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MILLIMETER-WAVE ATMOSPHERIC SOUNDER (MAS)
(E034)

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MAS is a remote sensing instrument for passive sounding (limb sounding) of the Earth's atmosphere from Space Shuttle. Millimeterwave radiation emitted by the atmosphere in the height range between 20 km and 100 km will be measured at 61, 62, 63, 183, 184, and 204 GHz with a height resolution as low as 4 km.

MAS data yield direct information about the altitude distribution of temperature (T), pressure (P), water vapor (H_2O), ozone (O_3), and chlorinemonoxide (ClO) in the atmosphere and mesosphere, over the latitude ranges ±45 deg or ±74 deg depending on the Shuttle mission (28 or 57 deg orbit inclination).

Besides new information for basic research (geophysics), MAS can be regarded as an early warning system for important environmental effects, e.g., the man made (anthroprogenic) destruction of the ozone layer.

MAS is a passive total power microwave radiometer-spectrometer for Earth limb observations from space. It measures the radiation emitted by various constituents in the atmosphere of the Earth.

The millimeter wave radiation from the Earth's limb is collected by a steerable parabolic antenna (ANT), consisting of a 1-m diameter main reflector and a smaller sub-reflector, and the radiation is focused into the MAS Receiving Electronics (MRE) (Figs. I-14 and I-15). The antenna positioning in elevation over a range of about 4 deg within a total scan range of 13 deg is done by a linear actuator. The position angle is measured by a resolver and is fed into the MAS Control Electronics (MCE). It controls the linear actuator's positions which are commanded by the Data Electronic Box (DEB). The antenna scan can be selected from several modes.

The MRE consists of three radiometers denoted as channel 1 through 3. Channel 1 operates at 61 to 64 GHz, channel 2 at 183 GHz, and channel 3 at 204 GHz (Table I-3). They down convert the signals to several intermediate frequencies (IF) below 6 GHz. These IF signals are fed through appropriate flexible connections to the Filter Electronic Box (FEB) where they are analyzed in five filterbanks consisting of 240 filters with bandwidths of 200 KHz, 2 MHz, and 40 MHz. The filters are followed by quadratic detectors, multiplexer, and A/D converters. The FEB furthermore contains a programmable frequency synthesizer for compensation of the Doppler shift.

The FEB communicates with the DEB that receives its data. All data telecommand execution and data handling is performed in the DEB. Based on attitude and orbit information available in real time (GN&C and Horizon Sensor Data), the DEB also checks on the antenna position.

The DEB formats all data including housekeeping information and transmits it to a HRM channel of the Shuttle's CDMS at a data rate of 86.4 kBit/s. The DEB also contains the MAS power supply.

The main objective of the MAS is to study the composition and dynamic structure of the stratosphere, mesosphere, and lower thermosphere in the height range 20 to 100 km, the region known as the middle atmosphere.

Clearly, global observations are of paramount importance in order to establish a data base for validating results from both one-dimensional and multi-dimensional photochemical models.

Two crucial parameters to be measured in the stratosphere and mesosphere are ozone concentrations and temperature. Temperature is important for many reasons. Using temperature and pressure data, the distribution of the geostrophic wind can be determined, which is a close approximation to the prevailing wind at stratospheric levels outside the tropics. Many important chemical reactions are temperature dependent, so that the temperature must be known before the chemical production and loss rates of several stratospheric constituents can be determined. The stratospheric temperature is also important in determining the exchange of infrared radiation with the troposphere below, with atmospheric regions above, and with space.

Ozone is important because of its effect in shielding the biosphere from harmful ultra-violet radiation and because it plays an important role in absorbing solar radiation and in absorbing and re-emitting infra-red radiation. It therefore plays a crucial part in determining the distribution of stratospheric heat sources and sinks, and thus helps to determine stratospheric temperature and wind structures. Further, since in the stratosphere O_3 is chemically longlived, it can be used as a tracer of atmospheric motions. Recent work on the photochemistry of ozone shows that there are still many important uncertainties in the chemistry, even though O_3 has been much studied.

There is much concern that the effects of chlorofluoromethanes (CFMs) and related chemicals in the atmsophere, which produce chlorine radicals, such as ClO, in the stratosphere may be deleterious to the ozone layer. Such is the uncertainty of these effects that the steady state depletion of ozone by CMFs is unknown by a factor of two, due to the crude treatment of transport alone. To date, there have been very few measurements of upper atmospheric ClO, with results varying by nearly an order of magnitude, and with no information on latitudinal variations. Clearly, global data on ozone and ClO, the most important product in the catalytic destruction of ozone by chlorine, will provide answers to the problem of anthropogenic influences on the ozone layer.

Photochemical models show that H_2O plays a central role in controlling the distribution of O_3 through odd hydrogen reactions. Water vapor, in addition, is a valuable tracer of vertical transport in the upper stratosphere and mesosphere and is energetically the most important gas, playing a major role in irreversible thermodynamic processes.

