A NEW DIRECTION FINDING NETWORK FOR LOCATING THE SOURCES OF ATMOSPHERICS

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Abstract

Aiming at automatically locating the atmospheric sources, a new direction finding network system has been planned by our Research Institute since May 1967.

The new automatic location system of atmospheric sources adopts the principle of triangulation network, consisting of the three direction finding stations, Moshiri Sakushima and Kagoshima. A direction finder of twin channel type each installed at a station, is tuned to 10 KHz and is used for locating distant sources, several hundred to several thousand kilometers away from each station.

Test observations using the new system have been continued from one to two weeks each month from July to October 1968. At present, the site error is being investigated, referring to these observation data. The routine observation, being delayed by the deficiency of the electronic computer, will be opened in spring 1969.

1. Introduction

For several years beginning from 1950, the observations of locating atmospheric sources were made to study the nature of atmospherics in our Institute. The observation techniques and the results obtained were described in the previous papers (Iwai et al, 1953, Kimpara 1953).

The previous direction finding system used photographic films to record the direction and the time of arrival of atmospherics. So that it required a great effort of a few months to reduce the data obtained from a week long observation.

Since IGY, the observation of locating the sources of atmospherics has been interrupted, because our interest mainly came to direct towards whistlers and VLF emissions studies.

Recently, the demands for locating the atmospheric sources begin to grow up to help in detail the study of whistlers, ELF, etc. Timely matched with the demands, Moshiri and Kagoshima Observatories were already constructed as the base of observation of whistlers and VLF emissions, etc. Therefore, a new direction finding network system using these observatories was planned to automatically locate the atmospheric sources.

2. Principle of devising the system

2. 1 Outline of the system

The principle used in this system involves a conventional twin channels radio direction finder of Watson-Watt type. But, the reading of the arriving direction is made with numerical tubes, in place of a cathode ray tube as in Watson-Watt type. At the same time, the coded data on arriving bearing and occurring time of atmospherics is punched out on a paper tape with a high speed mechanical puncher. These digital data of bearing and time of arrival are sent to the data reduction center at Toyokawa with three radio links or mails. Then, the individual position of atmospheric source is plotted on a map without delay by means of an electronic computer. In parallel with this, the coordinates of the source position is also typed out on a chart. The outline of this system and the location of the stations are shown in Fig. 1.

2.2 Principle of digital reading of bearing angles

To simplify the discussion, the atmospheric signal is assumed to be a continuous wave. The outputs from twin channels, N-S and E-W, can be written as $A\cos\theta\ \sin\omega t$ and $A\sin\theta\ \sin\omega t$, where A is a constant, θ the azimuth of an arriving atmospherics, ω the angular frequency. The twin signals are detected by a pair of phase detectors and transformed into D-C signals, $\pm|A\cos\theta|$, $\pm|A\sin\theta|$, respectively, where $\pm$ is to be decided in accordance with the quadrant of direction of the atmospherics. The twin D-C signals then go through a pair of balanced modulators and the signals are transformed here again into A-C waves, which are represented by $A\cos\theta\ \sin\phi t$ and $A\sin\theta\ \cos\phi t$, respectively, where ϕ is the angular frequency of the local oscillator, because a pair of local oscillating voltages, whose phase difference is adjusted to $\pi/2$, is applied to the twin balanced modulators. Then, either one output from the pair of balanced modulators is subtracted from the other and the resultant is given as follows:

$$A\sin(\phi t-\theta)$$

Comparing the phases between this resultant signal and a local signal of the twin balanced modulator, $\sin\phi t$, it will be found that the phase difference between the two is equal to the azimuth of the arriving atmospherics Therefore, the bearing angle of the atmospherics is read with a digital counter that measures the phase angle, where

