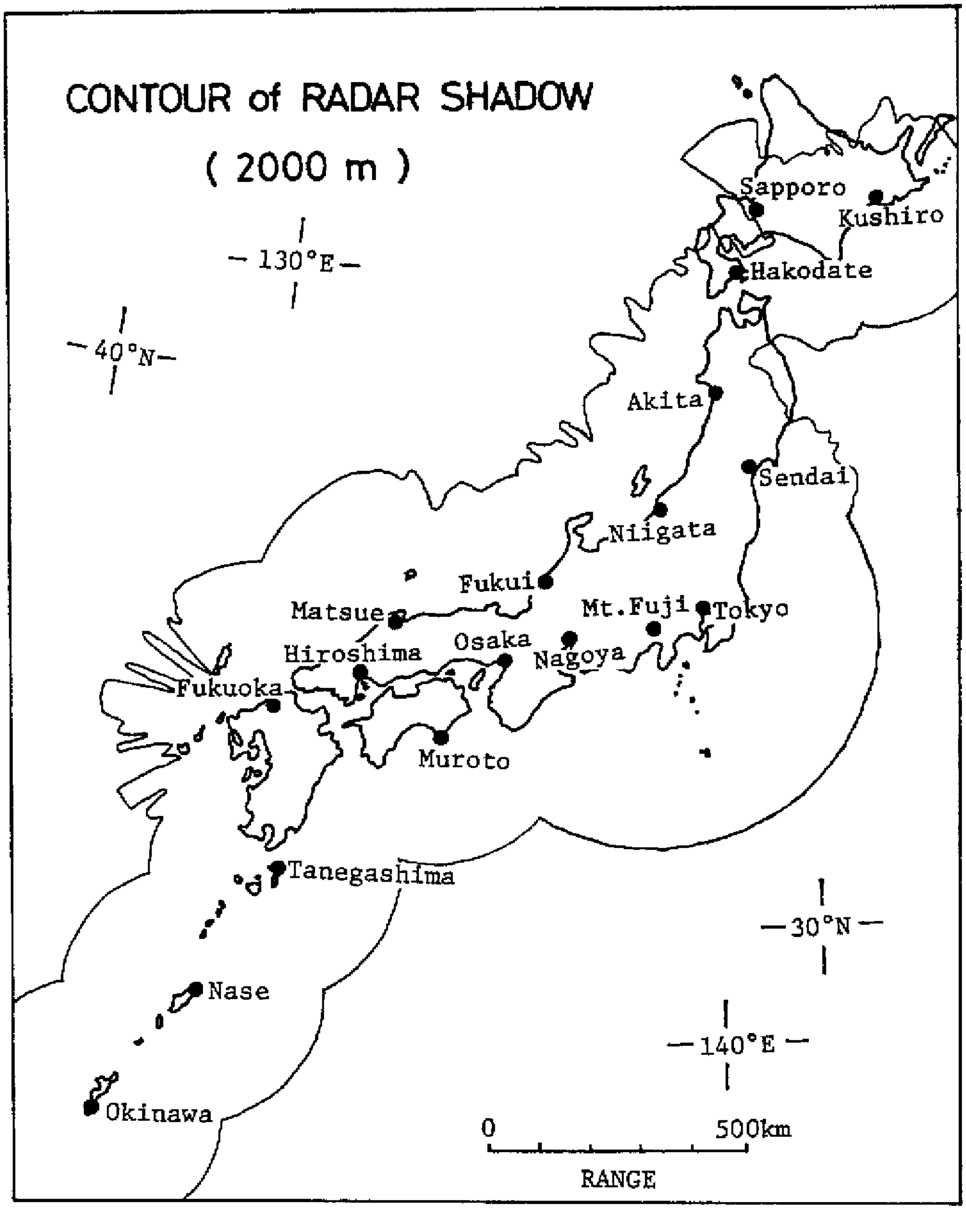


Fig. 8 Coverage of radars by Japan Meteorological Agency in terms of 2,000 m contour line of radar shadow. The Miyako-jima and Ishigaki-jima radar stations in the southwestern part of Japan are excluded out of this map. In addition to these twenty radar stations, two observation ships of the agency are installed weather radar sets in operation.

typhoons.

Major characteristics of the radar system are as shown in the following;

Wave length: 10.4 cm

Peak power:	1,500 kw
Pulse width:	1/3.5 μsec
Repitition rate:	310/160 pps
Noise factor:	3 dB
Antena Diameter:	5 m
Beam width:	1.6 degrees
Detectable range:	50, 100, 200, 400, and 800 km.

Block diagram of the radar site on the top of Mt. Fuji and the Tokyo observation and control center are shown in figure 9.

