AD NUMBER
AD396904
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Distribution authorized to U.S. Gov't. agencies only; Foreign Government Information; APR 1966. Other requests shall be referred to British Embassy, 3100 Massachusetts Avenue, NW, Washington, DC 20008.
AUTHORITY
DSTL, AVIA 6/21624, 17 Nov 2008; DSTL, AVIA 6/21624, 17 Nov 2008

CONFIDENTIAL

AD 396904

DEFENSE DOCUMENTATION CENTER

FOR

SCIENTIFIC AND TECHNICAL INFORMATION

CAMERON STATION, ALEXANDRIA, VIRGINIA

CONFIDENTIAL

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

NOTICE:

THIS DOCUMENT CONTAINS INFORMATION AFFECTING THE NATIONAL DEFENSE OF THE UNITED STATES WITHIN THE MEANING OF THE ESPIONAGE LAWS, TITLE 18, U.S.C., SECTIONS 793 and 794. THE TRANSMISSION OR THE REVELATION OF ITS CONTENTS IN ANY MANNER TO AN UNAUTHORIZED PERSON IS PROHIBITED BY LAW.

CONFIDENTIAL

TR 66107

APRIL 1966

ROYAL AIRCRAFT ESTABLISHMENT

TECHNICAL REPORT No. 66107

FACTORS AFFECTING THE RANGE OF A U.H.F. DIGITAL DATA SYSTEM IN THE REGION OF AND BEYOND THE HORIZON [C]

by

Donald P. L. May

MINISTRY OF AVIATION
FARNBOROUGH HANTS

CONFIDENTIAL

U.D.C. No. 621.396.933 : 621.3.092.4 : 621.3.029.63 : 621.391.812

ROYAL AIRCRAFT ESTABLISHMENT

(9) Technical Report ~~No. 66107~~

(11) April 1966, (12) 62p.

(7) ~~FACTORS AFFECTING THE RANGE OF A U.H.F. DIGITAL DATA SYSTEM IN THE REGION OF AND BEYOND THE HORIZON~~

by

(10) Donald P. L. May.

(14) TR-66107

SUMMARY

Practical radio ranges for a high data rate system, known as U.H.F. Data Link, obtained between ground transmitters and an aircraft flying at altitudes up to 18000 feet are analysed for transmitter powers of 100 watts and 3 kilowatts with three different degrees of aerial gain. The higher power transmissions provided beyond-the-horizon reception and the second part of this paper gives information concerning signal strength distributions, fading characteristics and their effects upon communication efficiency in this region.

Departmental Reference : Rad 919

Receding Page Blank-not Filled

CONTENTS

CONTENTS (Contd.)

ILLUSTRATIONS

1 INTRODUCTION

U.H.F. data link[1] is a high speed automatic digital data communication system for transmitting commands and information, obtained from radar computers, direct to fighter aircraft.

Following earlier flight trials of a prototype U.H.F. data link installation[2], pre-production (Stage B) models of the airborne converter were flown, during the period January to October 1964, in order to provide information on range limitations and to investigate beyond-the-horizon performance. To this end, the trials were divided into two broad stages. The first stage determined the average range which could be achieved before false information was accepted by the airborne equipment. As was expected, this occurred near the radio horizon. The second stage investigated the quality of the path beyond the horizon.

The only aircraft available for these trials was a Varsity, having a maximum altitude capability of about 20000 ft. This was by no means ideal, since the aircraft for which the U.H.F. data link system is designed are high altitude machines, but it had the comparative advantage of reasonably long range endurance, ample space for instrumentation and an observer could be carried. Unfortunately the Varsity became permanently unserviceable before the second stage of the trial was completed. Nevertheless, some useful data on beyond-the-horizon performance was obtained from this stage. In all, some 56 daylight flights were undertaken and the ranges provided by the use of three different ground station transmitter power output levels were compared for aircraft altitudes of 5000, 10000 and 18000 ft.

2 U.H.F. DATA LINK SYSTEM

The data link between ground stations and aircraft uses the U.H.F. spectrum 225·0 Mc/s to 399·9 Mc/s. Frequency shift keying of the transmitters is employed; binary 1 being represented by a frequency 20 kc/s above nominal and binary '0' by minus 20 kc/s from nominal.

Fixed length messages are transmitted from the ground to many aircraft, in turn, on a time and frequency sharing basis. Thus, each aircraft receiver has to be synchronized at the start of each message and for this purpose, the message begins with a 5 kc/s synch pattern. At the receiver, this synchronizing pattern is applied to a tuned circuit. When the voltage induced across the tuned circuit reaches a pre-determined level, the circuit becomes connected as part of an oscillator which is used to provide the programme pulses for the airborne data converter. The programme thus runs in phase synchronism with the initial instructions, obtained from the synch pattern,for the length of each message. Individual messages are therefore vulnerable to phase variations, occurring through changes in the propagation medium, if such changes are large enough to cause serious misalignment between the clock pulse programme and the incoming information. The maximum binary digit rate is 5000 per second[1].

3 MESSAGE FORMAT

The test messages used to assess the ground-to-air link were generated by the De-Multiplexers[3] at the rate of one 69 digit message every 14 milliseconds. The structure of these messages is illustrated in Fig.1. Before a message is accepted by the airborne data converter it has to pass the following checks:-

(1)	Synchronization	correct -	13 digits
(2)	Address	correct -	13 digits
(3)	Message No. and origin	correct -	6 digits
(4)	Parity checks	correct -	3 checks.

If all these checks are satisfactory, the converter produces a 'message read' pulse[4]. Thus, in perfect reception conditions, some 72 'read' pulses per second are available at the converter. The frequency of these pulses was used to indicate the percentage of 'correct' messages being received during the trials and provided an excellent check on propagation conditions since, at the speed of the test vehicle, this message rate represents about 1440 messages or nearly 100 000 digits per nautical mile.

4 CORRUPTION OF MESSAGES

At signal strength levels below about 2 μV and down to about 1 μV (closed circuit, at the receiver terminals) the presence of noise causes some messages to be rejected as a result of the checks listed in Section 3 above. However a small proportion of those messages in which the digital pattern has been changed due to noise, are accepted by the converter because the corruption occurred in the message content portion (Fig.1). This condition arises when the disturbance of the digital pattern in a parity check block is such that the number of binary '1's remaining in that block still satisfies the requirement for the parity check. In the prototype model case, the proportion of corrupted messages being accepted in this way, was found to be about 0·01%[2]. The pre-production ('B' Model) converters, to which this paper relates, include modifications to improve this situation. These modifications consist of a 7·5 kc/s low pass filter in the input video line, to reduce the unwanted high frequency components of the receiver's output and a device which checks the output condition of the signal interrogation circuits to guard against digit corruption by noise pulses. The pre-production models should therefore be slightly better than the prototypes in this respect.

5 GROUND EQUIPMENT

5.1 Transmitters

Two 100 watt transmitters type T7096, modified for U.H.F. data link used in FGRI X18189/3 were installed. One transmitter fed either a bicone aerial, design 41, type AJE, or a Quad aerial of R.A.E. design, both at a height of 45 ft. The other transmitter was used to drive a 3 kW Electronics Corporation INC. amplifier type N-2033. The ECI amplifier supplied a 'turnstile' aerial, mounted upon a 50 ft tower, the overall height of the tower and array being about 86 ft. This array provided an omnidirectional radiation pattern in the horizontal plane, and a nominal gain of 10 dB in the vertical plane. The transmitters were fed with a fixed pattern 'test' message, at 72 messages per second from a pair of de-multiplexers[3]. The U.H.F. frequency employed throughout the trials was 282·3 Mc/s, being chosen for its proximity to mid U.H.F. band. Figs.2, 3 and 4 show the 'Quad' aerial, the transmitters and amplifier with its artificial load and a view of the turnstile aerial, with a pair of bicones on the pole in the foreground. The ground station was sited at Cove Radio Station, Farnborough, which is at an elevation of 210 ft a.s.l.

5.2 Ground monitoring

In order to ensure that the full message rate was being transmitted, a monitoring airborne equipment Fig.5 was installed in a laboratory some two miles from the transmitting station. The message 'read' pulses from this equipment were applied to a pulse rate counter with an automatic warning system which was fed back as an alarm to Cove Radio Station if the pulse rate dropped below 100%. In addition, an alarm circuit was connected into the transmitters, so that a fall in power of 2 dB or more would operate the Cove warning.

6 AIRBORNE INSTALLATION

6.1 Data equipment

The data receiver was a pre-production (Stage B) model of the U.H.F. T/R X11672 (modified ARC.52). The specified quietening factor for this receiver, the nominal input impedance of which is 50 ohms, is 10 dB for not more than 10 µV input (open circuit). Sample models proved to be rather better than specified e.g. 10 dB for 2 µV, 13 dB for 2·2 µV, and 17 dB for 5 µV. The receiver was fed from a Dorne and Margolin AT256 wide-band blade aerial, mounted under the aircraft at the rear of the bomb bay. The video output from the receiver supplied the converter signal data and this output was monitored by an oscilloscope.

6.2 Airborne instrumentation first stage

During stage one, the main purpose was to determine the minimum range at which corrupted information was accepted by the converter. Indication of this event was given by a series of 54 lamps, connected to the 54 permanent stores of the data converter[4]. The connections were arranged such that, provided the message stored by the converter was correct, no lamp would be illuminated. However, as soon as a corrupted message was accepted those digits whose sign had been inverted were detected by their appropriate lamp being illuminated. A visual rate meter, measuring the percentage of 'read' pulses being generated, and a meter indicating the A.G.C. voltage of the receiver were provided to assist the flight observer. This simple approach was justified since, with the 100 W transmission, using either the bicone or the 'Quad' aerial, the range at which corrupted messages were accepted coincided closely with the signal strength permanently dropping below a usable level.

6.3 Flight observations first stage

In order to determine the nearest range from the ground station where corrupted messages were accepted by the data converter and to ascertain the depth of the 'corruption band', the flight observer noted the range at which any of the indicator lights came on (para 6.2) and the greatest range at which changes to these lights ceased to occur on an outbound flight and vice versa on an inbound run. In addition he observed the message 'read pulse' meter and the receiver A.G.C. voltage. In later flights, the range, read pulse percentage and A.G.C. level were recorded automatically.

6.4 Instrumentation for second stage flights

Preliminary runs, using the 3 kW transmission, showed that after the initial reception of corrupted messages, usable signals were still present for a considerable distance. However after this initial point, the signal sometimes passed through the critical level too frequently for manual observation. In order to investigate the usefulness of these extended range signals a type IT.3-12-61 recorder was added to the instruments used in the first stage. This recorder was fed with range markers every five miles together with the receiver A.G.C. voltage and the data converter 'read' pulse percentage.

7 COURSE OF FLIGHTS

The aircraft flew off from Farnborough on a heading of 260° in all the flights up to 10000 ft. Above this altitude, the course was usually 350°, for flight safety reasons. On the low power or low altitude runs the aircraft usually achieved four passes through the corruption band per flight, by doubling back on its track under the instructions of the flight observer.

8 STAGE 1 RESULTS

The number of flights made, altitude and equipment used is shown in the tables which follow. It should be noted that the outbound and inbound runs have been treated separately. This is because the polar diagram of the aircraft receiving aerial had a back to front ratio of approximately 6 dB - favouring signals arriving from the rear.

The results of the first group of flights, in the first stage, are given in Table 1 below.

8.1 10000 ft flights

Table 1

Analysis of runs during 16 flights at 10000 ft between 10th January 1964 and the 13th May 1964

282·3 Mc/s

Ground transmitter power - 100 watts

Ground aerial - bicone

Criterion	Nautical miles	
	Outbound	Inbound
Minimum range (no corrupted messages accepted)	113	103
Maximum range (no corrupted messages accepted)	134	130
Range before corrupted messages accepted: Average of 26 runs	119	
Average of 28 runs		118
Maximum corruption band	113 to 145	103 to 140
Average corruption band (28 runs)	119 to 134	118 to 123

The average of all runs in both directions is about 118 nautical miles or $1{\cdot}18\sqrt{h}$ nautical miles (h = height in feet)

NOTE: The term 'corruption band' is defined as the distance over which messages containing corrupted information were occasionally accepted by the data converter. At the greater distance shown in the tables, the signal had dropped to an unacceptably low level and no further messages were received.

8.2 Signal strength attenuation near the horizon

The A.G.C. level of the airborne receiver was taken at discrete points by the flight observer during the flights to which Table 1 relates and one became interested in the slope of the attenuation curve onwards from the optical horizon. The distance required to produce a 20 dB fall in signal strength is shown in Table 2. The average drop was shown to be about 1 dB per nm. The table also indicates the ranges at which the signal had dropped to 10 μV and 1 μV at the receiver terminals.

Table 2

Radio signal attenuation in the region of the horizon

10000 ft course 260°. f = 282·3 Mc/s

Ground transmitter. 100 watts

Ground aerial bicone

Analysis of 40 runs

Average slope of outbound runs		=	1·06 dB per nm
Average slope of inbound runs		=	0·96 dB per nm
Average slope of both directions		=	1·01 dB per nm
Spread of slope	(Maximum	=	2·2 dB per nm
	(Minimum	=	0·7 dB per nm
Average range for 10 μV* signal		=	107 nm
Minimum range for 10 μV* signal		=	87 nm
Maximum range for 10 μV*		=	127 nm
Average range for 1 μV* signal		=	129 nm
Minimum range for 1 μV* signal		=	113 nm
Maximum range for 1 μV* signal		=	143 nm

* This is the signal at the receiver input when connected to a quarter wave wide band unipole.

8.3 18000 ft flights

The analysis of the second group of flights in stage one, at a greater altitude, is given in Table 3, page 11.

Table 3

Analysis of results of six flights at 18000 ft between 26th May and 10th July 1964

Frequency = 282·3 Mc/s

Ground transmitter. 100 watts

Ground aerial Quad.

Criterion	Nautical miles Outbound	Inbound
Minimum range (No corrupted messages accepted)	153	154
Maximum range (No corrupted messages accepted	175	175
Nearer corruption margin, average of 12 runs	159	156
Distant corruption margin, average of 12 runs	170	167
	BOTH WAYS	
Minimum range (No corrupted messages accepted)	153	
Maximum depth of corruption band	153 to 175	
Average range before corrupt messages accepted	$= 1{\cdot}16\sqrt{h} = 155{\cdot}5$	
Maximum range for 100% reception	163 (24 runs)	
Minimum range for 100% reception	151 "	
Average range for 100% reception	$= 1{\cdot}15\sqrt{h} = 155$ "	
Maximum range for 80% reception	164 (24 runs)	
Minimum range for 80% reception	151 "	
Average range for 80% reception	$= 1{\cdot}17\sqrt{h} = 157$ "	

The average proportional range, in terms of $\sqrt{h}$, before corruption occurs is slightly less than in the case of the 10000 ft flights; $1{\cdot}16\sqrt{h}$ instead of $1{\cdot}18\sqrt{h}$ in nm.

8.4 'Quad' aerial runs

Between 13th and 24th of July 1964, six flights were made using the transmission aerial illustrated in Fig.2. The aerial was designed by the author and was tested on the aerial range at R.A.E. Lasham. Figs.6 and 7 show the polar diagrams obtained, for vertical and horizontal axes respectively, at the design frequency of 282 Mc/s. The V.S.W.R., as measured at the Cove transmitter, was found to be 1·43:1. The aerial was mounted, on a tower, at the same height and adjacent to the bicone aerial which had been used as the reference.

The flight results are shown in Table 4 where it will be seen that an improvement in average range of 11% was shown, compared with the same input power to the biconical aerial, i.e. the increase was 13 miles, from 118 nm to 131 nm at 10000 ft altitude. Since the path attenuation in this region was about 1 dB per mile (Table 2) a gain of 13 dB over the bicone can be attributed to the Quad aerial under these conditions.

Table 4

Analysis of results of 21 runs at 10000 ft during 6 flights, between 13th July and 24th July, 1964

282·3 Mc/s
Ground transmitter. 100 watts
Ground aerial. Quad

Criterion	Range in nautical miles	
	Outbound	Inbound
Minimum range (No corrupted messages accepted)	127	125
Maximum range (No corrupted messages accepted)	139	135
Maximum corruption band	127 to 167	125 to 143
Average range before corruption occurs; outbound + inbound = 131 nm		

8.5 Preliminary runs with 3 kW amplifier

During the period 13th July to 28th August, 1964, thirteen flights were made at 10000 ft using the 3 kW amplifier and turnstile aerial. The same procedure for determining the limits of the corruption band was employed so as to provide comparison in the same terms as previous flights. The improvement in maximum range was so noticeable that extra instrumentation was installed (para 6.4) for flights on and after the 12th August. Results obtained from this instrumentation will be dealt with later in the paper.

Table 5, page 13, shows the analysis of 13 flights and Table 6, page 14, gives the comparison of results from all flights so far described.

It will be seen that the 3 kW amplifier and turnstile aerial gave an improvement in average range of 33% before corrupted messages were accepted by the converter, compared with the reference 100 watt/bicone combination. A significant feature being an improvement by 89·5% in maximum range. (Maximum range being defined as the greatest distance from the transmitter at which messages were received, regardless of gaps in reception from the start of the corruption band, onwards.)

Table 5

Analysis of results of 13 flights at 10000 ft between 13th July and 28th August, 1964. 3 kilowatt amplifier and turnstile aerial

Range before corrupted messages were accepted:-

Average	157 nm
Maximum	205 nm
Minimum	135 nm

Maximum range regardless of corruption:-

275 nm.

8.6 Notes on results of Stage 1

During this stage no quantitative assessment was made of the percentage of messages received versus range. It had been seen that, for the 100 watt transmissions, the signal strength dropped below a usable level within a few miles of the onset of corruption. The useful range could not therefore, be considered to extend much beyond this point. Up to the near boundary of the corruption band, flight observations of the message rate meter indicated that the majority of the messages sent were received. The 3 kW transmissions showed an improvement of 33% in range, before the onset of corruption and an increase of nearly 90% in maximum range. It should be pointed out that the effective increase in power of the 3 kW/turnstile over the 100W/bicone system was probably more than the theoretical amount due to power and aerial gain. Measurements at a distance of about two miles showed the turnstile combination as having 53 dB greater output at low angles of incidence than the 100W/bicone. This was larger than the 24 dB expected from theoretical considerations and was probably due to a more favourable polar diagram in the case of the turnstile.

Since the angle between the ground station and aircraft was never more than a few degrees, this factor may have favoured the turnstile aerial by more than the theoretical power ratio during the trials. Typical polar diagrams of the turnstile aerial are shown in Fig.8.

Table 6

Comparison of results at 10000 ft on 282·3 Mc/s, between January and August, 1964

Equipment at transmitting station	Average range before corrupted messages are accepted	Maximum (1) range before corrupted messages are accepted	Minimum range before corrupted messages are accepted	Maximum (2) range for reception of messages	Relationship of range			
					Average	Max (1)	Min	Max (2)
100 watts and biconical omni-directional aerial	118 nm (54 runs)	134 nm	103 nm	145 nm	Ref.	Ref.	Ref.	Ref.
100 watts and Quad aerial	131 nm (21 runs)	139 nm	125 nm	167 nm	+11%	+3½%	+21·5%	+15%
3 kW and turnstile aerial	157 nm (21 runs)	205 nm	135 nm	275 nm	+33%	+53%	+31%	+89·5%

9 STAGE TWO PLANNING

In the light of the extended maximum range results, obtained from the initial 3 kW flights, it was decided to investigate the reliability of the communication path at beyond-the-horizon ranges over a period, so as to provide information on the path changes to be expected. Since diurnal propagation variations would have a greater bearing on this investigation than in the previous work, 100 watt and 3 kW flights at altitudes of 5, 10 and 18 thousand feet were interlaced so as to obtain a cross section of propagation conditions. As in earlier flights, the trials took place during daylight. It had already become evident that corrupted messages would occasionally be accepted from the near boundary of the corruption band onwards, until the ultimate limit of signal strength was reached. When the low power transmissions were used, this band was only a few miles in extent. With the 3 kW transmissions, it had become evident that the corruption band would extend over considerable distances. It was decided, therefore, to attempt to evaluate the usefulness of this part of the path by measuring the percentage of messages received and the relative signal strength from the region of the horizon onwards; on the assumption that the proportion of messages accepted as correct would include a similar proportion of corrupted messages as determined from previous work[2]. This would provide a guide to the number of times a message would have to be repeated to ensure correct reception, together with useful information upon signal attenuation and pointers to improved system design.

10 FACTORS AFFECTING EXTRACTION OF DATA

10.1 A.G.C.

The receiver A.G.C. characteristic was favourable for showing small changes of signal strength at the low input end of the curve, 0 to 10 µV being represented by a change of about one volt. Above this level the characteristic became asymptotical. The time constant was reasonably fast for showing changes in the propagation medium, e.g. 100% square wave modulation of a 1 m.v. carrier gave an A.G.C. voltage time constant of 2·3 milliseconds between the limits of 10% and 90% of the final amplitude.

10.2 Pulse rate integrator

The data convertor message 'read' pulses were fed to an integrator circuit having a growth (0 - 100%) of about four seconds and a decay time of about six seconds.

10.3 Recorder

Paper passed through the recorder at the rate of $\frac{1}{4}$ inch per second or about six inches per mile of flight, depending upon the speed of the aircraft. A casette lasted for some forty minutes of flying time. Event markers consisted of one second and five mile marks. Extra film casettes were carried and the flight observer endeavoured always to change casettes at a time when the least interruption to critical data would occur. By this means, reasonably continuous recordings of individual runs were obtained.

11 REDUCTION OF DATA

In order to compromise between excessive information and data reduction to a point where the true picture becomes obscured and since some 1600 ft of recordings had to be processed, it was decided to extract an average of the message received percentage for each unit of ten miles of each flight; to average these ten mile units for flights at each altitude and also show the spread of the percentage from which the average was obtained. The signal strength recordings were reduced to points one mile apart. Attention was also given to short term perturbations of the signal. Histograms reproduced in the appendix were prepared from the message percentage reduction. Since the minimum signal required for 100% reception is about 1 microvolt (closed circuit at the receiver terminals), the histograms also show the average percentage of each ten mile step during which the signal was at or above this level.

Representative graphs of signal strength are reproduced in this paper.

