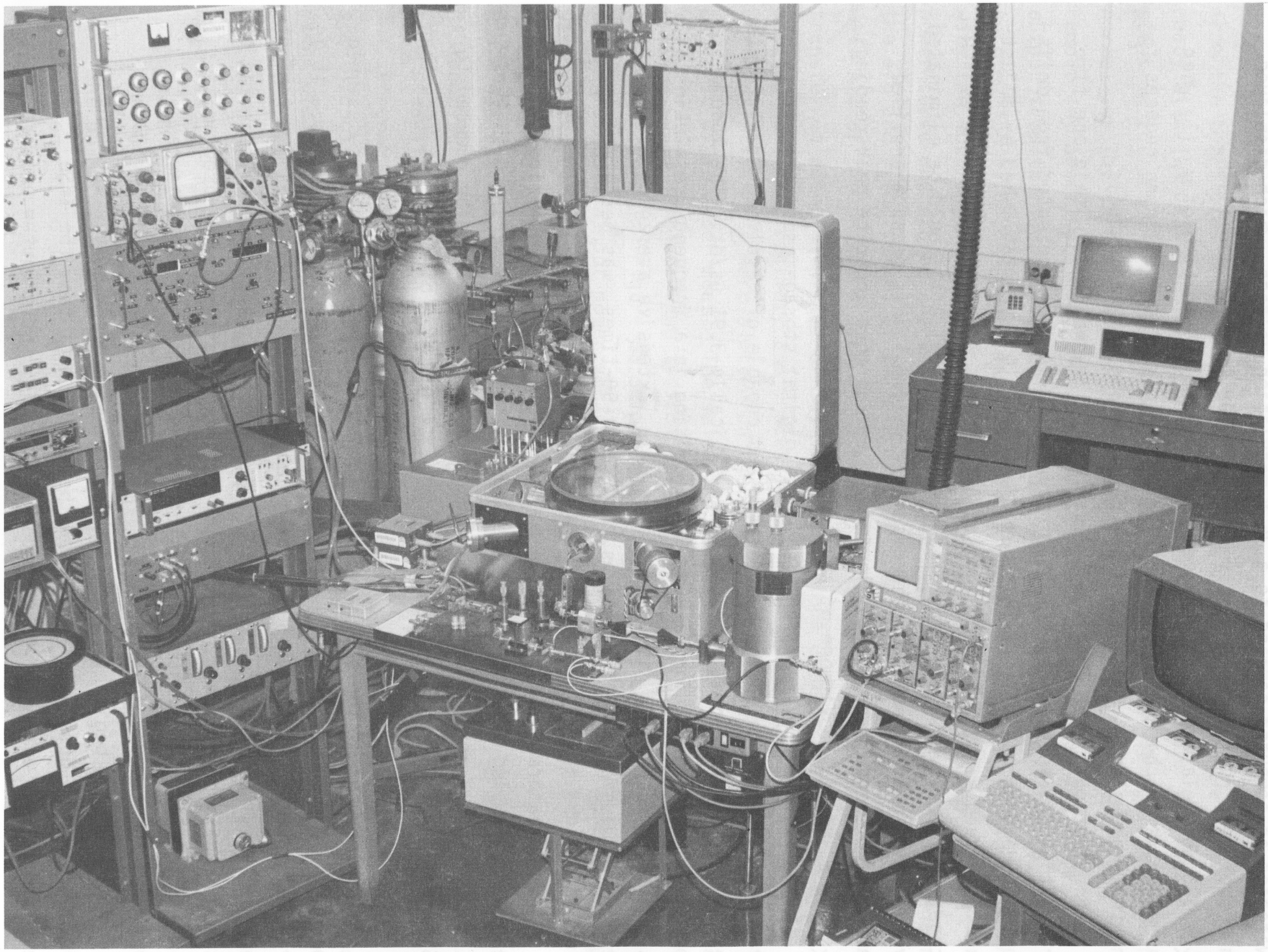


Figure 2. Photograph of millimeter-wave spectrometer.

The reference power $a_o = k \cdot a_K$ for (1) was measured by periodically (30s) switching on computer command to a 36 V modulation voltage, which displayed the power mode $A_K(t)$ with a peak value, a_K = 909 mV and a bandwidth, b_K = 186 MHz. This feature provided an automatic calibration of α_r (1) when the power level changed during a data run (e.g., refractive-tuning reduces f_R and the peak value a_K can change when the klystron is readjusted).

