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A study of reception of Omega transmissions by the Navaid sounding instrumentation on Indian Monex ships during Monex—79

N. SESHADRI

Meteorological Office, New Delhi

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ABSTRACT. During the global weather experiment and Monex-79 upper air observations were made over the Arabian Sea and the Bay of Bengal using for the first time the FGGE Navaid sounding systems. Two such complete Navaid systems were installed on board Indian Monex ships. These ships were deployed in the central and south Arabian Sea during May-June 1979 and in the Bay of Bengal during July 1979. In addition to this a data acquisition module of the Navaid system was fitted in the third Monex ship which was located in the south and central Bay of Bengal during May-July 1979. The three ships made 284 upper air ascents in all. The Navaid sounding technique and instrumentation proved their usefulness for upper wind measurements over sea areas from ocean platforms. A brief description of the Navaid instrumentation and the expendable Omegasonde used are given.

In this report an evaluation of reception pattern of the worldwide Omega transmissions obtained at the systems installed on board the Indian Monex ships over the Arabian Sea and Bay of Bengal during Monex-79 (May-July 79) is also presented. The Navaid instrumentation could receive Omega signals from a larger number of worldwide Omega stations over the Arabian Sea than the Bay of Bengal during Monex-79. Omega signals at least from three or more Omega stations were always received enabling the monex ships to be within the great circle triangle formation of combination of three Omega stations, thereby yielding a reliable upper wind data set over the sea areas in Monex-79.

1. Introduction

The determination of vertical wind structure in the tropics became imperative in order to achieve the scientific goals of the Global Weather Experiment and Monex-79. Emphasis was, therefore, laid on accurate measurements of upper wind speed and direction over the data sparse areas of the tropical oceans. The established conventional equipment used for measurement and computation of upper winds require complex and heavy stabilised platforms on board the ships for over ocean measurements.

The World Meteorological Organisation (WMO) instituted a pioneering attempt to collect upper wind information over the tropical oceanic areas of the world during the Global Weather Experiment. This was done by three special observing systems namely Tropical Wind Observing Ships (TWOS) system, dropwindsonde system and tropical constant balloon system. About forty ships carried out upper air soundings in the tropics during the special observing periods (SOPs) of the experiment. About a third of these ships were equipped with radar or radiotheodolites for wind finding, but for use in the remaining ships the FGGE Navaid sounding system was developed utilising the worldwide Omega navigation signals.

Two complete FGGE Navaid sounding systems acquired by India were installed on Indian ships INS *Darshak* and INS *Deepak*, deployed in the Arabian Sea and the Bay of Bengal during Monex-79. A third ship, INS *Betwa*, fitted only with a data reception module of the Navaid sounding system loaned by WMO operated in

the Bay of Bengal during Monex-79. Indian ships recorded upper wind data upto great heights over the Arabian Sea and the Bay of Bengal. While *Darshak* and *Deepak* recorded 193 ascents in all, *Betwa* made 91 flights.

In this study a brief description of the Navaid instrumentation used and an evaluation of reception of Omega signals from the eight worldwide Omega stations by the Navaid sounding systems on INS *Darshak* and INS *Deepak* in the Arabian Sea and the Bay of Bengal during May-July 1979 (Monex-79) are presented.

2. Omega broadcast

Omega is a very low frequency (VLF 10-14 KHz) phase comparison hyperbolic system. The global Omega network is operational since 1976. As currently configured it consists of eight Omega transmitting stations that are in operation at Japan, Norway, Liberia, Hawaii, North Dakota, Reunion, Argentia and Trinidad (likely to be replaced by Australia). During Monex-79, India utilised the Omega worldwide network of these eight stations. The stations transmit signals in a synchronized format on 10.2, 11.33 and 13.6 KHz.