In contrast to the molecules mentioned above, the oxygen molecule (O_2) has no electric dipole moment but does have a magnetic dipole moment. All O_2 resonances below 300 GHz are fine structure transitions between different orientations of the electron spin and the molecular rotation. Since in the atmosphere O_2 has a constant mixing ratio up to about 90 km, the measured thermal radiation can be used to determine the atmospheric temperature profile. Furthermore, since some of the higher rotational transitions are temperature dependent while the line width is pressure dependent, emissions from those lines can be used to derive atmospheric pressure profiles.

At altitudes above about 15 km (pressure $<$ 100 mb), most molecular resonance lines are well separated at microwave frequencies. Since coherent microwave receivers are capable of virtually infinite spectral resolution, the line shape can be measured accurately to very high altitudes (80 to 120 km, depending on line strength). Further, the microwave transitions of oxygen remain in local thermodynamic equilibrium up to altitudes over 90 km, allowing temperature measurements to be made up to these altitudes.

The Millimeter-Wave Atmospheric Sounder will provide, for the first time, information obtained simultaneously on the temperature and on ozone concentrations in the 20 to 90 km altitude region. The information will cover a large area of the globe, will have high accuracy and high vertical resolution, and will cover both day and night times. Additionally, data on the two important molecules, H_2O and ClO, will also be provided.

TABLE I-3. PARAMETERS AND CONSTITUENTS MEASURED BY MAS

Frequency (GHz)	Parameter/ Constituent	Height Range (km)	Accuracy	Integration Time (s)
Channel 1				
61,151	Kinetic Temperature	20 - 100	2°K	2-10
62,998	Pressure	35 - 70	1%	2
63,568	Pressure	35 - 70	1%	2
Channel 2				
183,31	Water Vapor	20 - 90	2×10^{-7} VMR*	2-100
184,37	Ozone	20 - 90	2×10^{-7} VMR	2
Channel 3				
204,35	Chorinemonoxide	30 - 45	2×10^{-10} VMR	100

* VMR: Volume Mixing Ratio

ANT	Antenna System
SPM	Scan and Pointing Mechanism
MRE	MAS Receiving Electronics
FEB	Filter Electronics Box
DEB	Data Electronics Box
MCE	MAS Control Electronics

Antenna-Diameter	:	1.0 m
Spectral Resolution	:	240 Channels (12 bit)
Datarate	:	86.4 kBit/s
Power Consumption	:	420 W
Mass	:	167 kg
Dimensions((LxWxH)	:	120 x 130 x 170 cm

