Testing Antenna Chip-Sets Under Thermal Conditions

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***Abstract*— The wireless community is concerned with proper operation of devices over wide temperature ranges, and as such the governing bodies are imposing radiated test requirements at hot and cold temperatures. These requirements become unique when new radio technologies are highly integrated, and the antenna is embedded on a chip or chip-set, or in packaged devices. The challenge starts with achieving junction temperatures from -30C to +90C while reaching the desired temperatures quickly and holding the temperature extremes for extended periods of time. The temperature change causes thermal expansion of antenna materials and may affect antenna performance under different thermal conditions. Furthermore, efficient heating and cooling is environmentally responsible and reduces lab power and HVAC costs. It also increases the longevity and safety of the device during field use. The goal is to measure antenna and digital radio quality metrics under these conditions extreme temperature conditions, while providing minimal perturbation of the beam. The paper presents a solution meeting these requirements and which has already deployed in industry. Performance data will also be presented. The users of the deployed systems continue to push for more temperature range and field of view of the measurement system. R&D efforts underway as well as future work will conclude the paper. Index Terms*—antenna, integrated antennas, 5G, temperature test, measurement.**

I. Introduction

Testing antenna performances over temperature has only been sparsely reported in the literature. Cold temperature testing was reported in [1] where a liquid Nitrogen Dewar was used with thermal conduction to cool an antenna under test to -100C in a spherical near-field antenna measurement system.

The sensitivity of performance parameters to temperature variations will come from the antenna itself, but integrated RF electronics can be an even greater concern. In past applications, the antenna was easily separated from the electronics such that thermal variations of the RF components could be tested in conducted modes independently of the antenna. The current focus on wireless developments for 5G wireless chipsets and small active phased arrays in millimeter wave frequencies involve high level of integration and components do not accommodate hard wired connections.

Table 1 Low and high temperatures requirement at chip junction level

Minimum Temperature	Maximum Temperature
-40°C	+90°C

This technology shift has led to increased requirements to measure radiated device performances over temperature.

A. Test Requirements

This paper will describe a small anechoic chamber and thermal test system that was developed to enable testing of small integrated antenna chipsets over temperature including the radiation patterns. The chip-sets have a requirement to be tested at the extreme temperatures given in Table 1

II. Over the Air Temperature Testing

Antennas are tested in anechoic chambers using instrumentation, cables, RF components, positioning equipment and absorbing materials that may not support accurate measurements under large thermal variations. To avoid cooling or heating the entire anechoic chamber with all its equipment and all the detrimental effects that would entail, the radiating device under test (DUT) is instead placed inside an insulating enclosure (radome) which is transparent to electromagnetic waves.

A generally accepted principle of testing an antenna versus temperature follows the following process:

a) Measure the DUT in an antenna measurement system, chamber at ambient temperature without radome
b) Cover the DUT with the radome and measure the DUT again in the same system at ambient temperature. This step will show the impact of the radome on the antenna pattern.
c) Measure the antenna including the radome over the full temperature range

By comparing the results from test c) and b) above, the variation of DUT performances versus temperature can be estimated. This process assumes the radome has negligible change in transparency vs. temperature. This assumption appears to hold as long as there is no condensation nor formation of ice on the radome.

A. Description of the Radome

The radome described in this paper is machined from a polymethacrylimide (PMI) rigid and closed cell foam used for lightweight sandwich construction. This material offers high stability over temperature and has a dielectric constant that is less than 1.05 providing excellent RF transparency and

