Proceedings of the Research Institute of Atmospherics,
Nagoya University, vol. 26 (1979)

RESEARCH REPORT

TRIANGULATION DIRECTION FINDING NETWORK FOR FIXING THE SOURCES OF ATMOSPHERICS

Akira IWAI, Mizuo KASHIWAGI, Masanori NISHINO
and Mitsugi SATOH

Abstract

In order to pull up to the most modern technical level, the direction finding network for locating the sources of atmospherics which has been used since 1968, was almost re-constructed in 1977-1978. Namely, the uni-directional type direction finders using the highly integrated analog and digital circuits are installed at all stations, the Automatic Repeat and Request System (ARQ) using mini-computers is introduced in the data transmission by a radio link and a new large capacity computer is introduced to reduce the observed data.

As a result, the performance of the apparata has been improved largely, the data reduction time being also saved remarkably.

We have been carrying out the routine observation using this direction finding network once a day except Sunday and Saturday.

1. Introduction

In Japan, direction finding observation for atmospherics has been developed by Prof. Kimpara, since the Second World War(Kimpara,1950). Then, after the test observations by several workers, a new direction finding network for atmospherics has been made by our Research Institute since 1968. (Iwai et al., 1969) In this network, direction finders for locating the sources of atmospherics are installed at

Moshiri, Sakushima and Kagoshima. Since the installation of the apparata, the improvements have been continued by us through the routine observations.

Especially, the following points were improved in 1977 and 1978.

1) All direction finders of bilateral type were replaced with the uni-directional ones.
2) Data acquisition apparata of the paper tape punchers were replaced with the cassette type magnetic tape recorders.
3) The ARQ system was introduced in the data transmission system from the observing stations to Toyokawa for the purpose of high reliable transmissions.
4) A large capacity computer was introduced to reduce the data transmitted from the observing stations.
5) The highly integrated digital circuits were used in the bearing reading circuits for the purpose of maintenance-free.

This paper shows the present state of our locating system for the sources of atmospherics and also shows the observing results obtained with this system.

2. Triangulation direction finding system

Fig. 1 shows the locating system for the sources of atmospherics by triangulation. As mentioned above, three observing points for measuring the arrival direction of atmospherics are Moshiri(geographic coordinate, 142°16'E, 44°22'N), Sakushima(137°03'E, 34°37'N) and Kagoshima(130°43'E, 31°29'). The distance between Moshiri and Sakushima is about 1200km, 700km between Sakushima and Kagoshoma, 1700km between Kagoshima and Moshiri and 30km between Sakushima and Toyokawa, respectively. At each station, the arrival direction of atmospherics is measured and recorded on cassette magnetic tapes with its arriving time. These data are transmitted to Toyokawa Central Station and then the fixings of atmospheric sources are made by a computer. Each station is made up of the same components, however Sakushima is a unmanned station, which is remort-controlled from Toyokawa Central Station by the micro-wave link. Data of arrival directions observed at Sakushima are sent to Toyokawa Central Station with the trigger signals showing the receiving of atmospherics which are used to make the coded signals of the receiving time of atmospherics and to

start the data acquisition system. The duration time of each observation is 3 - 5 minutes, because the distributions of atmospheric sources in the Far East can be decided within this duration time. It is very important to keep the accurate time at each station to take the coincidence of atmospherics recorded at the three stations. It is necessary that the clock of each station is kept within 1 m sec. using the standard time signal of JJY. Each station was, therefore, replaced with a crystal clock of 10^{-9}. Especially, the standard clock at Toyokawa Central Station has an accuracy of 10^{-10}. The duration and interval times of observations are automatically controlled with these accurate clocks. Data transmissions from Moshiri and Kagoshima to Toyokawa are made by means of SSB radio links of high frequency band(9165 kHz). As mentioned above, the ARQ system are, therefore, employed to improve the efficiency of data transmission. Moreover, Kagoshima station has another transmission channel by a telephone link for the back-up of the radio link.

