Mössbauer Spectrometer

The Athena Mössbauer spectrometer uses a vibrationally-modulated ^{57}Co source to illuminate target materials. Backscattered gamma signals are binned according to the source velocity, revealing hyperfine splitting of ^{57}Fe nuclear levels that provides mineralogical information about the target. The main parts of the instrument are the Mössbauer drive that moves the ^{57}Co source with a well-known velocity, the γ- and x-ray detectors that detect the backscattered radiation, the microcontroller unit, the ^{57}Co/Rh Mössbauer source, and the radiation collimator and shielding.

The spectrometer is split into the sensor head on the rover's Instrument Deployment Device (IDD), and the electronics in the warm electronics box (WEB). The sensor head carries the Mössbauer drive with the analog part of the drive control unit, the ^{57}Co/Rh Mössbauer source, the radiation collimator and shielding, the four PIN- diode detector channels including pulse amplifiers, and one reference detector channel to monitor the velocity of the drive using a weak ^{57}Co source and a well known Mössbauer reference absorber in transmission geometry.

The WEB electronics consist of the microcontroller and memories for data acquisition and temporary storage. An extra FPGA logic unit provides several functions for internal communication, generates the velocity signal for the drive, and contains fast pulse counters for the detector signals. The WEB electronics also contain voltage supply regulators and detector bias voltage generators.

The analog signals of the five detector channels are analyzed by discriminators for 14.4 keV and 6.4 keV peaks. Upper and lower threshold values of the discriminators are generated by digital to analog converters (DACs). These values can be changed automatically to follow the temperature drift of the amplifiers. Digital signals from the discriminators are sent to the velocity-synchronized counters whenever a detected pulse is within the specified range. Mössbauer spectra for the two different energies of 6.4 keV and 14.41 keV are sampled separately.

The Mössbauer spectrometer has its own internal microcontroller, so that it can collect data independently of the rover computer. Instrument parameters are stored in a fault-tolerant fashion in 3 separate FRAMs and default values for these parameters are taken from ROM in case of an error. Every 60 minutes during a measurement, data is stored into the EEPROM. In case of a failure of the power supply, after restart of the instrument the data acquisition will continue with this data. Each Mössbauer spectrum consists of 512×3-byte integers. The pulses from the 4 counters are added by hardware. Normally there is one spectrum for each detector. The spectra are sampled into an SRAM of 128 Kbytes size.

Measurements are made by placing the instrument directly against a rock or soil sample. Physical contact is required to provide an optimal measurement distance and to minimize possible microphonics noise on the velocity-modulated energy of the emitted γ rays. The mechanical construction of the IDD and the interface limit vibration-induced velocity noise at the sensor head to less than 0.1 mm/s. A contact plate is mounted at the front part of the sensor head, assuring an optimal distance from the sensor head to the sample of about 9 to 10 mm. A heavy metal collimator in front of the source provides an irradiated spot of nominally 15 mm (up to 20 mm, depending on actual sample distance and shape) in diameter on the surface of the sample. The IDD can position the instrument with an accuracy of 0.4 cm or better with respect to the position observed by other IDD-mounted instruments. The average depth of sampling by Mössbauer data is about 200 to 300 µm.

Mössbauer parameters are temperature dependent. Especially for small particles exhibiting superparamagnetic behavior (e.g., nanophase Fe oxides), the Mössbauer spectrum may change drastically with temperature. The observation of such changes will help in determining the nature of the iron-bearing phases. Therefore Mössbauer measurements will be performed over a range of diurnal temperatures spanning both the daytime maxima and the nighttime minima.

One Mössbauer measurement takes approximately 12 hours, depending on the phases present in the sample and the total iron content. The temperature variation for one spectral accumulation interval will not be larger than about ±10°C. When larger variations occur, spectra for different temperature ranges are stored separately, resulting in an increase in the total data volume (depending on the number of temperature intervals required), and a decrease of statistical quality for the individual subspectra.