3. Description of the Navaid sounding system instrumentation

FGGE Navaid sounding system was used in the Indian ships. This is an integrated array of electronic and mechanical equipment that senses certain meteorological parameters (temperature, humidity, barometric pressure) and utilises the worldwide Omega navigation signals to determine the upper air direction and speed. The Navaid system uses a balloon borne sensor package (Omega radiosonde) to monitor meteorological and location parameters and transmit these data through a telemetry link of 403 MHz to a receiver and magnetic tape recorder unit on board the ship. The data is recorded as the sonde rises from sea level into the atmosphere, for about 2 hours. The system is designed to be used in either of two following alternative configurations:

(a) *Data acquisition sub-system (Module-A)* — This basic version, receives the data transmitted by Omega upsonde by an omnidirectional antenna. The receiver demodulates the signals and with the help of a central data entry and display unit converts the received signals into digital form and records the data on magnetic cassettes. The Mod-A consists of the following:

(*i*) *UHF and VLF antennae* — The UHF antenna is optimised for radiosonde signal reception. VLF antenna is of whip type about 3 metres long with a preamplifier for reception of 13.6 KHz Omega signals.

(*ii*) *UHF receiver* — This receiver is a single superhet type tuned to 395-410 MHz frequency range. There are two demodulated outputs, one for the pressure, temperature, humidity (PTH) data in the form of signals in 46-56 KHz range and the second output contains retransmitted 13.6 KHz Omega signals from the radiosonde.

(*iii*) *Omega Receiver Processor Unit (RPU)* — The RPU provides the functions needed for Omega signal processing by isolating met. data signals. It also edits and filters uncontaminated met. data to be filled in the data memory.

(*iv*) *Control data entry and display* — This unit enables feeding of preflight/surface information into the system such as sonde identification, latitude/longitude and ambient pressure.

(*v*) *Data recorders* — There are two magnetic cassette recorders for recording, storing and reading alphanumric information. The recorder includes a 'write and read' capability.

The Module-A is operated by a bank of two sets of lead acid batteries completely isolated from ship's power to avoid mains interference and protect from mains failure during ascents.

