

# High Temperature Antenna Measurement System with GSG or GS Contact Probing Capability

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## Introduction

Applications that require data transmission at high temperatures are becoming more common due to growing commercial and military needs. Antennas are an indispensable part of these systems and the ability to characterize them at elevated temperatures is quite complicated with little or no information being reported on the subject [1]. This paper describes a measurement system that can characterize planar antennas up to 600°C with ground-signal-ground (GSG) or ground-signal (GS) probe contacts. The return loss and radiation patterns of a folded slot antenna (FSA), designed to operate at 5 GHz (no ground plane on back side) and fabricated on an alumina substrate, are presented at room temperature (RT) and 250°C [2]. All measurements were made with Agilent's Precision Network Analyzer (PNA) E8361. The return loss and radiation patterns were also measured on a Styrofoam chuck to illustrate the effect the high temperature measurement system has on the patterns.

## High Temperature Measurement System

The high temperature antenna measurement system is shown in Figs. 1a and b. The system consists of a ceramic heater (A) which sits on three pieces of shuttle tile which are 2 inches tall, 6 inches long and 6 inches wide (B). A thermocouple (C) is positioned on the ceramic heater to accurately record the temperature of the heater and a GSG probe (D) is used to make contact with the FSA (E). A 2 to 18 GHz wideband gain horn (F) is used to record the radiation patterns and gain of the FSA. A rotational stage and Plexiglas arm (G) are used to rotate the gain horn around the FSA. A distance of 54 cm separates the FSA and the wideband gain horn but this distance can be extended to 85 cm. The base of GSG probe positioner and thermocouple sit on a table and extend onto the ceramic heater which is supported by a Styrofoam arm that extends out from the bottom of the table thus giving the system 360° pattern characterization. The entire chamber is 7 feet long, 5 feet wide and 8 feet tall. Three of the chamber walls are retractable to accommodate antennas that operate at longer wavelengths which require more area to ensure farfield. All the walls, floor and ceiling are covered with RF absorber. The rotational stage, PNA, and temperature are controlled by a LabVIEW program developed for this system.

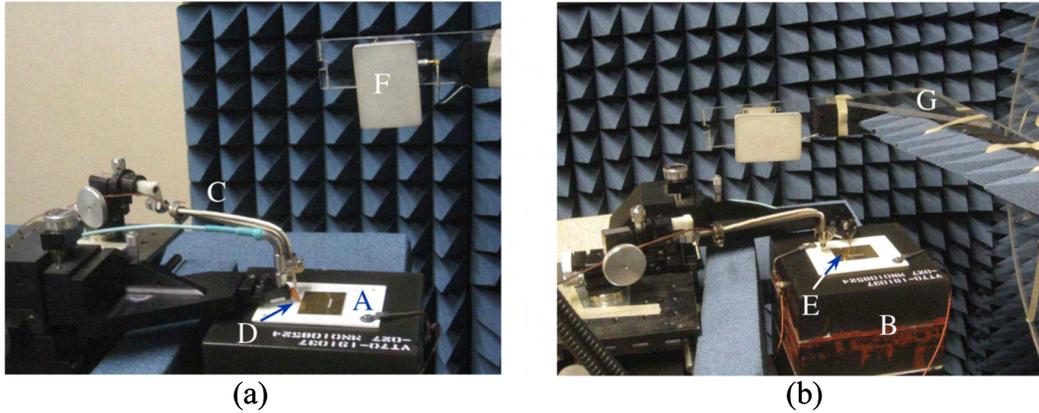


Fig. 1. High temperature antenna measurement system with GSG probing capabilities, a) H-field and b) E-field measurement configuration.

### Measured Results

The return loss of the FSA was recorded on Styrofoam and on the ceramic heater/shuttle tile chuck to determine the effects the ceramic heater had on the performance of the FSA and the results are seen in Fig. 2. A calibration was performed at the GSG probe tips using a GGB Industries CS-5 calibration substrate and PNA 1-port calibration routine. When the antenna is measured on Styrofoam, the antenna operates at its design frequency of approximately 5 GHz. The antenna shifts down to 4 GHz when measured on the ceramic heater and shuttle tile. The antenna was measured on a chuck made of only shuttle tile and it was determined that the shuttle tile had no effect on the return loss. This is because the shuttle tile has a dielectric constant,  $\epsilon_r$ , of 1.2 but the ceramic heater has an  $\epsilon_r$  of approximately 4.4 which reduces the operating frequency of the antenna. The shift in resonant frequency was verified in Ansoft's High Frequency Structure Simulator (HFSS) [3]. The magnitude of  $S_{11}$  remains relatively constant at approximately 16 dB on both the Styrofoam and heater chucks. Also it was noticed that the resonate frequency of the FSA is very sensitive to its placement on the heater. This is due to the heater elements that are within the ceramic heater. Therefore, great care was taken to maintain its position in the center of the heater throughout the measurement process.