In parallel with the measurements of samples, calibration spectra will be taken using the reference channel implemented in the instrument. A calibration target containing a thin slab of magnetite-rich rock will also be included on the rover where it can be viewed directly by the instrument immediately after landing, as well as later in the mission if necessary.

The performance of the Mössbauer Spectrometer can be defined by measurements made in transmission geometry with a Mössbauer source in front of the instrument at a distance of 5 cm, and in a backscattering geometry with the source internal to the instrument in its flight configuration. Instrument performance requirements for such purposes are specified for a Mössbauer source strength of 100 mCi for the backscattering mode, 10–20 mCi for transmission mode, an integration time of 10 minutes for the energy spectra (backscattering and transmission), and an integration time of 10 hours for the Mössbauer backscattering spectrum.

(1) Specifications for the energy spectra taken in transmission mode (see Figure 1) at a temperature of +20 (±1)°C are:

- noise level: The intensity at (A) (channel 11) will not exceed 20.000 (±1000) counts;
- at (B) ("valley", channel 15), the intensity will be less than 8900 (±500) counts; and
- the peak-to-valley ratio (ratio of intensities at (C) (channel 19) and (B)) will be equal to or larger than 1.5.

(2) Specifications for the energy spectra taken in backscattering mode (see Figure 2) at a temperature of +20 (±1)°C are:

- noise level: The intensity at (A) (channel 18) will not exceed (50 ±10) counts;
- at (B) (channel 36) the intensity will be less than 23 ±5 counts;
- within the energy range channel 25 to channel 50 the intensity will be between 2 and 25 counts; and
- at (C) (channel 145) the tantalum X-ray line generated in the collimator will be visible; the intensity will be 18 ±4 counts.

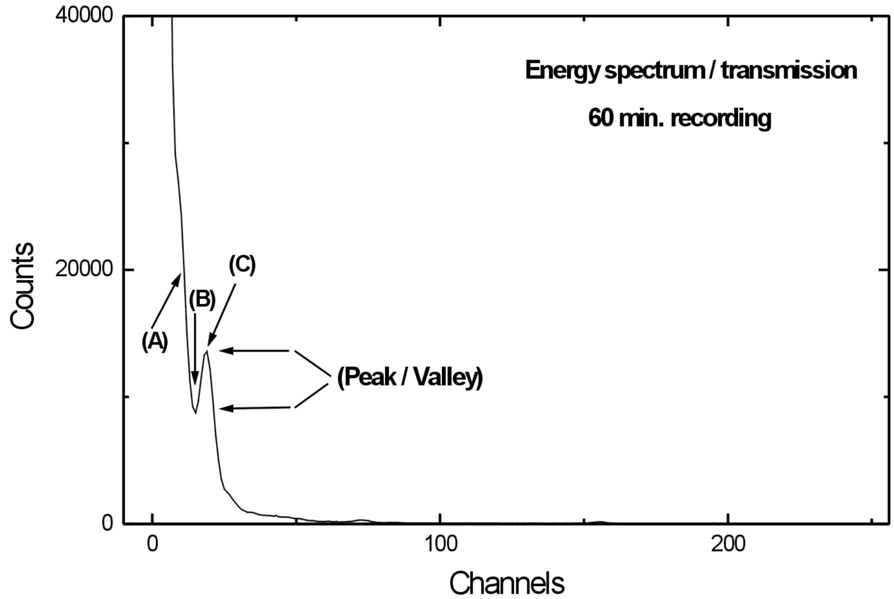

Figure 1: Energy Spectrum of a ^{57}Co Mössbauer Source, taken in Transmission Mode