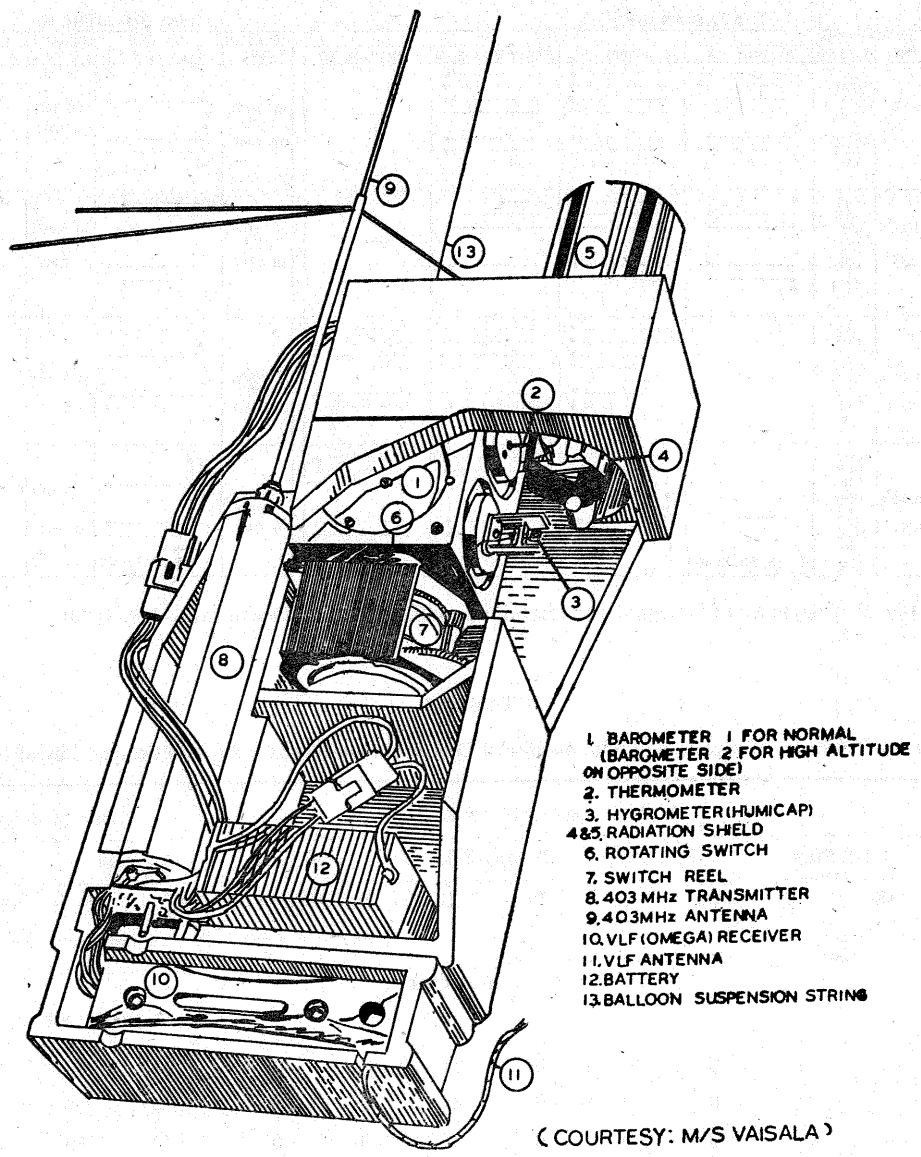

Fig. 1. Sectional view of Omegasonde used in MONEX-79

(b) *Data processing Module* (*Module-B*)— This module complements the MOD-A by providing a suitable processor for computations of data conversion, data quality control and coding of upper air reports in the standard format. The Mod-B consists of (*i*) Mini computer including a Central Processing Unit (CPU) 2×16 K core memory, basic input/output controller, (*ii*) Printer terminal for operational control and printout, (*iii*) paper tape punch usable for data output in 5 channel code for Telex transmission, (*iv*) paper tape reader for entry of programmes and calibration coefficients of the radiosondes and (*v*) ventilation, power and mains, regulating units.

Computer programmes — The Navaid sounding systems are provided with a specific set of operational programme written in assembler code. It performs the functions of preparation of sounding, hardware set up checks, radiosonde verification, software initialisation, surface data entry,

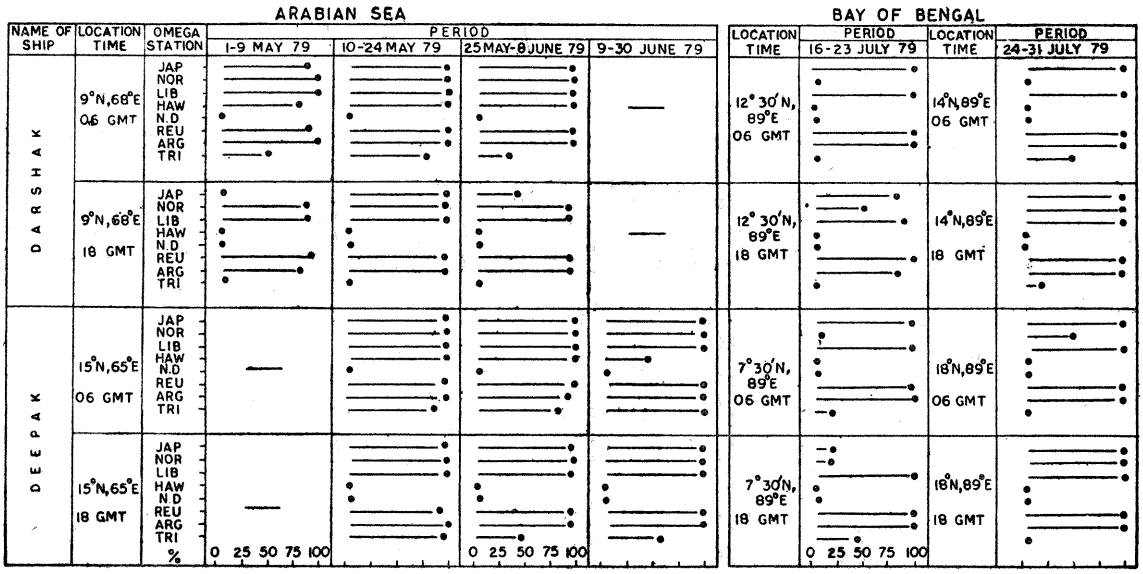

Fig. 2. Frequency of Omega signal reception in nothern Indian Ocean (May-July 1979)

TABLE 1

Percentage frequency of reception of total number of Omega stations over the Arabian Sea and Bay of Bengal

