THE MU RADAR FOR REMOTE SENSING OF THE MIDDLE AND UPPER ATMOSPHERE

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Abstract: The MU radar (Middle- and Upper-atmosphere radar) of Japan is a 46.5-MHz pulse-modulated monostatic Doppler radar with an active phased array system. The nominal beam width is 3.6° and the peak radiation power is 1 MW with maximum average power of 50 kW. A brief description of the system is presented.

1. INTRODUCTION

The use of high-power Doppler radars to continuously measure wind velocities over a wide range of heights is well suited to observe wind systems and waves on various time scales in the middle atmosphere (the region between the tropopause and 100 km) [e.g., Kato et al., 1982]. This technique, which is generally referred to as the MST (Mesosphere-Stratosphere-Troposphere) radar technique, is capable of inferring wind velocities through Doppler shifts of radio echoes from weak fluctuations in the atmospheric refractive index. Radar-determined winds have been shown to compare favorably with winds measured through other conventional techniques such as rawinsonde ascents in the troposphere and stratosphere and rocket flights in the mesosphere [Kato et al., 1982].

An MST radar operating in the VHF-band was completed in November, 1984 at Shigaraki, Shiga, Japan (34.85°N, 136.10°E), by Radio Atmospheric Science Center of Kyoto University [Kato et al., 1984]. This radar has been named "MU radar" in reference to the middle and upper atmosphere, since the system will be extensively used also for investigation of various aeronomical phenomena and dynamical processes occurring in the upper atmosphere (the region above 100 km).

2. ACTIVE PHASED ARRAY SYSTEM

The most outstanding feature of the MU radar is an active phased array system [Fukao et al., 1980]. In conventional MST radar systems a high-power transmitter feeds all array elements via an appropriate cascading feeding network. On the other hand, the MU radar system does not employ such a passive array connected to a high-power transmitter. Instead, each element of the phased array is activated by a low-power transmitter, and all the transmitters are coherently driven by low-level pulses in order to produce the desired peak output power.

This system configuration enables very fast and continuous beam steering as well as various flexible operations made possible by dividing the antenna array into independent subarrays. With these capabilities we can expect various sophisticated observations of the fast changing dynamical behavior of the middle atmosphere.

3. SYSTEM OUTLINE

The operational frequency of the MU radar is 46.5 MHz and the nominal peak and average radiation powers are 1 MW and 50 kW, respectively. The antenna is a circular array with an aperture of 8330 m^2. The nominal beam width is 3.6°. The shortest 1-μs pulse width which provides an equivalent 150-m range resolution is available. Figure 1 shows a block diagram of the MU radar system [Kato et al., 1984]. The basic parameters of the MU radar are given in Table 1.

This system is composed of 475 array antenna elements and an identical number of transmitter-receiver (TR) modules [Fukao et al., 1980; Kato et al., 1984]. The TR modules are accommodated in six booths in the antenna field. The whole system can be divided into 25 groups (i.e., one group consists of 19 array antenna elements and 19 TR modules). Each array element is driven by its own TR module.

The main constituents of the TR module are a solid-state transmitter, a receiver preamplifier, a mixer, a T/R switch, and a digital phase shifter. The final power amplifier stage is composed of four push-pull circuits operating in parallel mode (Eight high-power transistors are employed) [Fukao et al., 1985a].

Both the up-convert from and the down-convert to the intermediate frequency (IF) of 5 MHz are made inside the TR module. The signal is transferred at the IF between the control building and the remote TR booths. This way of frequency conversion prevents instabilities in the power amplifier due to possible leakage of output power into the input signal.