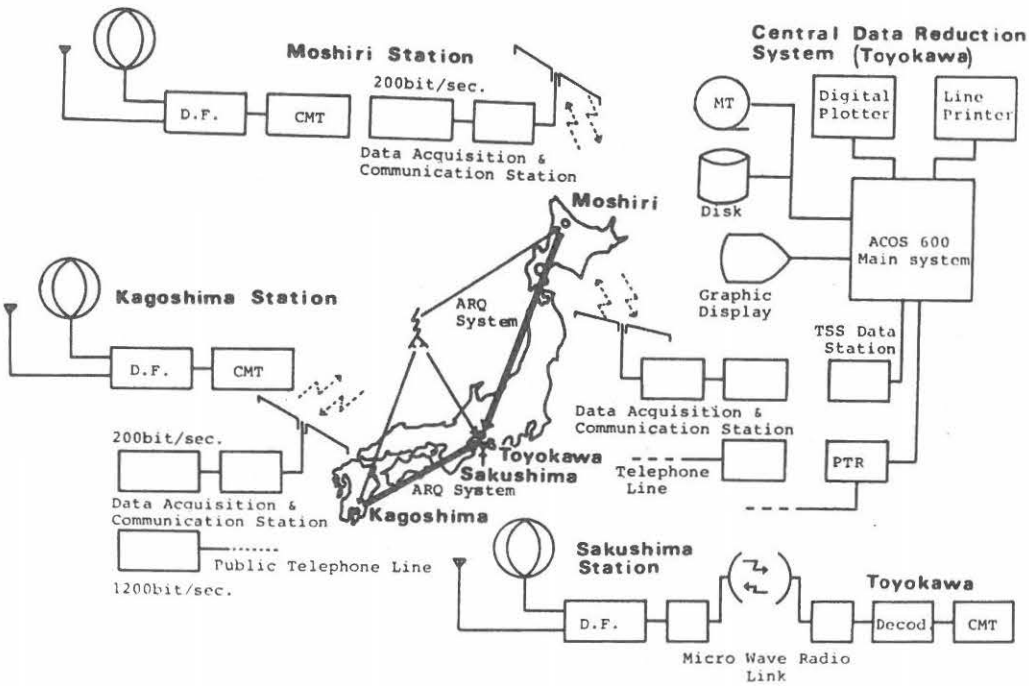


Fig. 1 : Locator system of atmospheric sources

Fig. 2 shows the measuring system of arrival angle at each station. The principle used in this system is a conventional twin-channel radio direction finder of instantaneous type. In this case, the third channel amplifier is added to decide the sense of the direction. the observing frequency is fixed at 7.3 kHz to avoid the interference from the Omega system, and its band-width is about 300 Hz. The three channel amplifiers are usually operated at 80 - 90 dB. The perfromances of these amplifiers are very stable so that the identities of electric characteristics among them are usually kept by only twice readjustment per year. The measuring part of arrival angle consists of a hybrid of analog and digital circuits. This part had been constructed only by analog circuits but is now highly digitalized so that its performance is extremely stable and perfectly maintenance-free.

Fig. 3 shows the principle of digital reading of bearing angles which is the same as that of former type reported in the previous paper.(Iwai et al., 1969) The explanation of this principle can be found in that paper.

Fig. 4 shows the block diagram of the improved digital reading circuit constructed by the principle mentioned in the previous paper. Thick lines show the flow of digital signals and thin lines the flow of analog ones. This part is made of a hybrid of digital and analog circuits and is now highly digitalized, so that its performance is fairly stable. The three outputs from N-S, E-W and vertical ampli-

