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Wireless Temperature Sensor Performance

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Dr. Otto J. Gregory Distinguished Engineering Professor at the University of Rhode Island and the founder and Director of the URI Center for Sensors and Instrumentation Research. Prior to this, he was Director of the Rhode Island Center for Thin Film and Interface Research, a joint Brown University-University of Rhode Island NSF Engineering Center of Excellence. He has held several administrative positions at the University of Rhode Island, including Associate Dean of Research and Graduate Studies. During the past twenty five years, his research has focused on thin film sensors for harsh environments, specifically for advanced instrumentation for gas turbine engines. Dr. Gregory has published more than 85 peer reviewed journal articles in high temperature materials science, which has provided the background for 22 US Patents. Currently, Dr. Gregory is developing passive wireless strain and temperature sensors for the gas turbine engine environment and thin film strain and temperature sensors for CMC's.

WIRELESS SENSOR TECHNOLOGIES

UNIVERSITY OF Rhode Island

Outline

Introduction

how the wireless temperature sensor works

components of the wireless temperature sensor

Experimental

Results

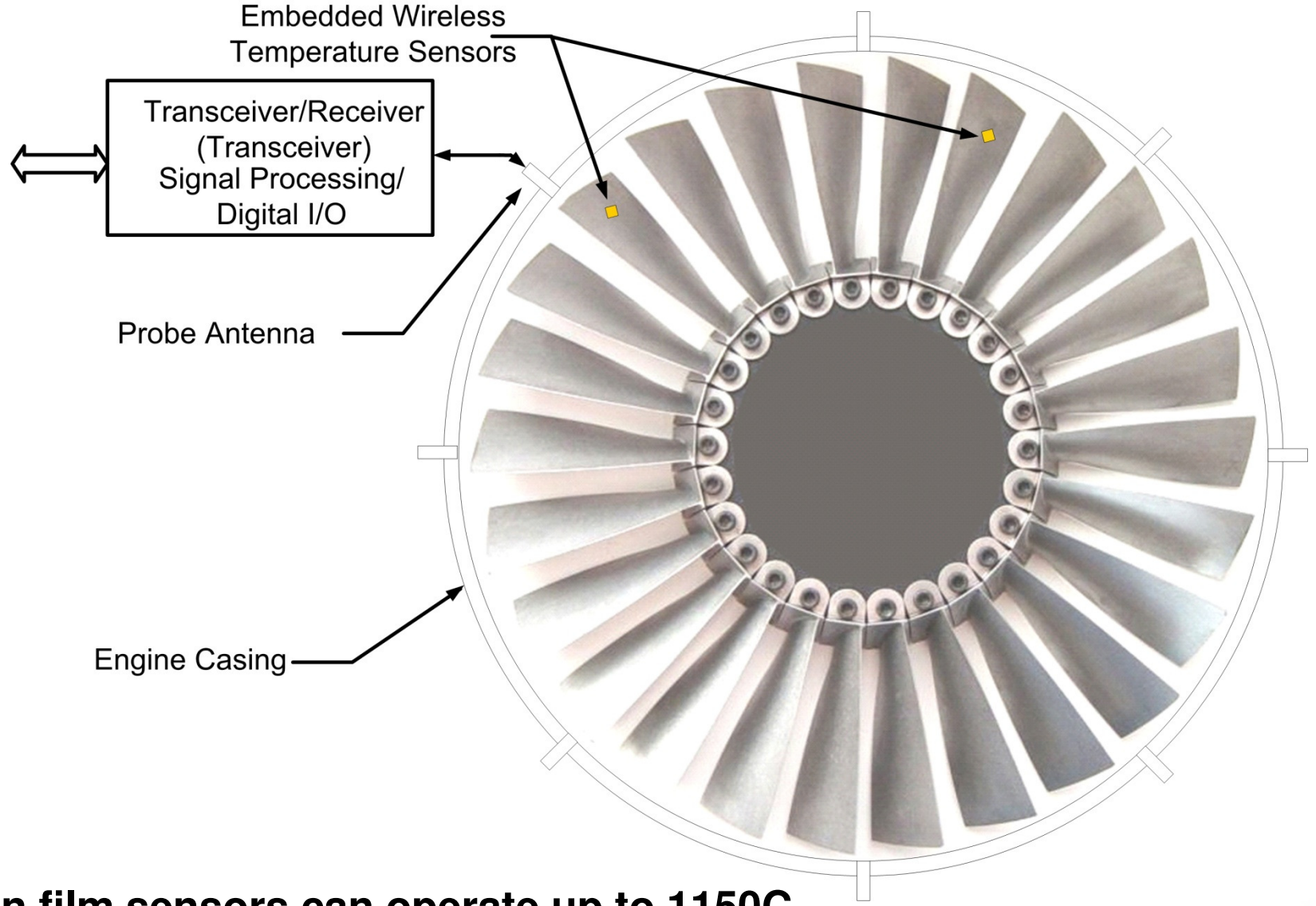
characterization of wireless sensor components