The image from this radar system on the top of the mountain is transmitted over a distance of 100 km through a 7,000 MHz band microwave link to Tokyo Meteorological Observatory in the same form as the indication on the mountain station; the radar system is remotely controlled from the observatory in Tokyo through this microwave link. Atmospheric temperature and pressure, dew point, wind direction and speed, and solar radiation are included in the weather data which is collected and indicated in the mountain-top observation room and is relayed by the telemeter device. This data is also transmitted automatically and periodically through the microwave link to the observatory in Tokyo.

The radar station is a two-story building. On the top of the roof is installed a 5 m-diameter parabolic radar antenna protected by a radome. A radar indicator and a data indicating panel of the weather telemeter are installed in the observation room on the ground floor. On the second floor, are a radar transmitter-receiver and a relay terminal. As for the remaining mountain-top facilities, a transmitter and receiver for relaying is installed in the microwave radio room, while above the room a 3 m-diameter relay antenna is installed protected by a radome. To provide an ample power to all the facilities on the mountain when the commercial power fails, three 20 KVA and two 7.5 KVA diesel generators are installed for operation.

In Tokyo Meteorological Observatory, a 4 m-diameter relay antenna is installed on the roof of the building. This antenna and other microwave radio equipments amd carrier terminals constitute a relay link with the radar system on the top of the mountain. An indicator of a 5,300 MHz Tokyo radar set of the Tokyo Meteorological Observatory is equipped in the observation room together with the indicator of the Mt. Fuji radar system. A PPI/RHI indicator only for photographic recording is also set in the room and used for both the Mt. Fuji radar system and the Tokyo radar set. For this indicator, a CAPPI system (see the next chapter) is employed and