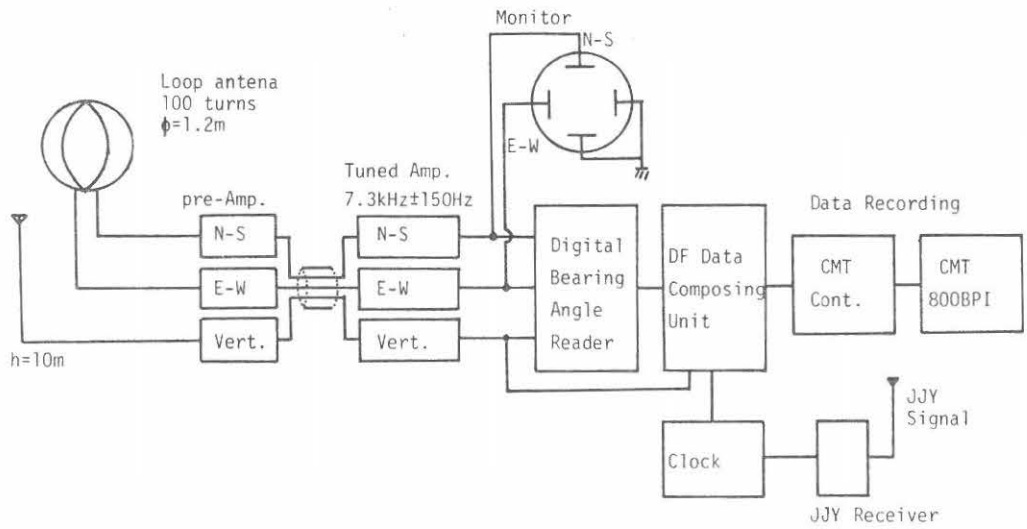


Fig. 2: Block diagram of the DF system

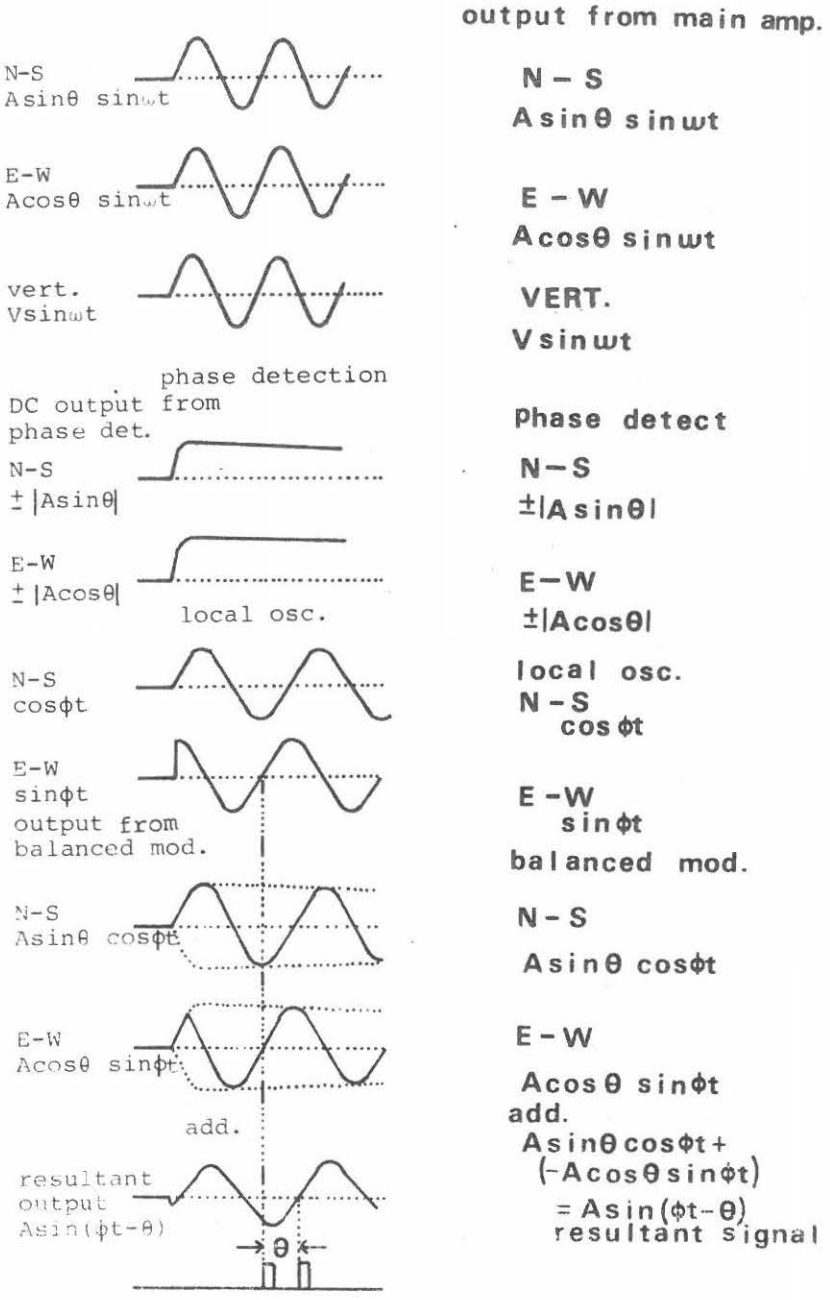


Fig. 3 : Principle for measuring the bearing angle

fiers are transformed into digital signals by an analog-digital converter (ADC). Then, N-S, E-W digital signals are integrated for several mSec. by a pair of digital counters. And then, the didital output from the integrator is supplied to the input of multiplying digital analog converter (MDAC). On the other hand, the digitalized signal of the local oscillator A $\sin\phi t$ is also supplied to another input of the MDAC. Phase shift of $\pi/2$ for the local signal to another MDAC is made by the digital shift registers corresponding, so that the degree of stability of phase shift is very high. By this way, these MDACs operate as a pair of balanced modulators of digital inputs and analog outputs. Then, the analog output of MDAC is subtracted from the analog output of another MDAC and the resultant analog signal is given by A $\sin(\phi t-\theta)$. To read the angle θ, this resultant analog signal goes to the ADC and transformed again into the digital signal for finding the arrival angle θ. We can read the angle θ from the time difference between the zero crossing times of local and resultant signals. The zero crossing time of the digitalized signal can be easily found by the change of $\pm$ sign of the signal. By this system, the dynamic range of measuring the arrival angle is improved by more than 30 dB.