integrated sensor performance

characterization of engine environment

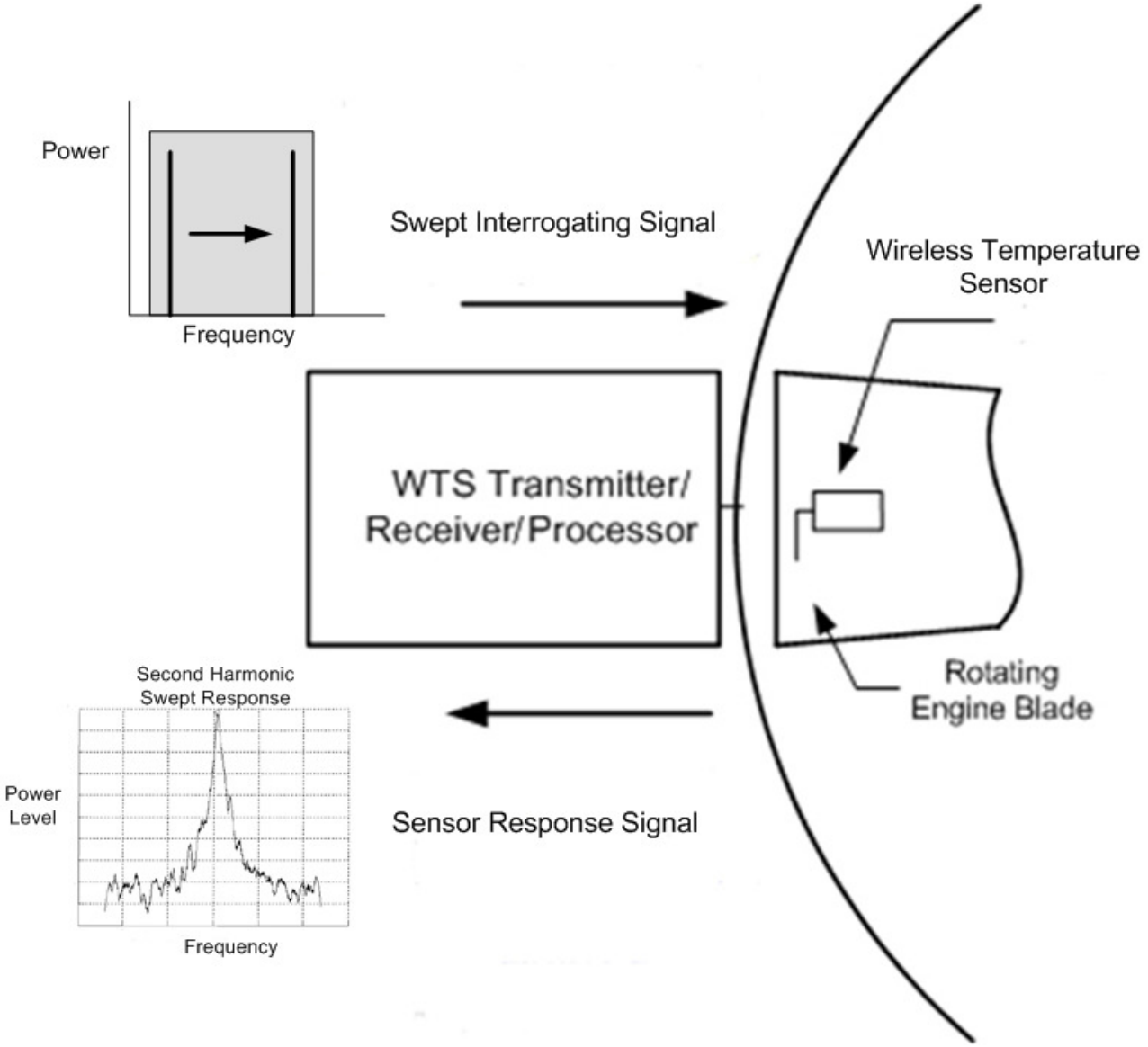
Summary

Wireless Temperature Sensor: passive wireless sensor concept

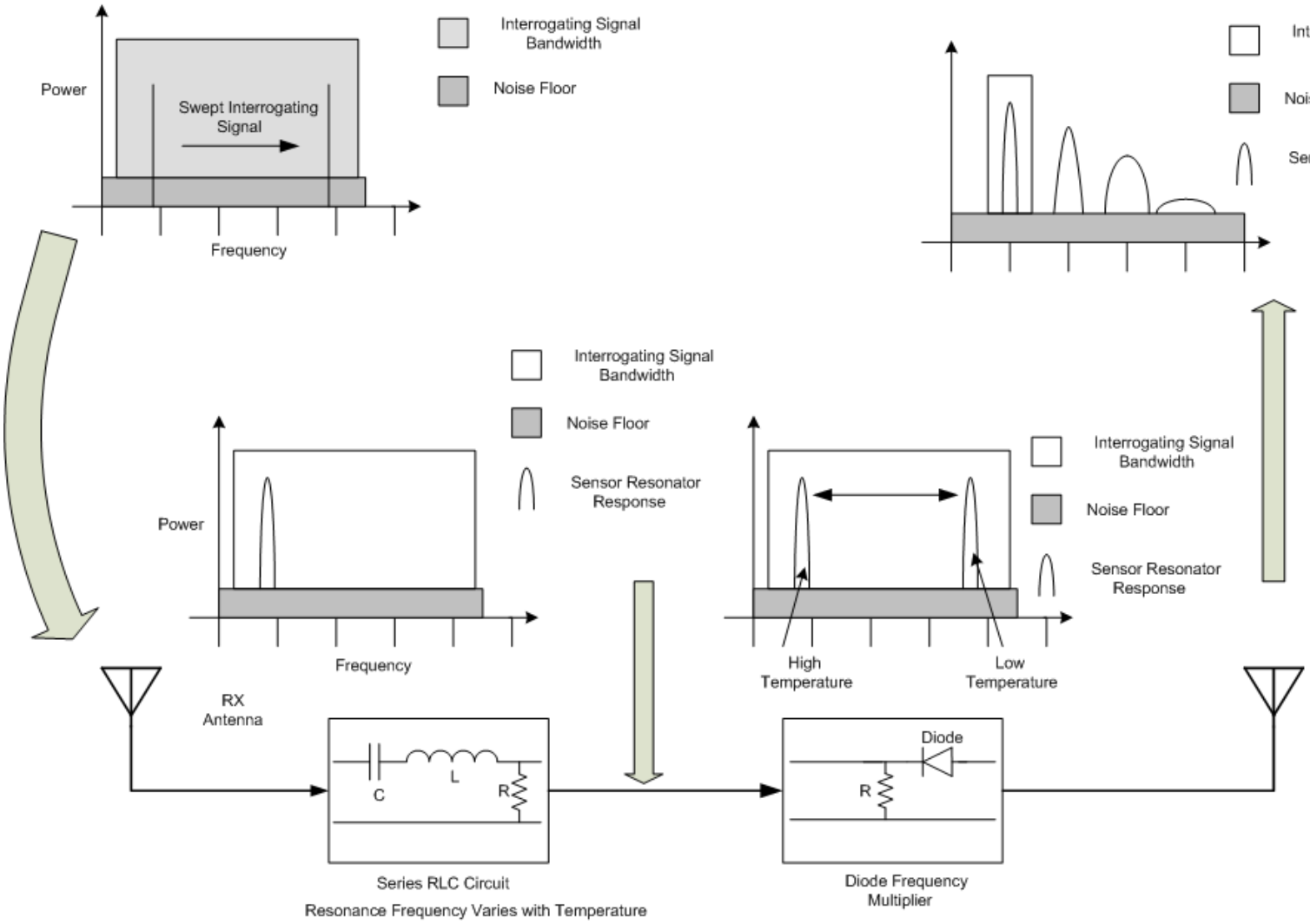


Thin film sensors can operate up to 1150C

System Interrogation Concept



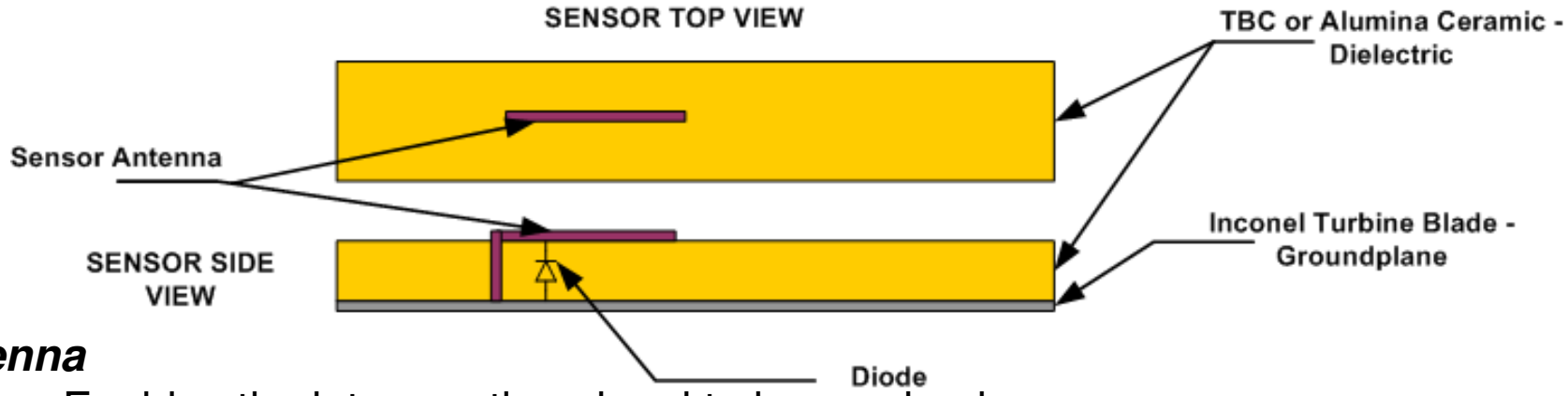
How does the passive wireless temperature sensor work?



Wireless Temperature Sensor: characteristics of the passive thin film sensor

- Wireless sensor is passive: requires no power to operate
- Wireless sensor can operate in the hot section of gas turbine engines without affecting gas flow path….thin film integrated sensor has extremely low profile (well within boundary layer thickness)
- Wireless sensor can be “printed” on a blade or other component surface using lithography / thin film deposition
- Wireless sensor has a small footprint and thermal mass: will not affect vibrational characteristics of the blades, exhibits a rapid response and can measure the true surface temperature of components

Wireless Temperature Sensor: Components of passive sensor



Antenna

Enables the interrogating signal to be received
Determines the frequency of operation of the sensor
Enables the return signal to be transmitted back the the Tx/Rx/Signal Processing