12 STAGE TWO RESULTS

12.1 Message percentage at 5000 ft

Fig.9 indicates the average percentage of messages accepted as correct during 14 runs using 100 watts and the bicone aerial compared with 13 runs using 3 kilowatts and the turnstile aerial. The 100 watt/bicone combination shows that the average distance where reception starts to drop from 100% was at 60 nautical miles; well before the radio horizon. By the time the radio horizon was reached, message reception was down to about 60%. The average range for the limit of reception was about 95 nautical miles. In the case of the 3 kW/turnstile transmissions however, the deviation from 100% was at 90 miles, some 7% beyond the radio horizon and the average range to the no reception point was about 185 nm.

12.2 Message percentage at 10000 ft

Fig.10 compares 18 runs using 100 watts and the Quad aerial with 8 runs using 3 kW and turnstile.

The former combination was just sufficient to provide 100% reception up to the radio horizon (120 nm) from where the reception fell to zero at about 170 nm.

Using the higher power, the percentage started to drop from 100 at 130 nm and did not fall to zero until about 280 nm.

12.3 Message percentage at 18000 ft —

Fig.11 illustrates the average of 20 runs using 100 watts and bicone compared with 2 runs each way 3 kW and turnstile - the small sample of higher power runs obtained was due to the test aircraft becoming permanently unserviceable, causing the trials to be abandoned (this also accounts for the lack of 10000 ft/bicone samples for this stage of the trial).

The lower power curve compares closely with the 100 W/bicone results at 5000 ft, message percentage being down to 60% at the radio horizon in both cases (161 nm and 85 nm respectively). No further messages were received beyond an average of 180 nm. The 3 kW and turnstile combination provided 100% reception up to 190 miles. The range to the point of no reception was not determined, since the aircraft's flight endurance was insufficient to reach this range and return to base. Bursts of 100% message rate were still occurring at 340 nm.

NOTE: The information contained in the message percentage graphs referred to above has been limited for quick reference purposes. The appendix to this paper contains histogram (Figs.'D' to 'M') showing the average percentage in units of ten nm and the spread of the steps from which the average was obtained.

12.4 Meteorological conditions versus range

During the period covering flights where extended range was obtained by the use of the 3 kW amplifier, all available meteorological information for areas in the vicinity of the flight paths was collected with a view to attempting to establish factors which affected the ranges achieved.

The 5000 ft and 10000 ft flights were on a course 260° from Farnborough and for these flights the meteorological data was taken from Farnborough, Hants and St. Mawgan, Cornwall. Information in regard to inversions and tropospheric height was taken from Crawley, Sussex and Camborne, Cornwall. Information with respect to the 18000 ft flights, which were on a course of 350°, was taken from Farnborough, Crawley, and Leuchars, Scotland.

The meteorological data were available for 10.00 and 13.00 hours. Tropospheric heights and intervening inversions were given for 12.00 hours. Ranges obtained for flights between these times were plotted against the various items of data, such as barometric pressure, vapour pressure, inversions and tropospheric height, temperature and so forth. Particular attention was paid to the relationship between range, versus the presence of inversions and tropospheric height, since it has been suggested[5] that at least some of the beyond-the-horizon propagation phenomena can be explained by the mechanism of specular reflections from elevated discontinuity layers.

Examination of the results failed to disclose positive correlation between ranges obtained and individual or collective data in regard to temperature and pressures, possibly because these referred to ground level at the Meteorological Measuring Stations rather than at the level at which the aircraft was flying. In addition, this information was usually at least an hour out of synchronism with the time at which maximum range was reached. There was, however, a tendency for range to increase with higher temperature and pressure.

The 5000 ft flights showed range increasing with tropospheric height, but this was not confirmed by the results at 10000 or 18000 ft, where range and tropospheric height appeared to be completely unrelated. Neither could any connection be found between inversions and range except that, at each altitude, the flight during which the greatest range was obtained occurred when an inversion between 600 and 2000 ft at both tropospheric sounding stations along the flight path had been discernible.

Ranges versus meteorological and tropospherical data for flight altitudes of 5, 10 and 18 thousand ft are shown in the Appendix Tables A, B and C respectively.

It became evident, as the trials progressed, that there was a strong connection between weather conditions and radio range. During settled periods where little or no cloud existed ranges were invariably long. As soon as conditions became even slightly unsettled the ranges were reduced. The presence of clouds near the aircraft resulted in a reduction of the messages received percentage. Once the region of cloud was cleared by the aircraft the rate would increase. Unusual conditions were experienced during the

18000 ft flight of 3.9.64, where 100% messages were still existing at 340 nm. This flight was carried out between two layers of cloud, except for the last few miles where the sky was completely clear. Unfortunately the aircraft had to return for fuel before the ultimate range could be found. In this case the propagation medium was presumably a duct between the cloud strata.

Although no firm conclusions as to the mechanism of beyond-the-horizon propagation could be drawn from these trials, it seems reasonable to suggest that diffraction in the region of the horizon and terrestial magnetic effects cause a small proportion of the signal to travel at angles substantially parallel to the earth's surface and that the presence of water vapour is a significant factor causing attenuation of this signal. Thus, during periods of settled weather when atmospheric moisture is low, usable signals are still present at ranges well beyond the horizon. These ranges could be greatly extended by ducting effects and modified by changes in the refractive index of the atmosphere, since the latter changes the constant which determines the effective radius of the earth.

12.5 Signal strength distribution

Figs.12 and 13 show typical examples of signal strength of the 3 kilowatt and turnstile combination plotted against distance, for aircraft altitudes of 5000 and 10000 ft. These graphs were obtained by reading off the photographic recordings at intervals of one nm, so that fast variations have been smoothed out. The horizontal portion, to the low mileage end of the curves, should not be taken as representative of the signal strength fall off over line of sight, since, at this level, the receiver A.G.C. was approaching saturation*. Examples of and comments on the photographic recordings will be given later.

It will be seen that a sharp step appears in the slope in the vicinity of the horizon, after which the signal fall off is relatively shallow and fluctuating. The results of a number of runs were processed for each altitude and the following information was extracted.

(a) The average distance from the transmitter to the top of the step was $1{\cdot}4\sqrt{\text{height}}$ in feet = nm for both altitudes, with a spread of $1{\cdot}3\sqrt{h}$ to $1{\cdot}54\sqrt{h}$ over a dozen runs.

(b) The average attenuation down this step was about 1·5 dB per nm during the same runs.

* Hitherto unpublished work at the R.A.E., on V.H.F. propagation indicates that the attenuation characteristic over the line-of-sight path is greater at 5000 ft than at 10000 ft. Figures so far quoted are: 5000 ft 0.35 dB/nm average, with a spread from 0.2 dB/nm to 0.65 dB/nm; 10000 ft, 0.27 dB/nm average, with a spread from 0.2 to 0.3 dB/nm. (See Para.12.5 (d) above.)

(c) The average distance to the foot of the step, in both cases, was $1{\cdot}63\sqrt{h}$ nm, with a spread from $1{\cdot}43\sqrt{h}$ to $1{\cdot}95\sqrt{h}$.

(d) There was a marked difference in the beyond-the-horizon attenuation between the 10000 ft and 5000 ft results from the foot of the step onwards. The average attenuation at 10000 ft being 0·1 dB per nm, whereas at 5000 ft it was 0·173 dB/nm.

Unfortunately, insufficient samples were available for 18000 ft flights to permit valid comparisons to be made with the lower altitudes in regard to (d) above. It would have been most interesting to determine whether still further reductions in attenuation occurred at higher altitudes.

Only two flights could be carried out at 18000 ft during the second stage, before the aircraft became unserviceable. Since the propagation conditions were completely different for these two flights, the signal strength graphs for the outbound runs are reproduced in Figs.14 and 15. The outbound run on 31.8.64 (Fig.14) was carried out under fairly average propagation conditions, the attenuation being similar in character to the typical 5000 and 10000 ft results. The signal had dropped to the 1 µV level at about 195 nm ($1{\cdot}45\sqrt{h}$), gradually falling to zero at about 285 nm. Fig.15, relating to the outbound flight on 3.9.64, is very different in character. On this occasion the aircraft was flying between two cloud layers and there was an inversion at 1500 ft discernible at both ends of the track. The signal level was exceptionally high throughout, being about 60 µV at 200 nm ($1{\cdot}5\sqrt{h}$) where the top of the step occurred. The signal did not drop to 10 µV until about 265 nm and apart from two areas between 284 and 288 and 306 to 308 nm, the signal strength did not drop below 2 µV during the remainder of the run, which extended to nearly 340 miles. The aircraft then had to return due to fuel shortage. Other interesting features of this flight are the double step between about 200 and 260 nm (Fig.15) and the greater tendency for the signal to remain at steady levels over various sections of the route. At about the point where the aircraft emerged from between the cloud layers into clear sky (i.e. 316 nm from the transmitter) up to the turning point, the variations in signal level were considerably reduced in frequency, with very little overall attenuation occurring.

12.6 Fading

Referring again to Figs.12 and 13. The intervals of extraction from the recordings were of the order of 20 sec apart. These graphs being typical of results at 5000 and 10000 ft, provide information upon the longer term fading to be expected at these altitudes.

Examples of the various types of short term fading encountered are illustrated in Figs.16 to 19 inclusive. These are direct extractions from the recordings at beyond-the-horizon distances and were chosen from sections where the message reception was being badly affected by signal perturbations. One should bear in mind, when examining these recordings, the time constants of the A.G.C. and message rate instruments, (Paras 10.1 and 10.2). Due to the relatively long time constant of the message received pulse integration, there is some cause and effect time displacement between the two traces.

Figs.16 and 17, relating to 5000 ft and 18000 ft respectively, are examples typical of the majority of short term fading versus message reception conditions encountered at all three altitudes flown during the trials. The positions where these examples occurred are annotated on the signal strength graphs, Figs.12 and 14. In these cases, the signal varies in rather random fashion. An appreciation of the fading rate can be obtained by comparing the signal strength curve of Fig.17 with the one second vertical markers. In this case, the aircraft has flown through an area of disturbed signal strength extending about five miles in depth. The beginning and end of this area is clearly visible on the recording.

Fig.18 is a sample of message drop-out which occurs only occasionally. The signal strength falls slowly and then starts to oscillate with increasing amplitude at about two cycles per second for about half a mile, after which the signal gradually recovers its previous value. The cause of this type of fade is uncertain, but the indications were that it may be connected with turbulence near cloud formations.

A sample of the third group of fading patterns encountered is shown in Fig.19. At first sight this type of fade, which happens very seldom, appears to be similar to that of Fig.18. However in this case, the signal fall-off is not evident and the oscillations start and finish at a high rate, slowing down to zero in the centre of the disturbed area. Although the presence of other aircraft was not noted at the time, reflections from such objects appears to be the most likely cause of this effect, which in character is similar to the beat fading experienced with television reception in the neighbourhood of aerodromes.

12.7 Cause of message loss

The recordings were examined in order to determine the cause of lost messages. This could be due to interference from other transmitters, phase changes in the propagation medium (Para 2) or the loss of signal strength.

None of the recordings revealed evidence of radio interference, 100% message reception being indicated at all times when the signal was above the critical level (Para 4). This also implied the lack of significant phase changes in the medium, since the data converter will fail to process messages correctly if the frequency of its video input (from the U.H.F. receiver) changes by thirty cycles or more from nominal frequency during a message period. The U.H.F. transmission modulation system is by frequency shift keying of the carrier, therefore the accuracy of the receiver's video output is directly related to the frequency of the radio transmitter. Certainly there was no evidence of message loss, due to this cause, when the received signal was above a few microvolts. However, at the extended ranges when the signal was fluctuating rapidly around the 1 μV level some message loss could have been present without this showing up on the message percentage trace, owing to the integrating time of the galvanometer driving circuit.

No adverse effects resulting from a signal minima, attributable to interference between direct and indirect rays[6] were encountered over line-of-sight ranges. Beyond the horizon, short term reductions of signal frequently occurred, but these appeared at random distances, flight by flight, despite the fact that on each occasion the aircraft flew over the same track. During the 5000 and 10000 ft flights, the aircraft was over land for the first 170 nm from base and over sea for the remainder of each outbound leg. No discernible change in the fading or attenuation characteristic occurred after leaving the land and flying over the sea or vice versa, e.g. Figs.12 and 13.

13 CONCLUSIONS, STAGE ONE

Stage one of these trials showed that the 100 watt transmitter and bicone aerial combination, which is in use for R/T purposes and is proposed for U.H.F. data link, has insufficient radiated power to ensure, at all times, 100% uncorrupted message reception from the transmitter site to the radio horizon for aircraft heights up to 18000 ft. It would appear that this deficiency is of the order of 10 dB, since the use of the Quad aerial, the gain of which was of this order, demonstrated reliable communication to the radio horizon when used with the same transmitter. This type of aerial would, however, not provide omnidirectional radiation in the horizontal plane and would therefore be unsuitable for normal ground to air communication. Transmitters having 100 watts output power would probably give all round coverage to the radio horizon if they were used to feed an aerial system having 10 dB gain in the vertical plane and an omnidirectional pattern in the horizontal plane, e.g. the type of aerial used with the 3 kilowatt amplifier as described in this paper.

Stage one results demonstrated that an increase of output power to 3 kW and the use of a horizontally omnidirectional transmitting aerial having 10 dB vertical gain was sufficient always to ensure 100% reception of U.H.F. data link messages (requiring a minimum of 1 μV input to the receiver) up to the radio horizon and that, on most occasions, the 100% reception distance extended to more than 10% beyond the radio horizon for aircraft heights up to 18000 ft.

It should be pointed out that it may not be safe to extrapolate the range results shown for these trials for aircraft flying above the tropospheric boundary. If the assumptions made by other writers, e.g. Refs.7 and 5, are correct the signal attenuation characteristics could be different from those experienced for sub-tropospheric heights.

14 CONCLUSIONS. STAGE TWO

Use of the 3 kilowatt amplifier, turnstile aerial and the airborne data converter enabled a large amount of data to be extracted in regard to propagation conditions in the region of and beyond the horizon. Due to the characteristics of the airborne receiver and data converter combination, it has been possible to provide comprehensive information upon the percentage/range factor, where signals exceed a field strength equivalent to that required to produce a 1 μV, closed circuit, signal at the output terminals of a standard U.H.F. airborne aerial.

It has been shown that usable signals are normally present at ranges far beyond the horizon, provided that sufficient power is radiated at low angles of incidence to ensure that a large enough residual signal remains after the horizon attenuation. This can be achieved with powers as low as 3 kW and the use of high data rate, involving bandwidths of 7·5 kilocycles and radio receivers of old design.

The propagation medium between the ground and airborne stations flying at between 5000 and 18000 ft altitude, produces three distinct attenuation characteristics over the path from the source of radiation to the limit of range. The first of these occurs between the source and the visual horizon and was not investigated during these trials. Contemporary work on V.H.F. propagation so far indicates that this slope is of the order of 0·3 dB per nautical mile, (see footnote to Para.12.5) with considerably more attenuation sometimes occurring at lower aircraft altitudes.

Just beyond the optical horizon the attenuation at U.H.F. increases rapidly and maintains an average of about 1·5 dB per nautical mile between the distance limits set out in Para.12.5. The distance from the source at which this slope began was found to vary by 24%, with that to the foot varying by as much as 52%. The average distance to the beginning of this second slope, for aircraft altitudes of both 5000 and 10000 ft, was found to be $1{\cdot}4\sqrt{\text{height in feet}}$ = nm and in both cases the average distance to the foot of the slope was $1{\cdot}63\sqrt{h}$. From the foot of this second slope onwards, considerably less attenuation occurs, averaging only 0·1 dB/nm at 10000 ft and 0·173 dB/nm at 5000 ft. This greater attenuation of the third slope at the lower altitude is of interest in connection with the previously mentioned findings at V.H.F. over the optical path, since preliminary data from the V.H.F. trials also shows more rapid attenuation of the third slope at 5000 ft compared with that at 10000 ft aircraft altitude.

The trials have shown that it is possible to process high data rate messages with a fair degree of reliability at beyond-the-horizon distances in daylight and that, with the system used, the determining factor for reception was sufficient signal strength. Loss of communication due to interference, phase changes or other causes was not encountered. It is evident that still further range improvements could be obtained by bandwidth reductions and the use of a lower data rate.

15 Acknowledgements

Acknowledgements are made to Mr. A. Stembridge for aerial polar diagram measurements and comparison of notes on contemporary V.H.F. range work; to Messrs. P.R. Burkitt and C. Corlett for their help in providing a reliable transmission service from Cove Radio Station and to Mr. P.T. Waite for his diligent flight observations and help in the tedious task of reducing the large amount of data to manageable proportions.

Appendix A

Flights between 10.00 and 13.00 hours a

Date	Time	Ground at South Farnborough			Ground at St. Mawgan			I		
		T°	VP	P	T°	VP	P	Hb	T°	H
13.10.64	10.00	2·4	5·5	1005	8	9	1005·4			
	13.00	11·6	7·1	1005·1	12	7	1005·9	Nil		
16.10.64	10.00	10·1	9·5	1011·9	11·2	10·8	1016·5			
	13.00	13·5	7·6	1013·2	12·4	10·8	1018·2	5·5	-02	6·
14.10.64	10.00	7·3	9·4	998·9	9	10·3	996·6	20·5	-34	23
	13.00	8·8	10·6	997·9	12	10	996·8			
5.10.64	10.00	10·8	12·3	1024·8	14·1	15·9	1021·9	Nil		
	13.00	19·8	15·7	1023·1	14·5	16·5	1020·8			
23.9.64	10.00	20·6	8·9	1021·4	17	13·2	1016	2	+12	2
	13.00	21·8	9·8	1019·3	18	12·3	1014·1	8·5	+ 5	9

Legend:- T° = temperature in °C

VP = vapour pressure

P = barometric pressure

Hb = height of base of inversi

Ht = height of top of inversi

Trop. = height of troposphere i

Appendix A

...nd 13.00 hours at 5000 ft 3 kW Course 260°

Inversions and tropospheric height 12.00 hours at Crawley						Camborne						Range obtained
Hb	T°	Ht	T°	Trop.	T°	Hb	T°	Ht	T°	Trop.	T°	
Nil		Nil		28	-55	Nil		Nil		35	-51	145 nm
						5·5	+01	6·0	0			
5·5	-02	6·0	-01	33	-55	9·0	-04	9·3	-03	36	-57	150 nm
20·5	-34	23	-32	33·5	-52	15	-19	17·5	-18	35	-54	160 nm
Nil		Nil		39·5	-60	Nil		Nil		45·4	-62	175 nm
2	+12	2·5	+14			0·6	+14	0·75	+20			180 nm
8·5	+ 5	9	+ 6	41	-63					45	-64	

...e in °C

...ssure

... pressure

... base of inversion in thousands of feet

... top of inversion in thousands of feet

... troposphere in thousands of feet.

2

Appendix B

Flights between 10.00 and 13.00 hours at 10000 ft

	Ground at South Farnborough				Ground at St. Mawgan			Inversions Crawle			
Date	Time	T°	VP	P	T°	VP	P	Hb	T°	Ht	T°
29.7.64	10.00	16·8	16	1017·7	16	17	1018·6	4	+ 8	4·9	+10
	13.00	18·5	16·2	1018·6	18	17	1019·5				
21.8.64	10.00	10·3	11	1017·7	14	-	1017·1	Nil		Nil	
	13.00	17	10·7	1017·2	17	-	1017				
28.8.64	10.00	17·5	14·7	1018·9	16	-	1020·9	3·6	+10	4·4	+11
	13.00	22·4	13	1017·9	16	-	1021·2				
24.8.64	10.00	17·4	18·2	1018	16	-	1018·7	7·1	+ 7	7·4	+ 8
	13.00	18	18·8	1018·2	17	-	1019·4				
28.7.64	10.00	16·9	15·4	1012·6	16	16	1016·3	3·3	+11	3·8	+16
	13.00	21	14·2	1013·2	17	16	1017·3				
31.7.64	10.00	18·5	17·2	1019·9	15·4	17·5	1021·5	4·7	+11	5·0	+12
	13.00	21	18	1018·7	16·2	16·1	1022·4	6·5	+ 9	7·0	+10
								10·7	+ 2	11·2	+ 3
5.8.64	10.00	20	18·1	1021·4	19	17	1021·3	6·8	+ 7	6·9	+ 9
	13.00	25·1	18·4	1019·8	22	17	1020·5				
26.8.64	10.00	22·7	17·2	1012	16	-	1011·3	1·4	+21	2·7	+23
	13.00	28·2	16·2	1012·2	21	-	1011·8				

* Aircraft returned at 270 nm, due to fuel shortage. Indication of message rate meter

Legend:-

T°	=	temperature in °C
VP	=	vapour pressure
P	=	barometric pressure
Hb	=	flight of base of inver
Ht	=	flight of top of invers
Trop.	=	height of troposphere i

Appendix B

10.00 and 13.00 hours at 10000 ft 3 kW. Course 260°

l at awgan		Inversions and tropospheric height, 12.00 hours at Crawley						Camborne						Range obtained
	P	Hb	T°	Ht	T°	Trop.	T°	Hb	T°	Ht	T°	Trop.	T°	
	1018·6	4	+ 8	4·9	+10	41·5	-58	4·8	+10	5	+11	44·5	-63	
	1019·5													220 nm
	1017·1	Nil		Nil		37	-58	5·2	- 1	5·7	0	36·7	-59	
	1017													245 nm
	1020·9	3·6	+10	4·4	+11	40·8	-56	5·1	+ 4	5·4	+ 5			
	1021·2							7·7	+ 2	7·7	+ 3	37·6	-56	245 nm
	1018·7	7·1	+ 7	7·4	+ 8	42·8	-67	Nil		Nil		44	-67	255 nm
	1019·4													
	1016·3	3·3	+11	3·8	+16	40	-60	2·8	+ 9	3·2	+15	42·5	-63	
	1017·3							16·2	-10	16·5	- 8			
								19	-13	19·7	-12			260 nm
5	1021·5	4·7	+11	5·0	+12	38·3	-60	2·75	+10	3·05	+13	41	-60	
	1022·4	6·5	+ 9	7·0	+10			4·4	+12	5·0	+14			
		10·7	+ 2	11·2	+ 3									270 + *
	1021·3	6·8	+ 7	6·9	+ 9	40·8	-60	3·6	+13	4·2	+14	45	-61	
	1020·5													270 + *
	1011·3	1·4	+21	2·7	+23	49	-63	1·5	+14	2	+17	39·9	-57	285
	1011·8													

. Indication of message rate meter were that the ultimate range may have been about 280 nm.