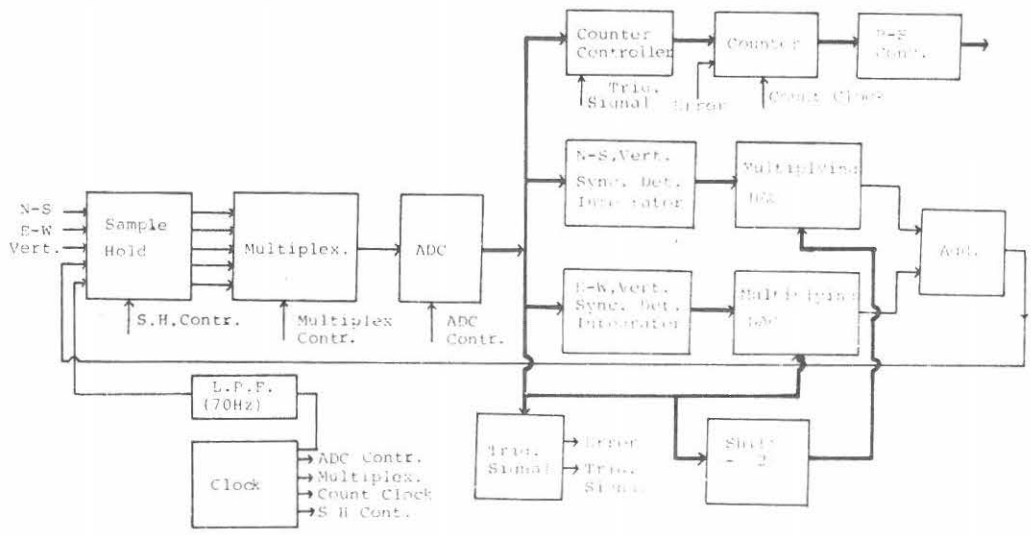


Fig. 4 : Block diagram of the digital reading circuit

Fig 5. shows the system storing the DF data on the cassette magnetic tapes (CMT). The data of receiving time are composed of the triggering signal from vertical channel and the arrival angle data from the digital reading circuit. These data of time and arrival angle are sent to a memory. This system has a pair of memories, #0 and #1, one of which stores the data. When the memory is filled up with the data, these data are sent out to the CMT every 256 characters (32 data). During the period of recording from the memory to the CMT, another memory stores the following data. These memories are operated by the write read memory unit controller.

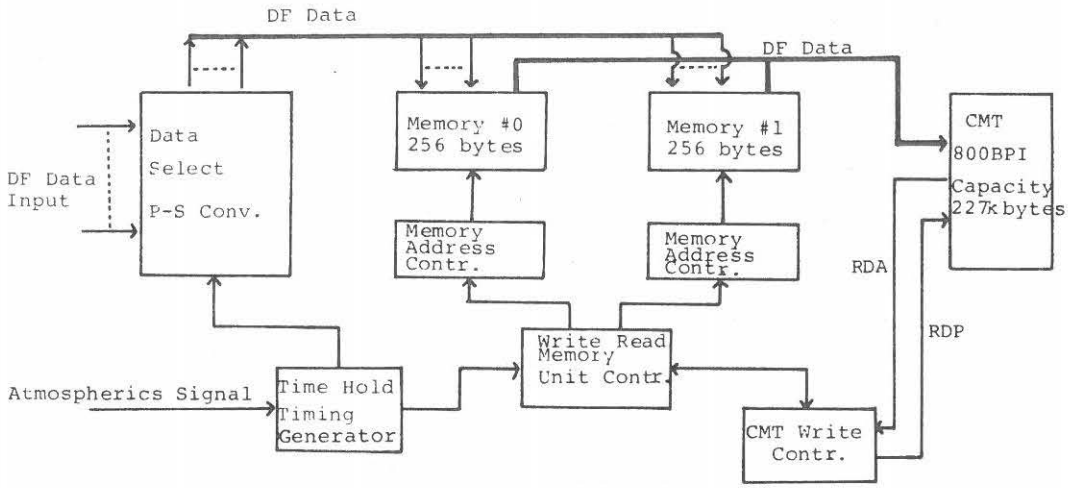


Fig. 5 : Storing the DF data on the CMT

3. Data transmission system

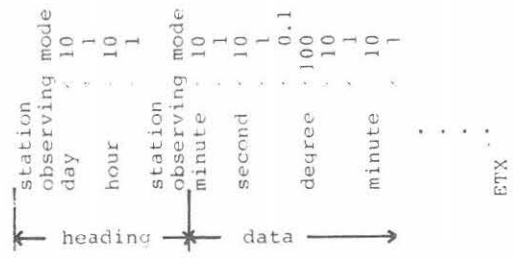
Fig. 6 shows the format of direction finding data. A heading, consisting of the station name, day and hour, is recorded on the CMT at the beginning of each observation. Then, a datum is recorded on every receiving of atmospherics. The datum consists of 8 characters of receiving minute,second and angle in degree. Each character is used in JIS-8 Code. Therefore, 36,000 data can be recorded on a cassette magnetic tape. The data of an observing duration recorded on the CMT are transmitted to Toyokawa Central Station by a SSB radio link of 9 MHz. As mentioned above, data transmission is made by

means of the ARQ system using the mini-computers. The speed of data transmission is 200 bits/sec.

Fig. 7 shows the block diagram of the data transmission system with the ARQ.

Fig. 8 shows the message format transmitted on the radio link and Fig. 9 shows the flow chart of the ARQ system.

Fig. 10 shows an example of the result indicated on the CRT display of the mini-computer using the ARQ system. This example transmitted from Kagoshima was obtained at 9 o'clock of 17th July. In this case, the block size of data transmission was 256 characters, namely, 32 data are transmitted in a group and the errors of the received signals are checked by the mini-computer at Toyokawa. In the case of no errors, the next block of DF data is sent. But, when the error is found, this data block is sent again. This transmission result shows that for 46 blocks



using JIS-8 code
station: station code
Kagoshima: K
Sakushima: S
Moshiri : M
ETX: End mark of data