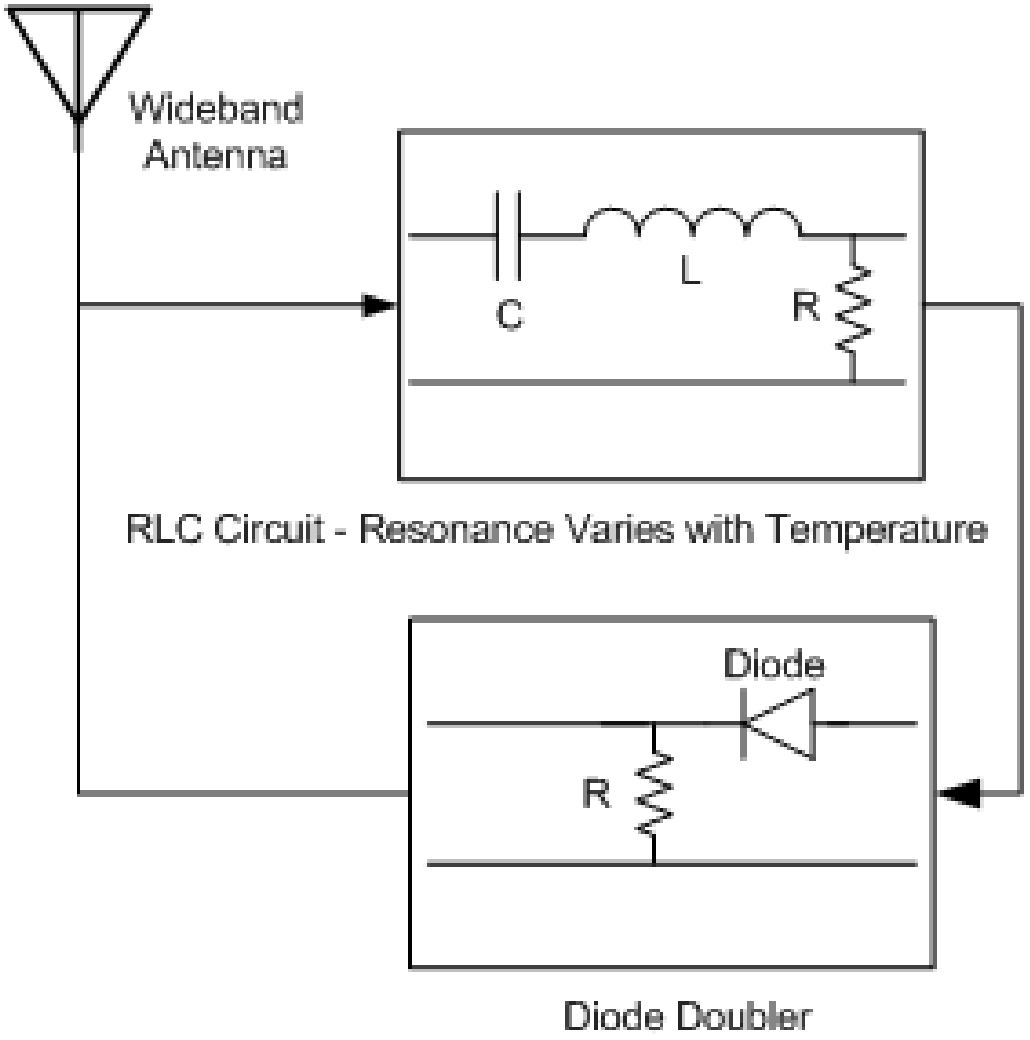
Diode

Produces RF harmonics of the interrogating signal (as filtered by the antenna) which allow the return signal to be easily separated from the interrogating signal by the Tx/Rx/Signal Processing

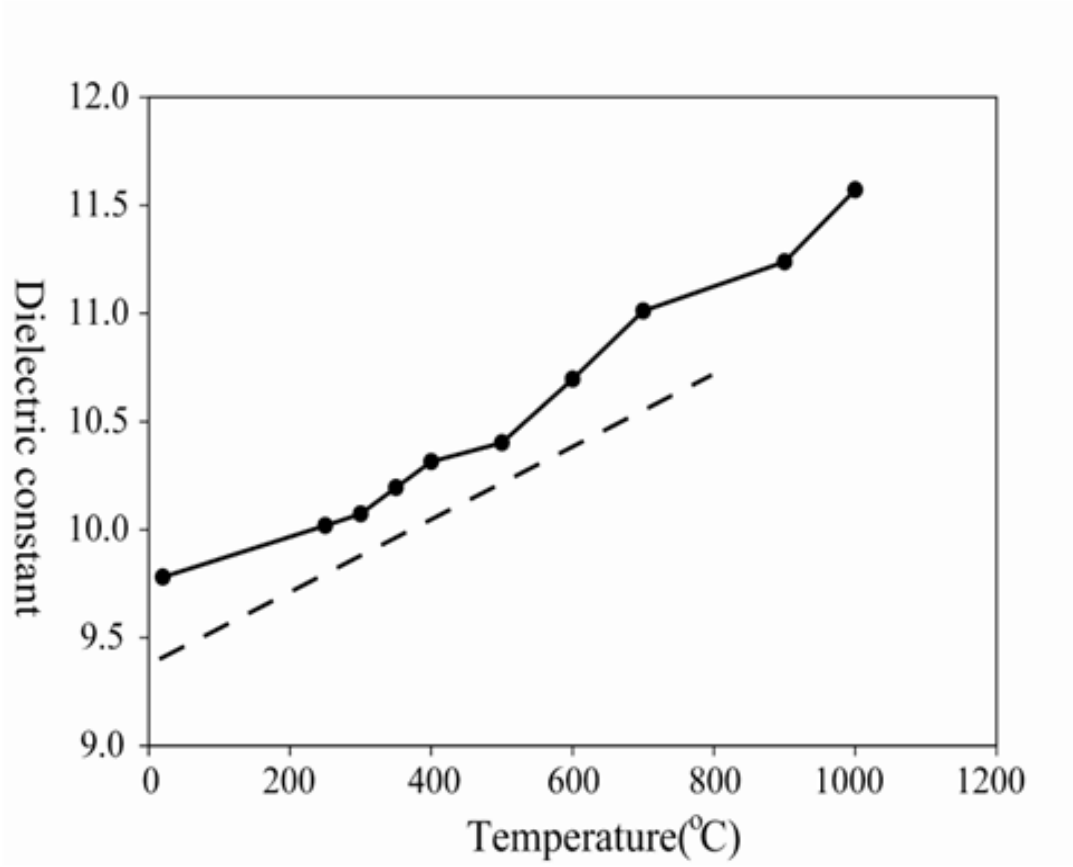
Dielectric (Alumina or TBC)

Establishes the desired temperature-dependent electrical properties (DK, dielectric constant) which alters the antenna center frequency as the temperature changes