:- T° = temperature in °C

VP = vapour pressure

P = barometric pressure

Hb = flight of base of inversion in thousands of feet

Ht = flight of top of inversion in thousands of feet

Trop. = height of troposphere in thousands of feet.

2

Appendix C

Flights between 10.00 and 13.00 hours at 18000 ft 3 kW Course 350°

	Ground at South Farnborough				Ground at Leuchars			Inversions and tropospheric height, 12.00 hours at Crawley						Leuchars						Range obtained
Date	Time	T°	VP	P	T°	VP	P	Hb	T°	Ht	T°	Trop.	T°	Hb	T°	Ht	T°	Trop.	T°	
31.8.64	10.00	13.8	10.4	1033.7	13	12	1034.8	5.2	+ 3	5.3	+ 7									
	13.00	17.6	11	1032.7	15	11	1034.5	7.0	+ 3	9.0	+ 4	43	-66	3.1	+ 6	3.4	+ 7	43.4	-67	290 nm
3.9.64	10.00	13	12.9	1015	12	13	1016.9							1.5	+12	3.0	+14			
	13.00	23.4	14.3	1013.6	16	15	1015.8	1.5	+17	2.0	+18	37	-58	5.0	+ 9	5.5	+10	37	-56	340+ *

* Aircraft returned, due to fuel shortage. Message rate meter indicating 100% at 340 miles.

Legend: T° = temperature in °C

VP = vapour pressure

P = barometric pressure

Hb = height at base of inversion in thousands of feet

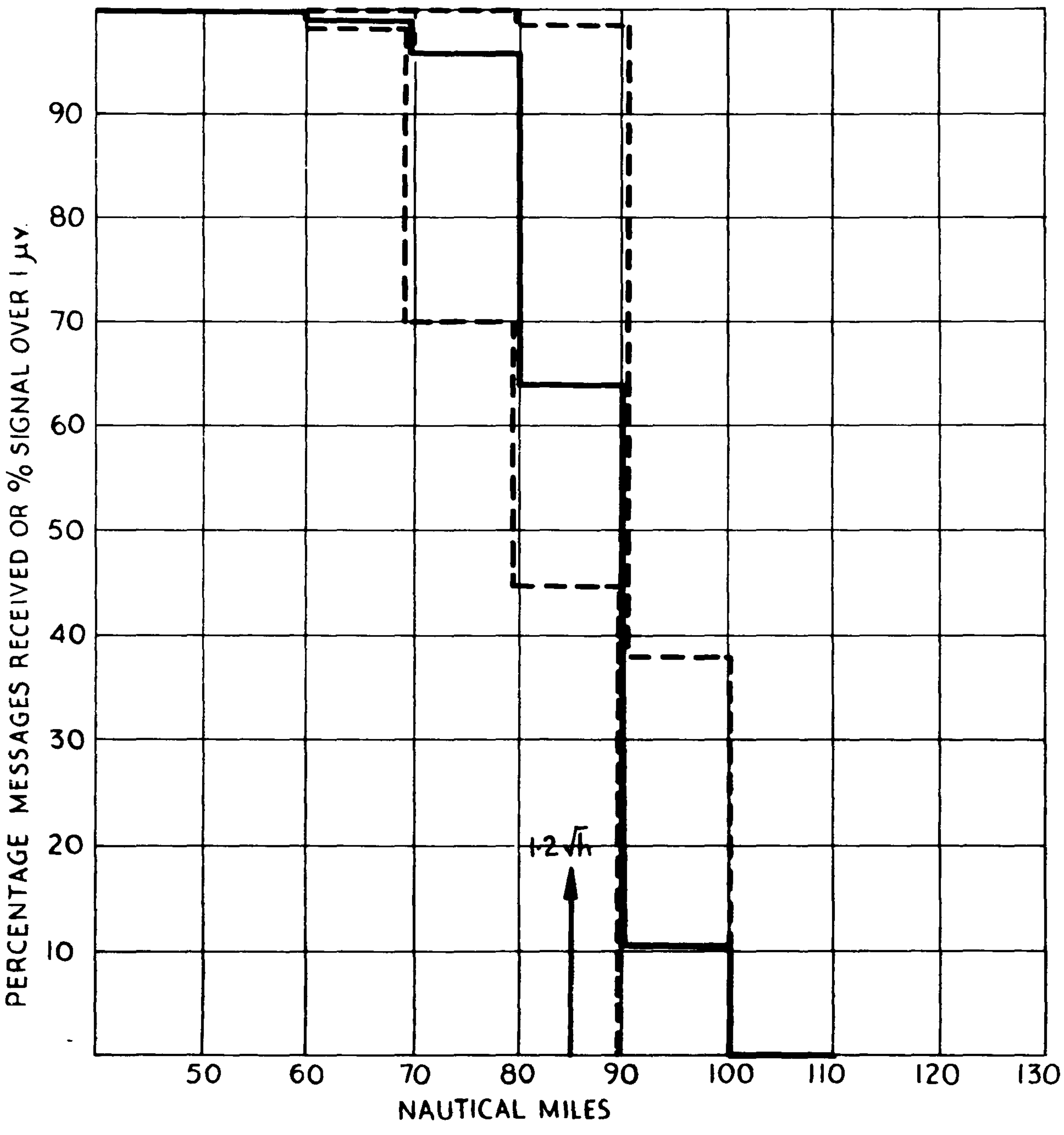
Ht = height at top of inversion in thousands of feet

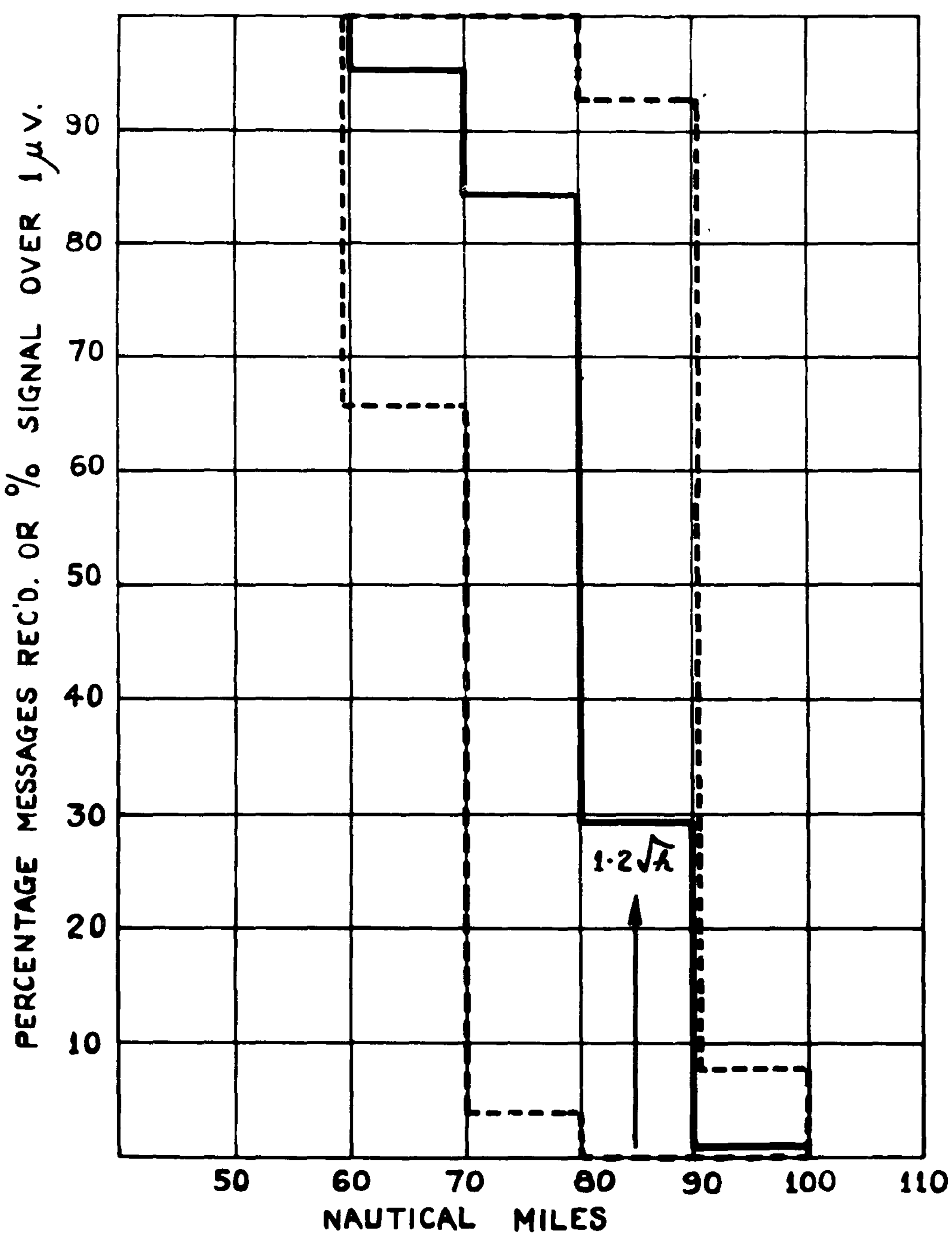
Trop. = height of troposphere in thousands of feet.

APPENDIX D

OUTBOUND RUNS
5000 FT. 100W & BICONE
14 RUNS 24/9/64 TO 7/10/64

SOLID LINE = AVERAGE
DOTTED LINES = SPREAD

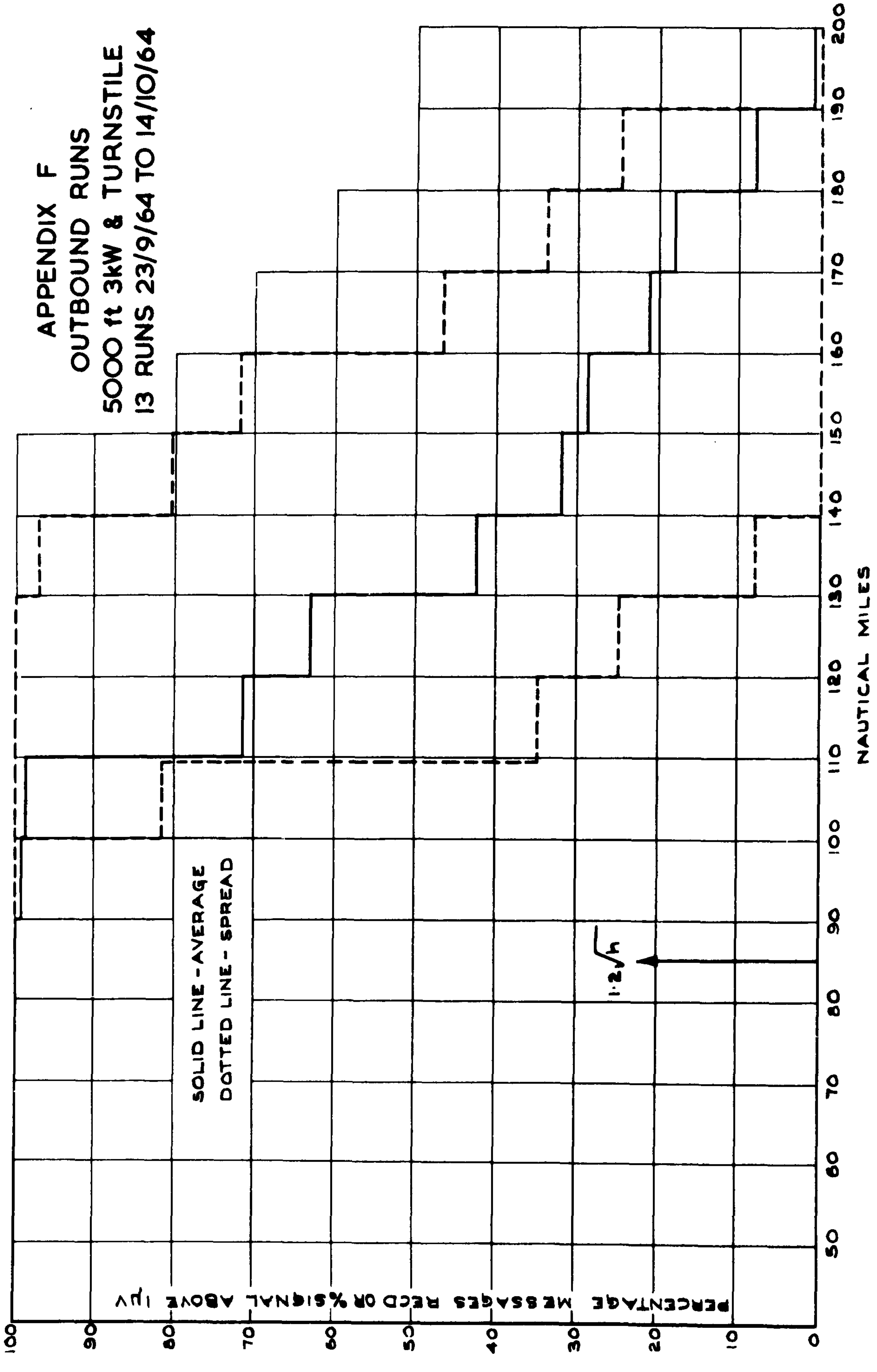


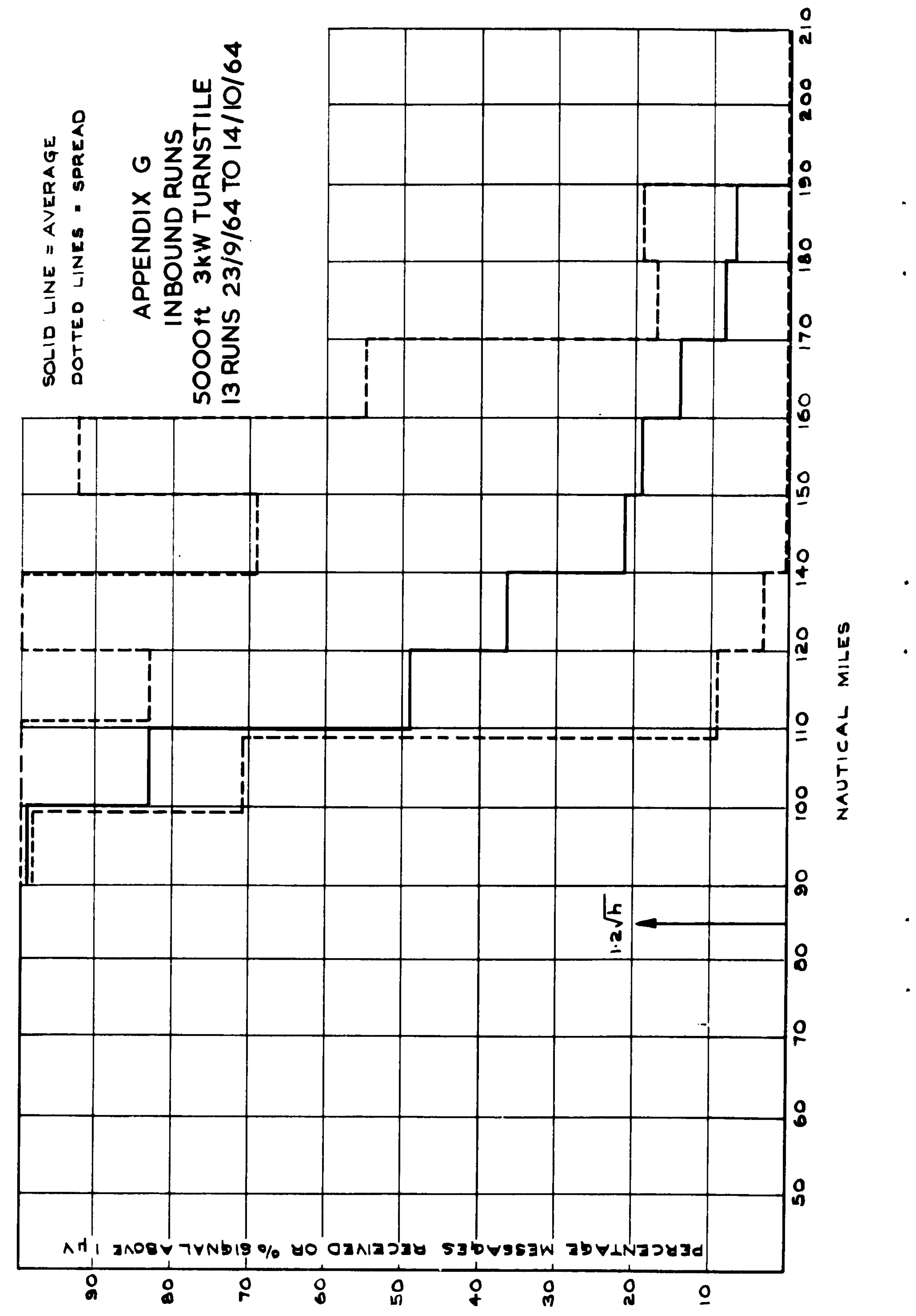


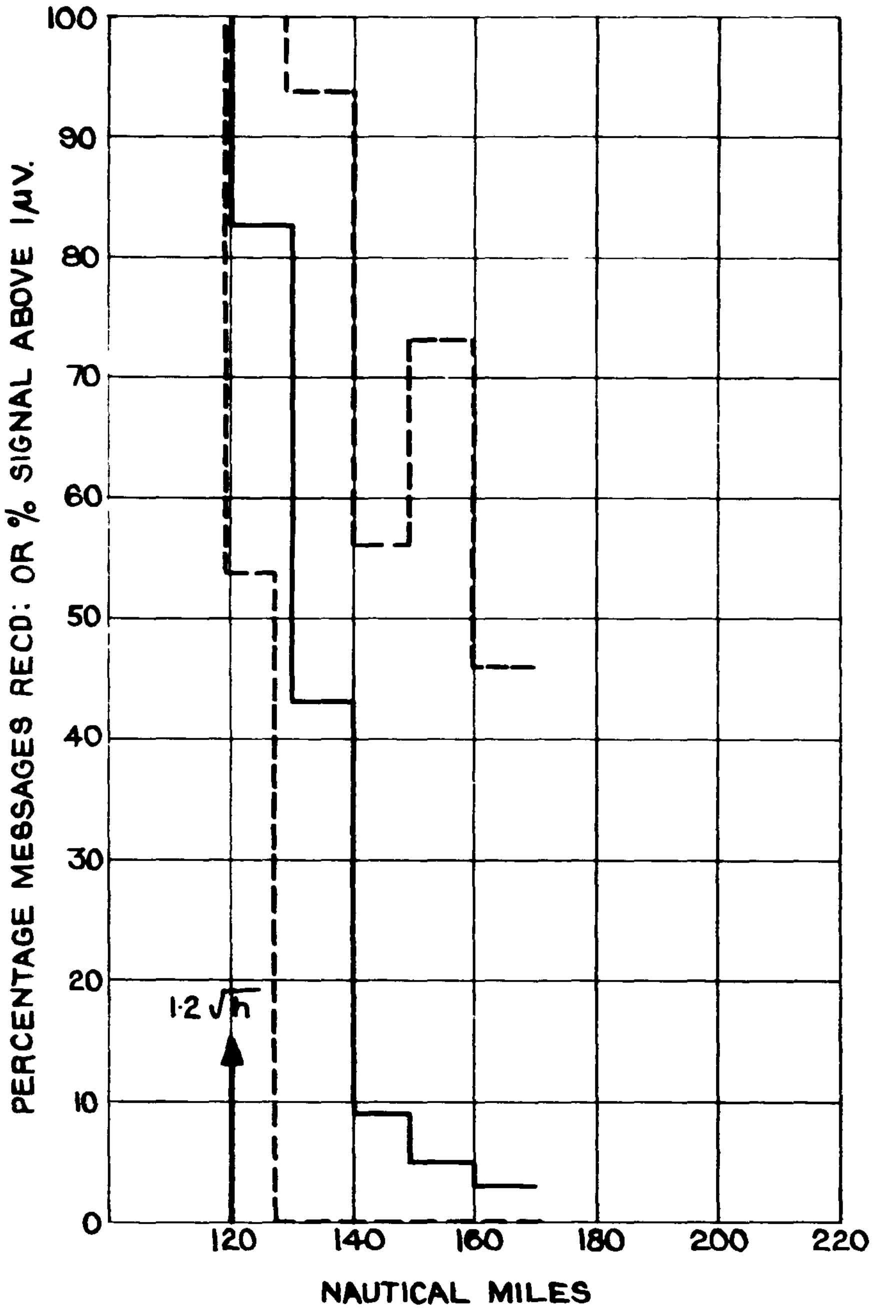
SOLID LINE = AVERAGE.
DOTTED LINES = SPREAD.

APPENDIX E

INBOUND RUNS 5000FT. 100W &
BICONE 14 RUNS 24·9·64 TO 7·10·64.