An electronic lock-on circuit centered the resonance f_R within one time frame; that is, the klystron center frequency $f_K(a_K)$ was prevented from drifting with reference to f_R. A flat baseline A(t) = 0 was established by adjusting f_K in such a way that two adjacent A(t) frames were displayed on a control scope and kept level. The reflected resonance signal A(t) could be eliminated by injecting a steel rod into the resonance volume. This measure provided baseline reference data in the "low" (0.36 V) and more accurate peak readings a_K in the "high" (36 V) mode of the modulator.

The waveform processor for A(t) was a digital storage oscilloscope, synchronized with the sawtooth modulator and capable of resolving 512/1024 pts per 2000 μs. Operational resolution was typically 3.91 μs/pt. The modulator voltage for A(t)-detection was 0.360 V resulting in a frequency resolution of 9.2 kHz/pt, which is an improvement over (4). Extensive averaging of the repetitive waveforms A(t) 100 times, and $A_K(t)$ 50-times, was performed in real time to improve the signal-to-noise ratio of the a and b results.

For a measurement of the resonance bandwidth b_o, the digitizing increments were doubled (1024 pts) and the modulation voltage was varied in the 0.150 to 0.400 V range, allowing the resolution uncertainty to be reduced to ±5 kHz. The resultant error in an absolute calibration of α (3) was less than 3 percent.

The computer of the spectrometer had a control-program that was designed to be flexible in order to allow changes in data collection procedures. It is written in BASIC with about 500 lines of code to control the readings of eight temperatures, two pressures, and a/b values from the waveform processor and to store the data on a magnetic medium for future processing. The program is time controlled. The fastest acquisition time for a complete measurement cycle was 30 seconds.

Measurements begin by starting the internal program of the waveform-processor, which does 100 averages on the output A(t) from the InSb detector. Since averaging takes about 14 seconds, the computer program continues data recovery from the temperature sensors which measure chamber (T_c), water bath (T_w), room (T_r), gas ($T_{1,2,3}$), mirror (T_m) temperatures, and data from the total pressure meter (P). By this time the oscilloscope is nearly ready with its data so the computer program returns to wait for the final steps in the scope program. After the scope completes 100 averages on A(t) it normalizes (by setting cursors at 0.1 and 0.9 of the time base) the trace to remove any baseline slope, then stores the waveform. Next, an auxiliary output from the scope switches the sweep generator voltage from low (0.36 V) to high (36 V). The scope input changes to the power envelope of the klystron with the lock-on disabled. The scope program performs 50 averages on the power curve and stores the waveform A_K. The next computer step is to call for the a/b and a_k/b_k values of the stored waveforms.

All of the measured data were temporarily stored in computer memory and transferred along with time-of-day to magnetic tape or disk storage for safe keeping and later recovery and processing.