Wireless Temperature Sensor; Equivalent Circuit



Alumina DK Temperature Dependence

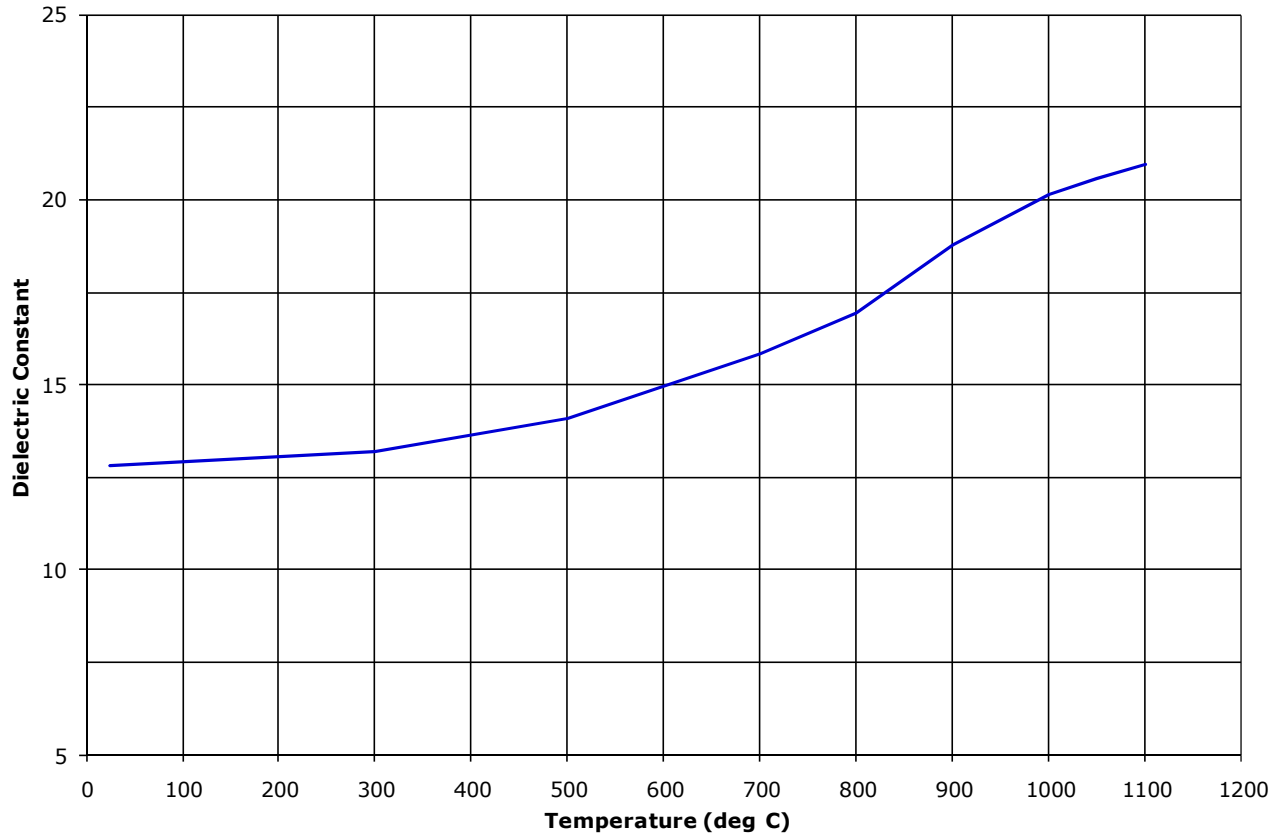


- Measured dielectric constant temperature dependence for alumina
-- Literature value dielectric constant temperature dependence for alumina

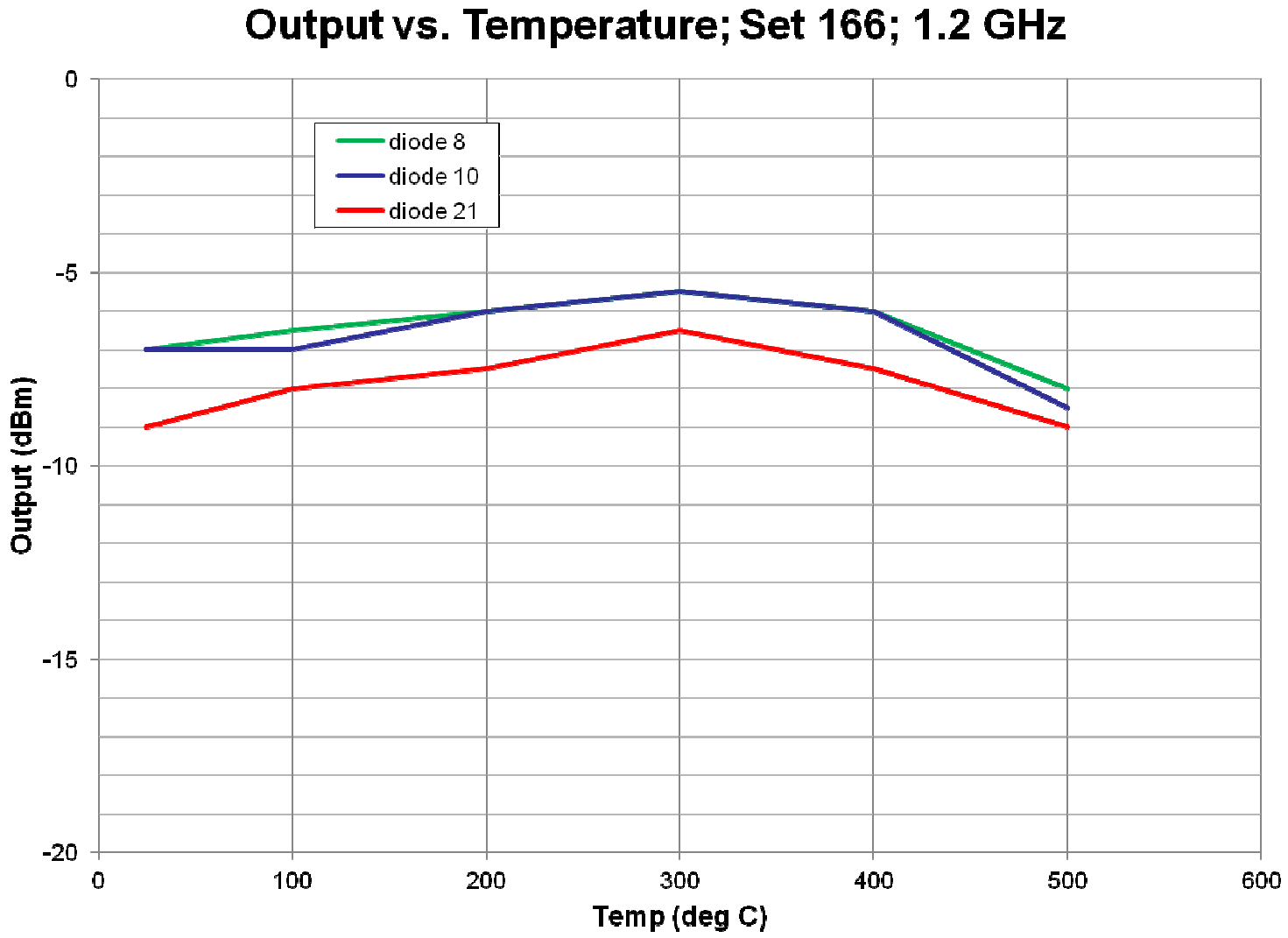
* "Dielectric properties of alumina ceramics in the microwave frequency at high temperature", Kim. et.al., *Solid State Phenomena Vols. 124-126, p.743-746 (2007)*