APPENDIX F
OUTBOUND RUNS
5000 ft 3kW & TURNSTILE
13 RUNS 23/9/64 TO 14/10/64
SOLID LINE - AVERAGE
DOTTED LINE - SPREAD
1·2√h
NAUTICAL MILES
PERCENTAGE MESSAGES RECD OR %SIGNAL ABOVE 1μV
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
0
10
20
30
40
50
60
70
80
90
100


SOLID LINE = AVERAGE
DOTTED LINES = SPREAD
APPENDIX G
INBOUND RUNS
5000ft 3kW TURNSTILE
13 RUNS 23/9/64 TO 14/10/64
$1{\cdot}2\sqrt{h}$
NAUTICAL MILES
50 60 70 80 90 100 110 120 140 150 160 170 180 190 200 210
PERCENTAGE MESSAGES RECEIVED OR % SIGNAL ABOVE 1 μV
10 20 30 40 50 60 70 80 90



SOLID LINE - AVERAGE
DOTTED LINES - SPREAD

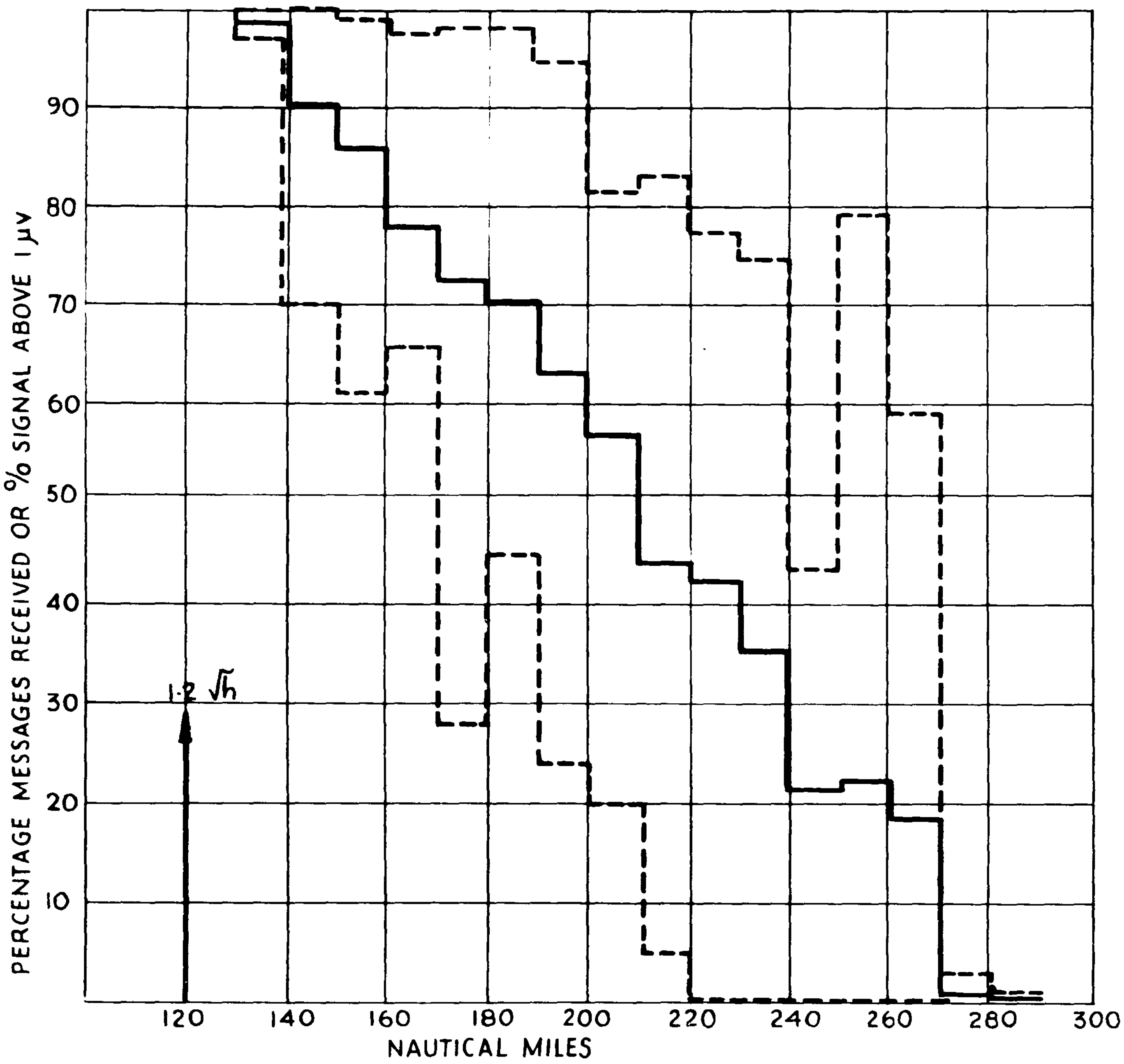
APPENDIX H

OUTBOUND + INBOUND
RUNS 10000 ft. 100 W.
& QUAD AERIAL. 18 RUNS
13/7/64 TO 24/7/64.

APPENDIX I

OUTBOUND RUNS 10000 FT 3 kW AND TURNSTILE 8 RUNS 28/7/64 TO 28/8/64

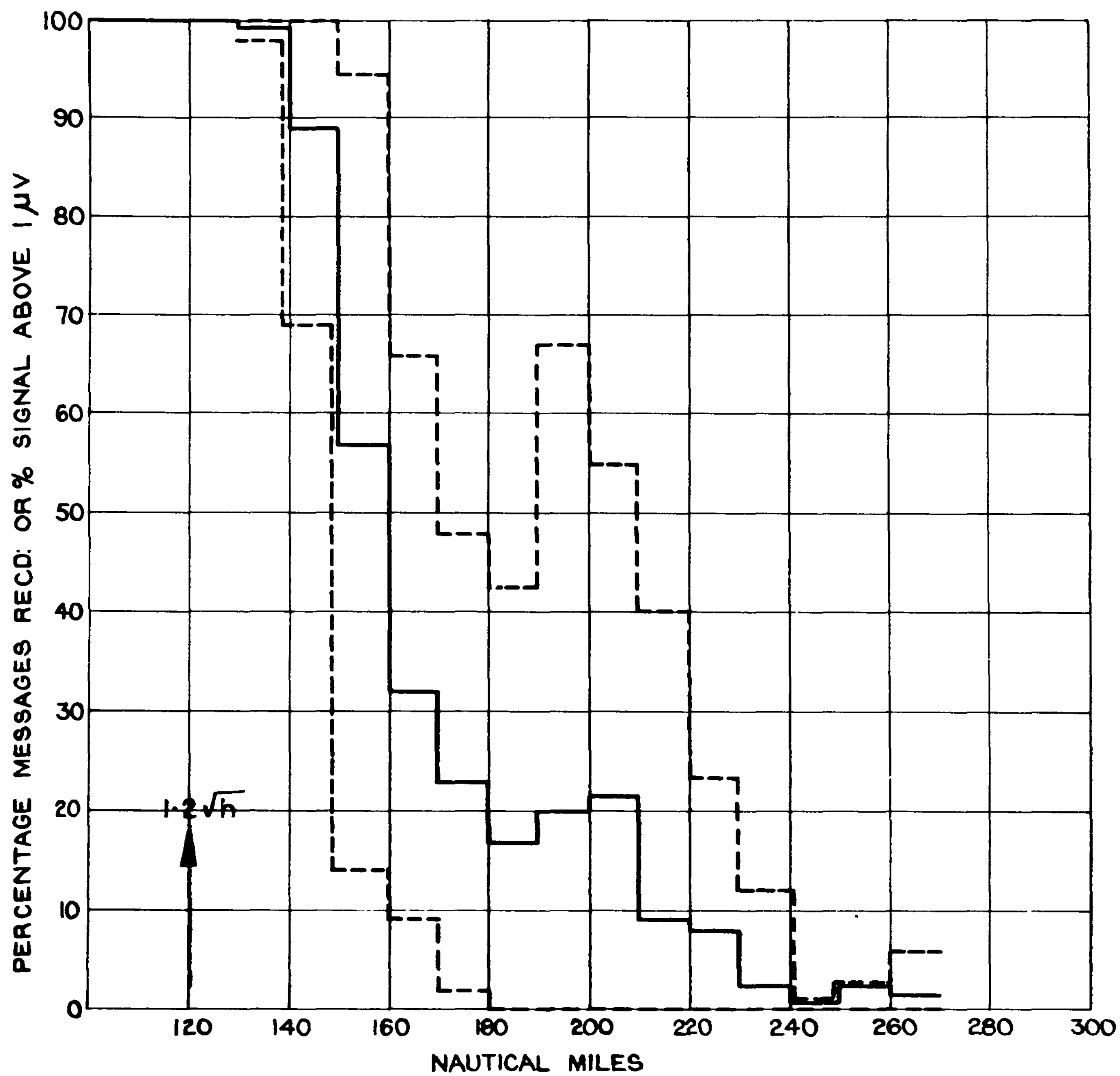
SOLID LINE = AVERAGE
DOTTED LINES = SPREAD

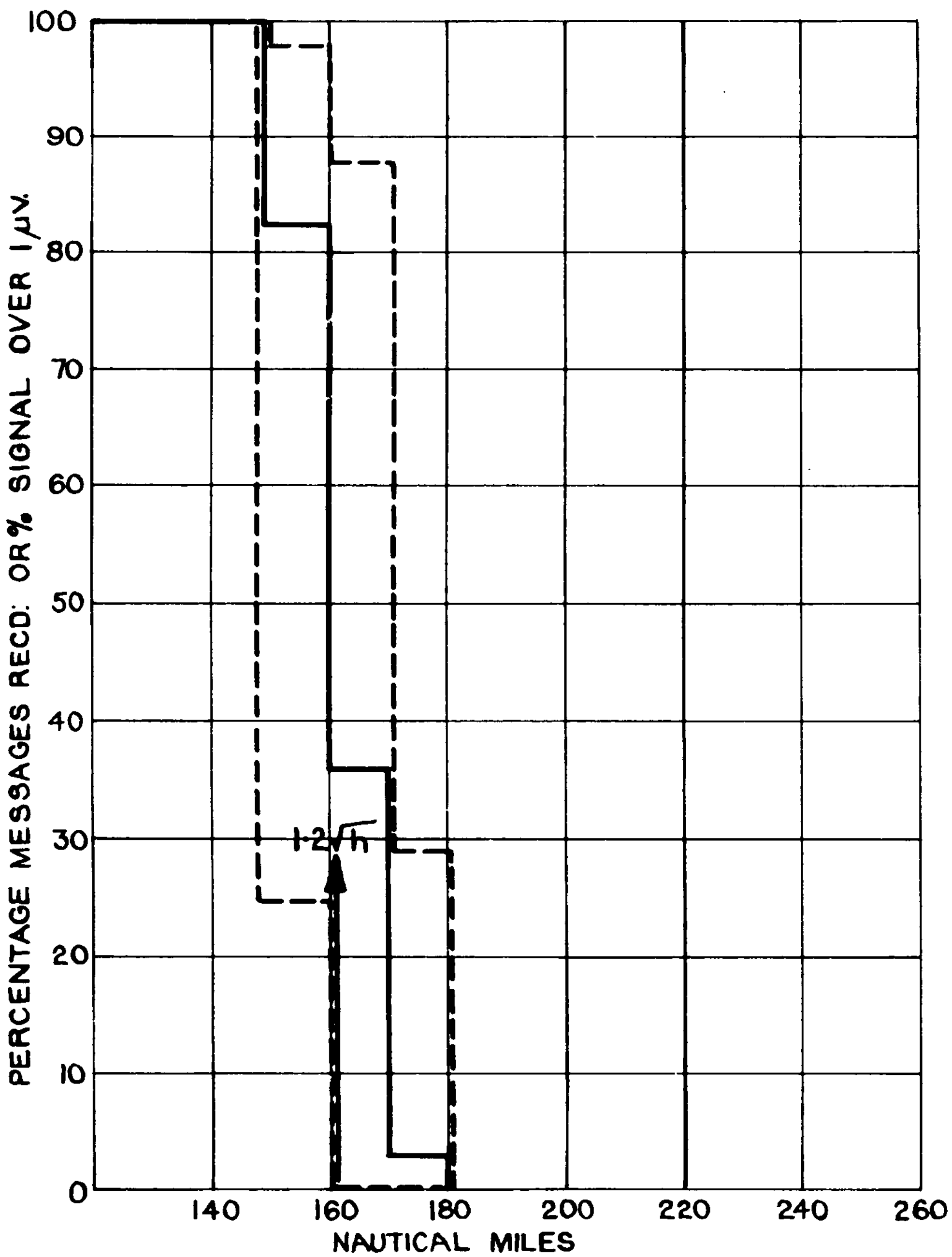


APPENDIX J

INBOUND RUNS 10 000ft.
3 kW & TURNSTILE. 8 RUNS
28/7/64 TO 28/8/64

SOLID LINE – AVERAGE
DOTTED LINES – SPREAD





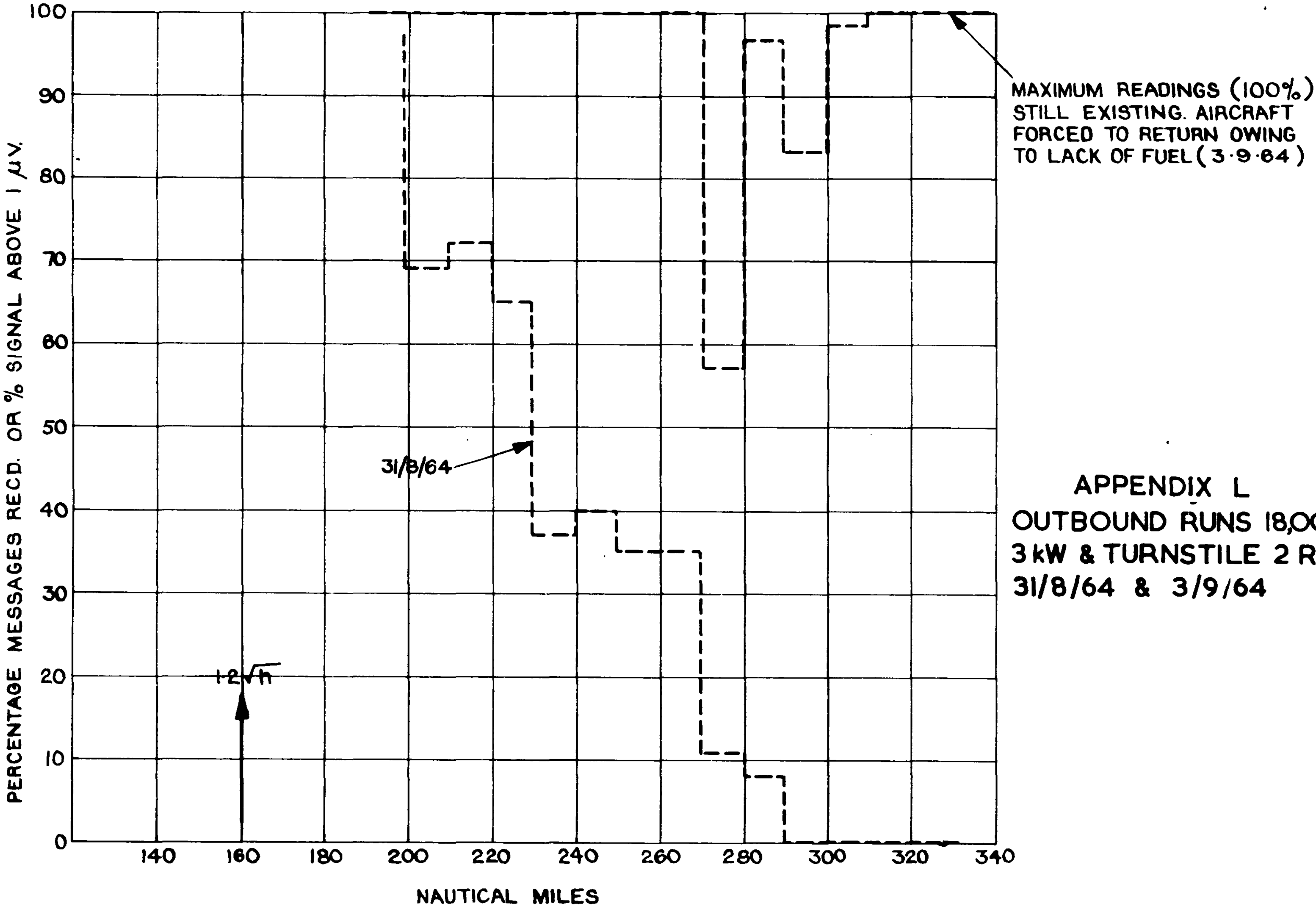
SOLID LINE - AVERAGE
DOTTED LINES - SPREAD

APPENDIX K

OUTBOUND + INBOUND RUNS. 18 000 ft. 100 W. & BICONE 20 RUNS. 20/5/64 TO 10/7/64

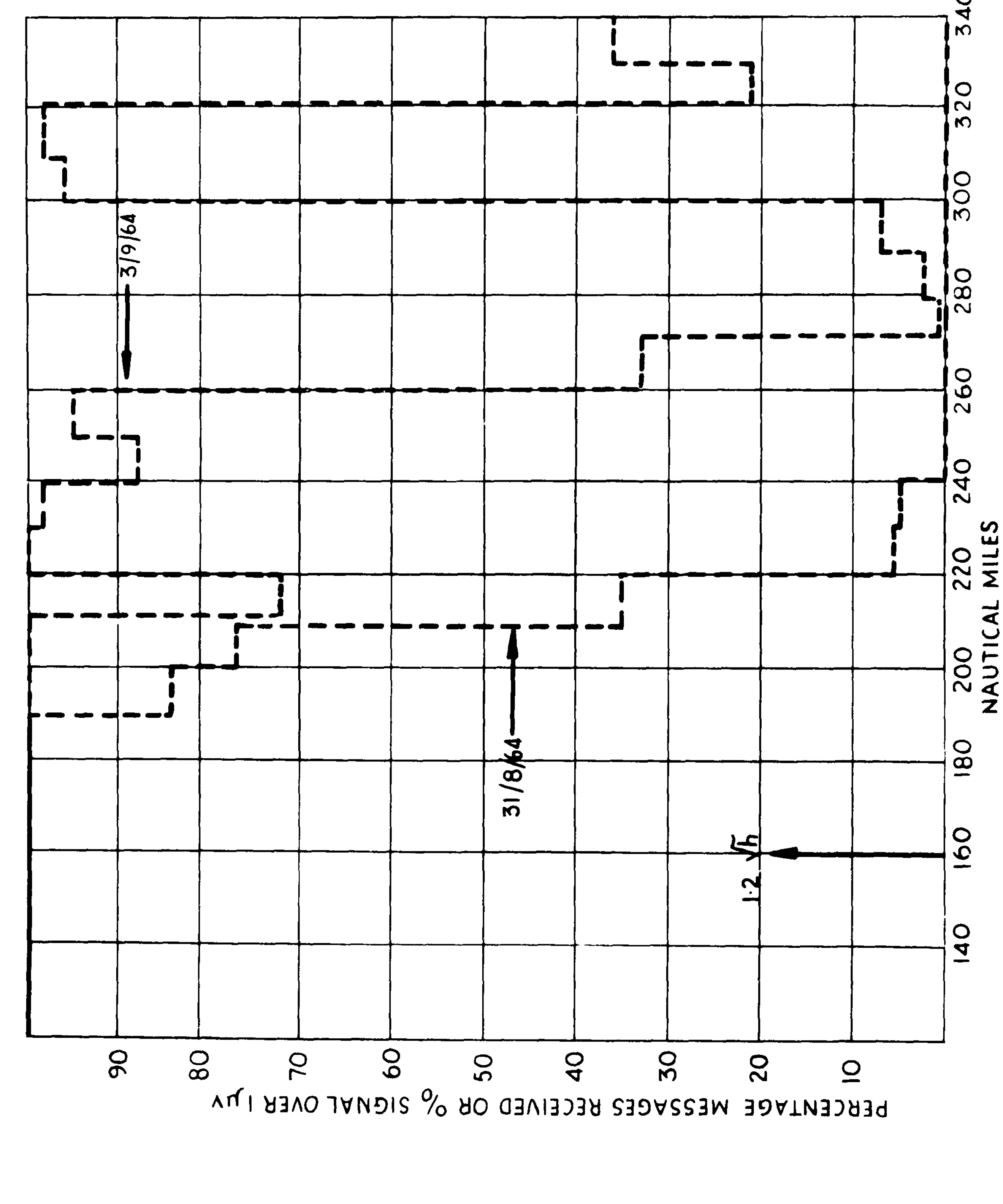
008-900213

APPENDIX L
OUTBOUND RUNS 18,000ft. 3kW & TURNSTILE 2 RUNS 31/8/64 & 3/9/64



APPENDIX M

INBOUND RUNS
18000 FT. 3kW &
TURNSTILE
2 RUNS 31/8/64 &
3/9/64.