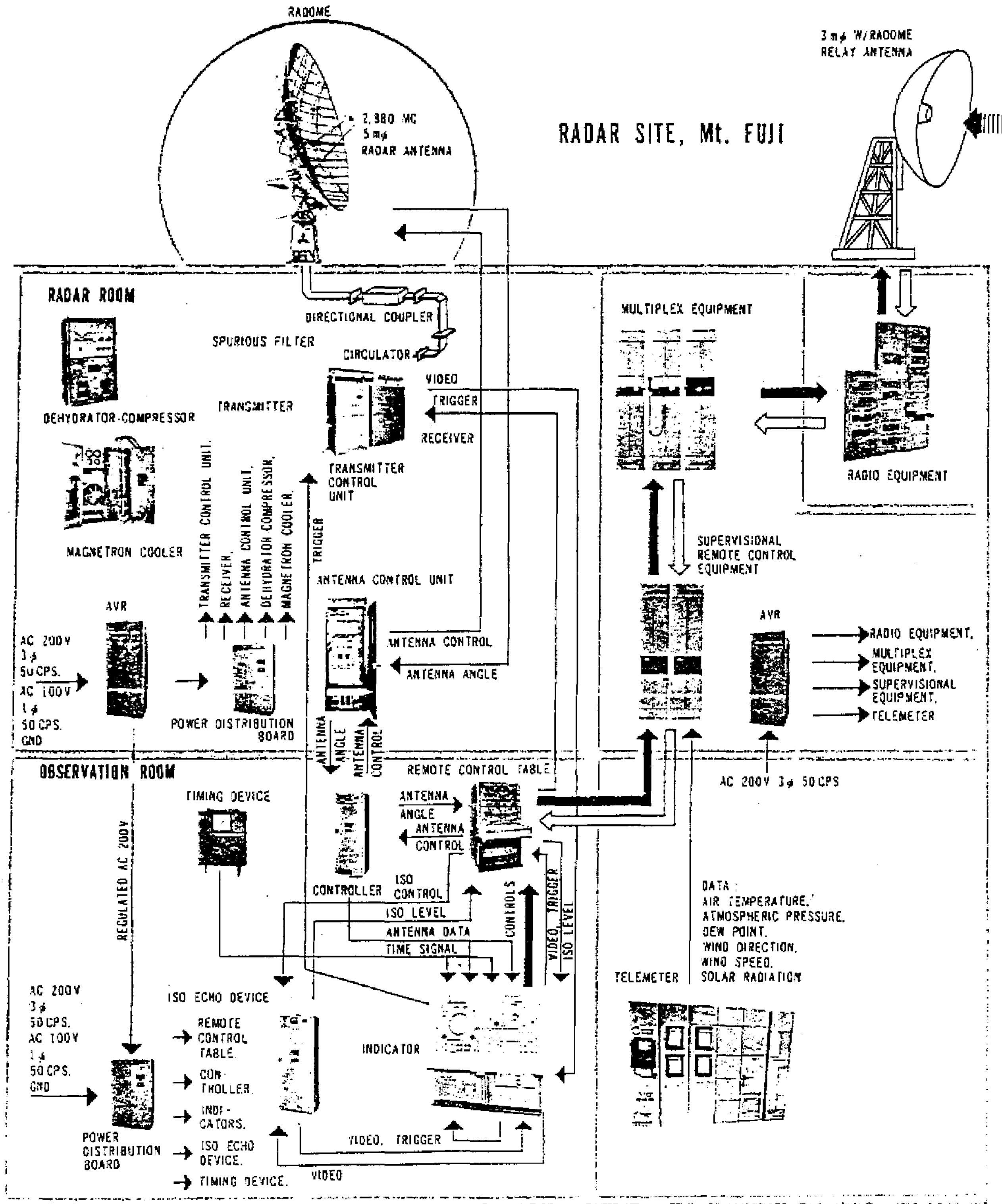
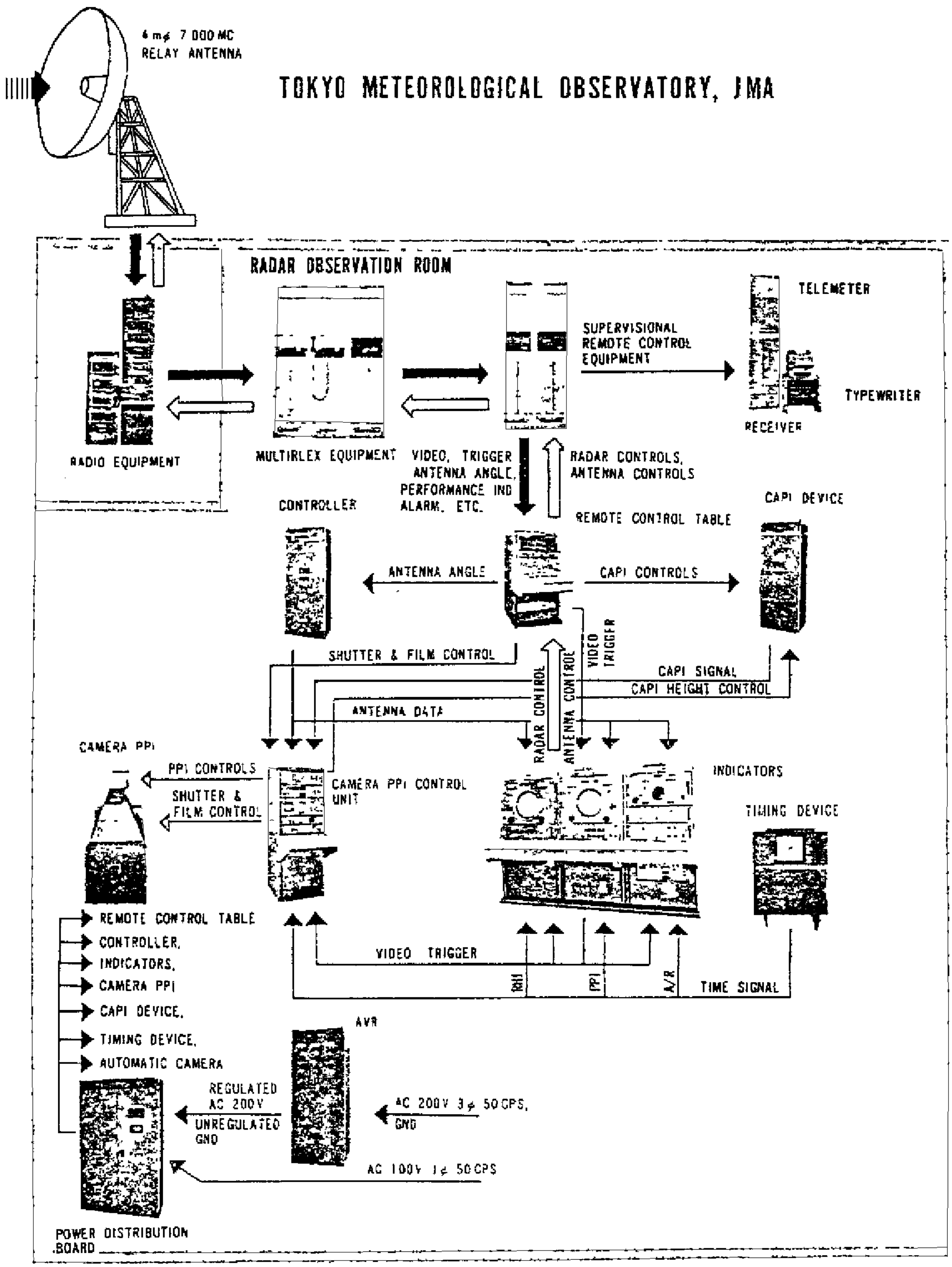


Fig. 9 Block diagram



of Mt. Fuji radar system

expected to display full capability and efficiency in analyzing damaging aerological conditions.