Measured DK of YSZ TBC

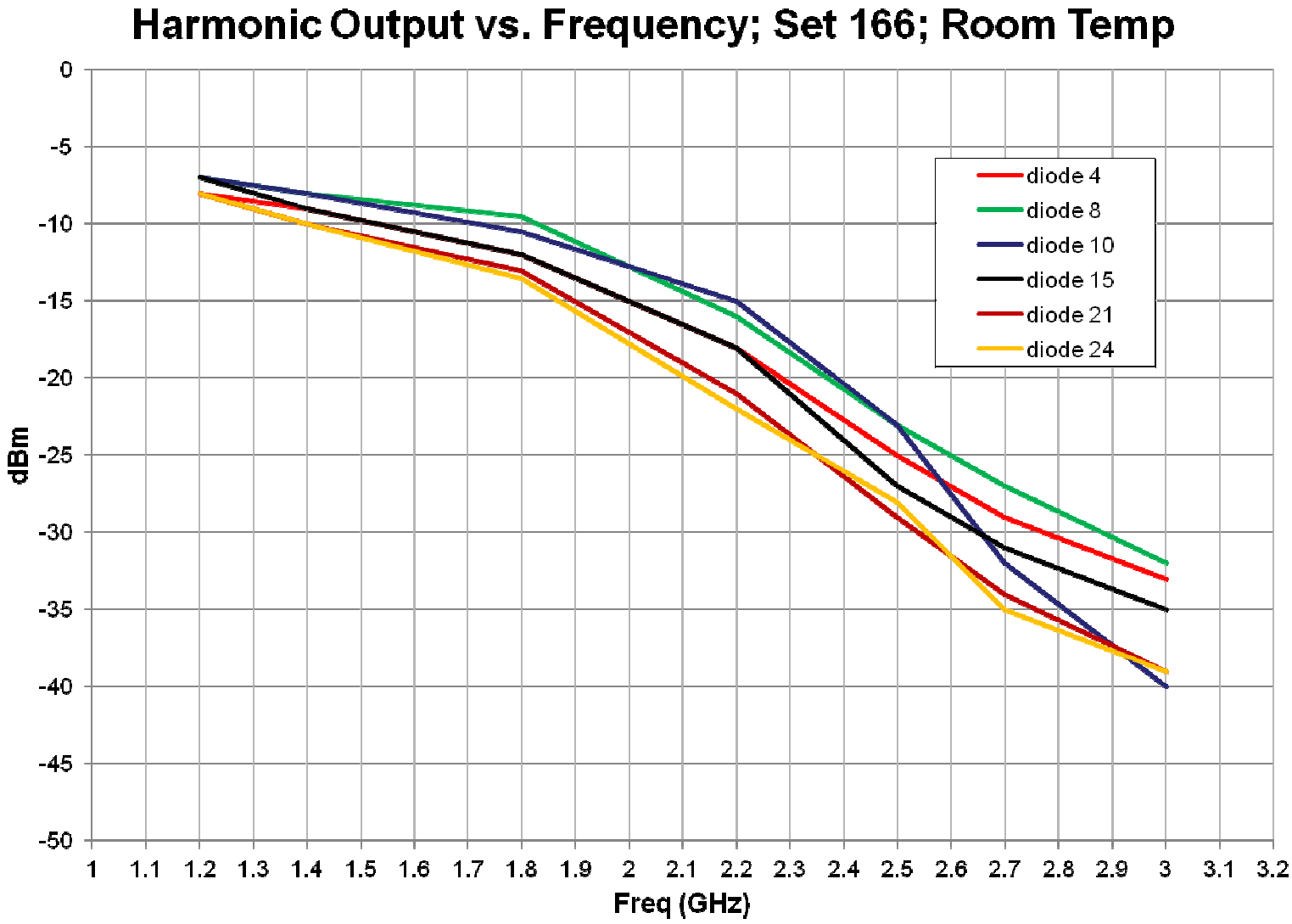
- Does TBC possess similar DK temperature dependence?
- Experiments showed that yttria stabilized zirconia (YSZ) is acceptable for wireless temperature sensor operation



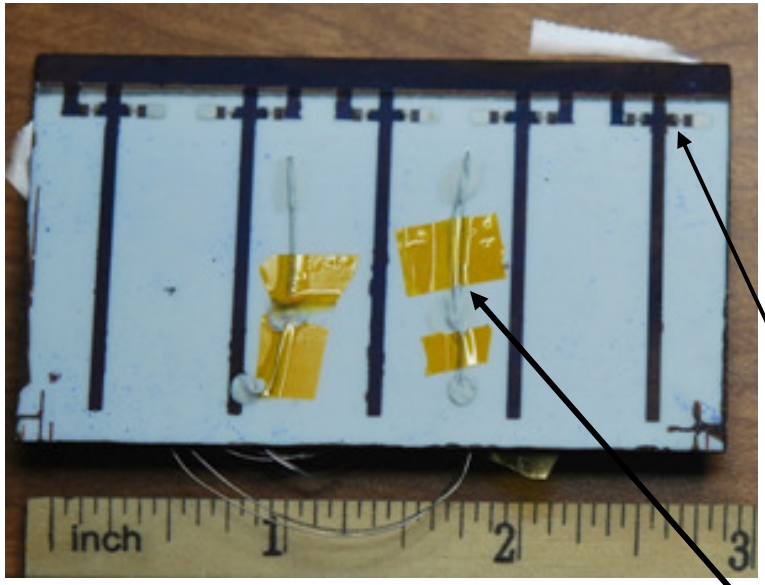
Thin Film Schottky Diode: RF Harmonic Output as a Function of Temperature

