A 95 GHz FMCW thermal-noise-limited radar: sensitivity and range-Doppler measurements

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Abstract— We present measurement results of a compact monostatic 95 GHz frequency-modulated continuous-wave (FMCW) radar that demonstrate state-of-the-art radar sensitivity limited only by the receiver thermal noise, for a watt-level transmit power and a 540 K receiver system noise temperature. Thermal noise limited radar performance is achieved by a combination of high transmit/receive (T/R) isolation and an RF circuit architecture with a large degree of phase noise cancelation. High T/R isolation better than 85 dB is achieved combining high-directivity and low-sidelobes T/R horns, with a high efficiency quasioptical transmit-receive duplexer system.

We also present outdoor radar measurements using a variety of targets at different range and velocities, such as rain, freeway cars, clouds, irrigation sprinklers and hillsides, to test the radar range and Doppler capabilities. For a given radar bandwidth and timing operating mode the measurements demonstrate a range and velocity resolution better than 10 m and 0.1 m/s, respectively, and a maximum unambiguous range of 5 km and velocity limit of 46 m/s. The maximum unambiguous velocity limit is tested with the detection of cars in the freeway moving at velocities greater than 30 m/s. Measurements of rain, cars and hillsides verify the maximum unambiguous range, with targets detected in the 4-5 km range frame. Rain measurements at such fine velocity and range resolution allow for the dynamics and potentially the formation of different raindrop populations to be distinguished at different ranges. Detection also of a non-precipitating cloud and its velocity structure, stress the radar's sensitivity and high velocity resolution capabilities.

The radar sensitivity and range-Doppler measurement results present the first demonstration of a thermal-noise-limited FMCW radar with high (1 Watt) transmit power and long-range Doppler detection capabilities. These experimental results together with the compact design, with a single 15 cm diameter primary antenna, makes this 95 GHz FMCW radar uniquely suitable for future space missions for Earth and Planetary Science applications.