No. of Omega stations	Arabian Sea (15°N, 65°E)								Bay of Bengal			
	1-9 May		10-24 May		25 May-8 Jun		9-30 Jun		16-23 Jul		24-31 Jul	
	06	18	06	18	06	18	06	18 GMT	06	18	06	18 GMT
						(a) **INS Deepak**						
									(7°30'N, 89°E)		(18°N, 89°E)	
<3	—	—	0	0	0	0	0	0	0	0	0	0
3			0	0	0	0	0	0	0	56	0	0
4	—	—	0	0	0	0	0	0	72	30	50	0
5			0	25	07	64	33	57	14	14	50	100
6	—	—	28	75	33	36	15	43	14	0	0	0
7			72	0	60	0	52	0	0	0	0	0
8			0	0	0	0	0	0	0	0	0	0
						(b) INS Darshak						
					(9°N, 68°E)				(12°30'N, 89°E)		(14°N, 89°E)	
<3	0	0	0	0	0	0	—	—	0	5	0	0
3	0	0	0	0	0	0			0	0	0	12.5
4	11	75	0	0	0	47	—	—	100	25	87	0
5	28	12.5	0	100	0	53			0	50	13	7.5
6	11	12.5	33	0	67	0	—	—	0	0	0	12.5
7	50	0	67	0	33	0			0	0	0	0
8	0	0	0	0	0	0			0	0	0	0

real time reception and logging of data and coding of data into standards code format.

The MOD-B combined with the basic version constitutes a complete automatic Navaid upper air sounding system. The Indian Monex ships used two such complete Navaid sounding systems during Monex-79.

The ship-borne Navaid instrumentation of the complete sounding system was used in the Indian Monex ships with the functional electronic units of modules A & B. The Omega upsonde used with Navaid sounding system is shown in Fig. 1. The Omegasonde was made by M/s Vaisala of Finland.

4. Data used

(a) The upper air sounding data collected in real time by the complete Navaid sounding systems on board the Indian ships (*Darshak* and *Deepak*) during Monex-79 has been used for this study. The data was available in the computed print-out form giving minute to minute values of meteorological parameters including the reception of Omega transmissions from the worldwide Omega network with the details of the stations used in every computation.

(b) The data analysed are collected at 06 GMT and 18 GMT over Indian Sea areas for the Monex ships using the Navaid sounding systems. In view of the peculiarity in the wave guide mode of propagation of the VLF Navaid signals, it has been found that observations taken during near sunset and near sunrise hours have been found to introduce large errors due to the instability of the ionospheric layers at dusk and dawn. It was, therefore, decided by WMO that during the Global Weather Experiment of the Tropical Wind Observing Ships fitted with Omega wind finding system will take observations at local noon and local midnight which corresponds to nearly 06 and 18 GMT over Indian sea areas, for all the ships operating in the FGGE area.

5. Analysis of reception of Omega signals

Table 1 presents a summary of reception of Omega stations by *Deepak* and *Darshak*. During May-June 1979 *Deepak* in the central Arabian Sea (15 deg. N, 65 deg. E) was more favourably situated for reception of Omega signals than *Darshak* in the south Arabian Sea (9 deg. N, 68 deg. E). At the northern location, a larger number of Omega stations was received more frequently than at the near equatorial latitude.

No wind determination in the Arabian Sea was based on reception of signals from less than four Omega stations.

On the other hand, in the Bay of Bengal wind determination has been based on reception of signals from a relatively smaller number of Omega stations than in the Arabian Sea, *Darshak* at 12 deg. 30′ N appears to have received Omega signals better than *Deepak* at 7 deg. 30′. While in the polygon formation at a still northern latitude (18 deg. N) *Deepak* received signals from a larger number of Omega stations than when it occupied a position closer to the equator.

6. Frequency and pattern of reception of Omega signals

Fig. 2 illustrates the frequency distribution of reception of signals from Omega stations over the Arabian Sea and the Bay of Bengal.