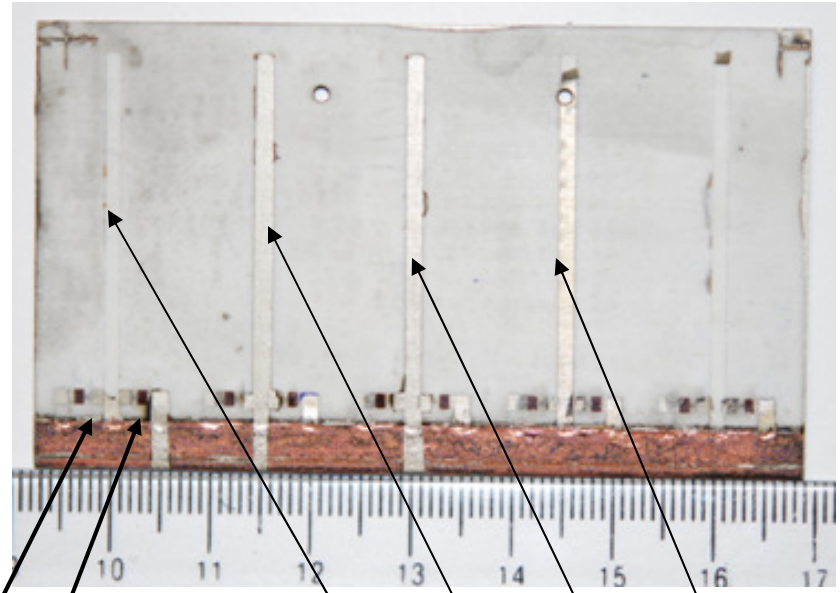


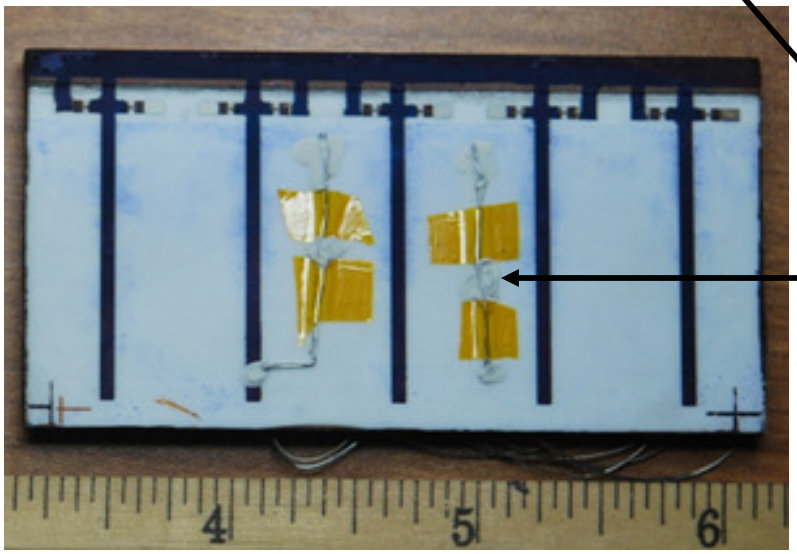
Thin Film Schottky Diode: RF Harmonic Output as a Function of Frequency