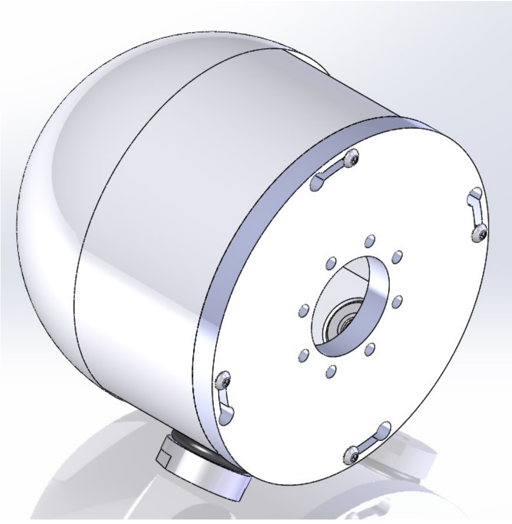

Fig.1 – 3-D Model of Radome

very low losses. Fig.1 shows the foam radome with machined interfaces to accommodate thermal ducting for both supply and vents. The radome also includes mounting provisions for attachment to a positioning system. The attachment to the positioner is via a twist/lock mechanism. A small hole is also provided to accommodate a thermocouple.

B. Testing the RF characteristics of the radome

The radome was designed so that the DUT is radiating without obstruction over a full hemisphere and through homogenous wall thickness and without any glue joints. Fittings for hoses and thermo-couples are all behind the DUT.

To verify that the manufactured radome had little impact on the antenna pattern of the DUT, an experiment was undertaken using a Standard Gain Horn in V-Band (60GHz). Fig. 2 and Fig. 3 show the test setup in a spherical near-field system (μ-Lab) without and with radome, respectively. An overlay of the co-polar radiation patterns with and without the radome is show in Fig. 4. It can be observed that the differences in radiation pattern is very small even at relative pattern levels of 30dB below the boresight peak. Losses through the radome were measured on boresight to be < 0.18 dB at 60 GHz. It is anticipated that at lower frequencies losses will be even lower.

C. Description of the antenna measurement system

A small far-field antenna test chamber was designed and constructed with a “roll-over-azimuth” (a.k.a “phi-over-theta”) DUT positioning system as shown in Figs. 5 and 6. Due to the dimensions and flexibility of thermal hoses and with shadowing from the positioning system, accurate antenna patterns can only be obtained in partial forward hemisphere.

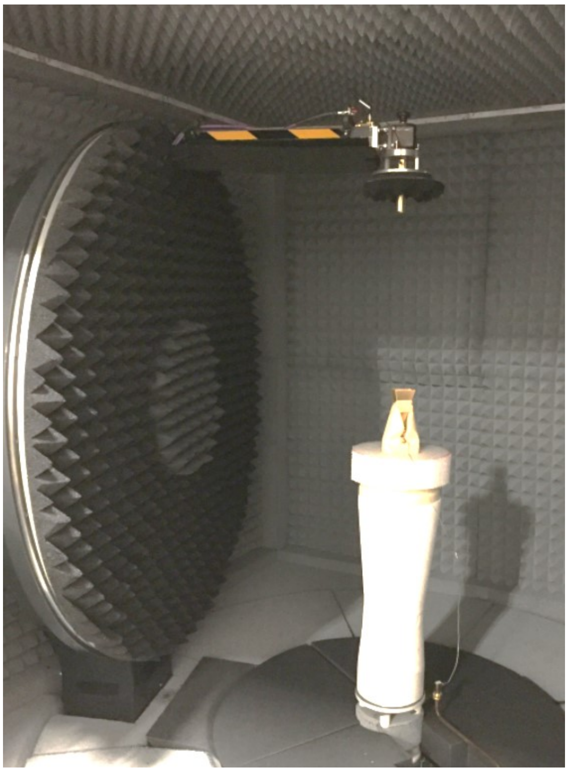

Fig. 2 V-Band Standard Gain Horn Tested in a spherical near-field antenna measurement system

Fig. 3 Test with V-band Standard Gain horn covered by the radome.