An antenna element consists of two orthogonally crossed three-subelement Yagi antennas pointed toward the zenith direction. Linear and

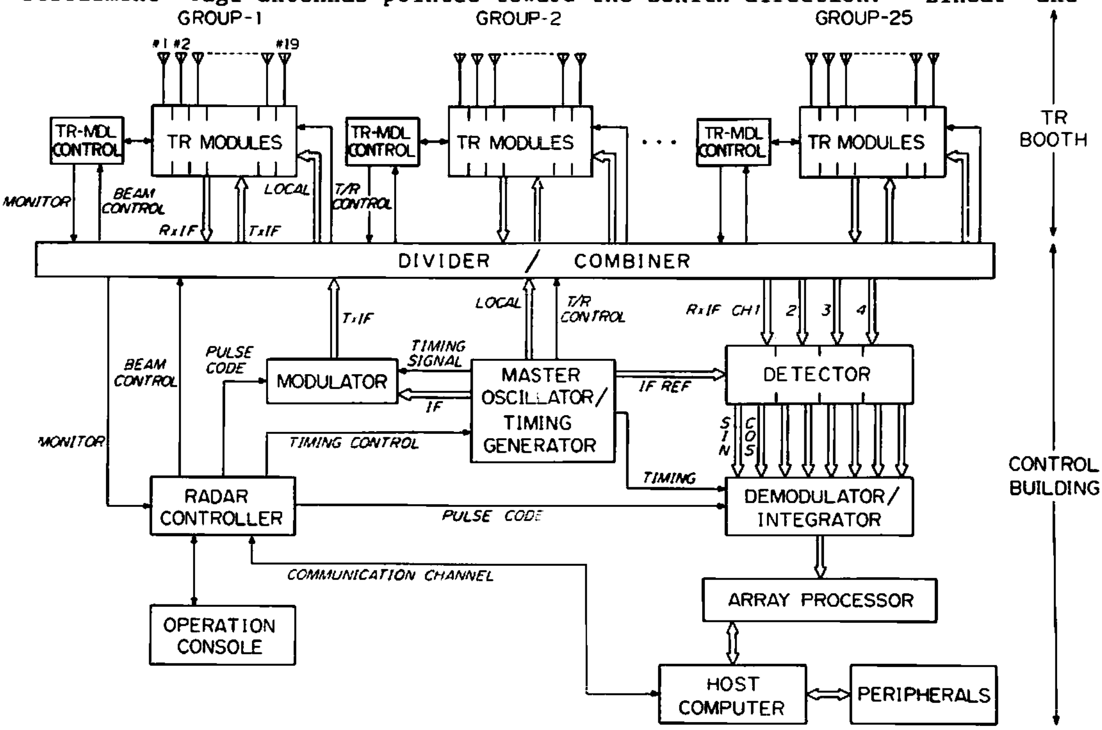

Fig. 1: General block diagram of the MU radar, Shigaraki, Shiga, Japan. The modules and TR module controllers are housed in remote TR booths built in the antenna field. Other system equipments are installed in the control building [Kato et al., 1984].

Table 1. Basic parameters of the MU radar.

Location	Shigaraki, Shiga, Japan (34.85°N, 136.10°E)
Radar system	Monostatic pulse radar; active phased array system
Operational frequency	46.5 MHz
Antenna	Circular array of 475 crossed Yagi's
Aperture	8330 m^2 (103 m in diameter)
Beam width	3.6° (one-way; half power for full array)
Steerability	Steering is completed in each IPP
Beam directions	1657; 0-30° zenith angle
Polarizations	Linear and circular
Transmitter	475 solid-state amplifiers (each with output power of 2.4 kW peak and 120 W average)
Peak power	1 MW (max)
Average power	50 kW (duty ratio 5%)(max)
Bandwidth	1.65 MHz (max) (pulse width:1-512 μs variable)
IPP	400 μs-65 ms (variable)
Receiver	
Bandwidth	1.65 MHz (max)
Dynamic range	70 dB
IF	5 MHz
A/D converter	12 bits × 8 channels
Pulse compression	Binary phase-coding up to 32 elements; Barker and complementary codes presently in use.

circular polarizations are available with the aid of a polarization-selection switch in the TR module.