Fig. 6 : DF data format

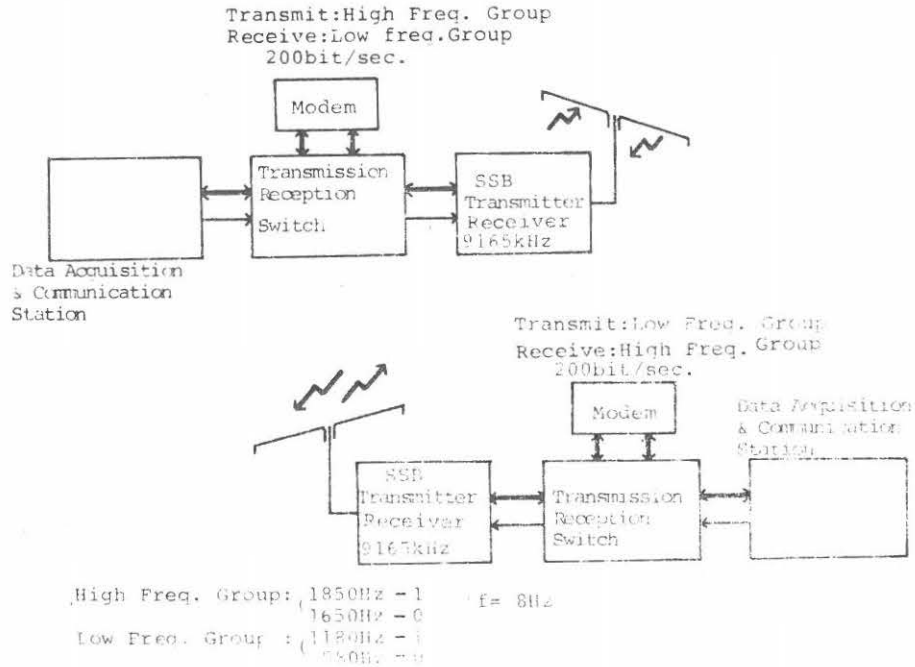


Fig. 7 : Block diagram of the ARQ system

of transmission data, 45 blocks were received without errors and only 1 block was disturbed by noises or interferences and was sent again. The ratio of no error transmission was 97.8 %. The time required to transmit 46 data blocks, namely, 1472 DF data, was about 10 minutes.

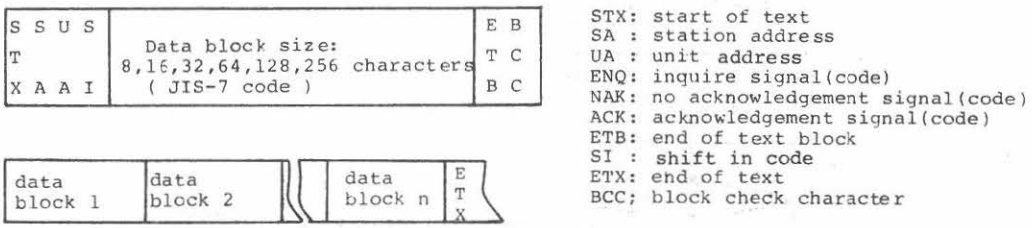


Fig. 8 : Massage format on the radio link

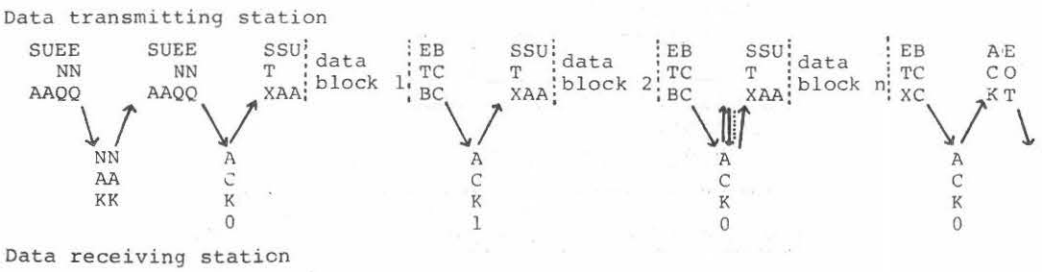


Fig. 9 : Flow chart of the ARQ system

```
E O R.I.A.                        NORMAL END
*
  ** COMMUNICATION PROGRAM **
    *DATE*       07/17/78      09:30
    *SEND-RECEIVE* (K,M,T)      K--T
    *MODE* (S,R)  R  +--***LOGGING***--+
  *SIZE*---------256 I REQUEST  BLOCK  I
    ( 8, 16, 32)     +---------(RATIO)-+
    (64,128,256)     I     0----  45   I
  *REPEAT*--------16 I          (97.8%) I
    (16,64)          I  1-15----   1   I
  *UNIT*-----------1 I          ( 2.2%) I
    (0,1)            I 16-63----   0   I
  *READY*----------Y I          ( 0.0%) I
    (Y,N)            I TOTAL----  46   I
  *START*----------Y +-----------------+
```

Fig. 10 : CRT display format of DF data communication system (ARQ system) Toyokawa

