Development of an electron cyclotron emission imaging system

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Despite the logistical challenges of the past year, we were able to proceed with the fabrication of the electronically variable reflective surface (EVRS) prototypes and the construction of an anechoic chamber for characterizing microwave optical components. (See Fig. 1.) Final assembly and testing of EVRS prototypes will occur this summer, after which the full electron cyclotron emission (ECE) imaging system can be constructed and installed on one of the Cyclotron Institute's electron cyclotron resonance ion sources (ECRIS).

The anechoic chamber houses a 17-45 GHz scalar network analyzer: A tracking generator with an up-converter drives a fixed position low-gain microwave transmitter horn, and a moveable high-gain microwave receiver horn is connected through a down-converter to a spectrum analyzer. The receiver horn and device-under-test (DUT) are mounted onto concentric turntables, allowing the microwave antenna horns and DUT to be positioned at arbitrary relative angles. The reflectivity and transmissivity of microwave optical elements for the final ECE imaging system can therefore be characterized at all important angles of incidence over the K- and Ka-bands.

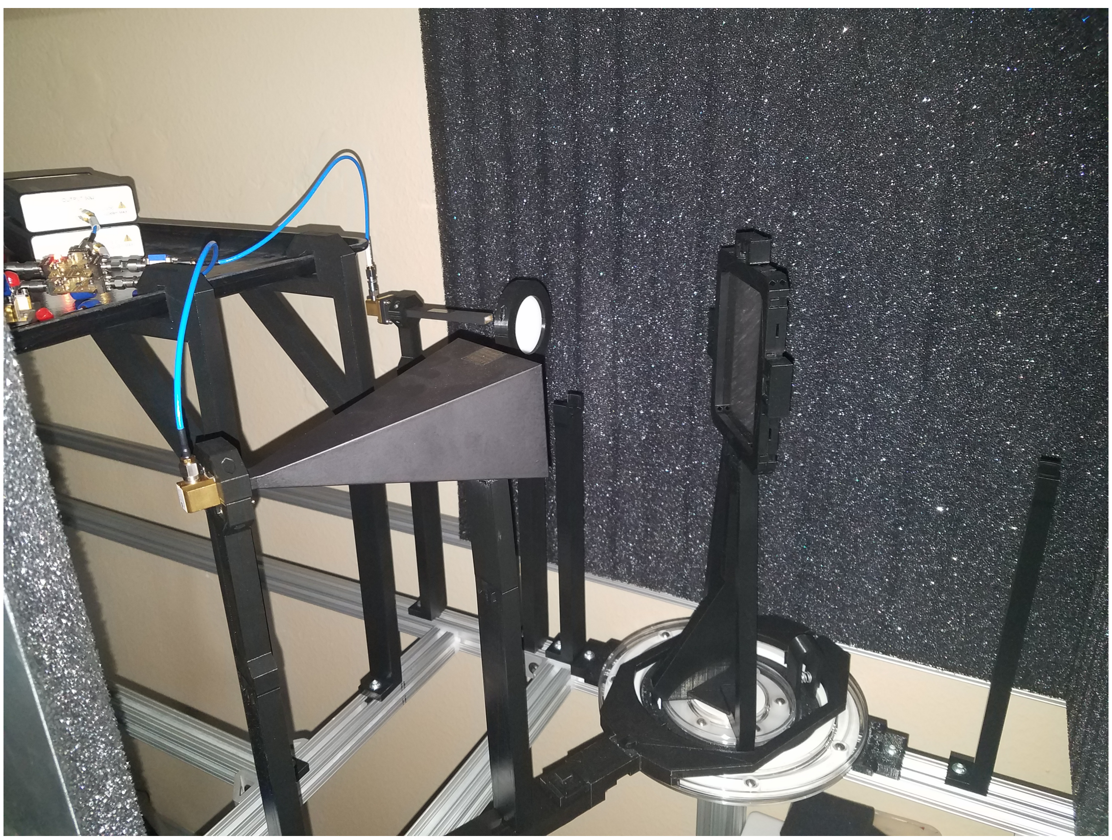

Fig. 1. View into anechoic chamber with calibration plate DUT.

A number of refinements to the anechoic chamber were made to ensure that microwave components behave like conventional optical elements. The combination of antenna gains adheres to the basic assumptions of geometric optics while still maintaining good angular resolution at the receiver. 3D-printed PLA posts, frames and clamps have been developed for mounting all microwave antennas, lenses, and DUTs. This plastic hardware demonstrated minimal reflectivity, as expected, while still being strong enough to replace metal mounting hardware. Off-the-shelf carbon-loaded foam panels along the walls of the anechoic chamber were found to be sufficient for absorbing stray microwave signals and dampening unwanted reflections. The only remaining optical issue to be addressed is the potential for standing waves to develop along the optical axis, which should be resolved by introducing the proper thickness of a carbon-film attenuator into the optics.

Some issues were found with the electronics themselves, including unwanted intermediate frequency (IF) feedthrough and standing waves developing on the longer coaxial cables, but those issues were addressed with an additional filter and additional attenuators. Neither off-axis coupling of the antennas nor the location of the electronics inside the anechoic chamber appear to contribute appreciably to noise levels.

Minor design revisions were made to the EVRS printed circuit boards (PCBs) in order to fit with available materials and manufacturing capabilities, but the revisions did not change the overall concept of operation or intended usage in the final detector. The revisions chiefly enabled PCB finishing operations to be carried out in-house. Facilities to perform those finishing operations – screenprinting carbon ink and electrical component mounting – have been built over the past year as well.

The EVRS test program planned for this summer will use the anechoic chamber to characterize and compare bare copper arrays, arrays with carbon traces, fully assembled PCBs, and several array design permutations. This test program will both verify the operation of components needed for the final ECE imaging system and validate the EVRS design principles inferred from simulations.

If the EVRS operate as expected, assembly of the ECE imaging system will be straightforward and will proceed immediately. However, before installation, the microwave lenses and waveguides needed to transport the ECE signal out of the ECRIS will also be characterized using the same anechoic chamber built for the EVRS. Like the tests of the EVRS prototypes, the measurements of these other optical components will test the results of design simulations and provide calibration curves for the final instrument.

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