A supervision of the overall operation of the MU radar is performed by a programmable radar controller (the main constituent is a desktop computer HP9835A) linked with the 25 TR module controllers. Various timing signals for real time system control are generated according to instructions from the radar controller. A variety of flexible operations are made feasible by sophisticated software of the radar controller. For instance, it is possible to steer the antenna beam in each interpulse period (IPP), i.e. up to 2500 times every second, virtually to any direction within 30° of the zenith. Moreover, it is possible to excite only a portion of the antenna array and receive the echo by other portions and/or to steer multi-beams in different directions [Fukao et al., 1985b].

A super-minicomputer (VAX-11/750) and an array processor (MAP-300) with a 2-MByte RAM (random access memory) are the main constituents of the data processing system. A fairly large amount of data (up to 1024 samples) can be processed in real time. Before being processed by the computer, the echo signals are decoded for pulse compression and then coherently integrated for data compression by special purpose hardware.

Also, high reliability of the system is expected to be achieved by means of a network of 25 TR module controllers which monitor the TR modules during operation [Fukao et al., 1985b].

Fig. 2 is a photograph taken in January 1985, showing the overall construction, the control building, crossed 3-subelement Yagi antennas and RF cables.

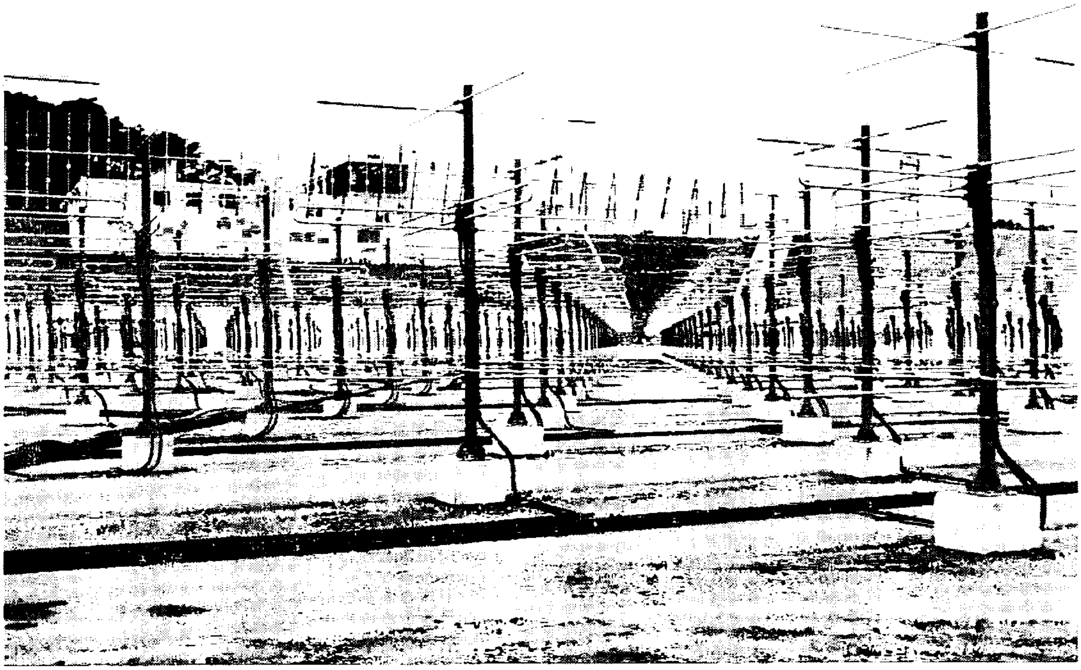

Fig. 2 Photograph taken in the antenna field.

4. CONCLUDING REMARKS

The present paper shows that it is possible to realize an active phased array system in the VHF band using available commercial equipments and devices. Short-term preliminary observations are also being conducted, early results showing that the MU radar is living up to the high standards of performance specified by the design.

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