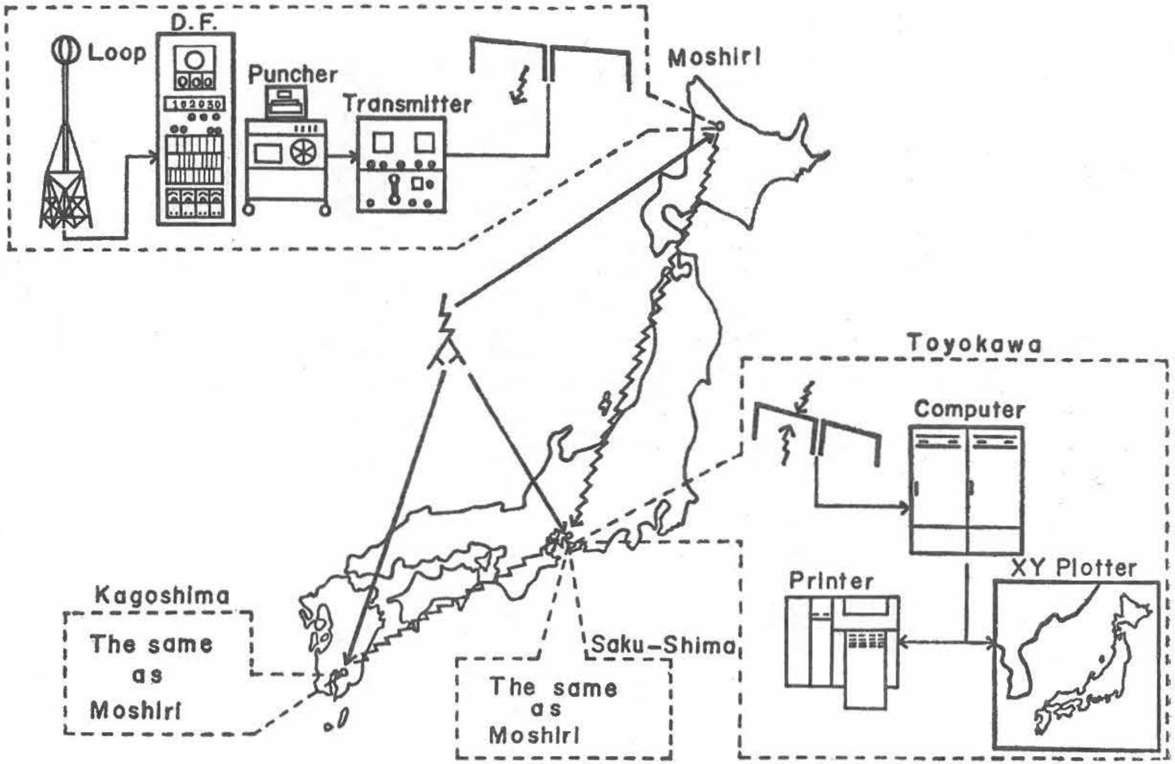


Fig. 1 Automatic locator system of atmospheric sources

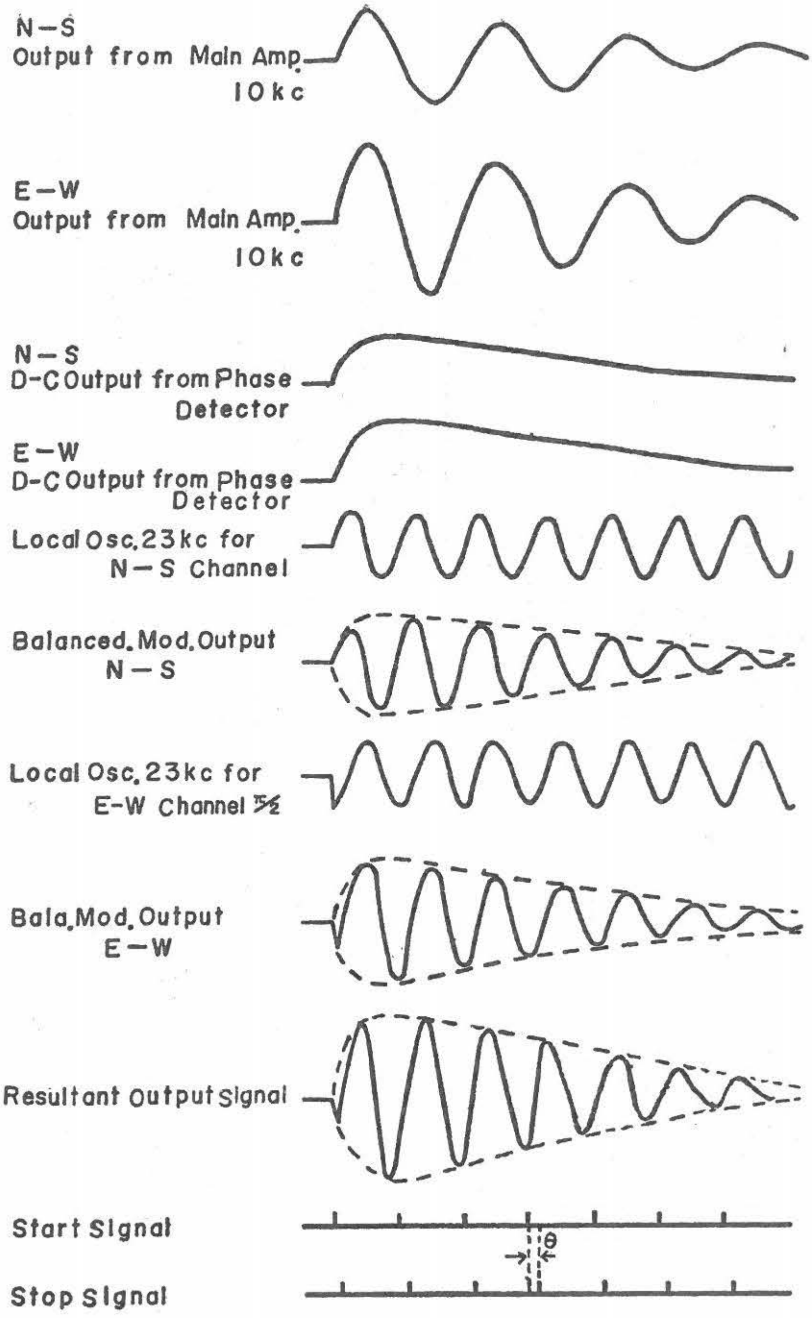


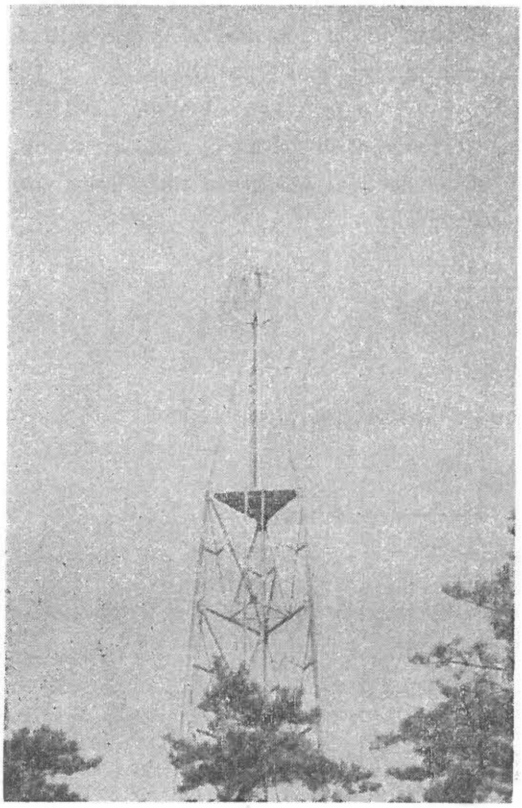
Fig. 2 Time chart showing the principle for measuring the bearing angle

the local signal is used as a start signal and the resultant as a stop signal. Then, the bearing angle can be indicated in degrees by using the repetition frequency of $360 \times \phi/2\pi$ Hz, as the counting pulse frequency.

The time chart of this principle is shown in Fig. 2.

3. Direction finder of the system

3. 1 Antenna



The crossed loop antenna used in the system is of a circular type of 100 turns of 0.18 m/m×7 wires and its diameter is 1.2 meter. The sensor part is supported on a duralumin pole of 4 meters long which is installed on a tower of 17 meters high. The preamplifier and the test oscillator are mounted on the base of the tower. The signal received by the loop antenna goes through the preamplifier, and is amplified by about 20 DB, transformed into a low impedance, and the output from it is introduced to the main amplifier through a feeder. An example of the loop antenna is shown in Fig. 3.

Fig. 3 Loop antenna installed at Sakushima

3. 2 Feeder

The loop antenna must be installed at the most suitable place around the observatories to reduce the site error. For this reason, the feeders are required the lengths of 250 meters at Moshiri, 500 meters at Sakushima and 1800 meters at Kagoshima, respectively. The feeder used is the cabtyre cable with 14 wires shielded with iron and copper tapes. Of 14 wires, two pairs are doubly shielded to feed N-S and E-W signals and the cross talk between them is kept below −60 DB for the length of 2000 meters. The remaining wires are allocated for power supplies and control signals.

3. 3 Main Amplifier

Each main amplifier, which amplifies the signal from the antenna, consists of four parts, i. e., two stages of single tuned feed-back amplifier, two attenuators, a phase adjuster and a output amplifier. The block diagram from antenna to main amplifier is shown in Fig. 4. The observation frequency is fixed at 10 KHz and its band-width is 300 ± 50 Hz. The total gain from the input of the preamplifier to the output of the main amplifier is about 110 DB, but the apparatus is usually operated at 80−90 DB. All circuit of preamplifier and the main amplifier is made of linear integrated circuits and the tuning circuits at 10 KHz are constructed with inductors which use the ferrite core of zero temperature coefficient and polystirole condensers.

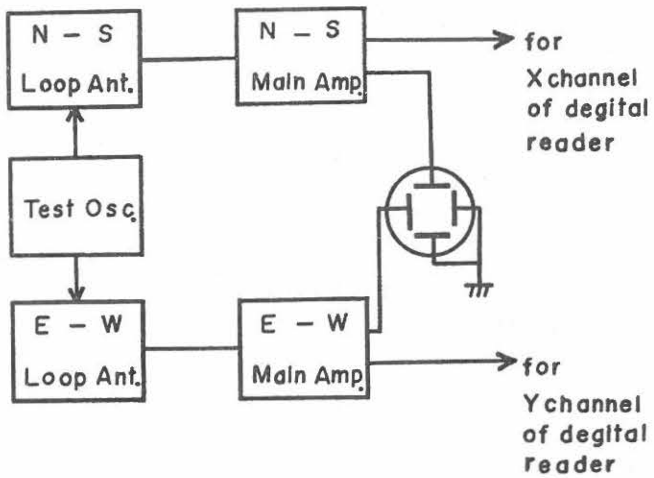


Fig. 4 Block diagram of the receiver

3. 4 Digital reading circuit of bearing angle

The reading circuit instantaneously reads the bearing angle of an incoming atmospherics and is divided into four parts as follows:

(1) The first ; the part for transformation of E-W(X) and N-S(Y) components of an atmospherics into two positive or negative D-C signals by means of phase detectors.

(2) The second ; the part for to set up two A-C signals with phase angles shifted by $\pi/2$ to each other, whose amplitudes are proportional to the two D-C signals obtained with (1).

(3) The third ; the part for to set up a signal lagged from the reference signal at the angle equal to $\tan^{-1}X/Y$ by means of subtracting two A-C signals set up with (2) from each other.

(4) The fourth ; the part for to measure in degrees the phase difference which is set up with (3).

The block diagram of the digital reading circuit is shown in Fig. 5.

