10.2.3 Solar Cell Calibration and Measurement

Calibration of solar cells for space is extremely important for satellite power system design. Accurate prediction of solar cell performance is critical to solar array sizing, often required to be within 1%. Calibration standards as a function of band gap are required to perform simulated AM0 efficiency measurements on earth. The calibration standards are produced by evaluating various cell types in space via the Shuttle or in the near future aboard the ISS. A less-costly means of developing standards is through the use of high-altitude aircraft or balloon flights. NASA Glenn Research Center solar cell calibration airplane facility has been in operation since 1963 with 531 flights to date [34]. The calibration includes real data to AM0.2 and uses the Langley plot method plus an ozone correction factor to extrapolate to AM0. Comparison of the AM0 calibration data indicates that there is good correlation with Balloon and Shuttle flown solar cells.

Solar intensity is a function of the thickness of the atmosphere that the sunlight must pass through (AM). Plotting the logarithm of solar cell short-circuit current, proportional to solar intensity, as a function of AM permits extrapolation to an unmeasured AM and AM0 (Langley Plot Method). Early ground-based measurements were based on the change in atmosphere that the sun would pass through as it moves across the sky (i.e. more atmosphere at dawn and dusk and a minimum at solar noon). This is the same basic method that is used with an airplane, changing altitude to vary the AM.

Data analysis from early flights between 1963 and 1967 showed that the AM0 extrapolation was slightly lower than what was expected from radiometer data. This was found to be due to ozone absorption of sunlight in the upper atmosphere. A change in the data linearity was also noticed when the plane flew below the tropopause. This was later correlated with Mie scattering from particulate matter in the atmosphere and with absorption by moisture. These effects are primarily manifested in the higher-energy region of the solar spectrum. Calibration flights currently are performed above the troposphere and a correction for ozone absorption is used. Today calibration runs are performed with a Lear 25A jet housed at the NASA Glenn Research Center (see Figure 10.7). It has flown 324 flights since 1984. The plane can fly up to $\sim$15 km and gets above AM0.2 at 45°N latitude. The data is now gathered using a continuous descent rather than remaining level over a range of altitudes.

The current Lear test setup has a 5:1 collimating tube in place of one of the original aircraft windows. This tube illuminates a 10.4-cm-diameter temperature-controlled plate. The tube angle can be adjusted to the sun angle. During descent IV curves for up to 6 cells, a pressure transducer, a thermopile, and a temperature sensor are all measured. The cells are held at a constant temperature of ± 1°C. A fiber optic connected to the test-plate is also connected to a spectroradiometer that can measure the solar spectrum from 250 to 2500 nm with 6-nm resolution, and a second spectrometer is used to measure the spectrum from 200 to 800 nm with 1-nm resolution. Both of these spectrometers are used to check for any spectral anomalies and to provide information on the ozone absorption.

There are currently several commercially available steady-state and pulse solar simulators that can simulate the sun's light in a variety of conditions (i.e. AM1.5, AM0). The NASA Glenn Research Center uses a Spectrolab X-25 Mark II xenon arc-lamp solar simulator. Steady-state solar simulators are generally used in laboratory or production environments for precision testing of PV devices. Solar simulators are also used on