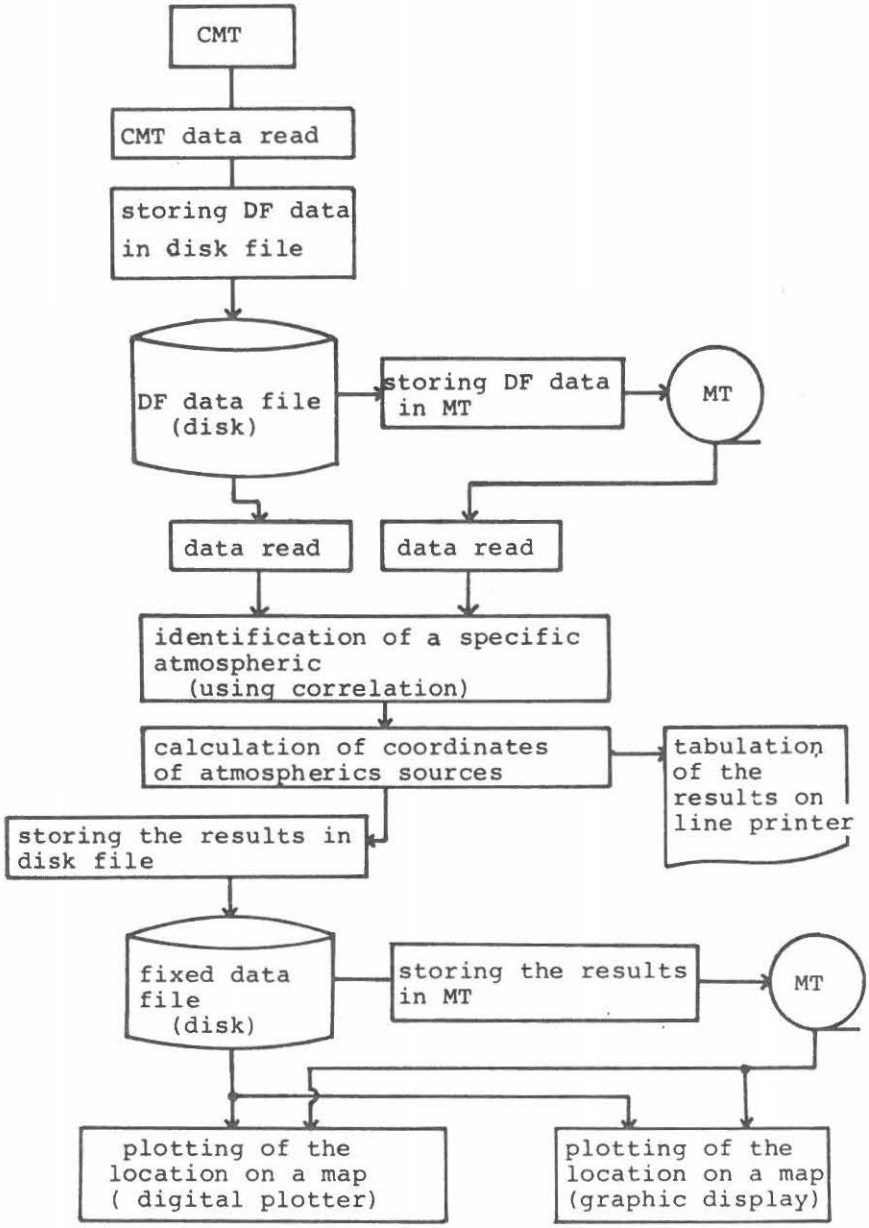


Fig. 11 : Flow chart of the data reduction

4. Data reduction system

The data transmitted from the three stations are introduced into the computer. Fig. 11 shows the flow chart of the computer data reduction. In the computer, these data are stored up in a magnetic disk according to the station name and the occurring time. When the magnetic disk is filled up with the data, these data are transfered into the magnetic tape to keep for a long time. The data can be introduced to the data reduction program from either the magnetic disk or the magnetic tape. Among the data of all stations, the atmospherics received at the same time are picked up and are used to calculate the coordinates of atmospheric sources by the computer. Namely, the data reduction system program has following three main functions.
The first is the storing of data on the magnetic disk and the magnetic tape, the second is to calculate the coordinates of atmospheric sources, and the third is the plotting of the locations of atmospherics on a map by a digital plotter or a graphic display.

5. Observational results

Figs. 12a and 12b show some examples of the results of atmospheric fixing obtained in 1977. The cross and sqare are the locations of atmospherics. These maps were obtained using the data observed on 12th July and on 19th September in 1977. For the sake of comparison, we have plotted the weather chart on each map. The distribution of atmospheric sources is found to agree well with the front and other meteorological phenomena.

Then, we show some examples of the correlation between the location of atmospherics and the cloud distribution observed by the NOAA-5 Satellite. These results were obtained on 18th and 20th July in 1978. Each observing duration was 5 minutes. Fig. 13 is a cloud map of the NOAA-5 in Far East on 18th July and Fig. 14 is the result of atmospheric fixing on the same day. The dotted line shows the distribution of cloud obtained with the NOAA. It is found that there are atmospherics associated with a Typhoon in the Pacific Ocean. In the same manner, Fig. 15 is a cloud map of the NOAA-5 on 20th July and

Fig. 16 is the result of atmospheric fixing on the same day. The atmospheric sources are found to distribute around to regions of the front, Typhoon and other meteorological phenomena.