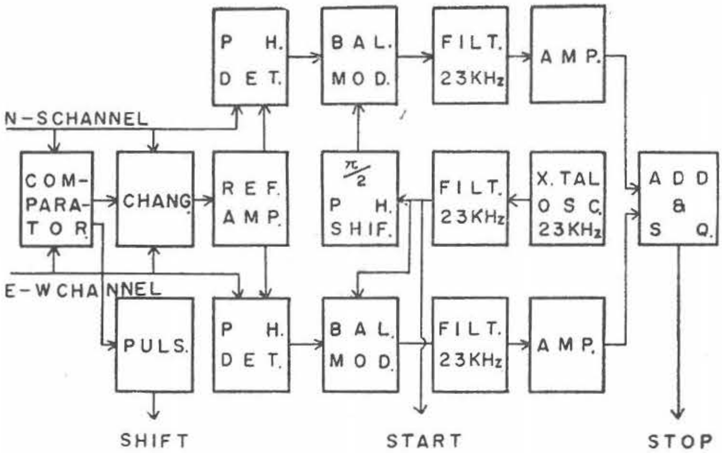


Fig. 5 Block diagram of the digital reading circuit

3. 4. 1 Circuit converting atmospherics into D-C

As shown in Fig. 5, this circuit consists of a comparing circuit, a changer, a reference amplifier and twin phase detectors. The wave form of output of the main amplifier is generally shown in Fig. 2. The E-W and N-S signals are supplied to X and Y input terminals of the converting circuit. First, in the comparing circuit, X and Y signals go through the envelope detectors and then are supplied to a differential amplifier. After this, its output is introduced to a Schmit circuit. By the use of 'on' or 'off' signal from the Schmit circuit, it is possible to distinguish which of X or Y signal is larger than the other. Next, the output from the changer is switched to the larger signal selected by the comparing circuit.

The reference amplifier, which supplies a reference signal to the phase detector, consists of limiting amplifiers, a filter and a phase inverting circuit. The input signal to the reference amplifier is transformed into a constant amplitude square wave by a function of limiting amplifiers and is filtered through a tuning circuit at 10 KHz. Then, its output comes to have a sine wave form of 10 KHz with constant amplitude. This signal, passing through a phase inverting circuit, is transformed into a balanced signal of low impedance, which is to be brought to the next phase detector as a reference signal. At the phase detector, X and Y signals from the main amplifier are detected and come to form positive or negative D-C signals, according as the phase difference between the incoming signal and the reference signal is in phase or out of phase. The charging and the discharging time constants of this phase detector are 0.06 mSec. and 6 mSec., respectively. Therefore, this circuit operates as a peak detector for atmospherics. A dynamic range up to about 80 DB is necessary on these circuits, to keep the measuring accuracy within $\pm 1^\circ$ for the ordinary observation.

3. 4. 2 Circuit converting D-C into A-C

As shown in Fig. 5, this circuit consists of a crystal oscillator at 23 KHz, a $\pi/2$ phase shifter, balanced modulators, filters at 23 KHz and level amplifiers. At first, a pure sine wave of 23 KHz is generated by the use of a crystal oscillator and a filter at 23 KHz. This sine wave, as a reference signal, is supplied to Y channel of a pair of balanced modulators, while the reference signal for X channel is supplied through a $\pi/2$ phase shifter. Therefore, the phase difference of the reference signals between X and Y channels is accurately $\pi/2$. And then, with aid of performance of a balanced modulator, the D-C signal from the phase detector is converted into an A-C signal of 23 KHz, whose amplitude is proportional to the amplitude of the input D-C signal. This output contains many harmonics. So, the output of sine wave is obtained through a low pass R-C filter of 23 KHz and is amplified to a sufficient value to be brought to the next stage.

3. 4. 3 Stop signal generating circuit

The outputs from X and Y level amplifiers, whose amplitude ratio contains the information of arrival bearing, are subtracted with each other in order to make a A-C signal, whose phase is lagged by an amount equal to the angle of arrival bearing from that of the reference signal of 23 KHz, which is inserted to Y channel of the pair of balanced modulators. Then, this output signal is introduced to a squaring amlifier of 90 DB and is differentiated to get a pulse for the stop signal, whereas, the start signal is constructed from the reference signal of 23 KHz by means of the same technique as to the stop signal.

3. 4. 4 Digital counter for measuring the bearing angle

The block diagram of this counter is shown in Fig. 6. As shown in this figure, the bearing angle is measured by the number of counting pulses passing through the 'And Gate', which is made 'on' phase only during the interval between start and stop pulses. The frequency of the counting pulse is selected at 8. 28 MHz (23 KHz × 360) in order to

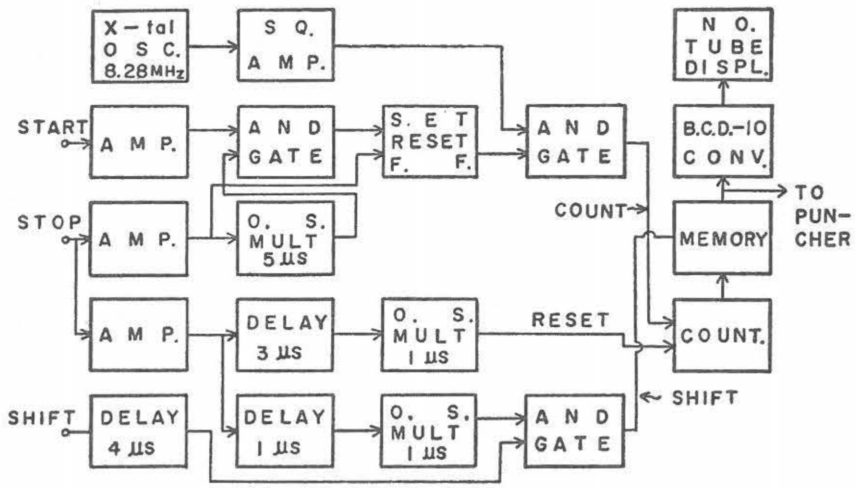


Fig. 6 Block diagram of the digital counter

measure the bearing angle in degrees. To avoid the confusion of miscount, the counter circuit is so designed as it is put into a 'reset' phase with the help of another pulse which is delayed by 3 μSec. from the stop pulse. Therefore, it can not be operated by a start pulse appearing within 5 μSec. after the previous stop pulse. The counted information on bearing angle is brought to the register by mean of a shift pulse delayed by 1 μSec. back from the stop pulse. But, this shift pulse can pass only when 'And Gate' is opened and this 'And Gate' gets open 4 mSec. after from receiving the atmospherics. The digital information memorized in the register is punched out on the paper tape together with the time information in a B.C.D. code. At the same time, this information registered in a B.C.D. code is translated into a decimal system and is displayed by numerical tubes. Another starting pulse which has a function of producing the shift pulse and of operating the puncher, is set up in a pulser and is ready to be sent out from pulser when the incoming atmospherics exceeds a threshold level decided in advance.

3. 5 Timing signal

In order to take the coincidence of occurring time of atmospherics, it is necessary to keep the time accuracy within 0.01 Sec. among three stations. For this purpose, the crystal oscillator of 50 Hz, calibrated by JJY, is employed and its output is divided into second, minute, hour and day in order by means of the frequency dividers constructed from digital integrated circuits. The time on this electronic clock is shifted to the register by the shift pulse synchronized to atmospherics. The occurring time information, which is stored on the register in a B.C.D. code, is then punched out on the paper tape together with the bearing information. Moreover, using this time signal, it is possible to operate this apparatus automatically according to a previously decided programme.

3. 6 Data recording and data transmission

As described 3.4, the data on direction and time are punched out on a paper tape in a B.C.D. code. The duration of an observation is five minutes at the most. Punched on a paper tape at each beginning of an observation is a heading, which consists of a start mark, the name of station, 10^1 day, 10^0 day, 10^1 hour, 10^0 hour, 10^1 minute and an end mark. And then, a text is recorded on every receiving of atmospherics. The text consists of 8 characters of 10^0 minute, 10^1 sec., 10^0 sec., 10^{-1} sec., 10^2 degree, 10^1 degree, 10^0 degree and the end mark of a text, and each character is constructed from 6 bits in a B.C.D. code, where the bits, No. 1- No. 4 represent 1-2-4-8, the bit No. 5 a control and the bit No. 6 a parity, respectively. The example of a format punched on a paper tape

