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The Atmospheric 60-GHz Oxygen Spectrum: Modeling and Laboratory Measurements
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Hans J. Liebe, George A. Hufford, and Robert O. DeBolt

Abstract: Molecular oxygen dominates the attenuation and delay rates of dry air throughout the V-band (5075 GHz). Both rates display as a function of altitude an intricate pattern which, for the most part, has never been confirmed by experiment. The collective spectral behavior of 38 pressure-broadened $\mathbf{O}_2$ lines is described by a complex prediction model (MPM89). For atmospheric conditions of pressure equivalent to altitudes between sea level and 30 km (100 to 1 kPa), this behavior was studied under controlled laboratory conditions. The spectrometer consisted of a one-port Fabry-Pérot resonator, which was excited by an automatic network analyzer. All operations were controlled by a microcomputer, including reference level calibrations at multiple (up to 15, separated by 0.73 GHz) resonances and control of the pressure steps. Introducing gas into the spectrometer cell changed the detected resonance response, from which was deduced a complex refractivity by means of a twin, nonlinear least squares method. The analysis of dry air measurements concentrated on the loss part, expressed as attenuation rate α in dB/km. The detection sensitivity was ± 0.01 dB/km for an effective path length of 0.24 km and a 5 percent coupling ratio of a resonance response. Coupling to a particular resonance and the duration (1-5 hrs) of a measurement sequence influenced the spectrometer performance. Over 4,000 attenuation values are reported. The results were measured between 53.9 and 66.3 GHz in 0.1 GHz frequency increments at eleven pressure steps (1-100 kPa) for three temperatures (7,30,52°C). The measurement uncertainties were estimated to be typically ± 0.05 below 3 dB/km and ± 2 percent for higher values (≤ 18 dB/km). A first comparison of experimental results with MPM89 predictions revealed, in addition to random data scatter, systematic differences that correlate with line broadening and overlap parameters.

Keywords: atmospheric oxygen spectrum; dry air; frequency range: 54 to 66 GHz; frequency, pressure and temperature parameters; laboratory attenuation measurements; parametric studies