REFERENCES

No.	Author	Title, etc.
1	A.T. Aust D.P.L. May	A U.H.F. automatic ground-to-air radio communication and control system. R.A.E. Tech. Note RAD.761 Nov. 1959
2	H.L. Spong	U.H.F. ground to air data link system trials Part II. R.A.E. Tech. Note RAD.812 Feb. 1962
3	A.T. Aust D.P.L. May	Data handling and landline system for U.K. U.H.F. data links. R.A.E. Tech. Note RAD.780 May 1960
4	R.F. Blackall	The logical operation of the U.H.F. data link decoding system. R.A.E. Tech. Note RAD.809 Feb. 1962
5	B.J. Starkey et al	The effects of atmospheric discontinuity layers up to and including the tropopause on beyond-the-horizon propagation phenomena. Proc IEE Vol.105 Part B 1958
6	E.H. Jones	A study of radio propagation in the band 220-240 Mc/s. R.A.E. Tech. Note RAD.484 Sept. 1950
7	B.J. Starkey	Some aircraft measurements of beyond-the-horizon propagation phenomena at 91·3 Mc/s. Proc IEE 1956 Sept. Part B, Vol.103

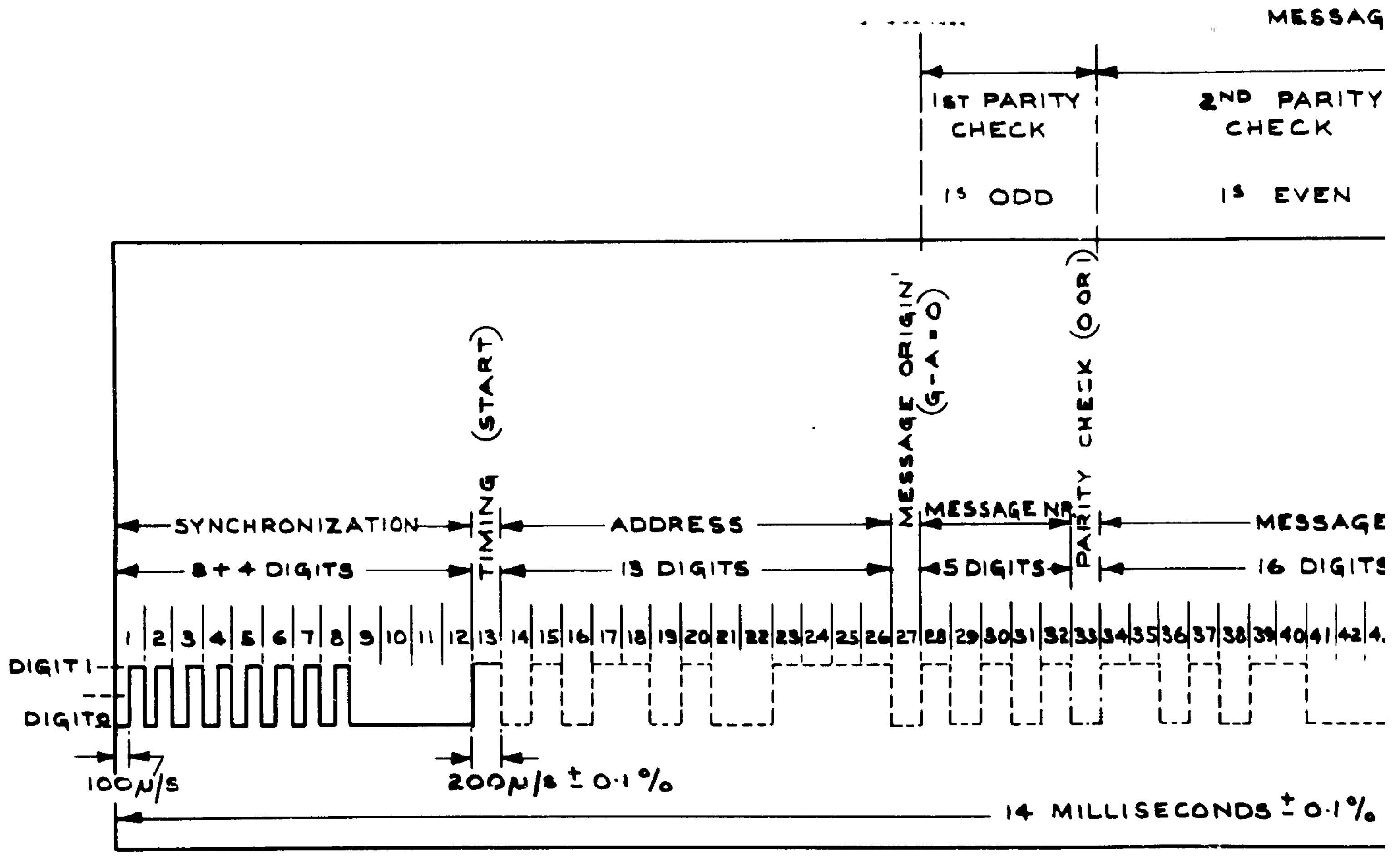
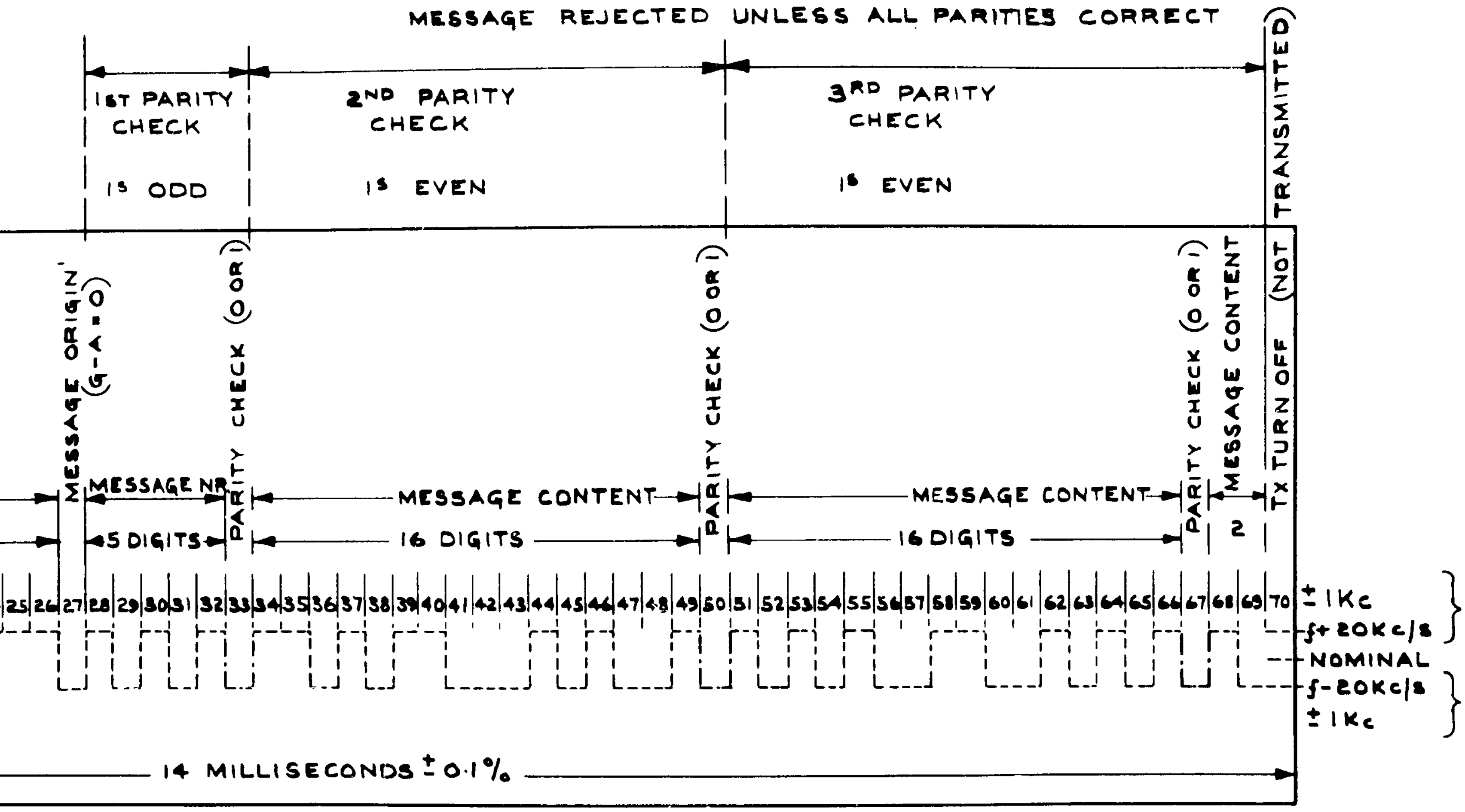


FIG. I. GROUND TO AIR MESSAGE

Fig.1



2

OUND TO AIR MESSAGE STRUCTURE.

Neg. No. C1957

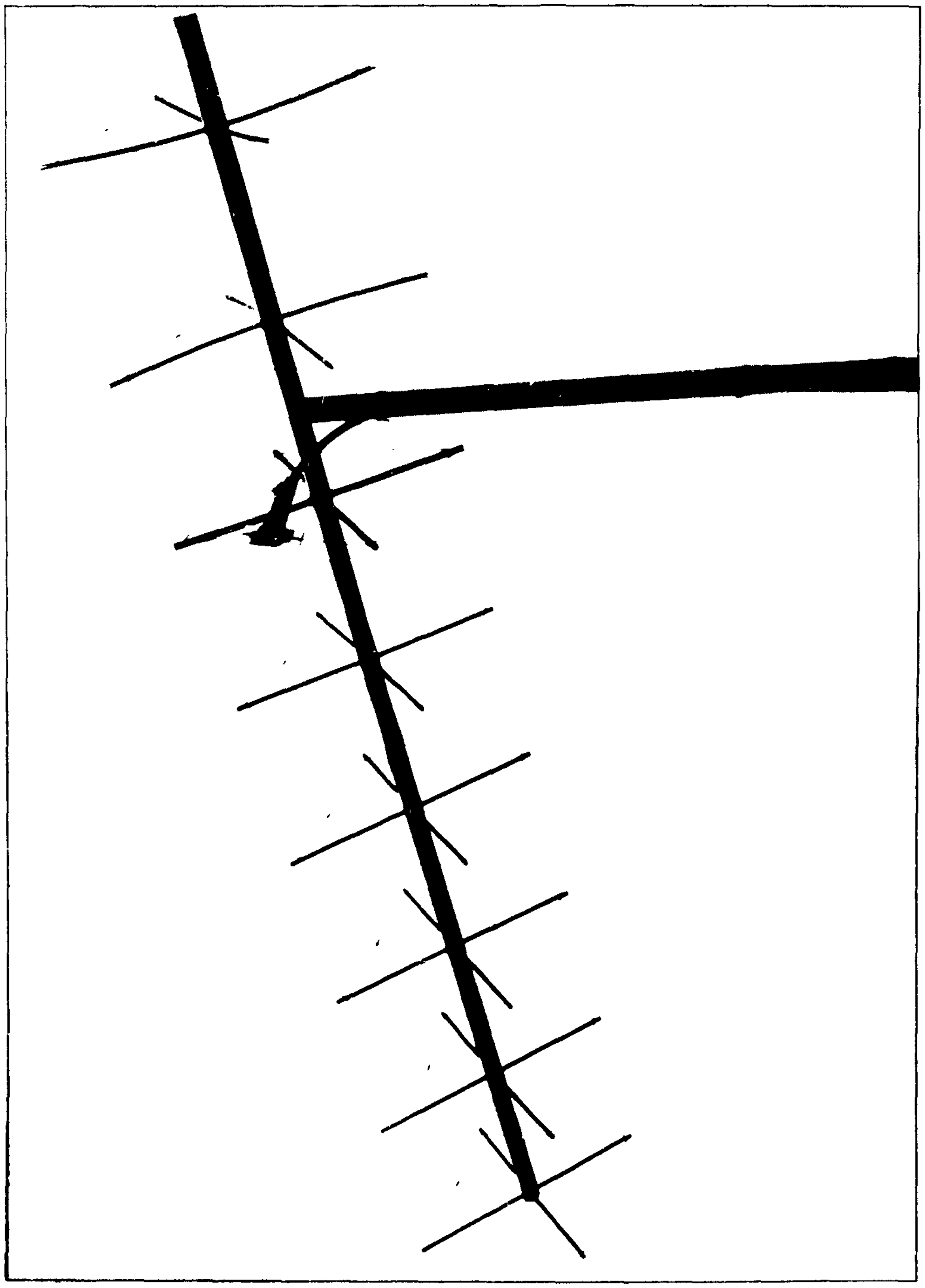


Fig.2 Quad aerial

R.66107

Fig.3

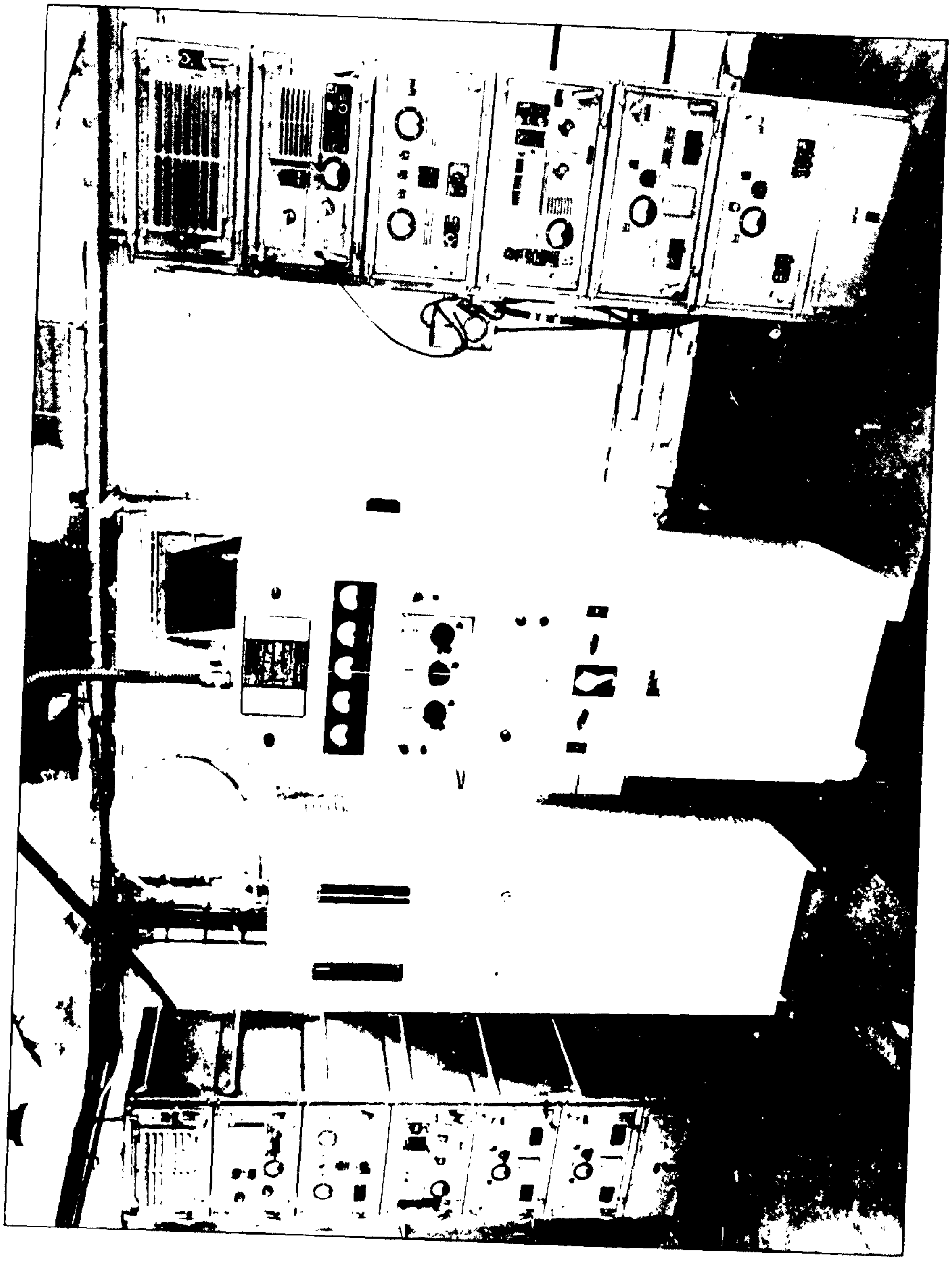


Fig.3 Transmitters and amplifier

R.66107

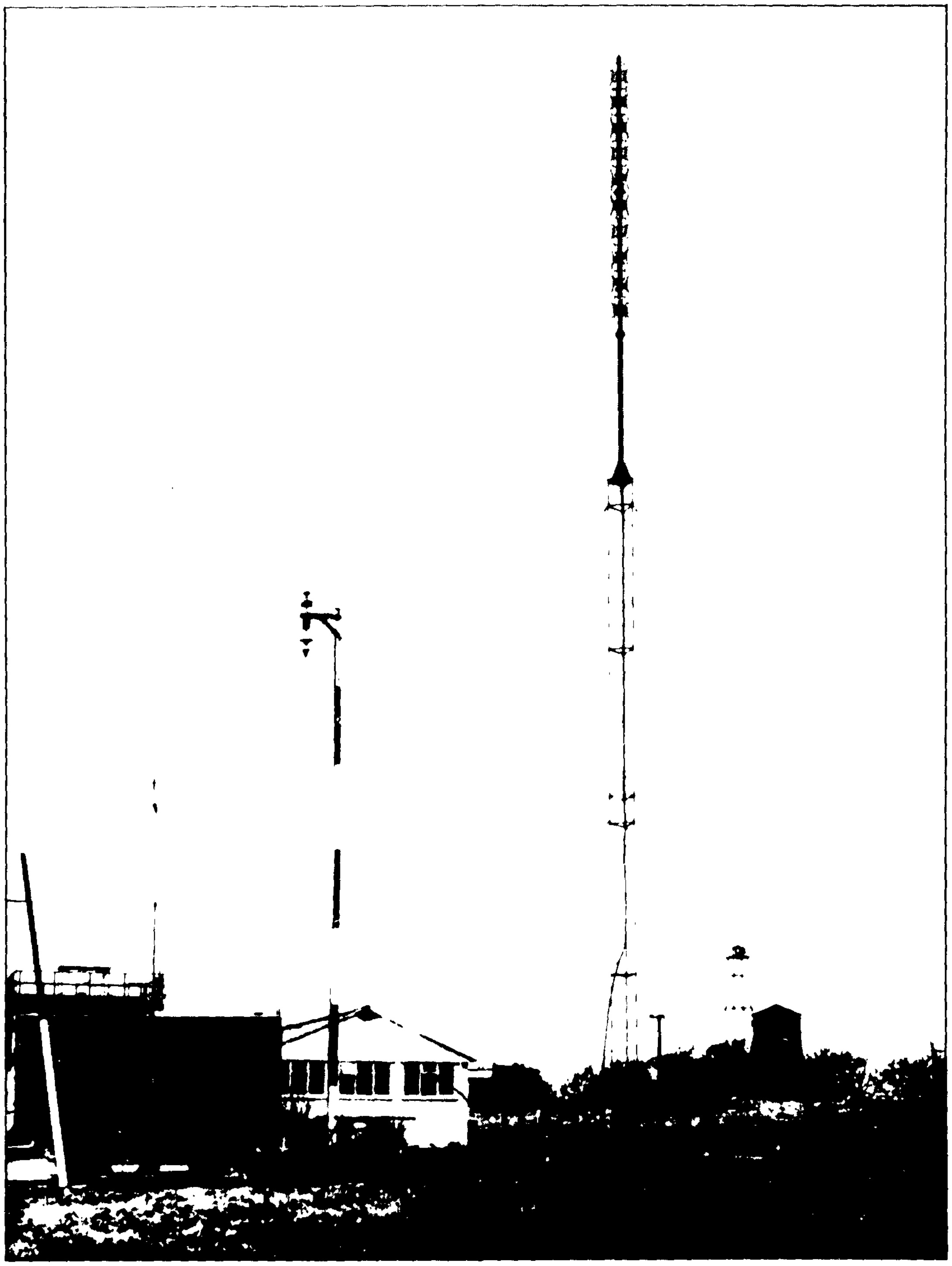


Fig.4 Bicones and Turnstile aerials

R.66107

Fig.5

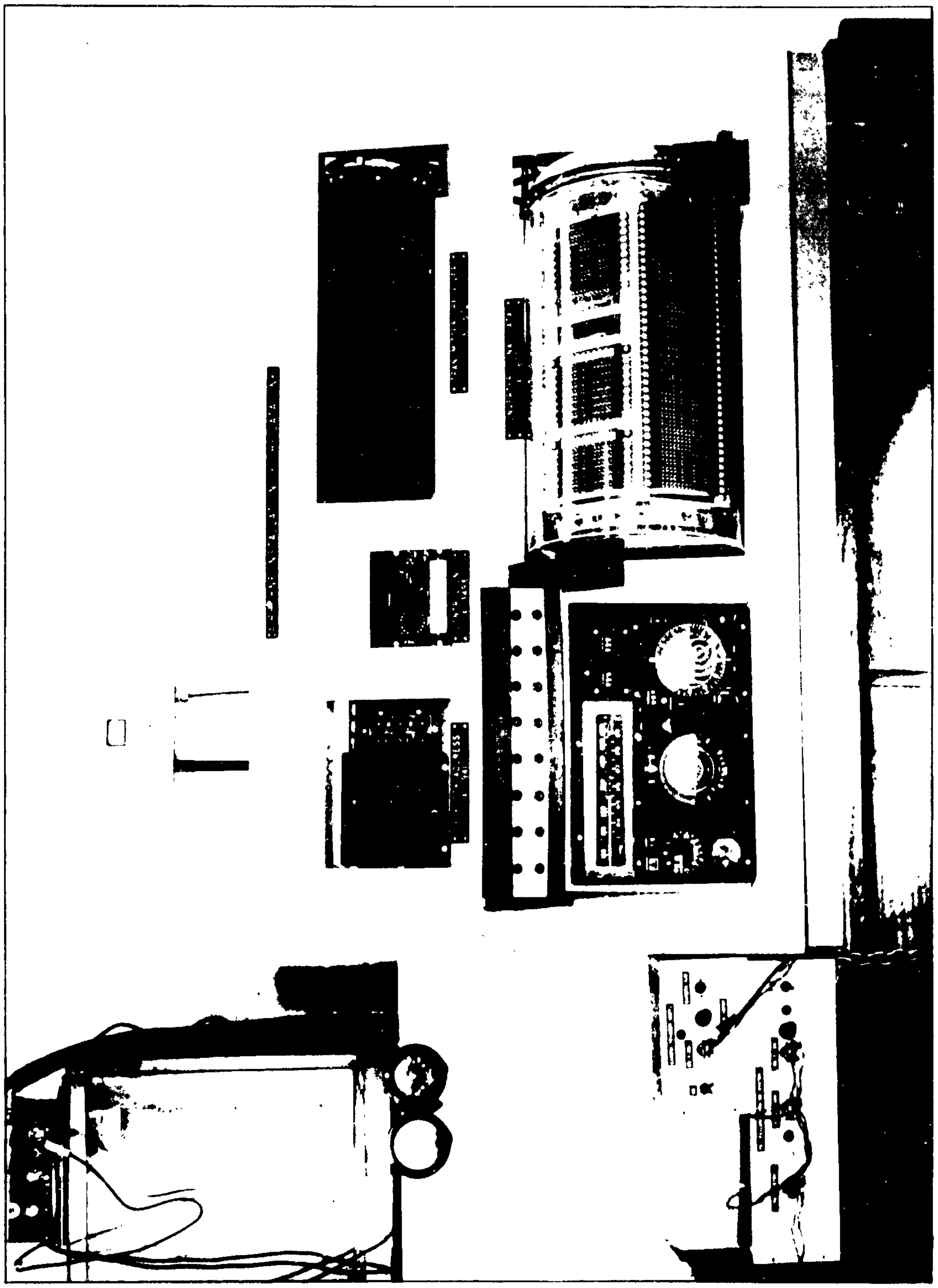


Fig.5 Slave data link installation

R.66107

Fig.6

008-900216

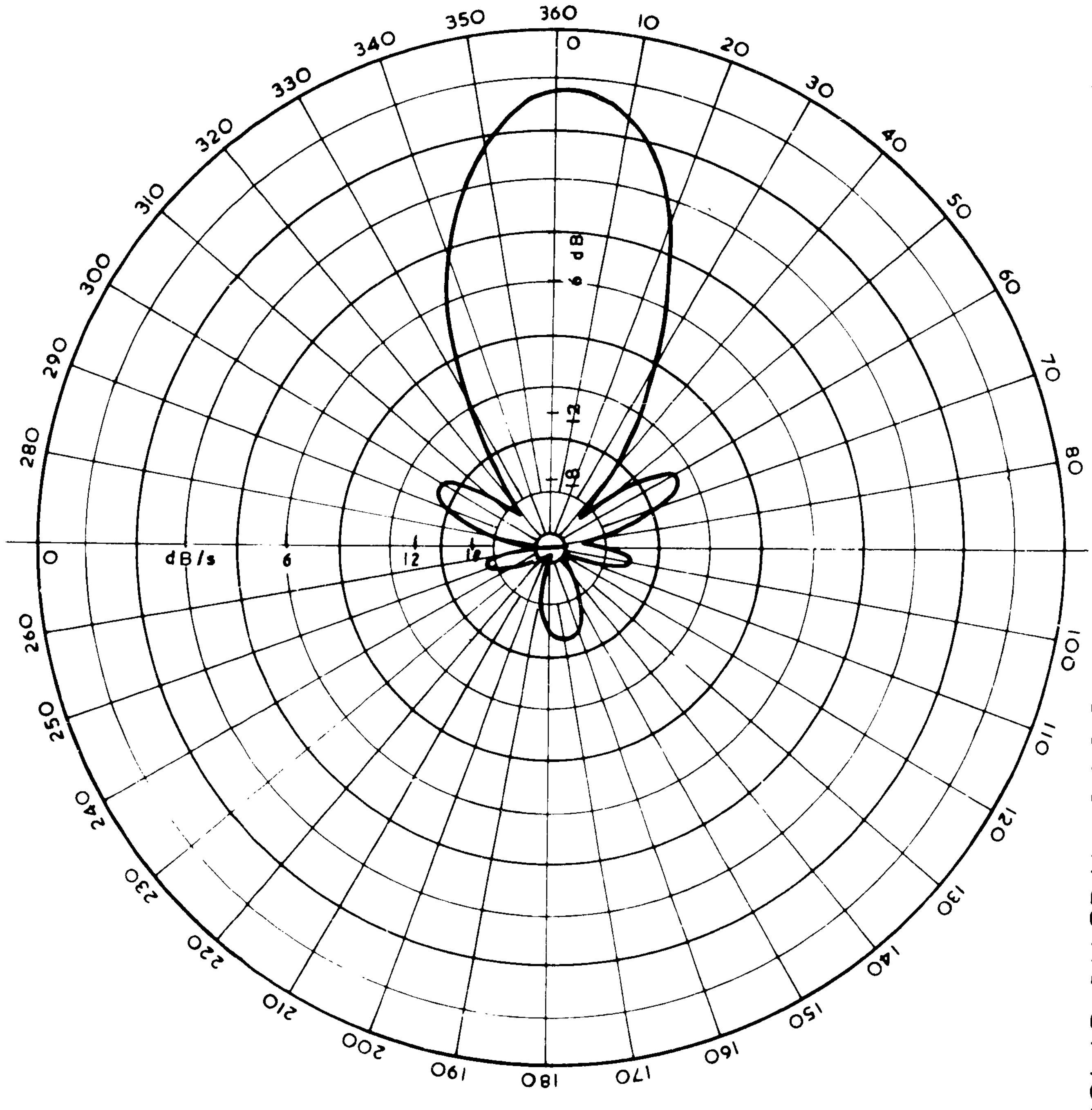


FIG. 6
VERTICAL POLAR DIAGRAM OF 8 ELEMENT QUAD AERIAL AT 282 Mc/s.