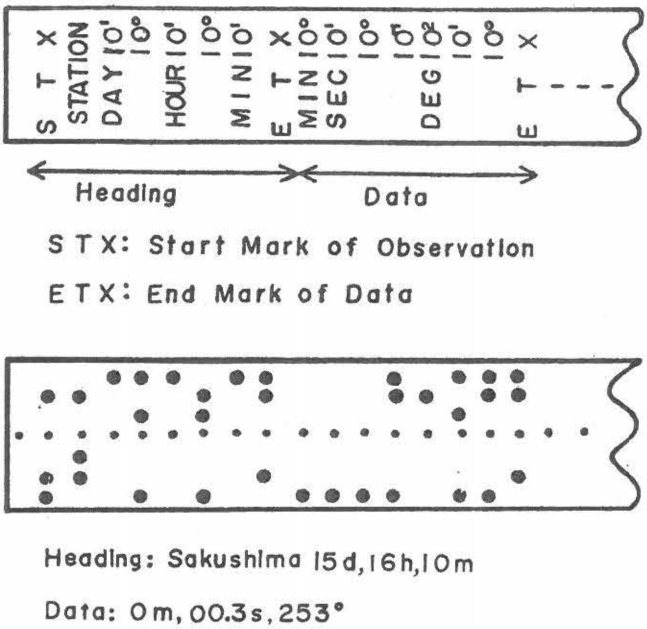


Fig. 7 An example of a format on paper tape

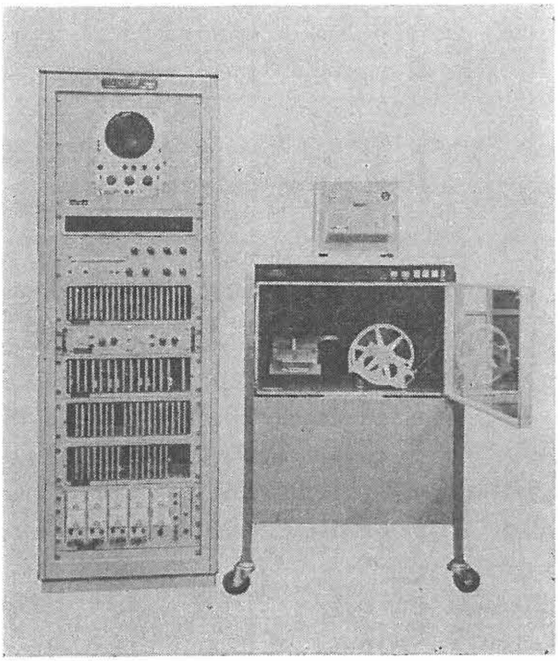


Fig. 8 Front view of the apparatus

is shown in Fig. 7 and it describes the detail of an atmospheric arrival direction measurement. A high speed puncher of 120 characters/sec. is employed to punch out the data very fast. Therefore, a text on an atmospherics, which is consisted of 8 characters is recorded within 0.1 second. As a result, the system has a time response of 0.1 second. The speed is mainly limited by the mechanical speed of the puncher used, but is sufficient enough for the recording of atmospherics, except for multiple strokes.

The data punched on a paper tape are read out in series by a tape-reader and are transformed into the sine waves of 1100 Hz or 1900 Hz according to 0 or 1 on the paper tape, respectively. A series of sine waves of 1100 Hz and 1900 Hz is transmitted to data center at Toyokawa by radio links of S.S.B. or V.H.F. Moreover, the paper tape is also sent to the data center by mail to compensate the data failure which is due to radio noises or interferences in radio links. The front view of this apparatus is shown in Fig. 8.

4. Central data reduction system

4. 1 Data receiving system

The data sent on the air from the three observatories are received in turn by the radio receivers at Toyokawa, and the output is fed to a demodulator, where the data arranged in a series code are transformed into a parallel code by a series-parallel converter. And then, the data in a parallel code is put into an electronic computer to calculate the coordinate of an atmospherics. The paper tape sent from the three observatories by mail is read out in a parallel code by a tape reader and is also fed to the computer in order to check the data sent by radio links.

4. 2 Data accessing process

The coded data subjected to a series-to-parallel conversion in passing through the converter, is brought to a communication control unit (CCU) and then to a core memory unit (CM) of a computer system* through a direct access controller (DAC). The data stored on CM are finally transfered to a magnetic disk (MD). The diagram of the data accessing process is shown in Fig. 9 and the front view of data reproducing system is shown in Fig. 10.

Main function of the CCU is as follows ; control of start or stop of data acceptance, discrimination of station name, checks on parity error, on format error and on station

* TOSBAC 3400 Model-30

code error and finally, change of data format. If there is any error checked out in the "heading", then error messages are introduced and the data acceptance is stopped. But the heading is arranged to be repeated successively two times so as to reduce the chance of acceptance-stop which results from errors in heading. If it happens any error to occur in the "data text", only that data text is dropped and the acceptance continues. Data coming from the series-parallel converter, each expressed with a B.C.D. code of parallel 6 bits, are subjected to a format change by CCU. The information thus obtained constructs one data word which is a sum of eight data each represented with parallel 6 bits, therefore is composed of parallel 48 bits. Thus "station name", "day" and "minute" in a heading or "minute", "second" and "bearing angle" in a data text can be expressed with this one data word. The main function of the DAC is to transfer the data from CCU to CM without any control of central processing unit (CPU) of the computer. Therefore, DAC makes it possible to do the fixing calculation of atmospherics even in the data accessing period.

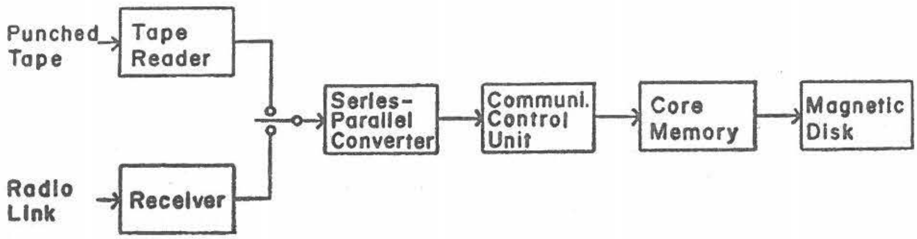


Fig. 9 Flow diagram in data accessing process

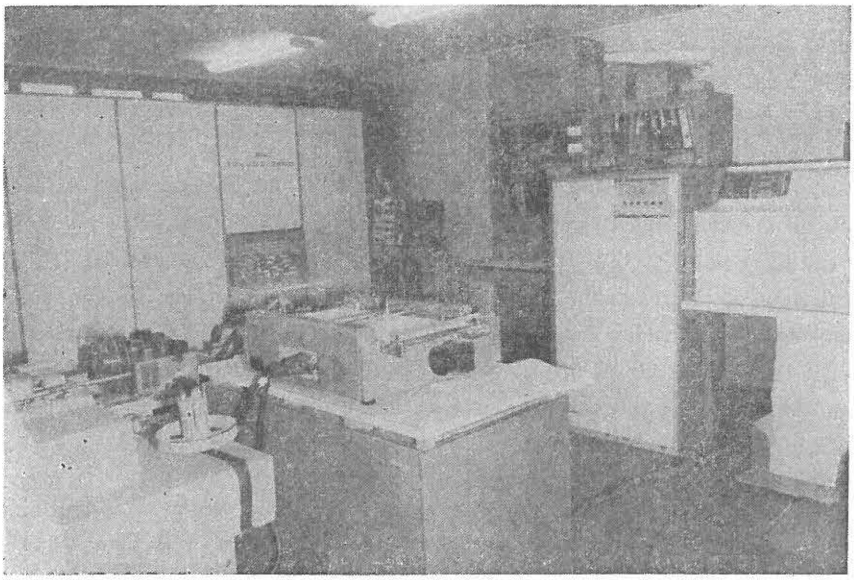


Fig. 10 Front view of data reproduction system

When the number of data stored on CM reaches 2,000 or when the end mark of a data transmission is detected by CCU, the data stored on CM are transfered quickly to MD. The transfer time from CCU to CM is less than 10 micro-second per one data and the transfer of 2,000 data from CM to MD can be finished within 200 milli-second.

A storage area of 50,400 data is reserved on MD for each field station, therefore seven day's data can be stored on it. The maximum acceptable number of one day's data is 7,200 which is estimated on an assumption that the observation is carried out once an hour and the number of data obtained at one field station does not exceed 300.* If the assigned data storage capacity on MD is overloaded, the oldest data are taken away from the allocated place, and the newly coming data come to fill up that place. Besides this, an area capable of storing 24,000 data is still left on MD, which may be used to store the data which are selected to be suitable for a study of site errors.