In the central Arabian Sea location of *Deepak* (15 deg. N) during May-June 1979 largest number of Omega stations are received (as many as 7) and frequency of such reception is consistently high (80-100 per cent). Reception conditions seem to be better at local noon (06 GMT) than at local midnight (18 GMT). In contrast, in July 1979, both in the central and north Bay of Bengal (14 deg. N to 18 deg. N) reception is from a smaller number of Omega stations (4-5) although frequency reception from these stations continues to be high and comparable to that in the Arabian Sea where frequency or reception remains high both at local noon and local midnight.

On the other hand, in the near equatorial Arabian Sea location of *Darshak* (9 deg. N) relatively less number of Omega stations (4-6) has been received than further north. However,

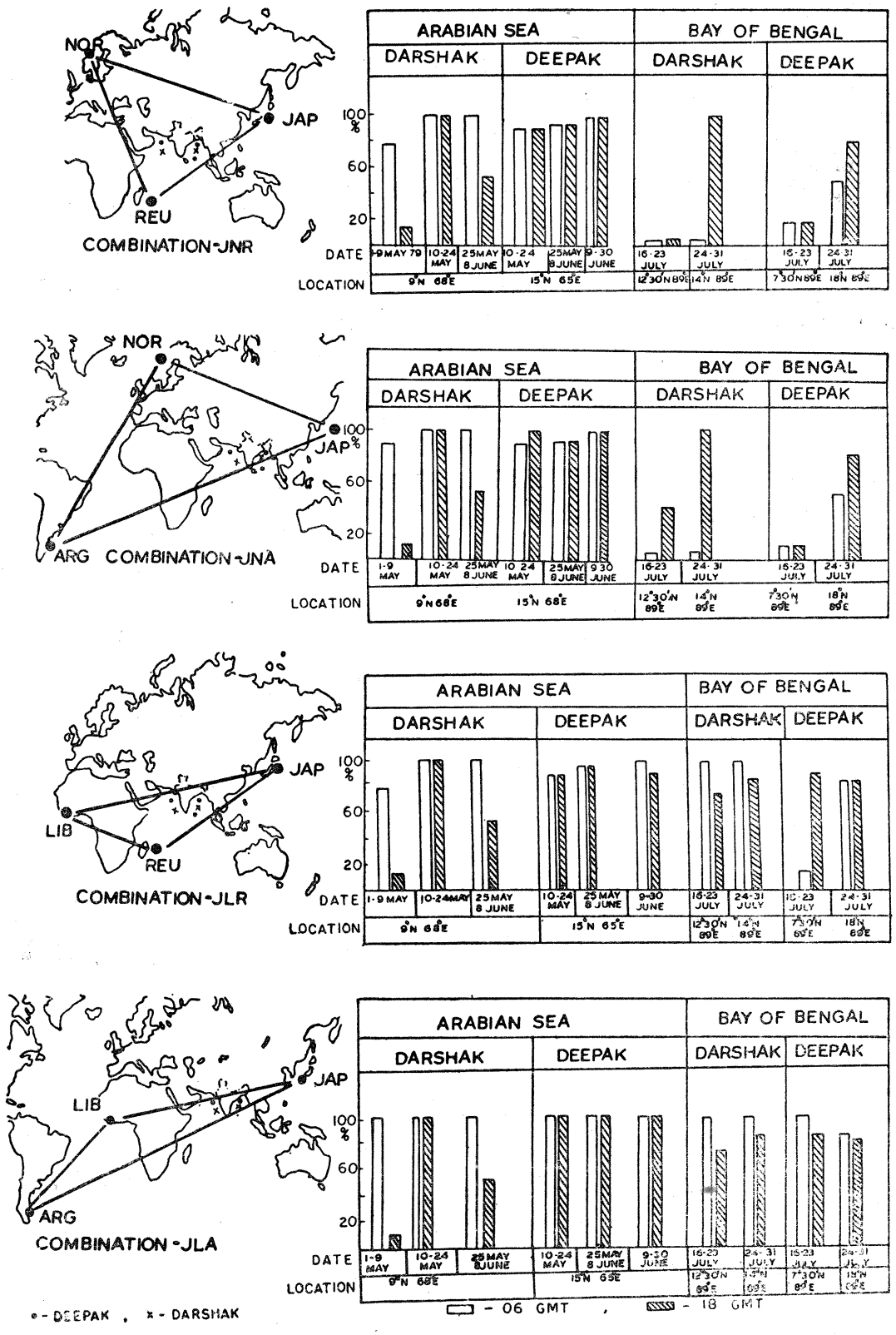

Fig. 3. Pattern of reception of Omega signals by NAVAID of Indian MONEX ships (May-July 1979)