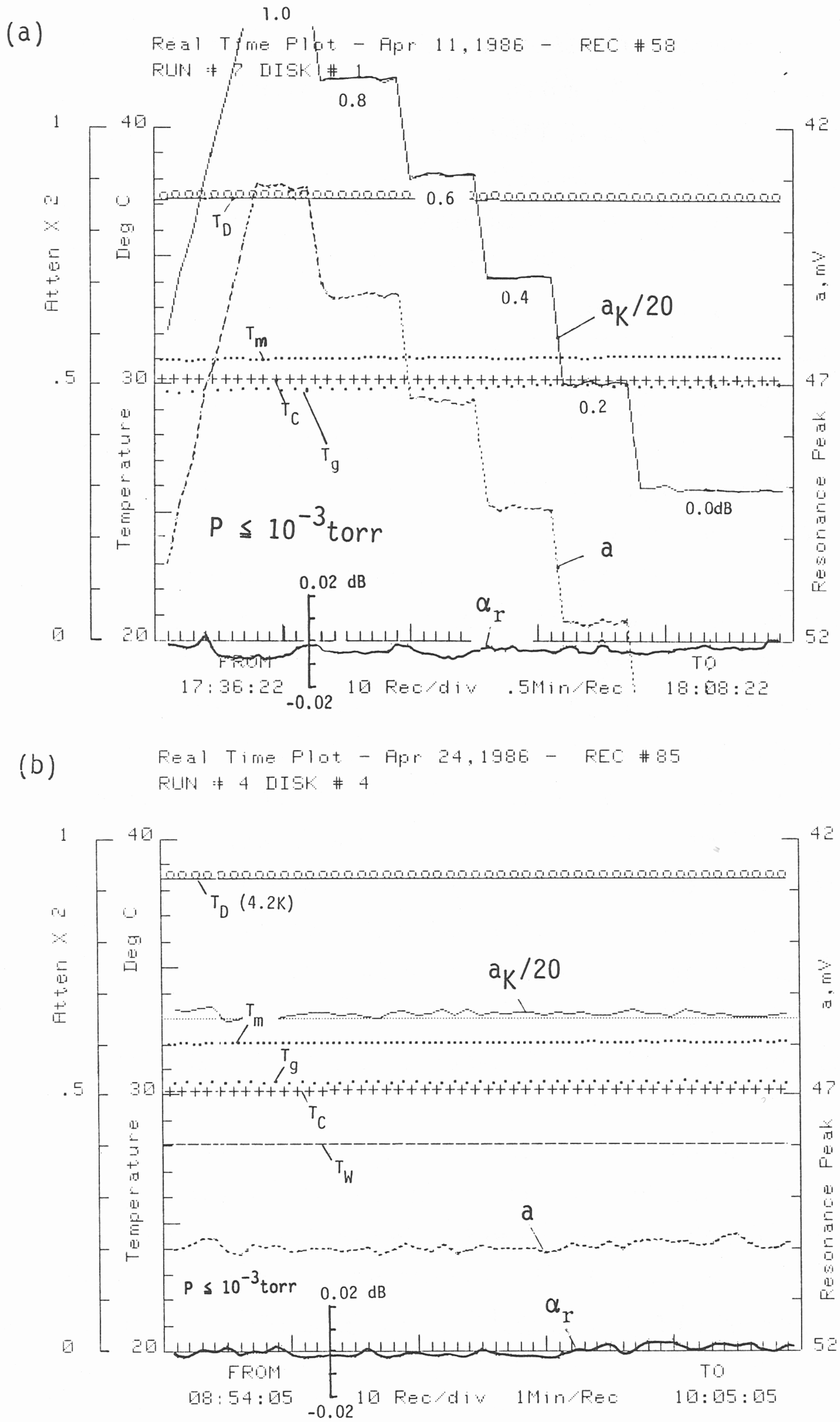
Real-time data were plotted on the CRT of the computer to follow the progress of an experiment. The selection of what was displayed is part of the program configuration. Two typical examples of 1-hour operating periods are shown in Figure 3. Figure 3a demonstrates the automatic calibration to α_r = 0 dB for input power variations of 1 dB. The reference power trace a_K was reduced by a factor 0.05 for display, but the correct coupling factor k = 0.0550 was applied for the relative attenuation trace (1) $\alpha_r = 8.686\ (\sqrt{k \cdot a_K/a} - 1) = 0$ dB. Each 1-hour frame represents averages of about 10^7 actually acquired data points. Detection sensitivity and long-term stability are displayed in Figure 3b.

Program configuration is stored in a separate file on disk. An auto-start function is available for studies that are conducted unattended. In the event of a power failure the program will automatically restart.

Post processing of data repeats calibrated signal corrections as done in the real-time mode. Scatter plots of α_r are made versus pressure in a point-mode (e.g., Figure 6).

2.2 Moist Air Attenuation Measurements

The objective of the experiments was to perform pressure scans of the attenuation rate α due to water vapor absorption in moist air. An extensive series of controlled measurements was performed at 137.8 GHz to determine



<u>Temperature Readings</u>

T_D=92mV, bias of InSb detector ($\propto$4.2K)

T_m=mirror

T_g=gas

T_C=cell wall

T_W=water (vapor source)

Figure 3. Mm-wave spectrometer operational data (five temperatures T_i) peak values of reference and reflected signals a_K, and a; and relative attenuation (α_r) for a 1-hour measurement period with an evacuated cell (f_R = 137.8 GHz):
(a) automatic calibration to α_r = 0 dB for changes, Δa_K = 0-1 dB;
(b) detection stability and sensitivity
($\alpha_{min} \approx 0.006/0.13 \leq 0.05$ dB/km).