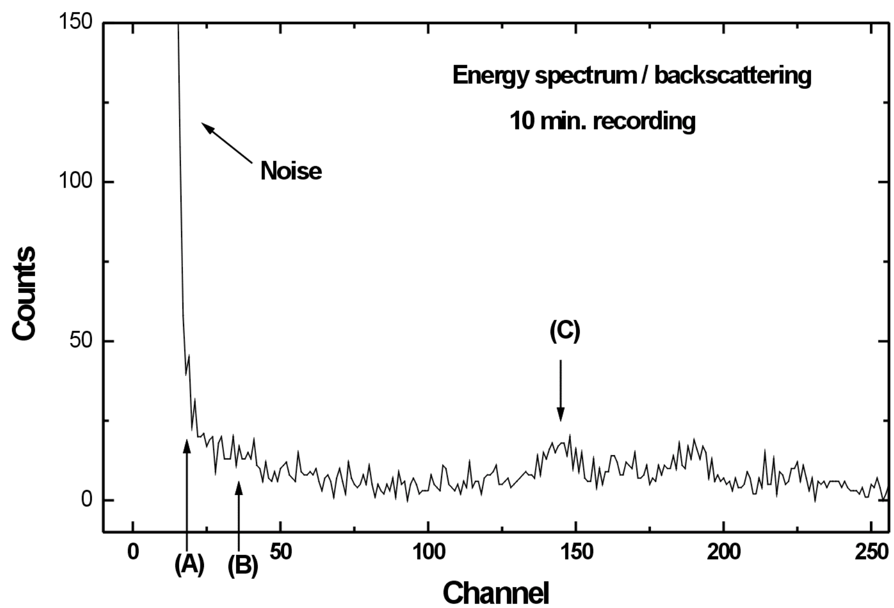

Figure 2: Energy Spectrum of a ^{57}Co Mössbauer Source, taken in Backscattering Mode on the Mössbauer Calibration Target

(3) Specifications for the Mössbauer spectra taken in backscattering mode (see Figure 3) on its magnetite-rich calibration target at a temperature of +20 (±1) °C are that:

- the peak/background ratio will not be less than 1.11, as shown in Figure 3; for a source activity between 80 and 120 mCi; and
- the magnetite signal will be visible with a peak/background ratio of not less than 1.005.

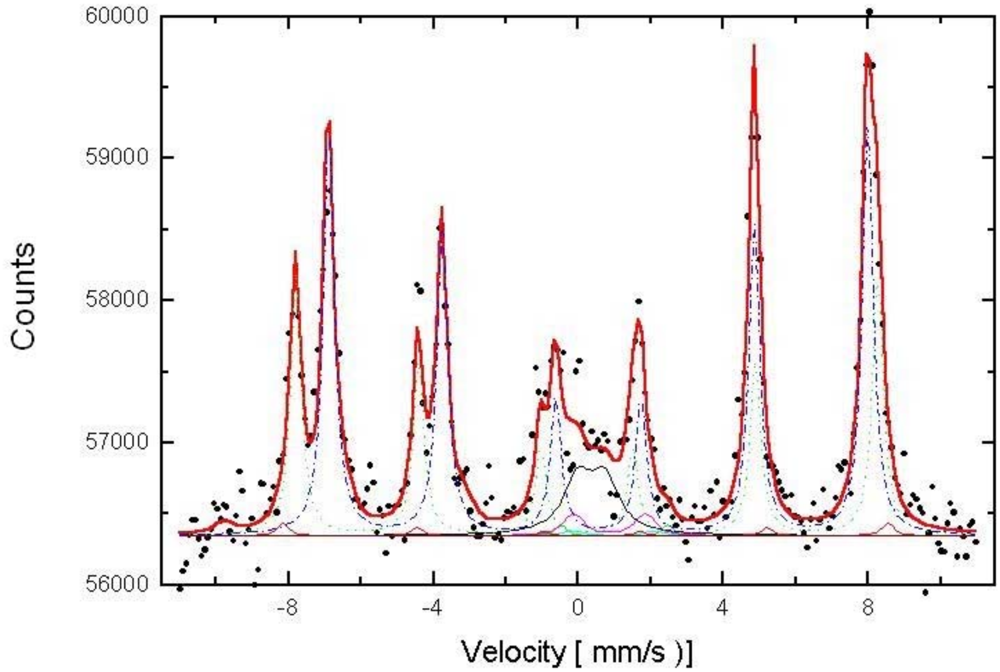

Figure 3: Mössbauer Backscattering Spectrum of the Compositional Calibration Target