frequency of reception remains almost as high as over the central Arabian Sea. Contrastingly, in the near equatorial Bay of Bengal location of *Deepak* (7 deg. 30′ N) still smaller number of Omega stations (3-4) are intercepted. During the period 4-13 August 1979, *Darshak* cruised in the Bay of Bengal along 84 deg. E from 15 deg. N to 7 deg. N. Thereafter she moved westwards along 5 deg. N to 73 deg. E in the Arabian Sea, from where she moved northwards along 71 deg. E to 15 deg. N. An examination of reception of Omega stations did not bring out any special characteristics. By and large, performance was better at local noon (06 GMT) than at local midnight (18 GMT).

North Dakota has not been received at all both over the Arabian Sea and the Bay of Bengal. Hawaii has not been received over the Bay of Bengal. But local noon seems a preferable time for Hawaii to be received over the Arabian Sea, while it blacks out at local midnight, for reasons not clear.

7. Combination of Omega stations

The best positional accuracy for reliable wind determination in hyperbolic navigation used in Navaid systems in the Monex ships is obtained whether over the Arabian Sea or the Bay of Bengal, when the observations are made within the great circle triangle formed by three or more VLF transmitting stations. The following combinations were obtained.

(*i*) Japan-Norway-Reunion (JNR).

(*ii*) Japan-Norway-Argentina (JNA).

(*iii*) Japan-Liberia-Reunion (JLR).

(*iv*) Japan-Liberia-Argentina (JLA).

Fig. 3 presents the pattern and percentage frequency of Omega signal reception during Navaid deployment on Indian Monex ships in the Arabian Sea and in the Bay of Bengal in the period May-July 1979. All the above four combinations realised over the Arabian Sea have contributed to wind determination at local noon. For reasons not clear, the period 1-9 May 1979 has not been quite favourable for such reception in the near equatorial Arabian Sea location of *Darshak* (9 deg. N) at local midnight.

On the other hand, in July 1979, only the latter two combinations, *viz.*, JLR and JLA have been most frequently received by the two systems. Performance both at local noon and local midnight over the Bay of Bengal as a whole has been quite good. JNR, JNA combinations which had contributed to the wind determination over the Arabian Sea have not been received so consistently in the Bay of Bengal. Here again, while JNA has been quite frequent at local midnight, reception of JNR has been frequent only at local midnight during 24-31 July 1979.

During the winters of 1976-1977, worldwide Omega navigation system signal data were acquired at locations in the Indian Ocean and India by the NCAR scientists, Dr. Olson and Clarke. In India the measurements were made at New Delhi and Ahmedabad and in the Indian Ocean at Diegogarcia. The observations made at these locations indicated that, in general, the signals from all the Omega stations except North Dakota and Trinidad were received in substantial strength both at local noon and local midnight. The strength of the signal from Trinidad was quite strong enough to facilitate good wind-finding of required accuracy. But some time during the measurement the signals from Japan were found to be attenuated at New Delhi and Ahmedabad. This was attributed to either Japan operating slightly at lower power or due to the long travel of the signal over land path or both. The above study reveals that the actual performance of Omega stations is in good agreement with predictions given by the NCAR scientists based on the measurements.

8. Conclusion

(*i*) The Navaid sounding technique for upper wind determination proved useful for the upper air sounding over the ocean areas in the Arabian Sea and the Bay of Bengal in Monex-79.

(*ii*) The Navaid sounding systems were found to receive more number of Omega stations in the Arabian Sea than in the Bay of Bengal. However, there was a decline in the reception as the location of the Navaid system shifted east of 80 deg. E in the Bay of Bengal near 10 deg. N latitude.

(*iii*) The great circle triangle combinations formed by the three Omega stations (JNR, JNA, JLR and JLA) were obtained in the wind determination over the Arabian Sea, whereas the combinations (JLR and JLA) alone were realised over the Bay of Bengal.

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