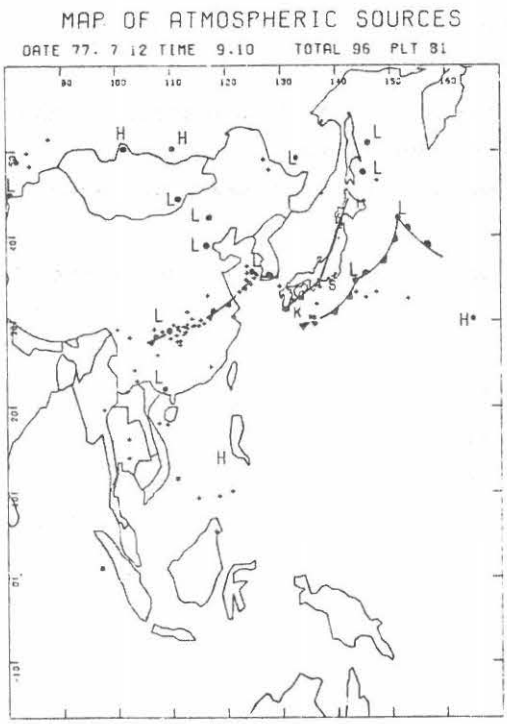


Fig. 12a

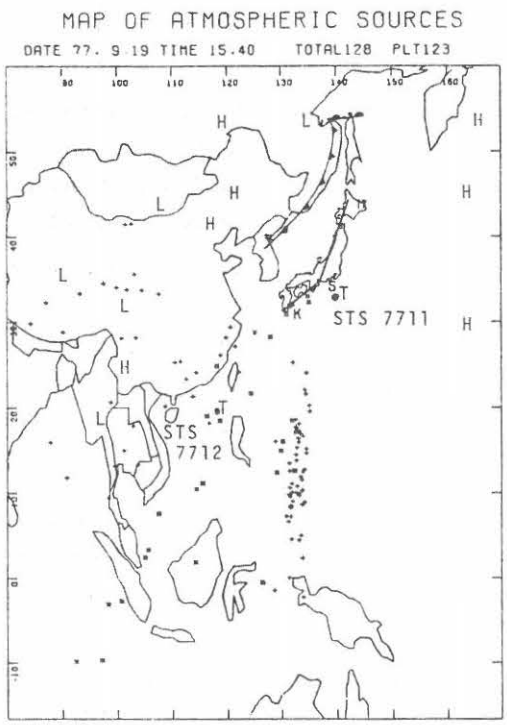


Fig. 12b

Fig. 12 : The sources of atmospherics
a : 0910-0915 JST on 12th July in 1977
b : 1540-1545 JST on 19th September in 1977
+ & * : the locations of atmospherics
L : Cyclone
H : Anticyclone
T : Typhoon
STS : Severe tropical storm

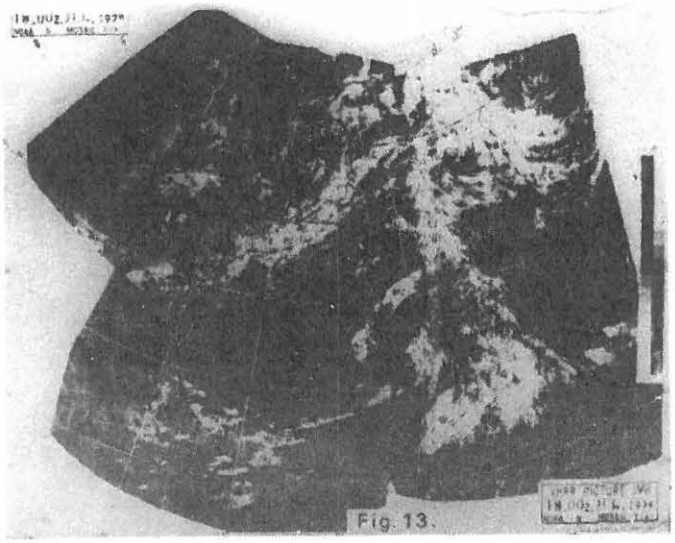


Fig. 13 : Cloud map of the NOAA-5
0000 UT 18th July in 1978

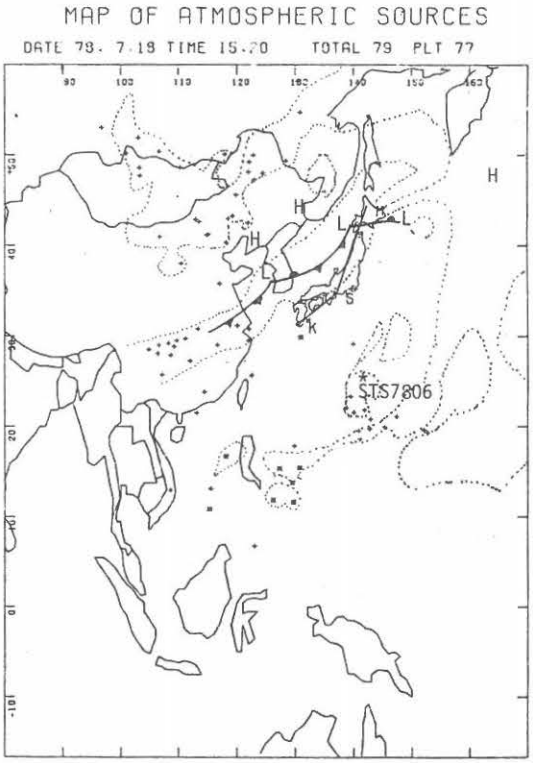


Fig. 14 : The sources of atmospherics
0620-0625 UT on 18th July in 1978
: cloud region

