SUBMILLIMETER MODEL MEASUREMENTS AND THEIR APPLICATIONS TO MILLIMETER RADAR SYSTEMS

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Abstract

A submillimeter-based modeling system has been developed and employed to obtain imaging and radar cross section (RCS) measurements of scale model targets. In these demonstration experiments three submillimeter frequencies at 1288, 2542, and 3125 GHz, obtained from a CO₂ optically pumped CH₃OH laser were used to model 37, 70, and 90 GHz, respectively. In addition, a CH₃OH laser line at 312.6 μm (7980 GHz) has been used to extend these measurements up to 228 GHz. The results obtained demonstrate that the system is capable of providing quantitative radar data.

Experimental Apparatus and Results

The initial experiments described herein involved imaging studies of scale models [1],[2] of tactical targets. Plastic models (35:1) were assembled, spray lacquered to reduce surface roughness, and aluminized with a 1000 Å layer by vacuum deposition. The models have a bright, shiny appearance, and the rms surface roughness is estimated to be no more than several microns.

The experimental setup of the imaging system is shown in Figure 1. Submillimeter radiation is directed by a mylar beamsplitter through a two-dimensional raster scanning system which scans the beam over a 25 cm diameter 12 spherical mirror. The near plane-wave 2 cm diameter Gaussian beam is focused to a waist and scanned over the target, which is positioned in the focal region of the mirror. The diffraction limited spot size is approximately (λd) or 25 μm for this system. Returns from the target are detected by either a 2K germanium bolometer or a Schottky diode receiver positioned behind the beamsplitter so as to obtain a monostatic image of the target. The submillimeter radiation is chopped and synchronously detected with a lock-in amplifier as the focused spot is slowly scanned over the target. The resulting video output of the lock-in amplifier is displayed on a storage oscilloscope.

Three methanol laser lines at 1288, 2542, and 3125 GHz were selected [3] to model 37, 70, and 90 GHz, respectively, thereby covering a substantial fraction of the millimeter region of interest. Figure 2 shows oscilloscope traces of the scanned radar image of the model target taken at a fixed aspect and depression angle. More recently these measurements have been extended up to 7980 GHz to model 228 GHz.

Narrowband RCS measurements of the fully illuminated target have been made. Initially a monostatic configuration similar to that used in the scan imaging setup was tried. However, the power return is considerably reduced in the fully illuminated RCS measurements, and diffuse scattering of the transmitter signal by the mylar beamsplitter was comparable to the target return. Replacement of the mylar sheet with a highly polished dielectric slab of low loss material such as crystalline quartz should reduce this scattering to a level well below that of the target return and such a beamsplitter is presently being fabricated. In the interim, to demonstrate the modeling system's capability for RCS measurements, a bistatic arrangement was used.

In the bistatic configuration the 2 cm diameter laser beam is expanded 10-fold and collimated. The nearly plane wave radiation illuminates the model which is rotated at fixed depression angles to obtain the target RCS as a function of aspect angle. A second mirror collects the target return and focuses the signal into the bolometer. Figure 3 shows a typical plot of RCS versus aspect angle for the model at a fixed depression angle, a bistatic measurement angle of 90°, and a modeled frequency of 37 GHz. Rapid oscillations in the RCS data, characteristic of target glint, is not observed. This is attributed to the substantial aperture averaging effect of the system's optics [4].

Future Work

We are currently upgrading the system to provide for digital acquisition and processing of data. For scan imaging measurements a dedicated minicomputer controls the illumination of the target by means of a gimbaled off-axis parabolic mirror which is driven by stepping motors. Each point on the target is individually addressed with a dwell time chosen to optimize the signal-to-noise for a given adjustable spot size. The data from the detector is digitized, averaged, stored on magnetic disks and finally displayed in a three dimensional format via interactive graphics. A schematic representation of the system is shown in Figure 4.

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References


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Figure 1. Initial Analog Model Facility.

Figure 2. Submillimeter Images of the Model Target.

Figure 3. Fully Illuminated RCS Measurements.

Figure 4. Digital Scan Imaging System.