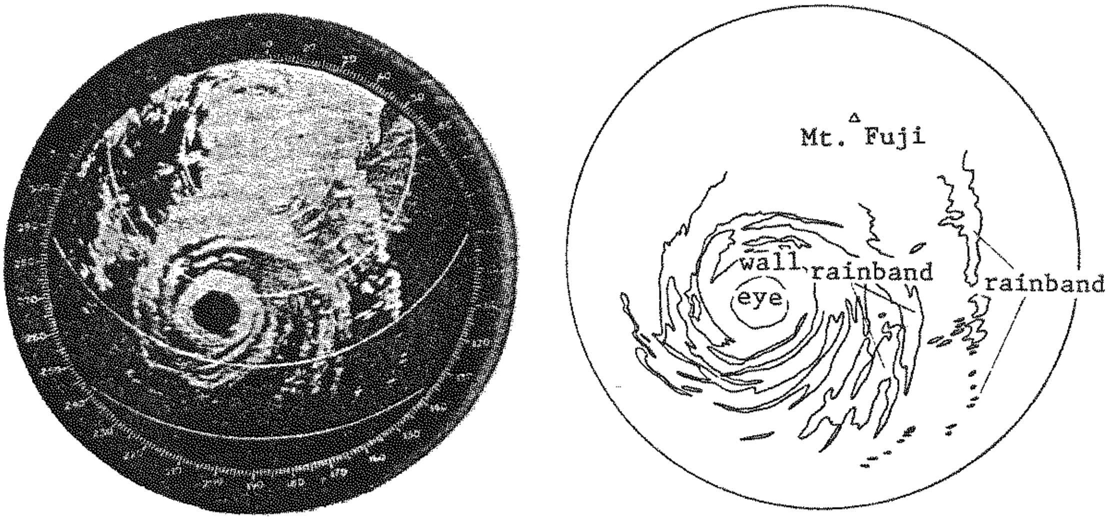


Fig. 10 Typhoon #6517 caught by the Mt. Fuji radar at 1037 JST, August 22, 1965. Concentric range marks are superimposed at every 100 km.

One of the most beautiful pictures of a typhoon observed by the Mt. Fuji radar is shown in figure 10 with a schematic diagram in aid of interpretation. The typhoon designated as #6517 occurred at southeastern water 700 km off the Wake Island at 0900 JST, August 15, 1965 as a weak tropical depression of 1004 mb. Six hours later she developed to a typhoon, and travelled in the direction of north-northwest reaching the Bonin Islands on 19 as shown in figure 11. At 30.4°N, 139.1°E on 21, she got matured with central atmospheric pressure of 940 mb and muximum wind speed of 55 m/sec, and her region with violent wind over 25 m/sec extended to 200 km in radius.

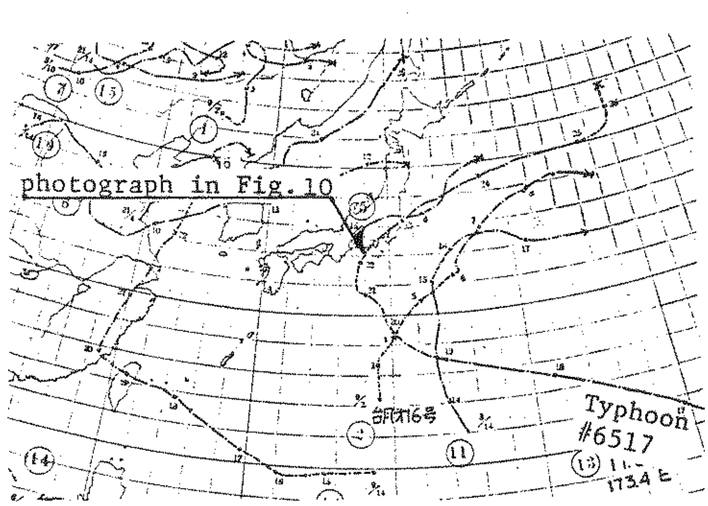


Fig. 11 Trajectory of Typhoon #6517

Then the typhoon began to change her direction of movement gradually to north with a slower travelling speed. The radar photograph in figure 10 was taken at 1037 JST, August 22, 1965. A predominant "eye" surrounded by circular eye wall is noted with spiral inner rainbands and separated heavy rain regions 200 km weat to the eye wall.