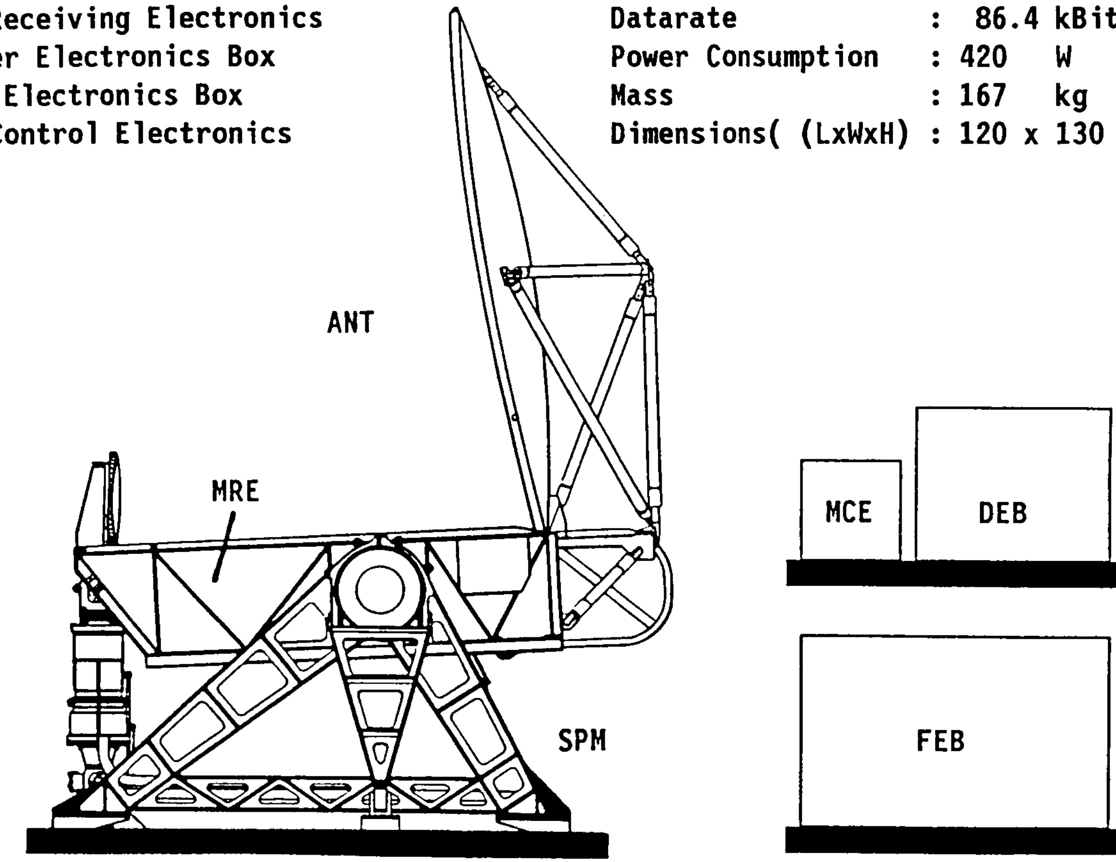

Figure I-14. MAS schematic configuration.

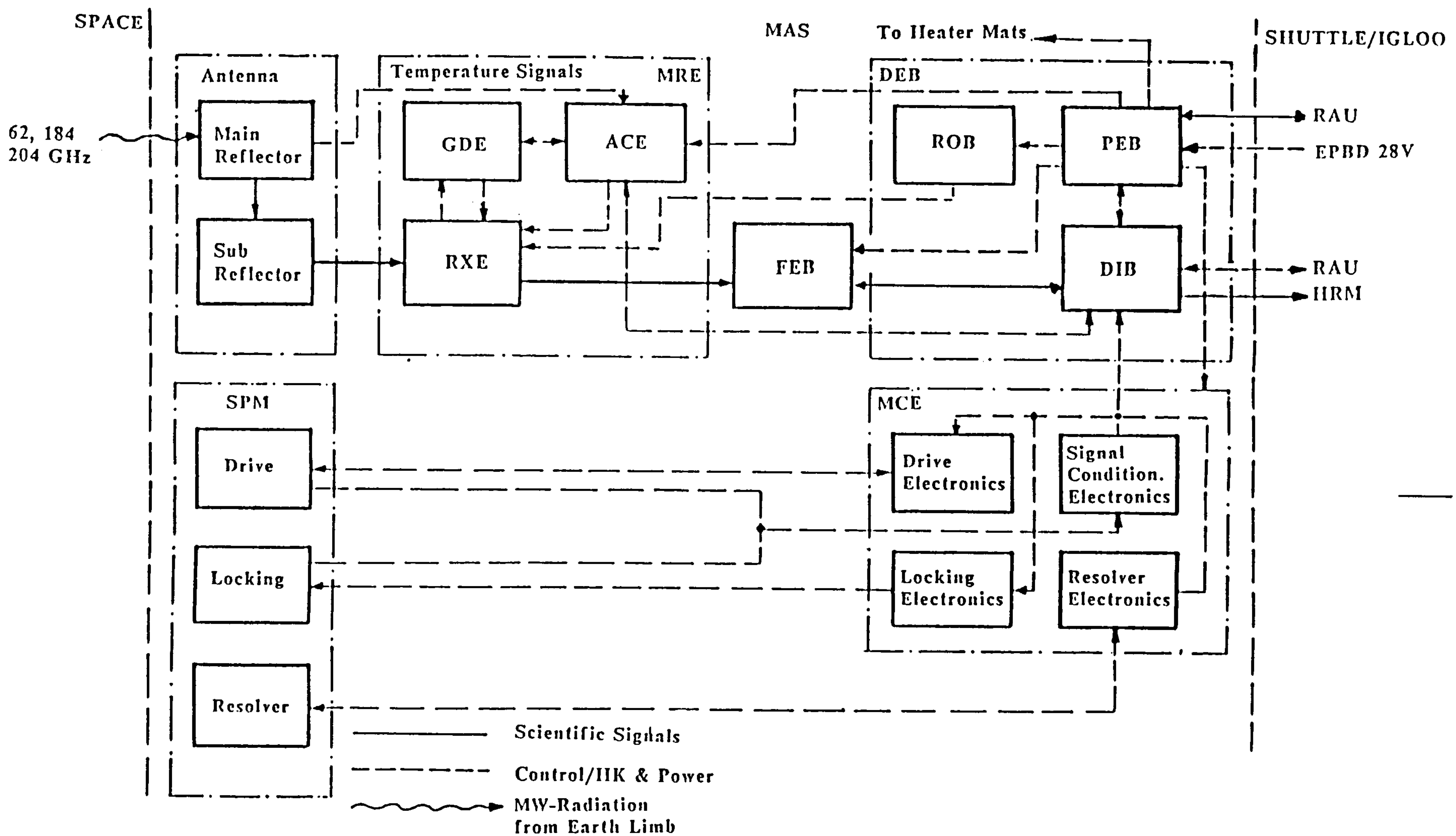

Figure I-15. MAS functional block diagram.