4. 3 Fixing process of atmospherics

When the storing process on a magnetic disk (MD) is finished, of the data which has been transmitted in turn from each of the three stations, a calculation by the computer starts automatically to fix atmospheric sources.

The calculation is controlled by an operation program stored on MD. The four main functions of the program are; 1. identification of a specific atmospherics, 2. correction of 180° ambiguity of a measured bearing angle, 3. calculation of coordinates of atmospheric source and 4. tabulation of the results and the plotting of the location on a map.

4. 3. 1 Identification of atmospherics

An atmospherics originating from a lightning flash can be received at each station with time differences less than 0.01 second, since it propagates with a velocity nearly equal to the light velocity and the length of thease-lines does not exceed 3,000km. Since the arrival time of an atmospherics is read out with an accuracy of the order of 0.1 second, the signal originating from a specific lightning flash will be detected at each field station as if the arrival times are coincident. Thus, an atmospherics which is received at each station, and has the same occurrence time, may be regarded as to be originated from the same lightning flash.

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* This format of data storage may be changed in the near future so as to eliminate the limitation on the number of observations in one hour, and in one day, as well as the limitation on the number of data in one observation, although the acceptable number in one day is kept 7,200 for each field station.

As the "time" setting on each local clock is manually refered to J.J.Y. at present, so the accuracy of 0.1 second is not always secured. The time difference between time settings made on each of the three local clocks located respectively at the three field stations, Moshiri, Sakushima and Kagoshima, can, however, be estimated by processing a program as follows. The time of occurrence of an atmospherics at Kagoshima or Moshiri is shifted from −0.5 to +0.5 sec successively in 0.1 sec step, and the number of coincidence with atmospherics at Sakushima is counted for each shift of occurrence time. In many cases the number of coincidence showed a steep peak as Tables 1(b) and 1(c). The time difference between the local time settings at Sakushima and Kagoshima and the time difference between those at Sakushima and Moshiri can be found from each correction time where a steep peak coincidence is secured. Then an atmospherics originating from the same flash may be identified. This method of identification will be useful and reliable when single steep peak appears. Neighbouring double peaks also can occur as seen in Table 1(a), as atmospherics occur at random in time and the time correction is made in the unit of 0.1 sec, and their magnitude may become comparable as the time difference in the order of 0.01 sec comes up to 0.05 sec. In this case the number of coincidence through the three stations, obtained by this time-shifting method, may be reduced very much.

As the time interval between atmospherics successively received at each station becomes short multiple peaks may appear and a chance to get an incorrect identification will increase. In order to diminish the incorrect identification, construction of an apparatus is planning which can automatically adjust the time of a local clock with an accuracy of 0.01 second. The programming described above will be omitted after the apparatus will have been equipped at each station.

Table 1 Variation of number of coincidence with Sakushima.

a. 1 July 1968 1510 J.S.T.

(sec.)	−0.5	−0.4	−0.3	−0.2	−0.1	0	0.1	0.2	0.3	0.4	0.5
K	57	51	69	63	58	102	132	62	62	56	51
M	37	31	29	28	30	38	25	149	32	34	37

b. 7 Sep. 1968 0910 J.S.T.

(sec.)	−0.5	−0.4	−0.3	−0.2	−0.1	0	0.1	0.2	0.3	0.4	0.5
K	26	20	29	20	27	37	98	54	30	25	32
M	33	29	37	42	159	48	39	26	39	48	30

c. 11 Sep. 1968 1510 J.S.T.

(sec.)	−0.5	−0.4	−0.3	−0.2	−0.1	0	0.1	0.2	0.3	0.4	0.5
K	25	37	23	33	36	54	108	38	34	26	29
M	36	26	37	28	58	97	27	35	21	26	35

4. 3. 2 Correction of 180° ambiguity for bearing angle

The bearing angle of an atmospherics measured at each station has 180° ambiguity, because the uni-direction finding technique has not been used in the present location system. So it is necessary to remove this ambiguity with a computer processing. This ambiguity removal can be made by knowing the direction of crossing point of two great circles representing respectively the measured bearing angle at each one of the two field stations. The direction of crossing point can be known by comparing two angles held between the base-line and the great circles. If the direction of the crossing point, seen from each one of the two stations, coincides with the measured direction, the measured bearing angle is correct, but if it is opposite to the measured direction the correction of 180° should be made on the measured bearing angle.

If the direction of two crossing points lying on a great circle comes to direct opposite, then the calculation for fixing of atmospherics is so programmed as not be processed. Such examples can be seen in Tables 2(a), 2(b) and 2(c).

4. 3. 3 Calculation of coordinates of atmospheric source

By using formulas of spherical triangle, the coordinates of a crossing point can be calculated for a pair of corrected bearing angles on an assumption that the earth is a sphere of radius 6, 370km. As there are three stations three crossing points generally exist for one atmospherics owing to the errors in measured bearing angles, e. g., site error, polarisation error, interference error and errors due to electronic equipments. The true location of the atmospheric source can not be made known from the locations of these three crossing points, so the center of gravity of the spherical triangle formed by the three crossing points is assumed to be the source location for the sake of convenience.

Besides the coordinates, three quantities are calculated which give informations about the quality of spheric fixing. They are given in the columns below the symboles; "RATIO", "DAN" and "VAN" in Tables 1(a), 1(b), and 1(c). The meanings will be explained in the next.

4. 3. 4 Tabulation and plotting of results

The results obtained by the computer calculation are tabulated with a line-printer as given in Tables 2(a), 2(b) and 2(c). The meanings of the symboles given in the tables are as follows;

TIME: elapsed time from the start of observation, expressed in minute, second and one-tenth of a second, measured refering to the local clock at Sakushima,

K, S and M : station names : Kagoshima, Sakushima and Moshiri,

K (KS) : indicate listed quantities relating to Kagoshima station and crossing point fixed by bearings at Kagoshima and Sakushima,

AZIMUTH : corrected bearing angle measured clockwise from the north direction,

COORDINATE : geographic longitude and latitude,

DIS-1 : distance from the station indicated on the left side of station symbol to the crossing point fixed by bearings at two stations shown by the station symbols in the parentheses,

DIS-2 : distance from the station indicated on the left side of station symbol to the crossing point fixed by bearings at this station and one remaining station,

RATIO : the difference between DIS-1 and DIS-2 divided by smaller one of DIS-1 and DIS-2,

DIS-G : distance from the station indicated on the left side of station symbol to the center of gravity of spherical triangle formed by three fixed points,

VAN : crossing angle at the fixed point (see Fig. 11),

DAN : angle between measured bearing at the station indicated on the left side of station symbol and bearing, seen from this station to the crossing point fixed by bearings at two other stations (see Fig. 11),

CENTER OF GRAVITY : coordinates of the center of gravity,

where all distances and angles are expressed in km and in degree.

VAN, DAN and RATIO can be used as indicators about the quality of fixing atmospherics. In general, the quality is good when the magnitude of VAN is large and the values of DAN and RATIO are small. Roughly speaking, the conditions of VAN $> 5°$, DAN $< 5°$ and RATIO < 0.2 may be enough for a meteorological purpose, but conditions of VAN$>10°$, DAN$<2°$ and RATIO<0.1 will be necessary for a detailed study on radio wave propagation at VLF and ELF bands.

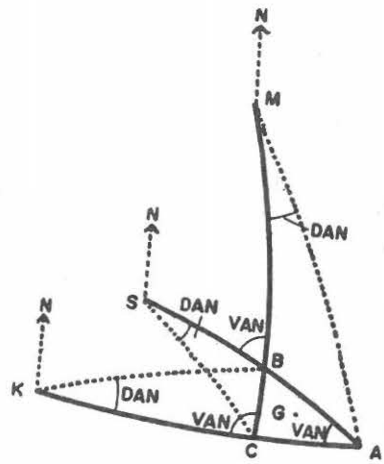


Fig. 11 Indication DAN and VAN

Locations of the gravity center of a spherical triangle, which is formed by three fixed points, are plotted on a map by a curve plotter as shown in Figs. 12(a), 12(b) and 12(c). The size of the map is 230mm × 300mm and the coverage of geographical area of the map can be made to change quite freely. At present a map which covers an area of radius of about 2,000km from Toyokawa has been used as a standard one.