According to the radar indication, the typhoon's center was measured to be located 280 km from the Mt. Fuji radar site in the azimuth of south-southwest at the photographed time, so that she was 150 km off the south coast of the Japanese mainland. Thus the great range radar can catch the approach of damaging typhoons far off the mainland coast and watch their selfwilled movement and dangerous structure.

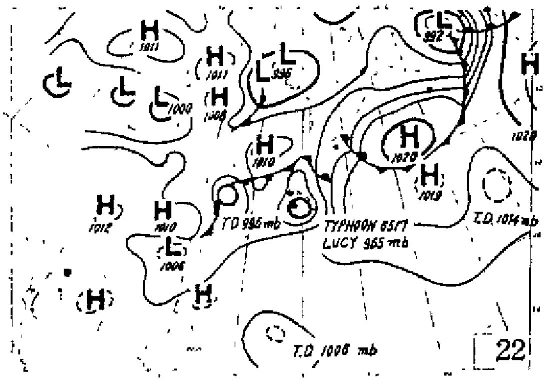


Fig. 12 Furface weather map at 0900 JST, August 22, 1965

The typhoon #6517 attacked Tokyo before daybreak on 23. Being bound northeast, she left the central Japan as a weak tropical depression in the morning of the day. A surface weather map at 0900 JST, August 22,1965 is shown in figure 12 for reference.

This typhoon was medium in strengh and small in scale when she struck the Japanese mainland. Damage and casualties reported are as follows;

Deaths and missings:	4
Injured:	5
Completely destroyed houses:	2
Partially destroyed houses:	7
houses inundated:	16911
vessels sunken:	3
Vessels partially destroyed:	2
Banks collasped:	4
Landslides:	64
Damage to traffic and comunication: many,	

4. THUNDERHEAD DETECTION BY A RADAR SYSTEM

Thunderbolts attack men and properties, sometimes without any signs. The thunderbolts, namely, the cloud-to-ground electrical discharges associates with a thunderstorm, manifested by a flash of light and a sharp or rumbling sound (thunder).

Necessary conditions for a thunderstorm are generally stated to be a thunderhead (cumulonimbus cloud) base lower than 0°C isotherm, such vertical depth of cloud as to ensure a cloud top of temperature less than about - 20°C, and the occurrence of precipitation. There are, however, well substantiated observations, mainly in low latitude, of the occurrence of lightning in clouds no part of which were at a temperature below 0°C. Charge separation in thunderclouds is such as to produce a positive charge in the upper part of the cloud and negative charge in the lower part; small regions of positive charge near the base have also been observed. Initial charge separation has been attributed by various workers to mechanisms such as the selective capture on ions by water drops or ice particles, the