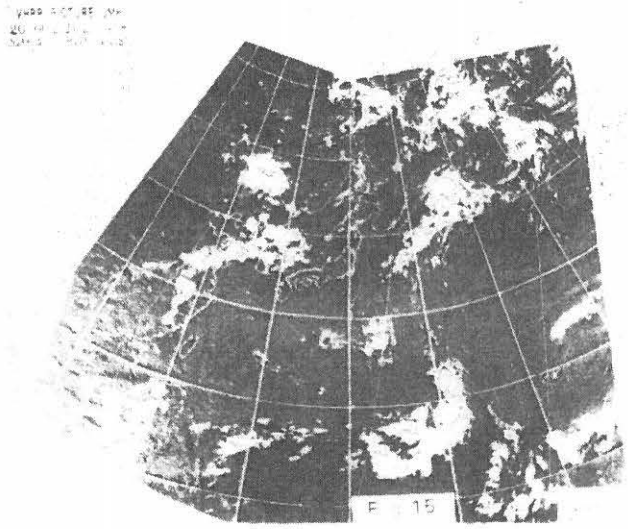


Fig. 15 : Cloud map of the NOAA-5
0000 UT on 20th July in 1978

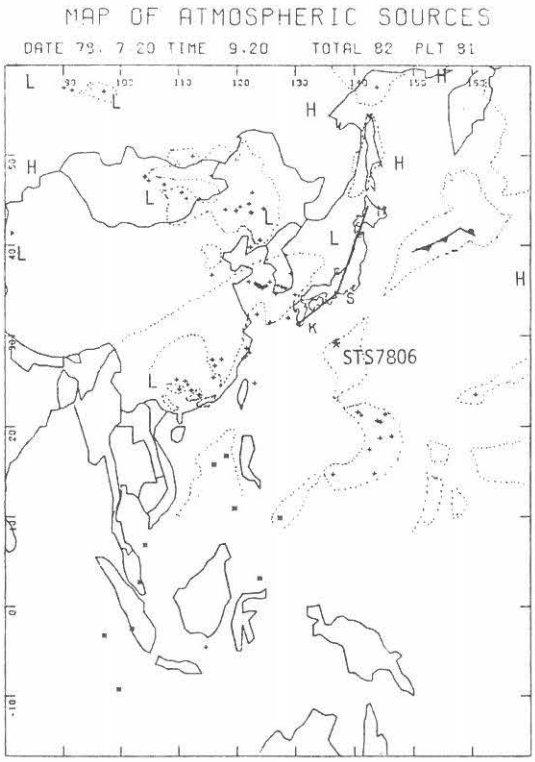


Fig. 16 : The sources of atmospherics
0020-0025 UT on 20th July in 1978
: cloud region

6. Conclusion

We have explained the system and some results of the triangulation direction finding network in our Institute. This system has an unavoidable demerit which is caused by the shape of the network, namely, by the shape of the Japanese Islands. Now, we can find the atmospheric sources over the Far East, but we have some problems when we make the map of the distribution of atmospheric sources in the Far East. These are as follows:

1) The fixing rate in the region along the base lines becomes lower than that in the other regions.
2) The fixing rate in the region far from Japan decreases if there is an active region near Japan, masking the distant atmospherics.

In order to solve these problems, a detailed investigation of site and propagation errors are necessary. The development of a single station method and others are also necessary. The observational plan is being made for comparing between the observing results at the source region such as Thailand and the fixed points locating by this direction finding network.

Acknowledgement

We wish to express our sincere thanks to Prof. A. Kimpara of Chubu Institute of Technology for his guidance and encouragement.

Thanks are also due to the Nippon Electric Company for constructing the ARQ data transmission and data reduction system.

Finally, we appreciate very much the faithful assistance of Messrs. T. Kato, T. Yamaguchi, Y. Kato, M. Sera, Y. Ikegami, M. Takasuga and K. Hidaka in constructing and operating this system, and the assistance of Mrs. Onoda in reducing the observed data.

References

Kimpara A.,;On the Distribution of Atmospheric Sources in the Far East, Bull. Res. Inst. Atmospherics, Nagoya Univ., vol. 1-1, 18, (1950)

Iwai A.,K.Ito,T.Tanaka and T.Ebuchi;Direction Finder of Atmospherics, Proc. Res. Inst. Atmospherics, Nagoya Univ., vol. 1,54,(1953)

Iwai A.,J.Ohtsu,M.Nishino and M.Kashiwagi;A New Direction Finding Network for Locating the Sources of Atmospherics,Proc. Res. Inst. Atmospherics, Nagoya Univ., vol. 16,17,(1969)

Nishino M. and M.Kashiwagi;The Characteristics of the Distribution of Atmospheric Sources and the Consideration of the Fixing Error, Proc. Res. Inst. Atmospherics, Nagoya Univ., vol. 23,1,(1976)