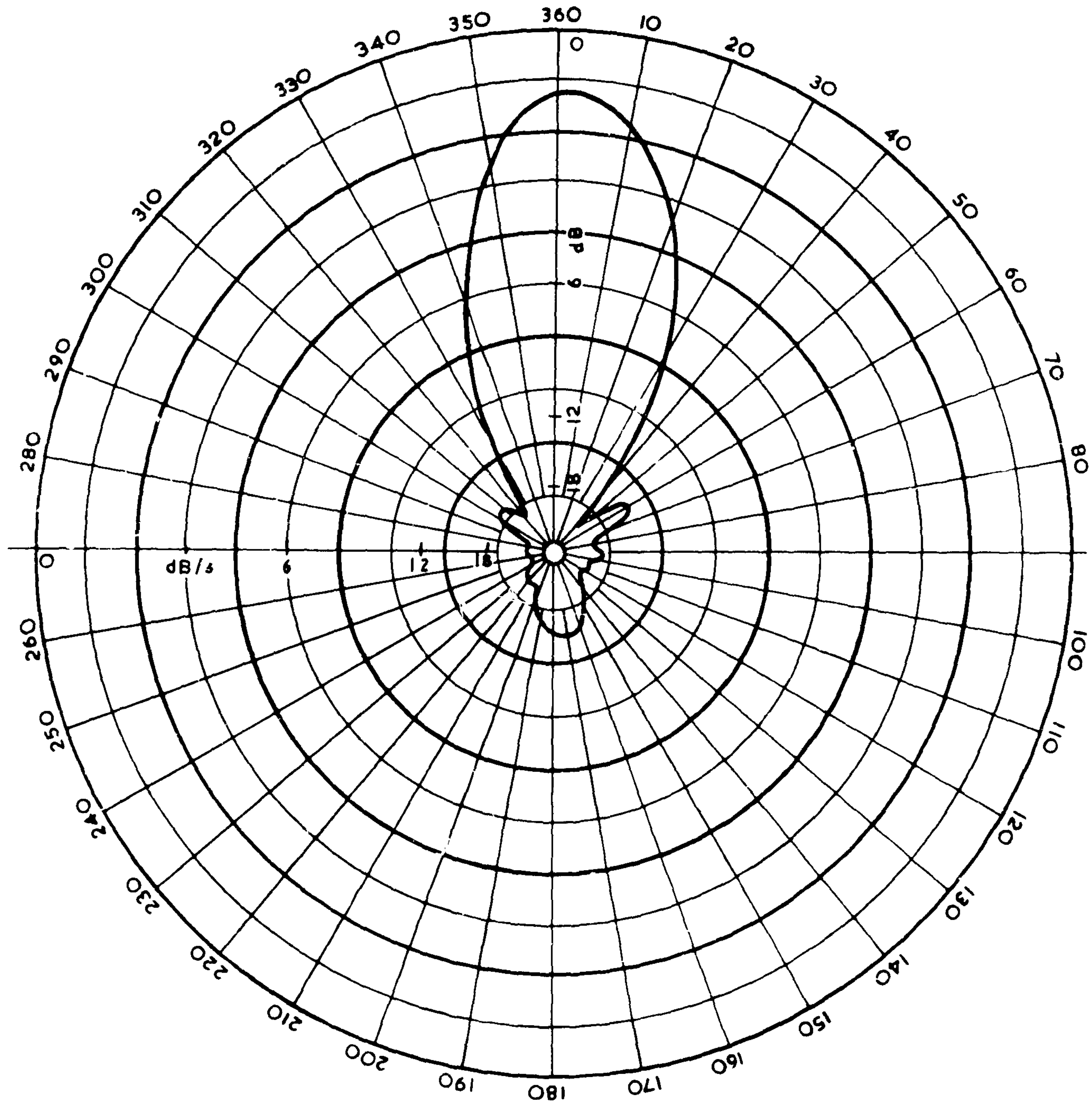
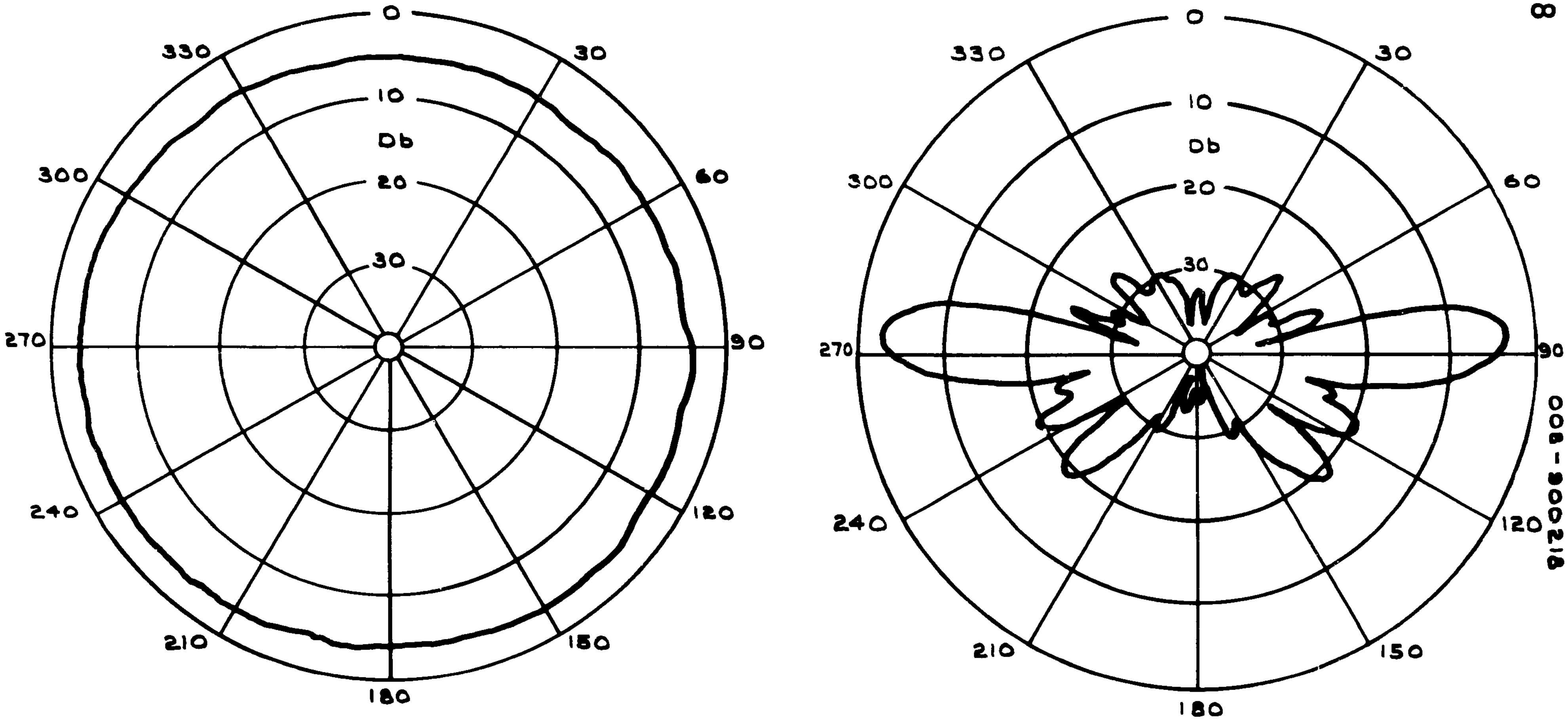


FIG. 7 HORIZONTAL POLAR DIAGRAM OF 8 ELEMENT QUAD AERIAL AT 282 Mc/s

Fig.8



HORIZONTAL

VERTICAL

FREQUENCY 225 M/cs

FIG. 8. TURNSTILE 600-10 AERIAL
THEORETICAL FREE SPACE POLAR DIAGRAM

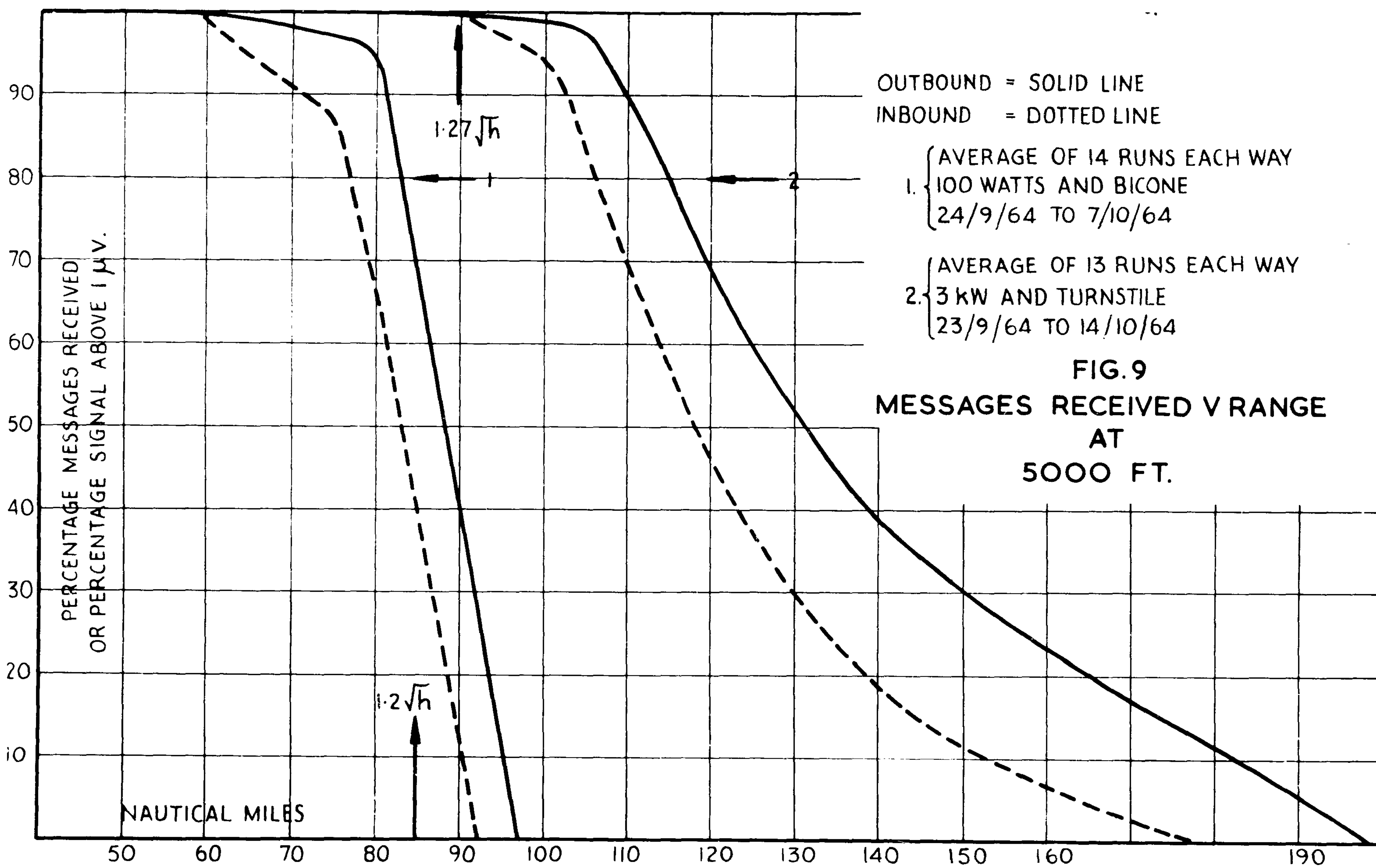


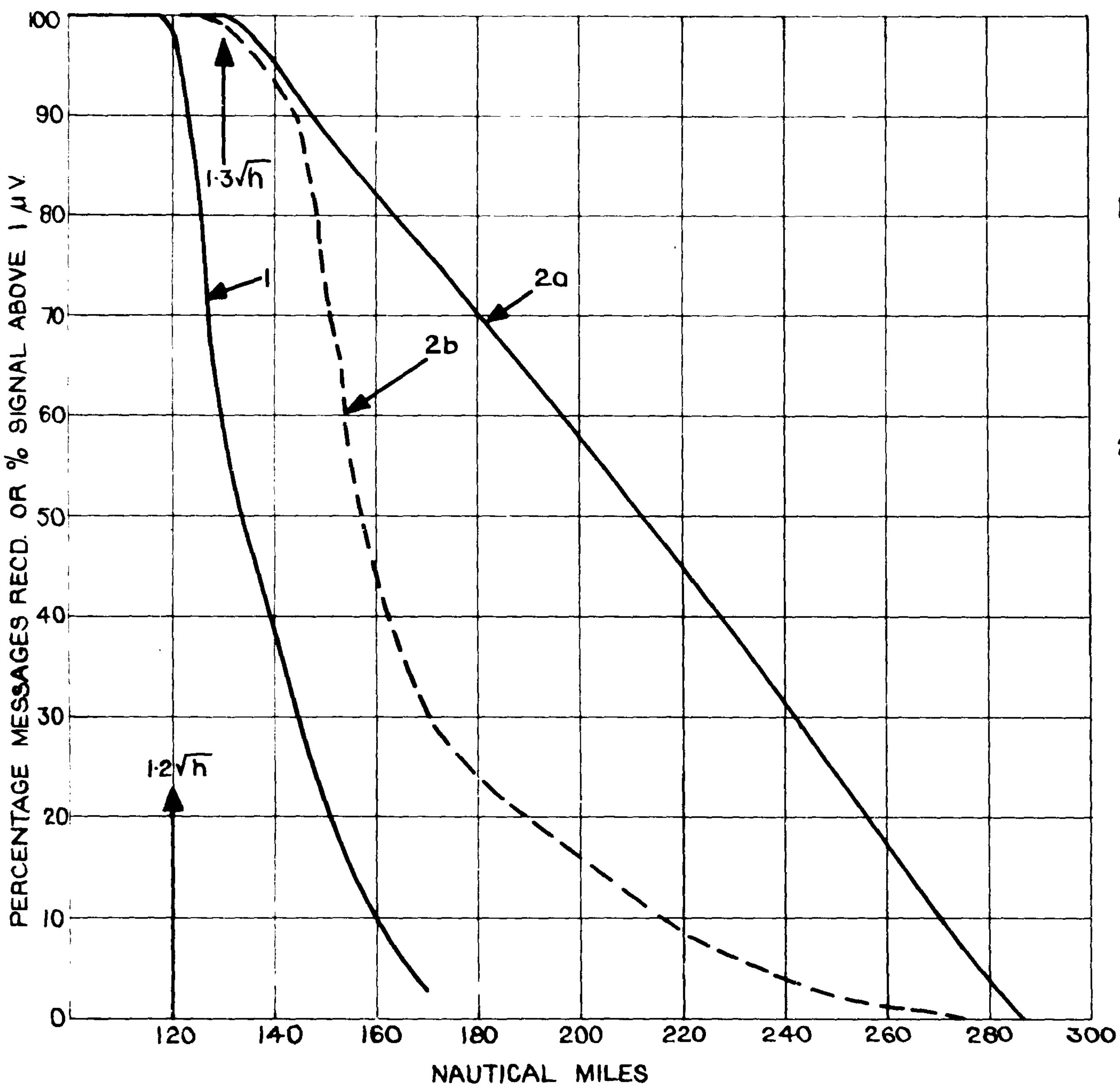
FIG. 9
MESSAGES RECEIVED V RANGE
AT
5000 FT.

008 - 900219

Fig.9

Fig.10

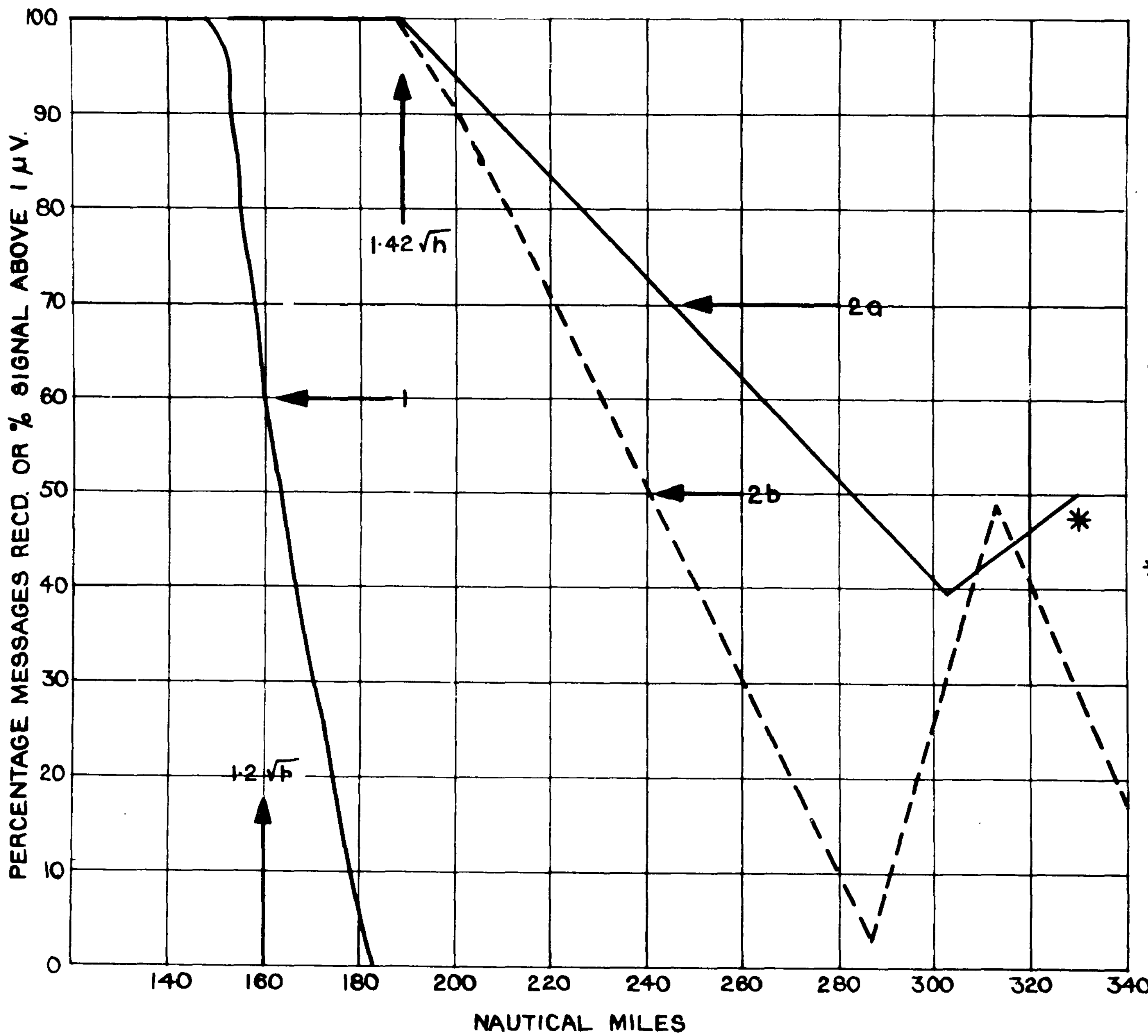
008 - 900220



1. AVERAGE OF 18 RUNS
100 WATTS & QUAD.
13·7·64 TO 24·7·64
OUTBOUND PLUS INBOUND

2. AVERAGE OF 8 RUNS EACH WAY
3 kW. & TURNSTILE
28·7·64 TO 28·8·64
2a - OUTBOUND
2b - INBOUND

FIG.10
MESSAGES RECEIVED V RANGE
AT 10000 ft.