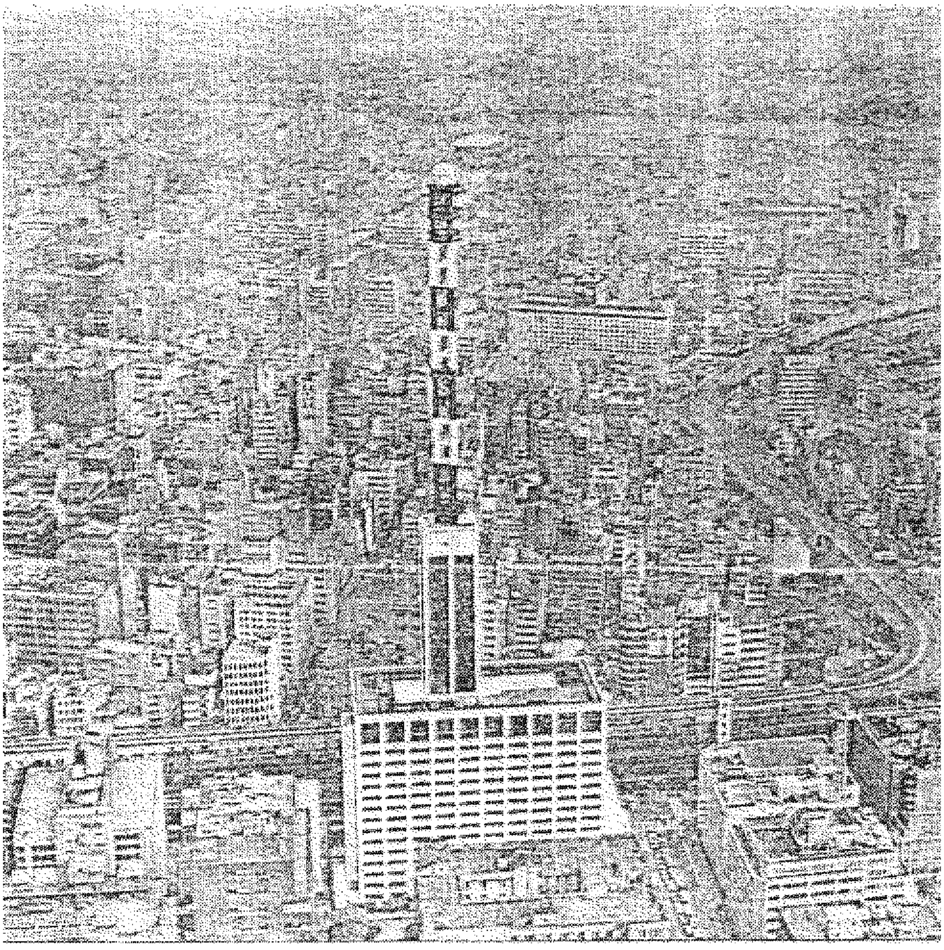


Fig. 13 Radar tower for thunderstorm detection

frictional rupture of large raindrops, and surface and volume interactions of water, in its various phases, contained in the cloud. Experimental support has been obtained for the most of the theories but the relative importance of the various mechanisms is get uncertain. The occurrence of each discharge neutralizes centers of charge of opposite sign. The typical lightning flash discharges a quantity of about 20 coulombs and involves a potential diggerence of some hundred or thousand million volts.

New York in the United States of America was struck by massive electric power failures twice in 1965 and 1977. The nerve center of the highly civilized city was paralyzed; the citizens were panic-stricken with a sudden blackout and the ensuing great social confusions for hours to a day. The direct cause of the power failures in both years was electrical dischrge associated with a thunderstorm onto a power plant of the city. In order to avoid such power failure accidents as in New York, a power supply system itself must have an rapid restoration ability as a matter of electric system engineering. Furthermore, the most important point is to have a detection and warning system for thunderstorms. Proper informations may make it sure to prepare for emergencies and restor damage.

Here in this article, a detection and warning system for occurrence and development of thunderstorms are described. The Tokyo Electric Power Company installs a radar in Tokyo to get informations on thunderstorms within the greater metropolitan area. Figure 13 shows its radar tower of 200 m height at the central part of Tokyo. The major characteristics of the radar are in the following;

Wave length:	5.4 cm
Peak power:	60 kw
Pulse width:	1 μsec
Pulse repitition rate:	400 pps
Antenna diameter:	3 m
Beam width:	1.5 degrees
Muxinum detectable range:	150 km.

The radar system comprises a weather radar, an analog computer, a digital computer and a device for indication of thunderhead informations. The analog computing system compensates the actual strengh of received echoes according to distance, selects those of a given altitude only, quantifies the input signals according to their unit distance and sends them to the digital computer. The digital computer sums the echoes for each observation unit, a sector subarea enclosed by an azimuth angle of 11.25°, and having a distance of 25 km between its inner and outer bordering arcs. The value obtained is compared with a given threshold value, a larger value indicating the inception of thunderhead and causing a lamp on the indication pannel to light. A value below the threshold indicates the absence of thunderheads.

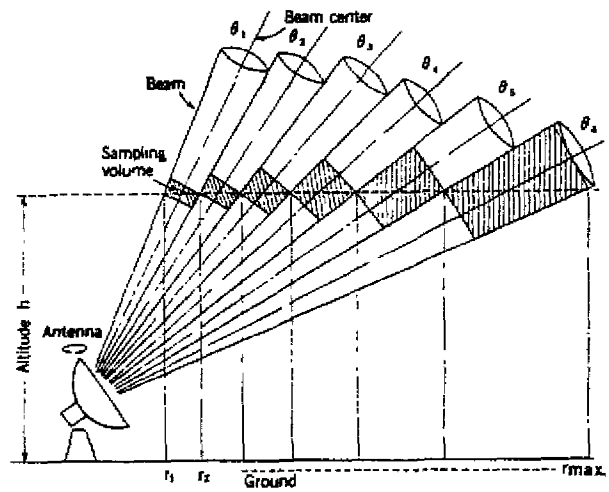
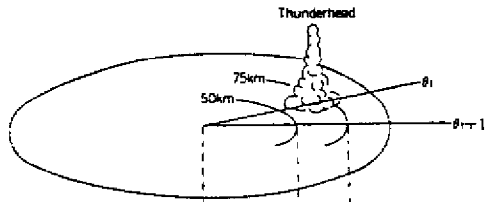


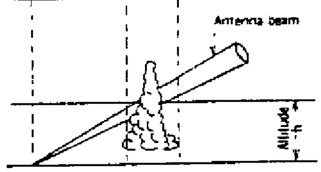
Fig. 14 Extraction of echo at constant altitude by CAPPI

The radar system observes thunderheads with a CAPPI mode. CAPPI means a constant altitude plan position indicator, or a constant altitude PPI. This device first sends a command signal to the antenna control device to move the antenna to a given angle of inclination. Then a gate is applied to the receiver output so as to extract only echoes from a sampling volume at a predetermined altitude. The angle is then changed and the gate value altered so that echoes from subsequent sample volume will be at the same altitude as seen in figure 14.