The average time needed for calculation, tabulation and plotting is about five minutes for the output data of about 30.

5. Some results of test observations

Three examples of result of spheric fixing are shown in Tables 2(a), 2(b) and 2(c) and in Figures 12(a), 12(b) and 12(c) which were obtained from the data observed during 1510~1513 JST July 1, during 0910~0913 JST Sep. 7 and during 1510~1513 JST Sep. 11, 1968, respectively. In each of the tables ten results are picked up from the full results for each observation. They are of rather a good quality compared with results unlisted here. The latter seems to be involved in the case of mis-identification.

The values of RATIO, VAN and DAN indicate that their accuracies are ranging from a very good one to a rather bad one, but the accuracy seems to be enough for a meteorological application on averages. It is not intended here to discuss the accuracy or the error involved in the measurement of bearing angles.

The plot of 1510~1513 JST July 1 (Fig. 12(a)) shows that the main source of atmospherics agrees well with a low pressure centered near the point located at Long. 144° and Lat. 44° and atmospheric sources of low activity are also seen on a stationary front which connects two low pressures respectively located near the two points Lon. 114° and Lat. 31°, and at Long. 157° and Lat. 38°.

In the case of 0910~0913 JST Sep. 7 (Fig.12(b)) the main source can be seen to exist close to a typhoon located near the point of Lon. 131° and Lat. 21° but no atmospheric sources are found near a severe low pressure or a tropical depression in the Pacific Ocean.

In the case of 1510~1513 JST Sep. 11 fixed points of atmospherics are distributed in an area between a low pressure centered near the point of Long. 111° and Lat. 47° and a high pressure centered near the point of Long. 125° and Lat. 43° but it seems to be strange that no atmospheric sources are detected around the two severe low pressures in the north-west of the Pacific Ocean and also no atmospherics near a tropical depression located far east to the Philippine Island.

More detailed study about the correlation of atmospheric activity to meteorological activity must be developed along with the study of errors which will be produced during the course of measurement of bearing angles.

Table. 2 Some results of spheric fixing

a. 1 July 1968 1510 JST

TIME		AZIMUTH	COORDINATE		DIS-1	DIS-2	RATIO	DIS-G	VAN	DAN	CENTER OF GRAVITY	
0. 14. 0	K(K S)	337.	123. 8	43. 4	1451. 2	1331. 7	0. 09	1361.	27.	4.	124. 6	42. 8
	S(S M)	314.	125. 5	42. 5	1318. 5	1493. 4	0. 13	1399.	51.	3.		
	M(M K)	267.	124. 5	42. 4	1454. 6	1365. 4	0. 07	1431.	79.	5.		
0. 28. 4	K(K S)	101.	140. 0	29. 6	911. 2	899. 2	0. 01	902.	49.	1.	140. 0	29. 7
	S(S M)	153.	139. 9	29. 9	608. 3	629. 9	0. 04	620.	32.	2.		
	M(M K)	188.	139. 9	29. 7	1663. 5	1627. 1	0. 02	1642.	81.	0.		
0. 59. 9	K(K S)	254.	120. 2	28. 4	1078. 2	1178. 9	0. 09	1141.	7.	1.	119. 6	28. 2
	S(S M)	251.	119. 4	28. 1	1836. 1	1746. 2	0. 05	1807.	20.	0.		
	M(M K)	236.	119. 2	28. 1	2741. 4	2722. 4	0. 01	2698.	26.	1.		
	K(K S)	250.										
	S(S M)	346.										
	M(M K)	339.										
1. 13. 2	K(K S)	327.	114. 8	47. 4	2223. 9	2022. 8	0. 10	2059.	18.	3.	116. 6	46. 5
	S(S M)	314.	118. 3	46. 0	2012. 9	2325. 7	0. 16	2157.	35.	2.		
	M(M K)	284.	116. 6	46. 1	2009. 7	1878. 0	0. 07	2008.	52.	4.		
1. 31. 8	K(K S)	331.	119. 5	45. 5	1829. 1	1676. 6	0. 09	1707.	21.	3.	120. 7	44. 7
	S(S M)	314.	122. 0	44. 3	1673. 0	1907. 3	0. 14	1782.	42.	2.		
	M(M K)	277.	120. 6	44. 3	1716. 6	1610. 5	0. 07	1705.	63.	4.		
1. 44. 1	K(K S)	320.	100. 7	50. 9	3269. 2	2759. 3	0. 19	2855.	12.	4.	106. 1	49. 4
	S(S M)	313.	110. 5	48. 5	2663. 3	3417. 6	0. 28	3000.	26.	2.		
	M(M K)	292.	106. 8	48. 5	2730. 7	2459. 4	0. 11	2778.	38.	6.		
2. 15. 4	K(K S)	329.	116. 4	47. 1	2120. 2	1931. 5	0. 10	1967.	18.	3.	118. 1	46. 3
	S(S M)	315.	119. 7	45. 8	1912. 5	2204. 1	0. 15	2047.	37.	2.		
	M(M K)	283.	118. 0	45. 8	1901. 0	1776. 8	0. 07	1897.	55.	5.		
2. 51. 8	K(K S)	330.	119. 2	45. 2	1819. 3	1528. 0	0. 19	1599.	21.	6.	121. 4	43. 9
	S(S M)	313.	123. 5	43. 3	1506. 4	1909. 6	0. 27	1685.	46.	4.		
	M(M K)	272.	121. 4	43. 1	1678. 5	1508. 6	0. 11	1662.	67.	9.		
	K(K S)	309.										
	S(S M)	311.										
	M(M K)	264.										

b. 7 Sep. 1968 0910 JST

TIME		AZIMUTH	COORDINATE		DIS-1	DIS-2	RATIO	DIS-G	VAN	DAN	CENTER OF GRAVITY	
0. 08. 9	K(K S)	165.	134. 8	16. 8	1683. 5	1354. 1	0. 24	1239.	19.	28.	135. 0	21. 0
	S(S M)	187.	136. 0	26. 5	923. 5	2000. 0	1. 17	1536.	8.	4.		
	M(M K)	198.	134. 1	19. 7	2857. 6	2064. 5	0. 38	2681.	27.	3.		
	K(K S)	171.										
	S(S M)	192.										
	M(M K)	200.										
0. 34. 8	K(K S)	337.	116. 1	52. 3	2595. 3	1874. 3	0. 39	2063.	14.	8.	121. 0	48. 6
	S(S M)	326.	125. 1	46. 5	1643. 4	2564. 4	0. 56	2027.	44.	6.		
	M(M K)	286.	121. 3	46. 7	1649. 4	1354. 4	0. 22	1686.	60.	18.		
0. 50. 3	K(K S)	167.	134. 6	15. 1	1867. 5	1704. 8	0. 10	1625.	17.	8.	134. 7	17. 4
	S(S M)	187.	135. 2	20. 4	1604. 2	2193. 9	0. 37	1944.	6.	1.		
	M(M K)	196.	134. 3	16. 5	3197. 3	2740. 3	0. 17	3085.	23.	1.		
0. 53. 0	K(K S)	160.	135. 9	18. 0	1589. 0	1435. 8	0. 11	1377.	21.	10.	135. 8	20. 0
	S(S M)	184.	136. 2	22. 7	1343. 5	1862. 3	0. 39	1641.	8.	2.		
	M(M K)	195.	135. 4	19. 3	2872. 3	2472. 3	0. 16	2774.	29.	2.		
1. 04. 2	K(K S)	152.	137. 1	20. 2	1410. 2	1310. 1	0. 08	1280.	25.	7.	136. 9	21. 4
	S(S M)	180.	137. 1	23. 1	1297. 5	1616. 4	0. 25	1479.	10.	2.		
	M(M K)	183.	136. 7	21. 0	2664. 9	2412. 6	0. 10	2598.	35.	1.		
	K(K S)	234.										
	S(S M)	239.										
	M(M K)	236.										
1. 31. 4	K(K S)	166.	134. 7	16. 0	1770. 6	1639. 6	0. 08	1572.	18.	7.	134. 8	17. 9
	S(S M)	187.	135. 2	20. 4	1604. 2	2092. 0	0. 30	1887.	6.	1.		
	M(M K)	196.	134. 5	17. 2	3126. 0	2740. 3	0. 14	3027.	24.	1.		
	K(K S)	173.										
	S(S M)	17.										
	M(M K)	19.										
2. 57. 8	K(K S)	160.	136. 1	17. 2	1681. 0	1645. 7	0. 02	1632.	20.	1.	136. 1	17. 7
	S(S M)	183.	136. 2	18. 3	1835. 4	1948. 4	0. 06	1898.	7.	0.		
	M(M K)	193.	136. 0	17. 5	3057. 1	2956. 4	0. 03	3024.	28.	0.		