1. AVERAGE OF 20 RUNS
   100 WATTS & BICONE
   20·5·64 TO 10·7·64
   INBOUND PLUS OUTBOUND

2. AVERAGE OF 2 RUNS EACH WAY
   31·8·64 AND 3·9·64
   3 kW. & TURNSTILE
   2a – OUTBOUND
   2b – INBOUND

* 100% READINGS STILL EXISTED. AIRCRAFT RETURNED DUE TO FUEL SHORTAGE.

FIG. 11
MESSAGES RECEIVED V RANGE AT 18,000 ft.

12006-800

Fig.12

008-900222

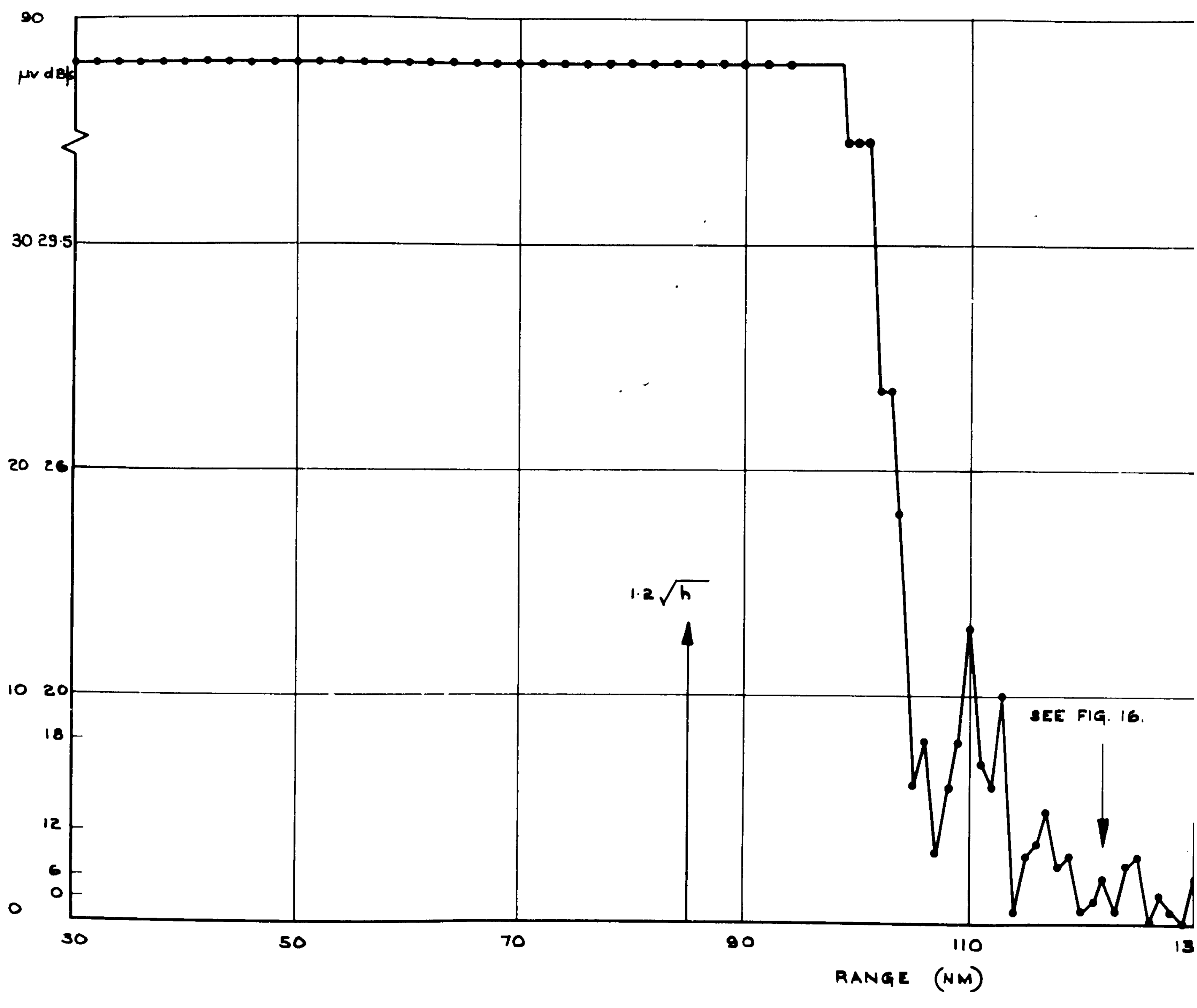
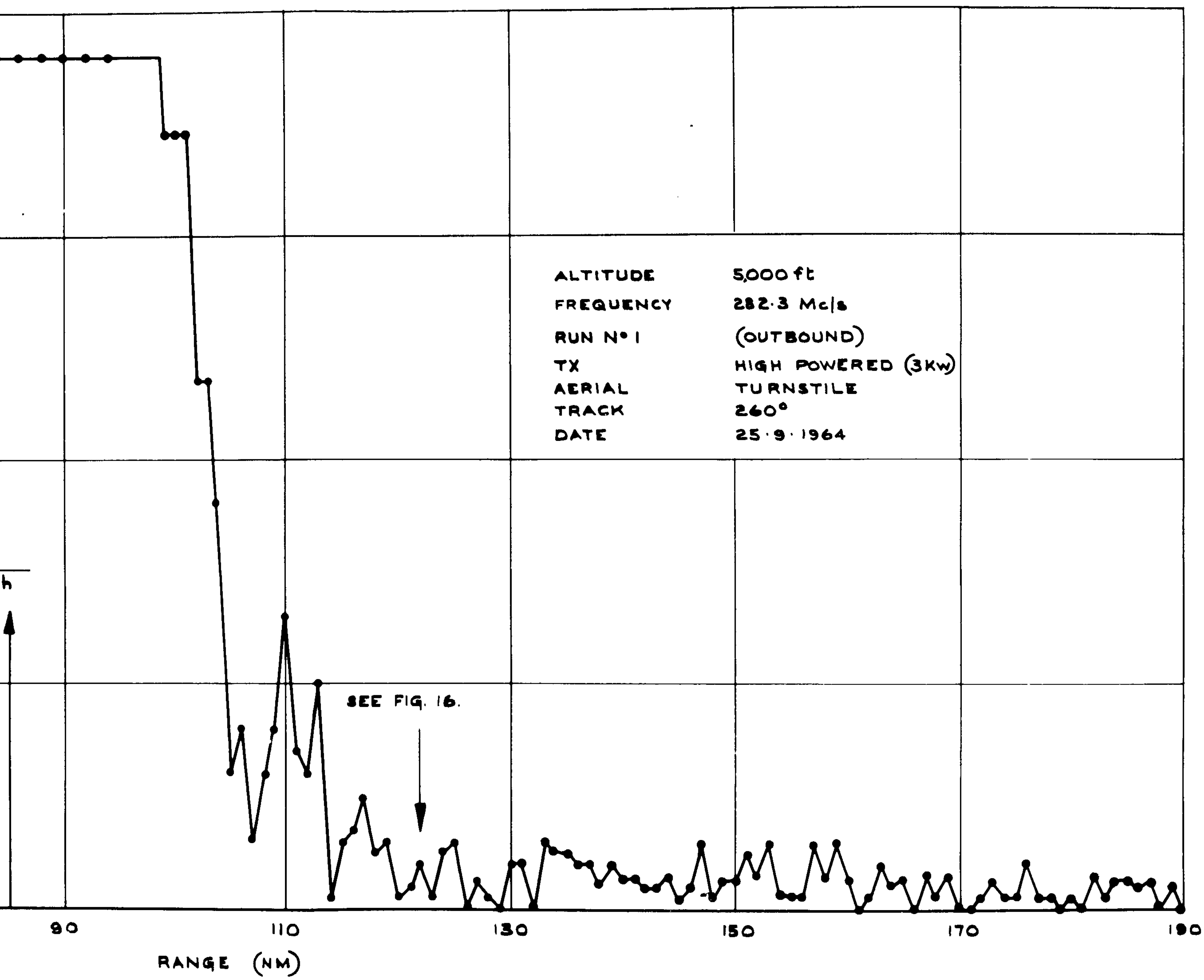


FIG. 12. SIGNAL STRENGTH GRAPH

008-300222



SIGNAL STRENGTH GRAPH 5000 ft.

2

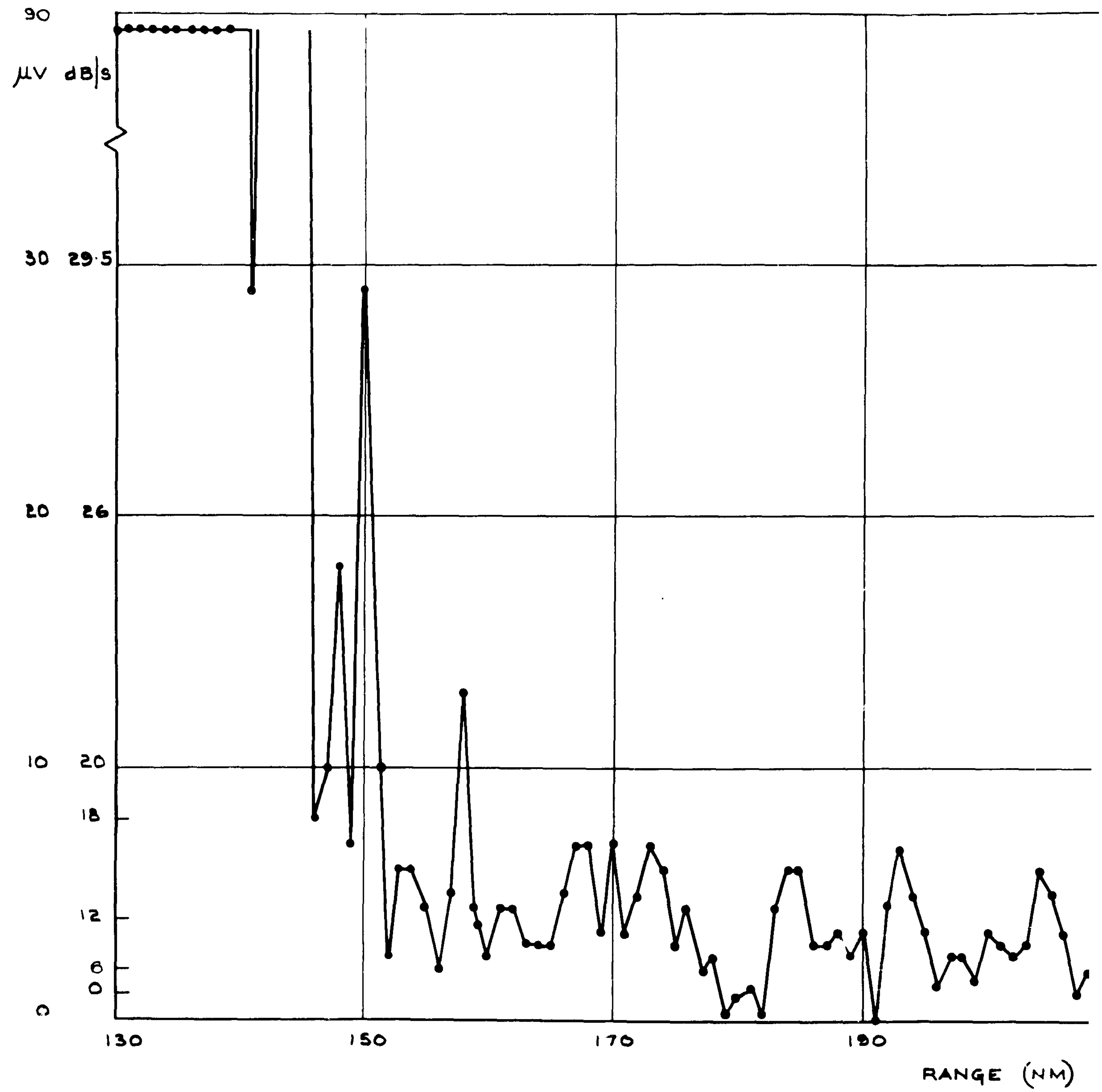


FIG. 13. SIGNAL STRE

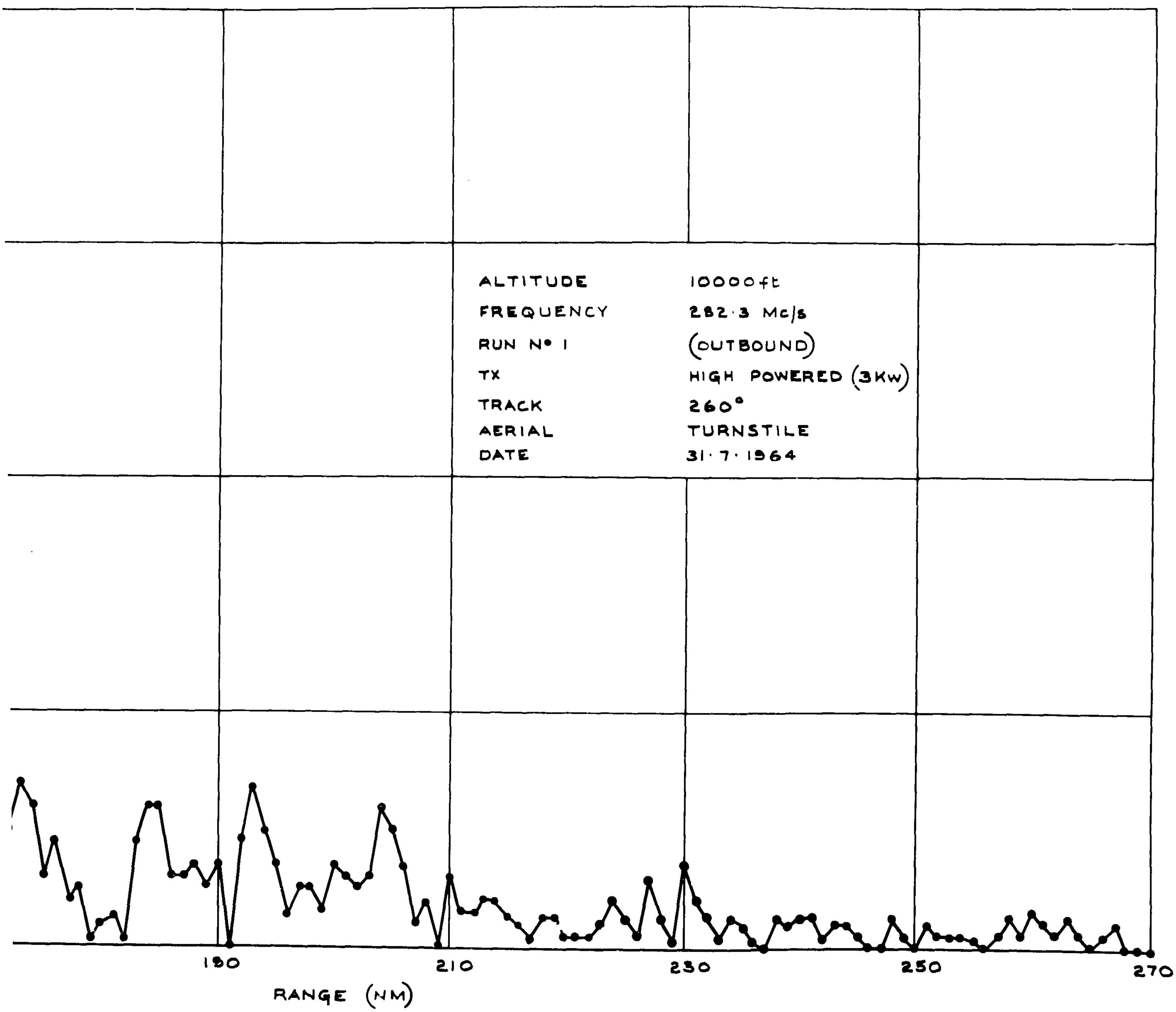
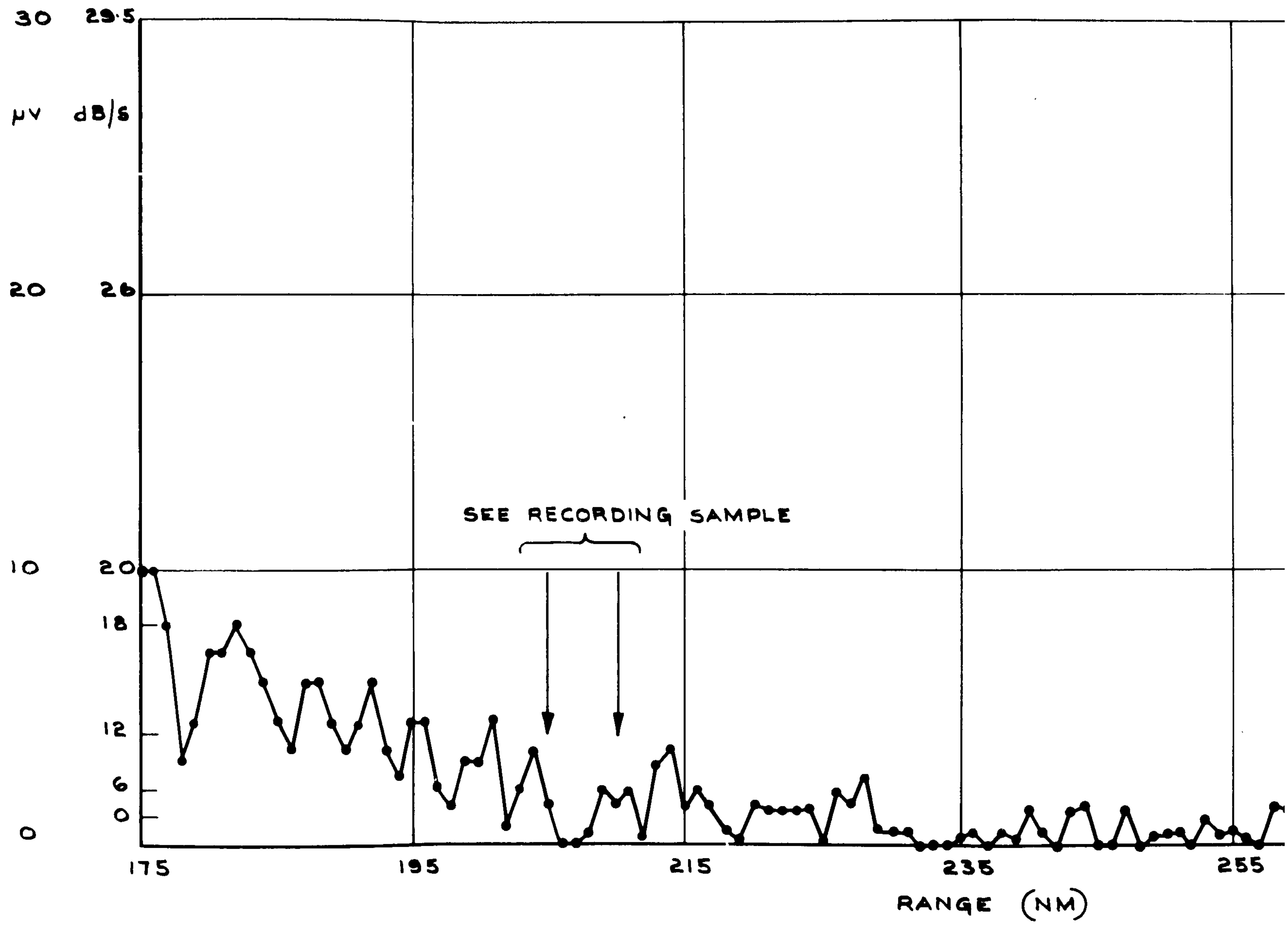


FIG. 13. SIGNAL STRENGTH GRAPH 10 000 ft.