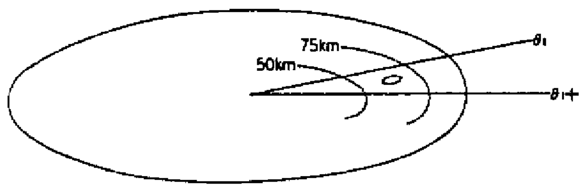
An automatic warning device is introduced in the system. This device, a processing mechanism of which is shown in figure 15, comprises separate input/output unit and computer units. The input/output unit quantifies the radial direction and strength of CAPPI video, which refers to the output of the constant altitude display device. The computer first memorizes the quantified data, and then adds them one by one. The compensation for range and atmospheric attenuation of the radio waves is performed analogously by the iso-echo device. The azimuth value varies at the division of azimuth direction, so upon arriving at that point a separate address (observation unit) is designated, and at that address the same kind of operation is repeted. When the antenna is at 0° and the measurement at that angle is completed (which means that at a given altitude the entire observation range has been measured), the number of echoes, added according to the



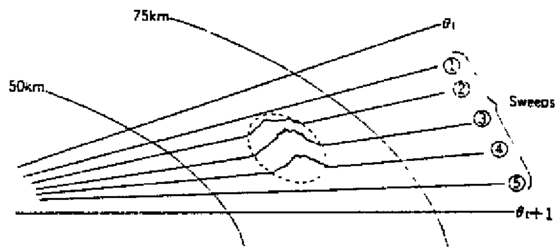
a) **Thunderhead at range of 50~75 km and azimuth θ_i and θ_i DB**



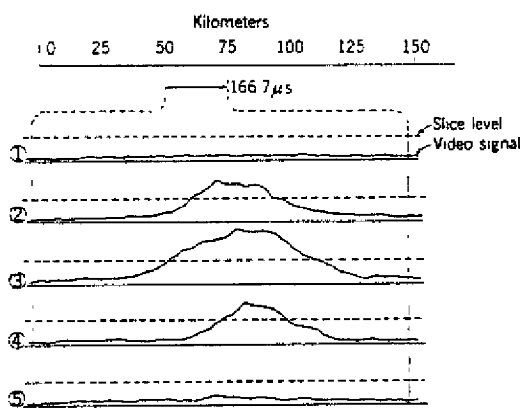
b) **Intersection beam with thundercloud at altitude h**



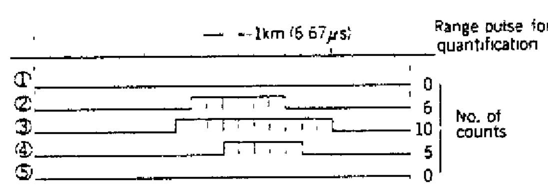
c) **PPI pattern of CAPPI output**



d) **Details of (c) showing five sweeps from (1 ~ 5)**



e) **Video signal and slice level**



f) **Quantification**

Fig. 15 Processing of received echo signal entire observation units and consolidated, is compared with the present number of thresholds, and if the number of the echo count is larger, the result is judged to indicate a thunderhead.

