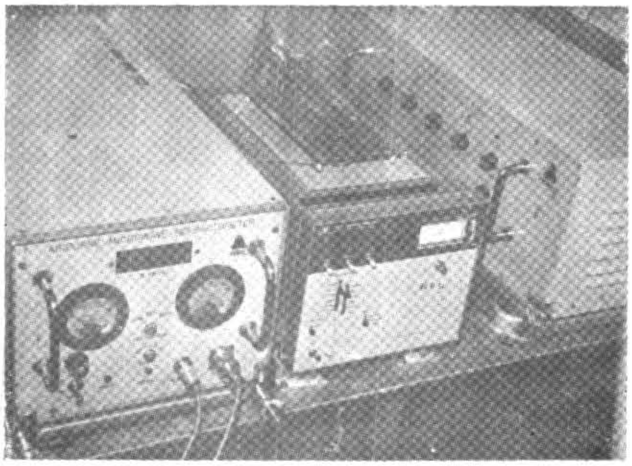

Fig. 3. Instrumentation of microwave refractometer


Fig. 4. Airborne sensor for microwave refractometer

hence a complete description of this parameter *versus* weather, time of the day, season, location etc, is highly desirable. With this view in mind the author has developed, fabricated and validated an airborne microwave refractometer at National Physical Laboratory, New Delhi and collected radio refractive index information over the oceans around the Indian sub-continent using a high speed defence aircraft and the results are presented in the next section. These data were compared with the ship borne radiosonde flight data taken over the oceans of the Indian sub-continent. In the subsequent section conclusions are given along with the future course of action.

### 3. Results

At present there is no authentic information on low level oceanic radio refractive structures in the Indian sub-continent. In order to develop techniques of predicting refractivity structures from air mass and weather considerations the data was collected over Bay of Bengal (off Madras cost) add Arabian Sea (off Bombay coast) during the month of June 1988. This mission was the first of its kind in India and has given an improved accuracy obtained during the above mission as shown in Figs. 1 and 2. In these figures ship borne radiosonde data have also been included for intercomparison purposes. This intercomparison exercise clearly indicates a real understanding of the strengths and weaknesses of the two systems. These figures indicate large differences in radio refractive index gradients at various heights through out the marine boundary layer. These differences are either greater or less at different heights. The fine structure information on radio refractive index is totally missing in the profile obtained by the ship operated radiosonde. The sharp gradient indicating the layer structures prevailing in the marine boundary layer are totally missing. There is a large disagreement even in the absolute values of the radio refractive index by these two techniques. The strong ducting layers, which are of vital importance for communication engineers (present in abundance over the sea), could only be detected by the airborne microwave refractometer and this data could be useful in the preparation of radar coverage charts and in modelling the ducting occurrence percentages in the coastal waters of India. While Fig. 1 indicates the normal behaviour of the marine boundary layer Fig. 2 indicates the non-standard behaviour (anomalous propagation) of the atmosphere. Under normal conditions the observed radio refractivity gradient is of the order of —70 N/km as depicted by Fig. 1 and in the case of non-standard behaviour (super refraction condition) the observed gradient is of the order of —110 N/km.

### 4. Conclusion

The results contain the first ever observation (in the Indian coastal waters) on the layer structures and ducting conditions to provide the opportunity for new insight into the radio climatology of marine boundary layer ducting. This study will aid in the improvement of the presently available radio climatological information on low level atmospheric radio refractive structure over the oceans of Indian sub-continent by way of incorporating the correction factors. Airborne microwave refractometers improve the accuracy of future measurements. Finally this data will act as an aid in determining the optimum flight profiles for attack aircraft to avoid detection by hostile radars. Further data collection using airborne microwave refractometers would contribute generally to programmes like IGBP (International Geosphere Biosphere Programme) and TOGA (Tropical Ocean Global Atmosphere).

### References

Barton, I. J., 1970, 'Construction and calibration of a microwave refractometer', RAAF Academy Rep. No. 58, University of Melbourne, Australia.

Birnbaum, G., 1950, 'A recording microwave refractometer', *Rev. Sci. Instrum.*, **21**, 169-176.

Chan, C.K., 1974, 'An expendable microwave radio refractometer', Ph.D. Thesis, London University.

Crain, C.M., 1950, 'Apparatus for recording fluctuations in the refractive index of the atmosphere at 3.2 cm wavelength', *Rev. Sci. Instrum.*, **21**, 456-457.

Fowler, C. S., Champian, R.J.B. and Tyler, J. N., 1966, 'A three-cavity refractometer and associated telemetry equipment, *Rad. and Elec. Engr.*, 186-190.

Kelly, A.J., 1972, 'Cut-off wave guide refractometer', Dynalysis of Princeton Rep. No. 24, Naval Air Systems Command, U.S.A.

Lane, J.A., Froome, D.S. and McConnell, G.J., 1961, 'The construction and performance of an airborne microwave refractometer', *Proc. IEE*, **108**, 398-402.

Sarma, S.B.S.S., Ramakrishna, M. and Dhaveji, C.V.R., 1975, 'Airborne microwave refractometer', *Ind. J. Rad. Space Phys.*, **4**, 285-288.

Sarma, S.B.S.S., Reddy, B.M., Rao, E.B., Rao, M.V., Sarebahi, K.N. and Verma, A.K., 1989, 'Design of airborne solid state digital microwave refractometer', *J. Phys. E. Sci. Instrum*, **22**, 958-961.

Thompson, M.C. and Vetter, M.J., 1958, 'Compact microwave refractometer for use in a small aircraft', *Rev. Sci. Instrum.*, **21**, 1093-1096.

Vetter, M.J. and Thompson, M.C., 1962, 'Absolute microwave refractometer', *Rev. Sci. Instrum.*, **33**, 656-660.

Vetter, M.J. and Thompson, M.C., 1967, 'Solid state microwave refractometer', *Rev. Sci. Instrum.*, **38**, 1726-1727.

Vetter, M.J. and Thompson, M.C., 1970, 'Direct reading microwave refractometer with Quartz-crystal reference', IEEE, Trans. IM-20, 58.