2

Fig.14

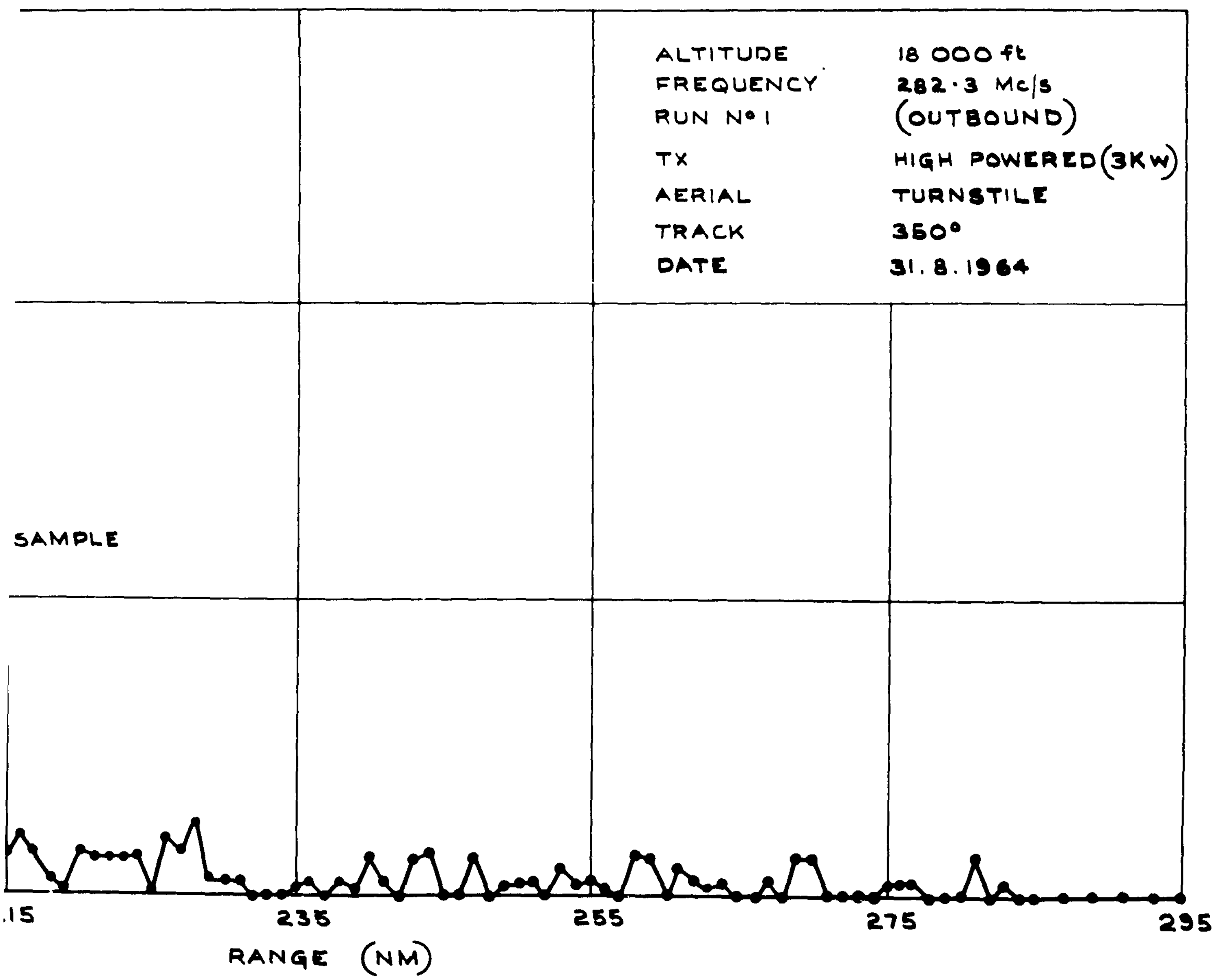
008-900224



/

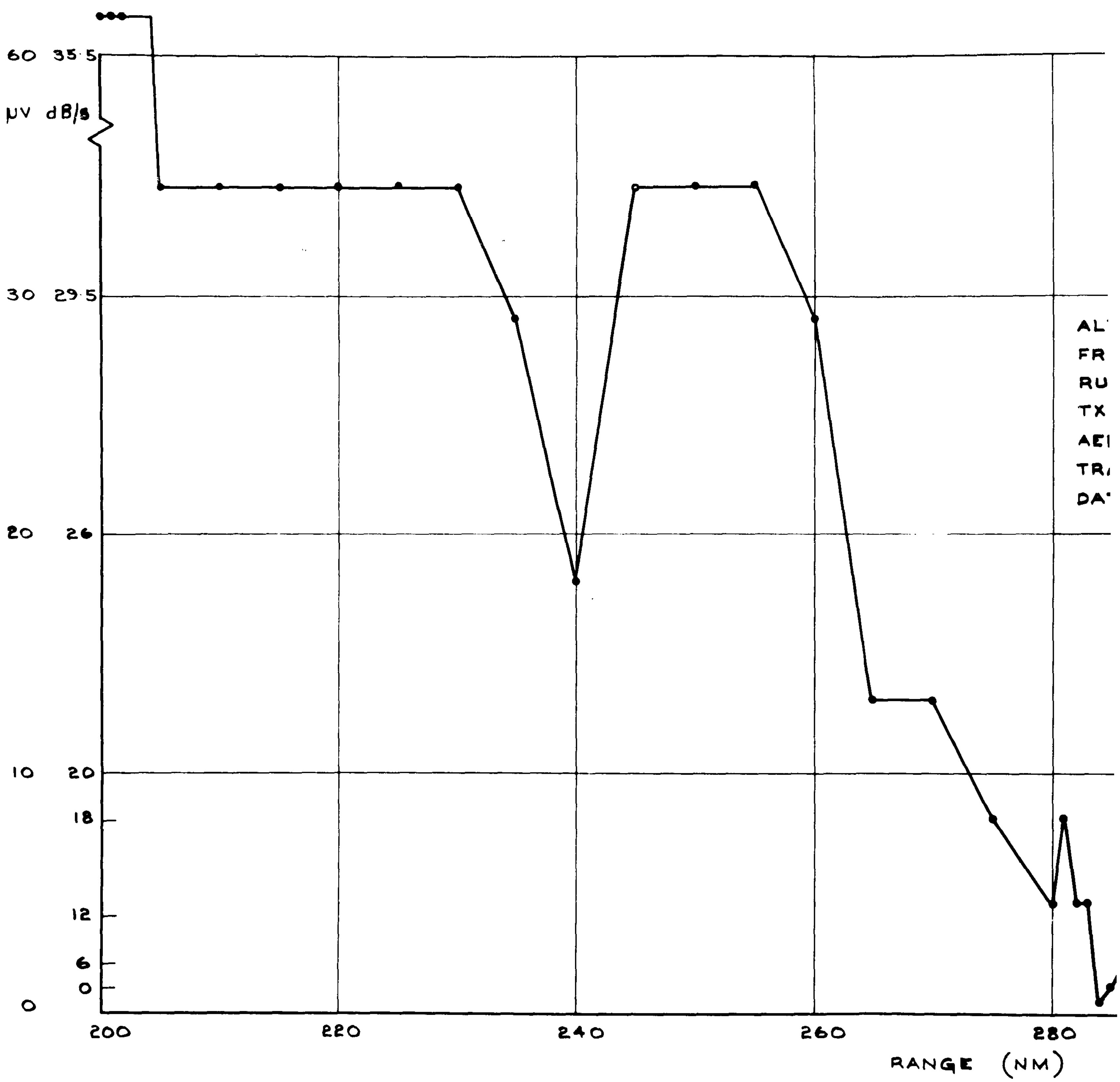
FIG. 14. SIGNAL STRENGTH GRAPH 18 OC

008-200224



NAL STRENGTH GRAPH 18 000 ft 31. 8. 64.

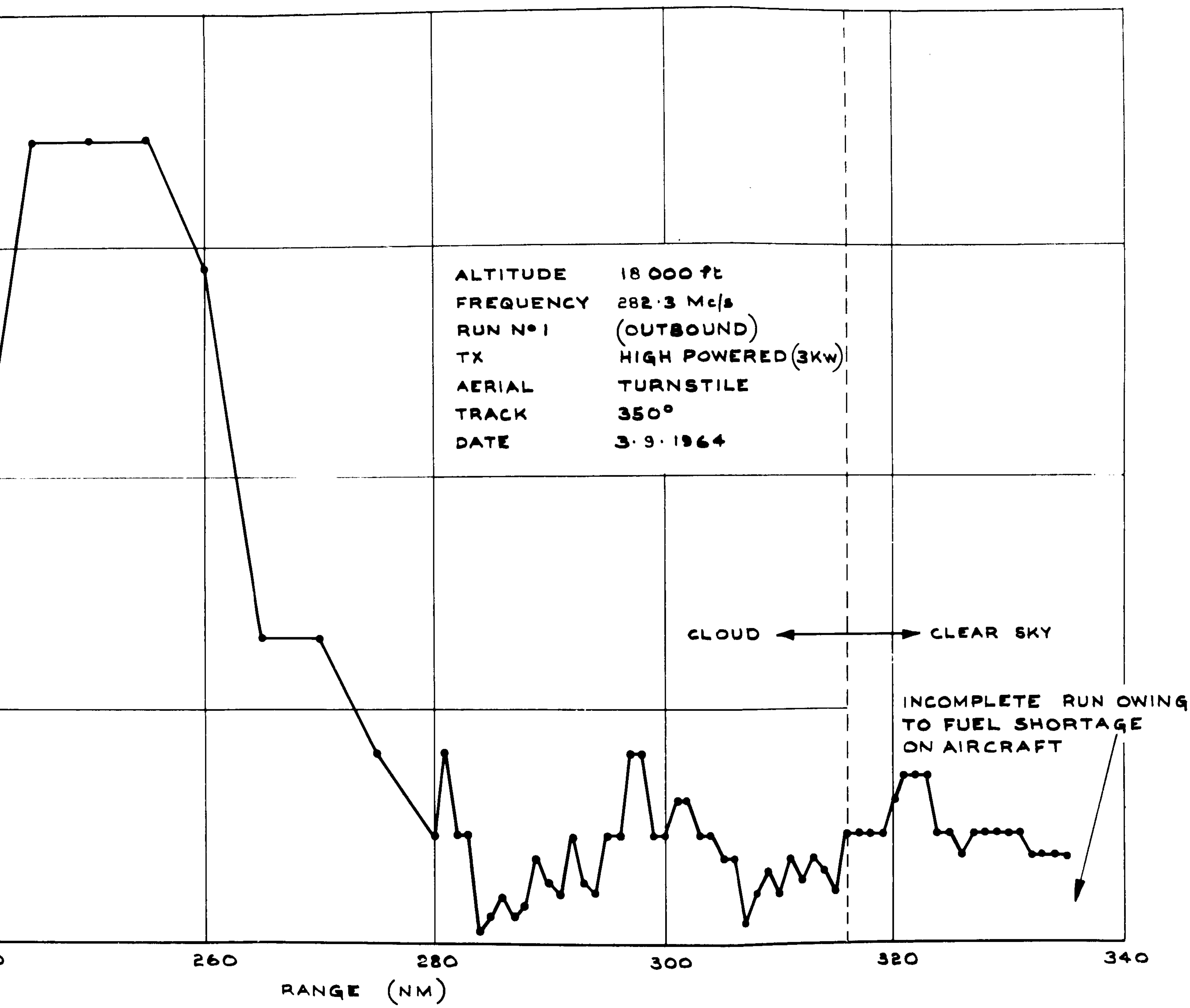
2



/

FIG. 15. SIGNAL STRENGTH GRAPH

Fig.15



SIGNAL STRENGTH GRAPH 18000 ft 3.9.64.

2

Fig.16

Neg. No. C2014

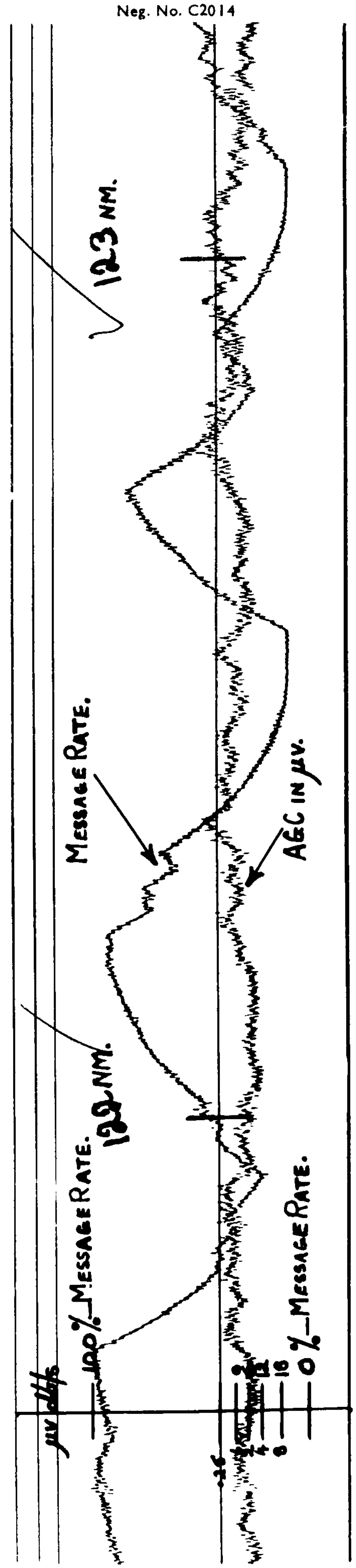


Fig.16 TX. 3KW. Altitude, 5000'; Run, outbound. Date 25. 9. 1964

R.66107

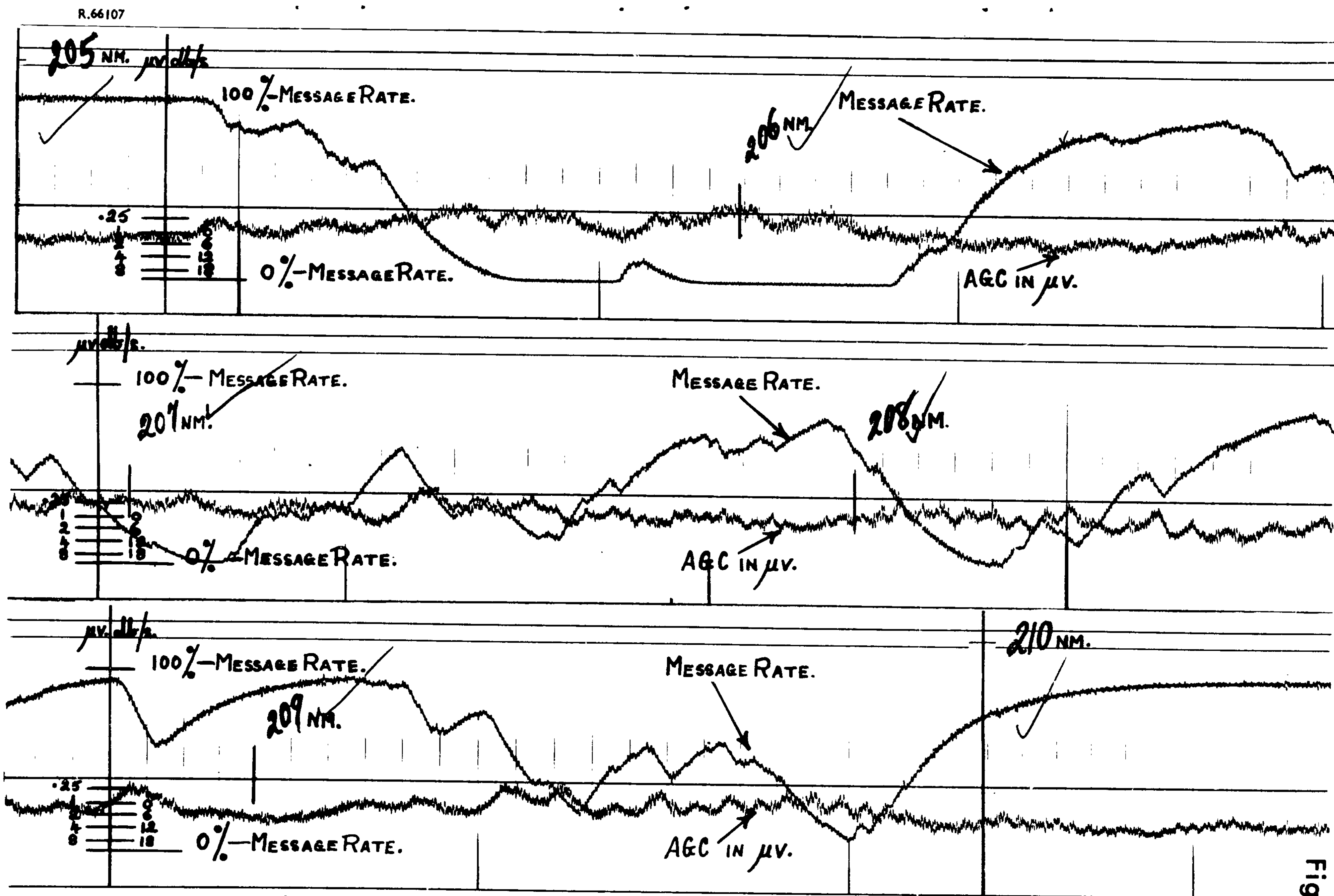


Fig.17 TX. 3KW. Altitude, 18000': Run, outbound. Date 31. 8. 1964

Neg. No. C2015

Fig.17

Fig.18

Neg. No. C2016

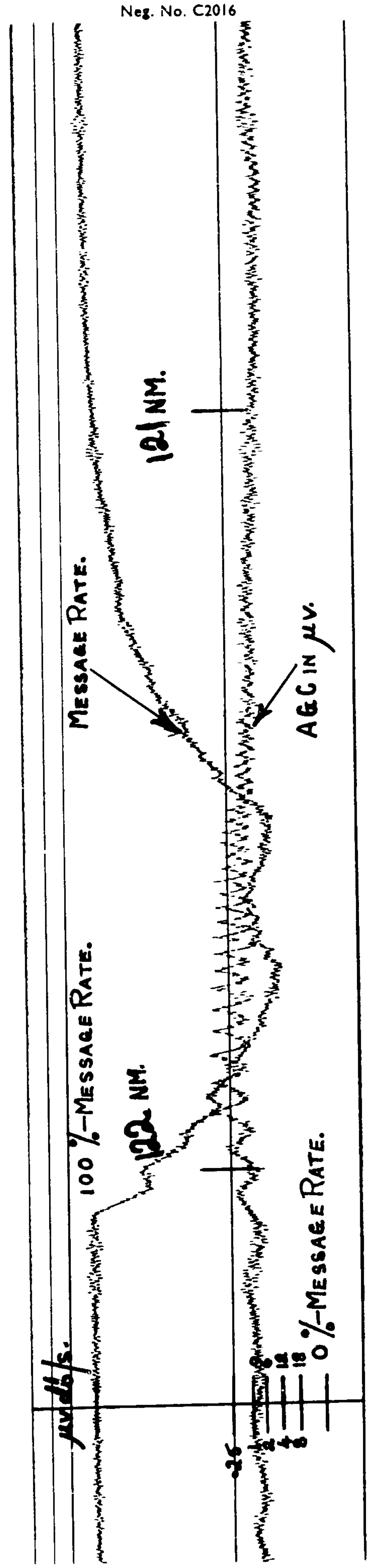


Fig.18 TX. 3KW. Altitude, 5000': Run, inbound. Date 5.10.1964

R.66107

Fig.19

R.66107

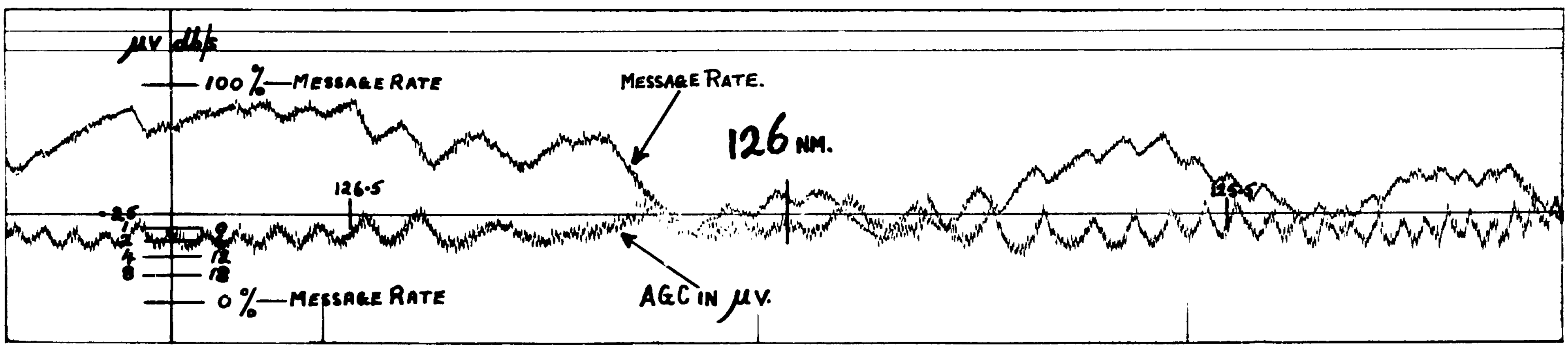


Fig.19 TX. 3KW. Altitude, 5000': Run, inbound. Date 23. 9. 1964

DETACHABLE ABSTRACT CARDS

These abstract cards are inserted in Technical Reports for the convenience of Librarians and others who need to maintain an Information Index.

Detached cards are subject to the same Security Regulations as the parent document, and a record of their location should be made on the inside of the back cover of the parent document.

CONFIDENTIAL

May, Donald, P.L. — 621.396.933 : 621.3.092.4 : 621.3.029.63 : 621.391.812

FACTORS AFFECTING THE RANGE OF A U.H.F. DIGITAL DATA SYSTEM IN THE REGION OF AND BEYOND THE HORIZON

Royal Aircraft Establishment Technical Report 66107 — April 1966

Practical radio ranges for a high data rate system, known as U.H.F. Data Link, obtained between ground transmitters and an aircraft flying at altitudes up to 18000 ft are analysed for transmitter powers of 100 watts and 3 kilowatts with three different degrees of aerial gain. The higher power transmissions provided beyond-the-horizon reception and the second part of this paper gives information concerning signal strength distributions, fading characteristics and their effects upon communication efficiency in this region.

CONFIDENTIAL

CONFIDENTIAL

May, Donald, P.L. — 621.396.933 : 621.3.092.4 : 621.3.029.63 : 621.391.812

FACTORS AFFECTING THE RANGE OF A U.H.F. DIGITAL DATA SYSTEM IN THE REGION OF AND BEYOND THE HORIZON

Royal Aircraft Establishment Technical Report 66107 — April 1966

Practical radio ranges for a high data rate system, known as U.H.F. Data Link, obtained between ground transmitters and an aircraft flying at altitudes up to 18000 ft are analysed for transmitter powers of 100 watts and 3 kilowatts with three different degrees of aerial gain. The higher power transmissions provided beyond-the-horizon reception and the second part of this paper gives information concerning signal strength distributions, fading characteristics and their effects upon communication efficiency in this region.

CONFIDENTIAL

CONFIDENTIAL

May, Donald, P.L. — 621.396.933 : 621.3.092.4 : 621.3.029.63 : 621.391.812

FACTORS AFFECTING THE RANGE OF A U.H.F. DIGITAL DATA SYSTEM IN THE REGION OF AND BEYOND THE HORIZON

Royal Aircraft Establishment Technical Report 66107 — April 1966

Practical radio ranges for a high data rate system, known as U.H.F. Data Link, obtained between ground transmitters and an aircraft flying at altitudes up to 18000 ft are analysed for transmitter powers of 100 watts and 3 kilowatts with three different degrees of aerial gain. The higher power transmissions provided beyond-the-horizon reception and the second part of this paper gives information concerning signal strength distributions, fading characteristics and their effects upon communication efficiency in this region.

CONFIDENTIAL

CONFIDENTIAL

May, Donald, P.L. — 621.396.933 : 621.3.092.4 : 621.3.029.63 : 621.391.812

FACTORS AFFECTING THE RANGE OF A U.H.F. DIGITAL DATA SYSTEM IN THE REGION OF AND BEYOND THE HORIZON

Royal Aircraft Establishment Technical Report 66107 — April 1966

Practical radio ranges for a high data rate system, known as U.H.F. Data Link, obtained between ground transmitters and an aircraft flying at altitudes up to 18000 ft are analysed for transmitter powers of 100 watts and 3 kilowatts with three different degrees of aerial gain. The higher power transmissions provided beyond-the-horizon reception and the second part of this paper gives information concerning signal strength distributions, fading characteristics and their effects upon communication efficiency in this region.

CONFIDENTIAL

[dstl]

Information Centre
Knowledge Services
[dstl] *Porton Down,*
Salisbury
Wilts
SP4 0JQ
22060-6218
Tel: 01980-613753
Fax 01980-613970

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#: AD396904

Date of Search: 17 November 2008

Record Summary: AVIA 6/21624

Title: Factors affecting the range of a UHF digital data system in the region of and beyond the horizon
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) TECHNICAL REPORTS 66107
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as UNLIMITED.