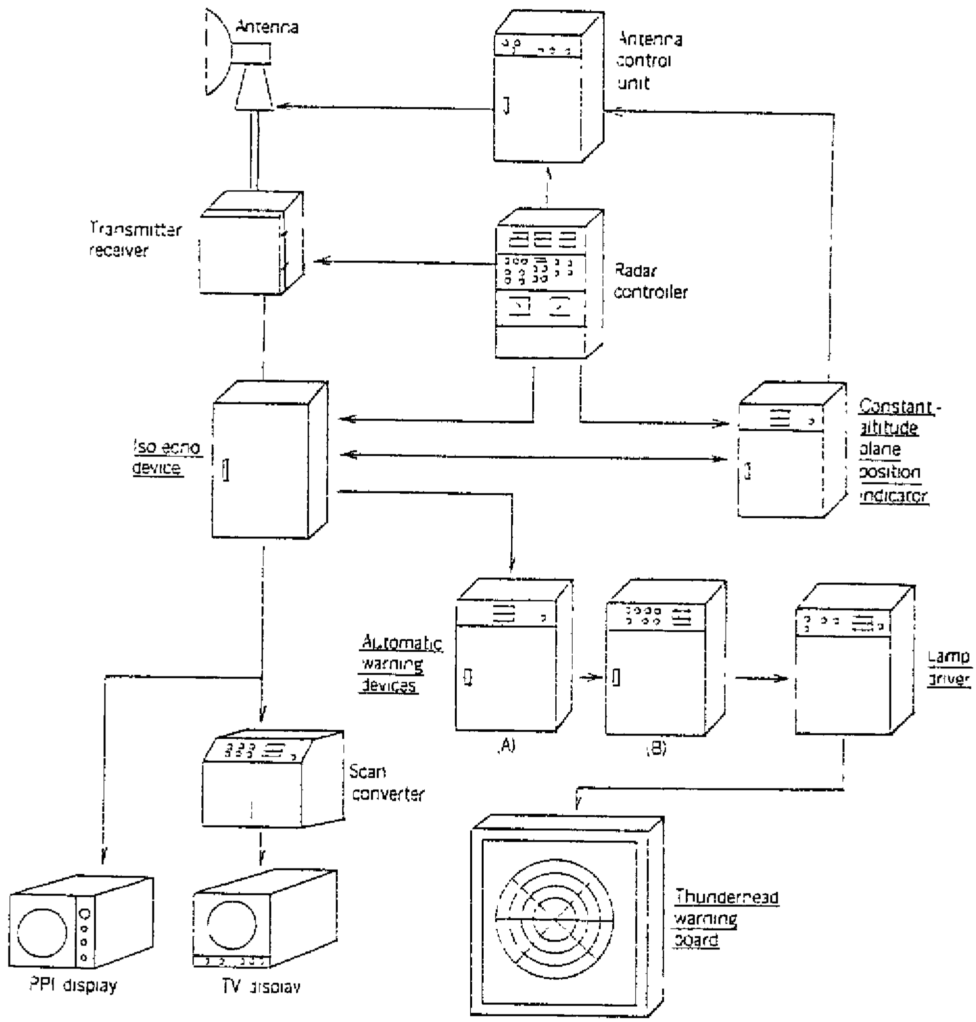


Fig. 16 Block diagram of the thunderhead detection system

Fig. 16 diagrams this thunderhead detection and warning system. The deveices underlined are for the purpose of thunderhead prediction which discussed above.

The observed and processed results are indicated on a thunderhead warning board. The indicator divisions of the board correspond to the respective observation units shown in figure 17. A red lamp is mounted on each observation unit. A lamp corresponding to a given area flickers upon interception of a thunderhead and changes to a continuous "ON" status when the thunderhead is continuously present in the same observation unit.

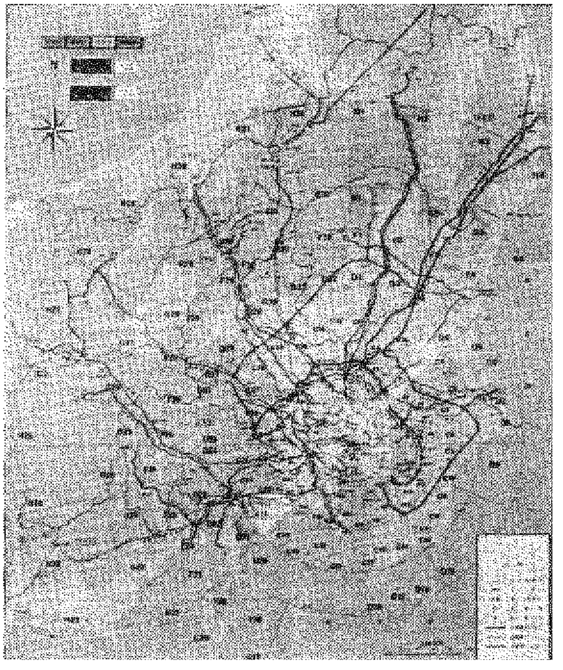


Fig. 17 Thunderhead warning board showing numbered observation units divided by concentric circles and radial lines.

5. POSTSCRIPT

This article for a seminar presentation first described the principle of radar device, then outlined its typical application to such fields as typhoon observation and thunderhead detection. For reference and advanced studies, a bibliography is shown in the last page of this article.

The chapter 2 of the article was refered to "Radar Observation of the Atmosphere" listed in the bibliography, and chapters 3 and 4 to publications by the Japan Meteorological Agency, the Mitsubishi Electric Corporation, Tokyo Electric Power Company and other organizations.

Another important application to flood warning has been presented in the 1983 version of the textbook (Volume 7) by the author.