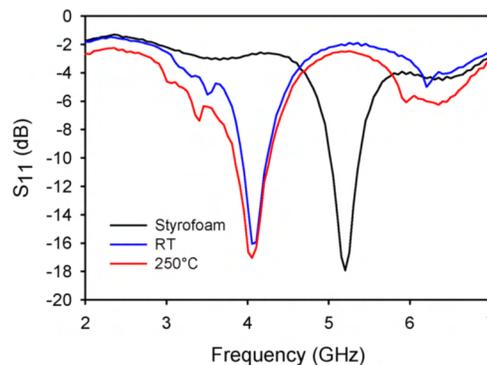


Fig. 2. Return loss of FSA on Styrofoam and ceramic heater/shuttle tile chucks at room temperature and 250°C.

The radiation patterns are shown in Figs. 3a and b. Figure 3a depicts the H-co and –cross pole patterns on Styrofoam and the ceramic heater at RT and 250°C. Figure 3b illustrates the same for the E-field. All the radiation patterns are bidirectional with the E-field patterns having a more pronounced null at 0 and 180° which is characteristic of an FSA. The E-co patterns on Styrofoam and heater displays a partial null at -60°. This is due to the interference of the metal arm that extends from the base of the GSG probe positioner when in the E-field configuration and can be seen in Fig. 1b. Figure 3a and b shows that the gain at 90 and -90°, for both the H- and E-field do not have the same magnitude. The discrepancy between the magnitudes of the gain at 90 and -90° is due to the ceramic heater. At 90° the gain horn is directly above the FSA and at -90° the gain horn is directly below the FSA. Thus more radiation is focused downward through the ceramic heater due to the thickness and dielectric constant of the heater, which acts as a lens. The phenomenon is also present on Styrofoam but not as predominant. The FSA and other omni-directional antennas are the hardest to measure on this system and therefore this is a worst case test. Directional antennas such as patches would not be as impacted by the surrounding system.

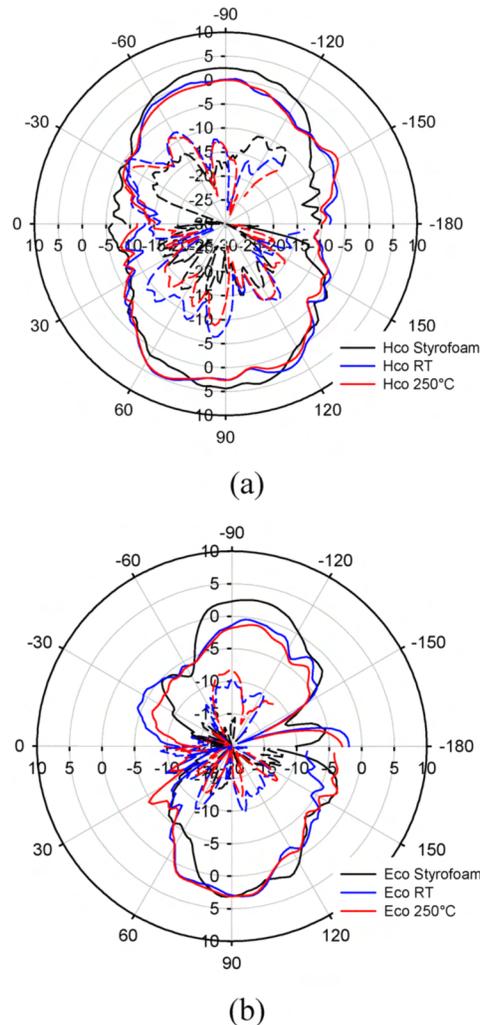


Fig. 3. (a) H-field and (b) E-field radiation patterns on Styrofoam and heater.

## Conclusion

A system to measure the return loss, radiation patterns and gain of planar antennas with GSG or GS probe connects at high temperatures has been presented. Antennas can be heated to 600°C and a radiation sweep of 360° is possible. The return loss, radiation patterns and gain of a FSA have been presented on Styrofoam and ceramic heater/shuttle tile chucks at RT and 250°C. The antenna was measured on a Styrofoam chuck to show the effect the ceramic heater has on the measured data. The heater/shuttle tile chuck shifts the resonant frequency from its design frequency of 5 GHz to 4 GHz but its effect is minimal on the magnitude of  $S_{11}$ . The magnitudes of the gain at 90 and -90° are not the same, which is due to the ceramic heater acting as a lens and focusing more radiation downward from the antenna through the ceramic heater. The phenomenon is also present on Styrofoam but not as predominant. The FSA and other omnidirectional antennas are the hardest to measure on this system and therefore this is a worst case test. Directional antennas such as patches would not be as impacted by the surrounding system.

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