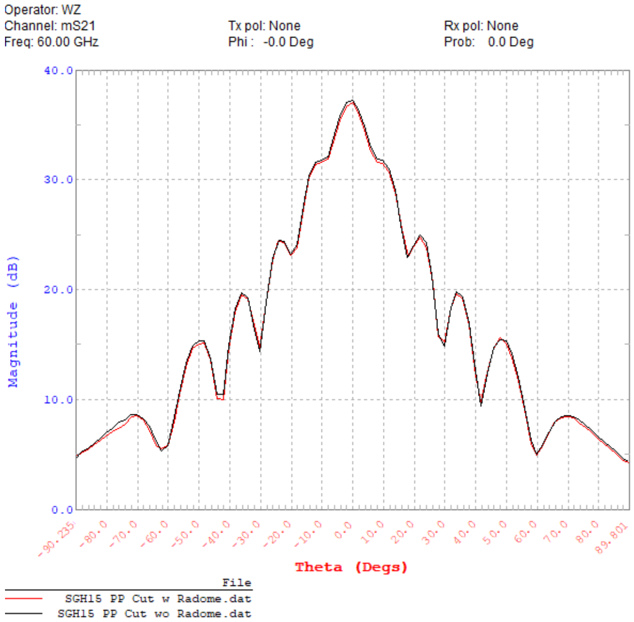

Fig. 4 Comparison of radiation patterns of the standard gain horn with (red) and without the radome (black)

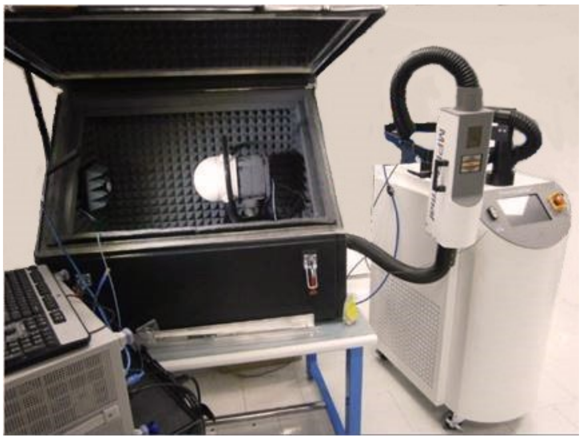

Fig. 5 Picture of radome installed on DUT in a small antenna test chamber that is also connected to a thermal control equipment providing hot and cold air as needed.

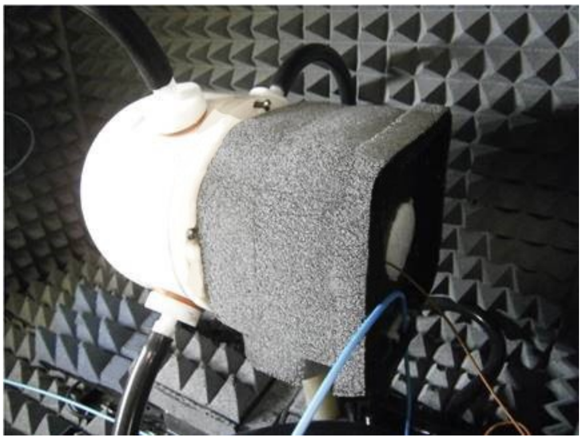

Fig. 6 Close-up picture of radome, thermal hoses, and the roll positioners covered with absorbing materials.

D. Results and Summary

Using the methods and systems described in this paper, the authors have validated that a small antenna test system can be interfaced with standard "air-stream" thermal control equipment for practical validation of device performance from -40°C to +90°C. Experience with the thermal antenna chamber showed that it is very important to flush the chamber and radome with dry air to reduce icing on the hoses and other equipment in the chamber. The thermal test system is currently also being interfaced to spherical near-field antenna measurement systems that will provide near-full sphere measurements. It is anticipated that testing antennas and their integrated RF components over temperature will be become increasingly important with continued miniaturization and integration of antennas and the associated electronics.

REFERENCES

[1] A. Giacomini, et al,"Thermal Testing of Small Antennas in Multi-Probe Spherical Near-Field Systems", AMTA, Atlanta, Georgia, USA, October 15-20 2017