c. 11 Sep. 1968 1510 JST

TIME		AZIMUTH	COORDINATE		DIS-1	DIS-2	RATIO	DIS-G	VAN	DAN	CENTER OF GRAVITY	
0. 07. 8	K(K S)	324.	112. 7	47. 3	2326. 1	1466. 4	0. 59	1703.	17.	13.	119. 4	44. 0
	S(S M)	312.	124. 5	42. 5	1389. 9	2457. 5	0. 77	1828.	48.	9.		
	M(M K)	268.	120. 4	41. 8	1795. 0	1447. 3	0. 24	1818.	65.	20.		
0. 26. 4	K(K S)	315.	117. 2	41. 1	1611. 3	1477. 7	0. 09	1501.	21.	3.	118. 5	40. 7
	S(S M)	298.	119. 7	40. 6	1659. 3	1877. 5	0. 13	1762.	38.	2.		
	M(M K)	265.	118. 5	40. 4	2002. 3	1894. 2	0. 06	1987.	59.	3.		
0. 26. 6	K(K S)	317.	116. 4	42. 2	1739. 1	1487. 0	0. 17	1541.	20.	5.	118. 6	41. 4
	S(S M)	301.	120. 6	41. 1	1604. 5	1976. 8	0. 23	1773.	40.	4.		
	M(M K)	266.	118. 8	40. 8	1962. 9	1798. 6	0. 09	1950.	60.	6.		
	K(K S)	37.										
	S(S M)	38.										
	M(M K)	46.										
0. 34. 9	K(K S)	316.	115. 3	42. 4	1824. 6	1502. 3	0. 21	1574.	19.	6.	118. 2	41. 4
	S(S M)	301.	120. 6	41. 1	1604. 5	2067. 5	0. 29	1811.	40.	4.		
	M(M K)	266.	118. 4	40. 7	1992. 9	1798. 6	0. 11	1984.	59.	7.		
0. 35. 5	K(K S)	313.	112. 8	42. 6	2004. 5	1641. 0	0. 22	1719.	17.	6.	116. 1	41. 6
	S(S M)	300.	118. 9	41. 3	1744. 9	2269. 3	0. 30	1978.	37.	4.		
	M(M K)	268.	116. 5	40. 8	2137. 3	1926. 8	0. 11	2139.	54.	7.		
0. 43. 0	K(K S)	321.	120. 3	40. 9	1399. 3	1542. 1	0. 10	1503.	25.	3.	119. 2	41. 4
	S(S M)	300.	118. 3	41. 5	1801. 5	1621. 5	0. 11	1724.	36.	1.		
	M(M K)	269.	119. 1	41. 8	1898. 9	1972. 5	0. 04	1899.	61.	4.		
1. 55. 4	K(K S)	331.	120. 1	44. 8	1742. 6	1339. 1	0. 30	1451.	22.	9.	122. 9	43. 0
	S(S M)	313.	125. 5	42. 3	1306. 3	1827. 0	0. 40	1529.	51.	7.		
	M(M K)	266.	123. 0	41. 8	1591. 0	1375. 5	0. 16	1561.	74.	13.		
2. 35. 3	K(K S)	111.	148. 4	24. 1	1917. 5	1980. 6	0. 03	1865.	20.	1.	148. 8	23. 9
	S(S M)	134.	149. 0	23. 6	1693. 5	1607. 4	0. 05	1656.	27.	0.		
	M(M K)	163.	149. 0	23. 9	2374. 4	2390. 1	0. 01	2356.	47.	1.		

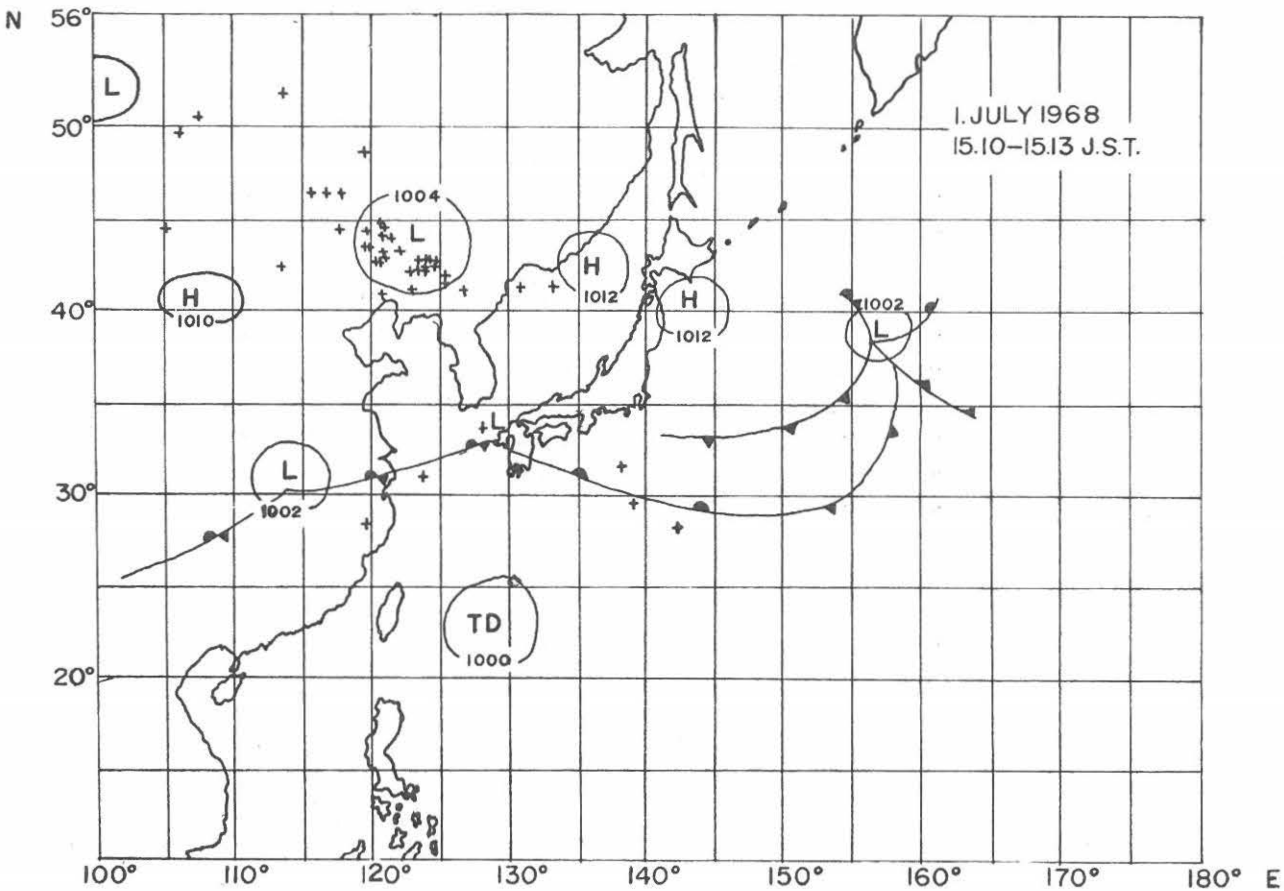
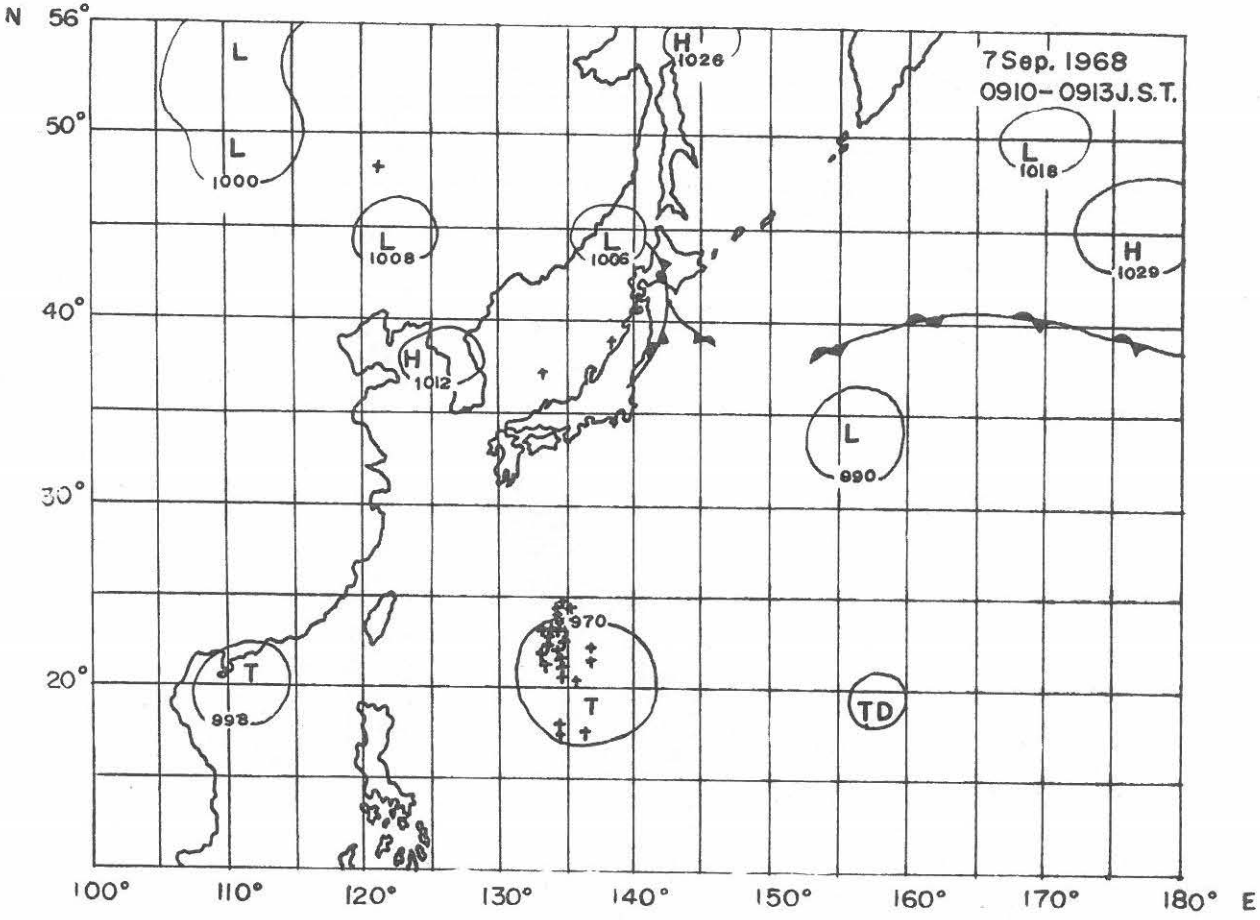
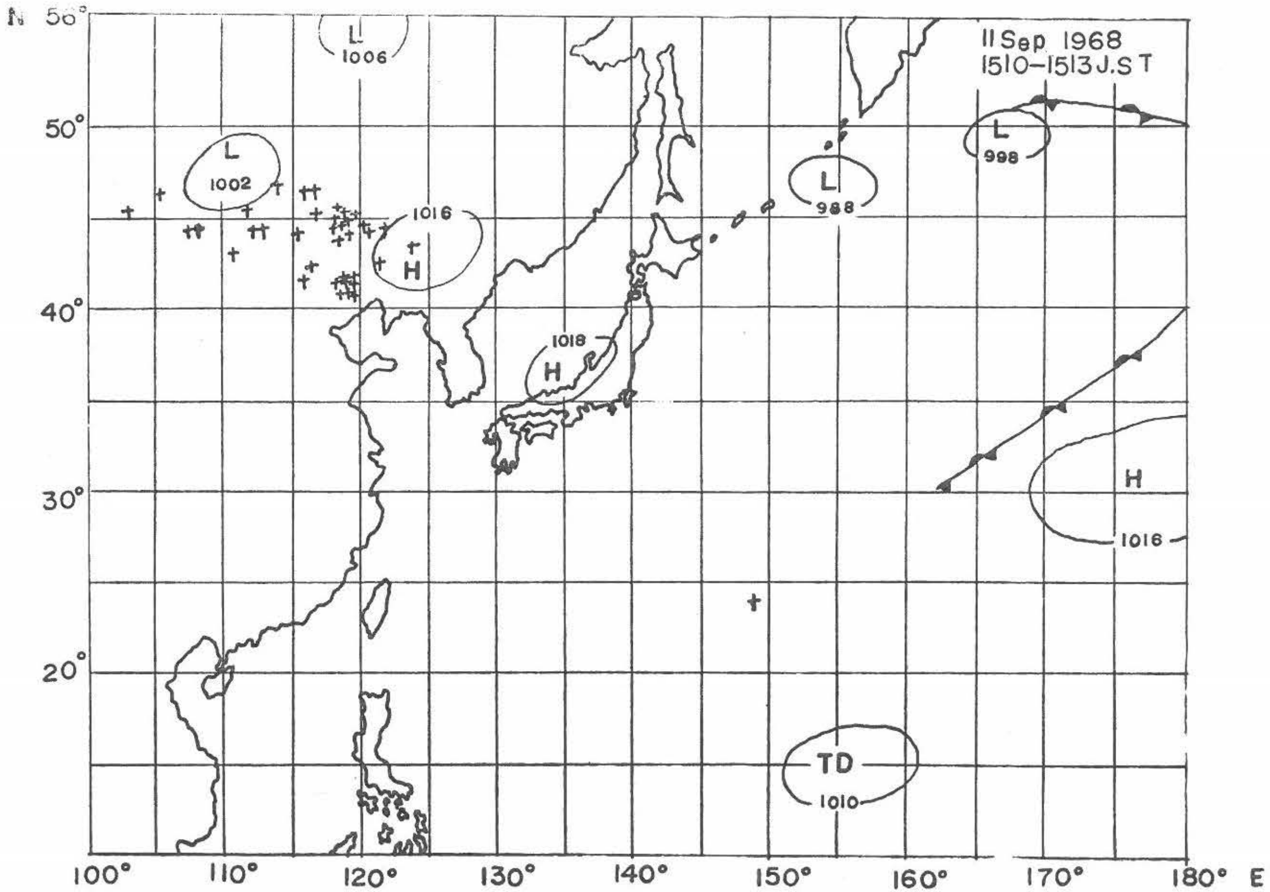


Fig. 12 Examples of distribution of atmospherics

a. 1 July 1968 1510 JST



b. 7 Sept. 1968 0910 JST



c. 11 Sept. 1968 1510 JST

6. Conclusion

This system is partly tested to bring it to a routine use. Even with the limited data obained from the present test observations, it may be concluded that the readings of bearing angle at each station involves some errors in themselves. Most of these are supposed to be site errors due to interferences caused obstacles to the antenna system. It is, therefore, necessary to correct these site errors by establishing a site error correction curve at each station. In order to establish an accurate correction curve at each station, it is necessary to set an additional direction finder around each station in turn, and to make a coincident measurement of arrival direction of individual atmospherics by operating the two direction finders in parallel at each station, and to compare the result of coincident measurement of arrival directions between the two direction finders. Therefore, a simultaneous test observation at each station is under planning aiming at the increasing of the fixing accuracy. There is some troubles, due to interfering disturbances, and noises, on transmitting the data by radio links. Therefore, the data transmission in routine observation in future should be changed from a radio link to a teletype transmission by the use of telephone lines.

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