Wireless temperature sensors: w/ high purity alumina dielectric





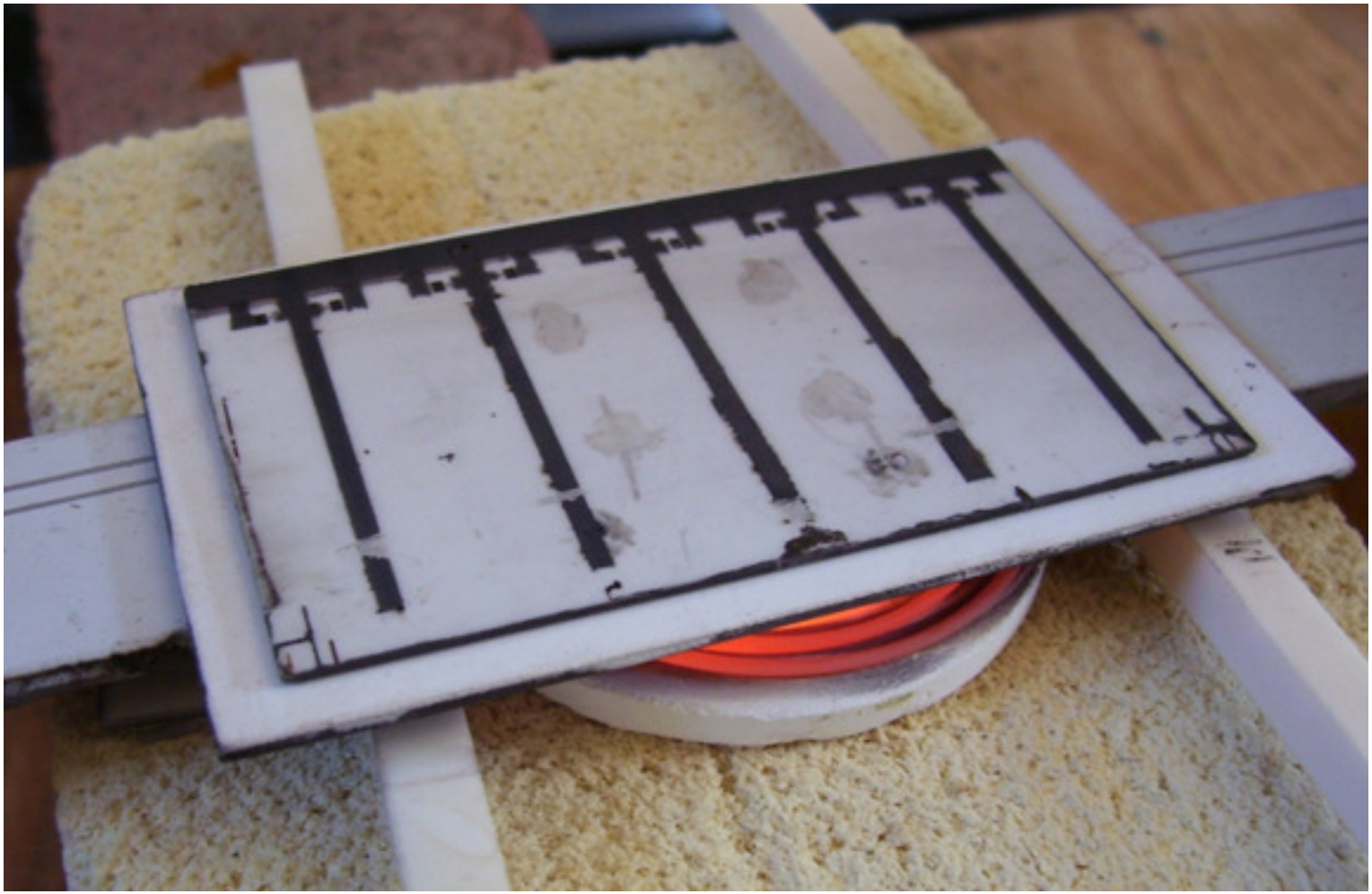


diodes

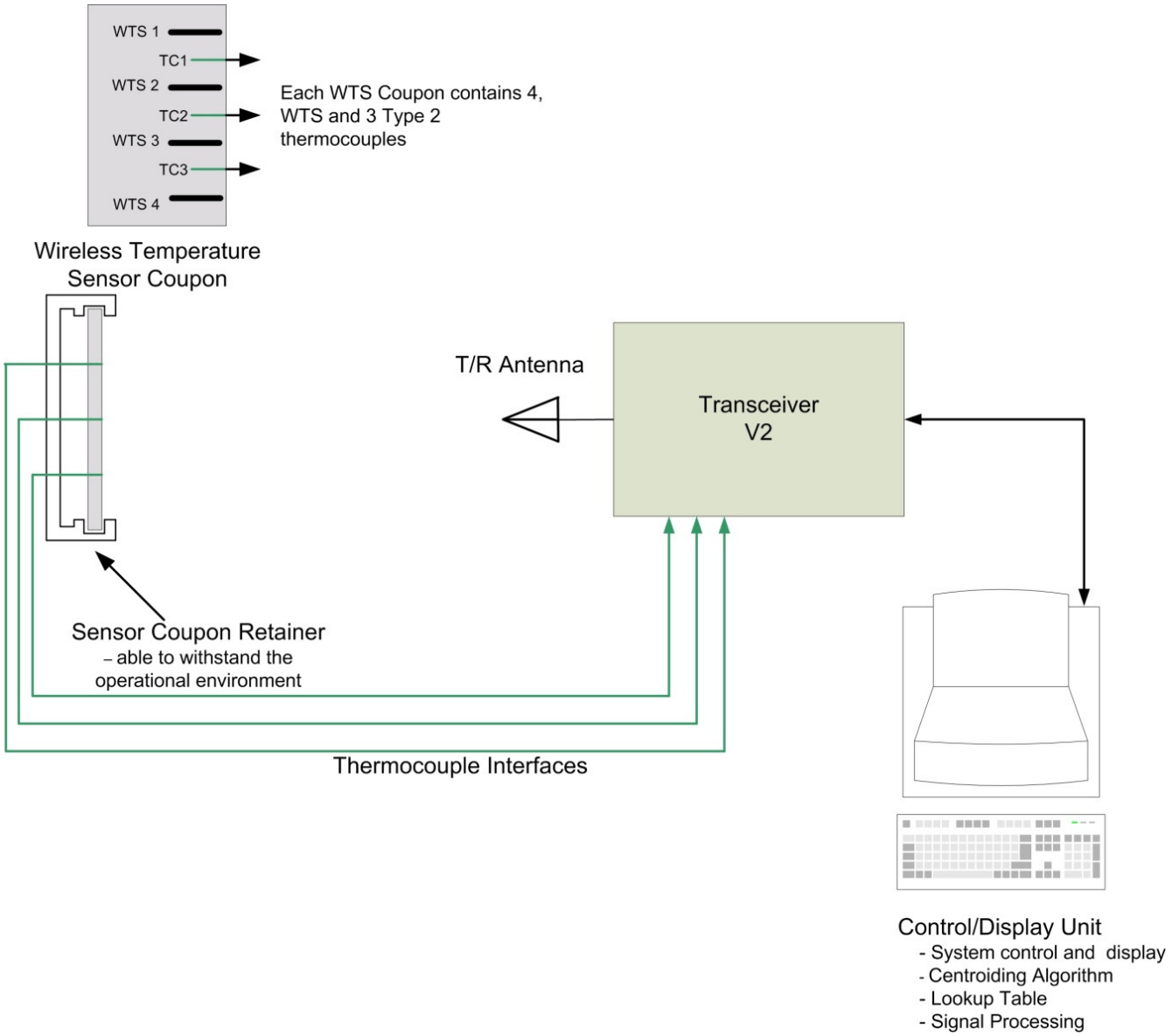
thin film antennae

embedded wire thermocouples

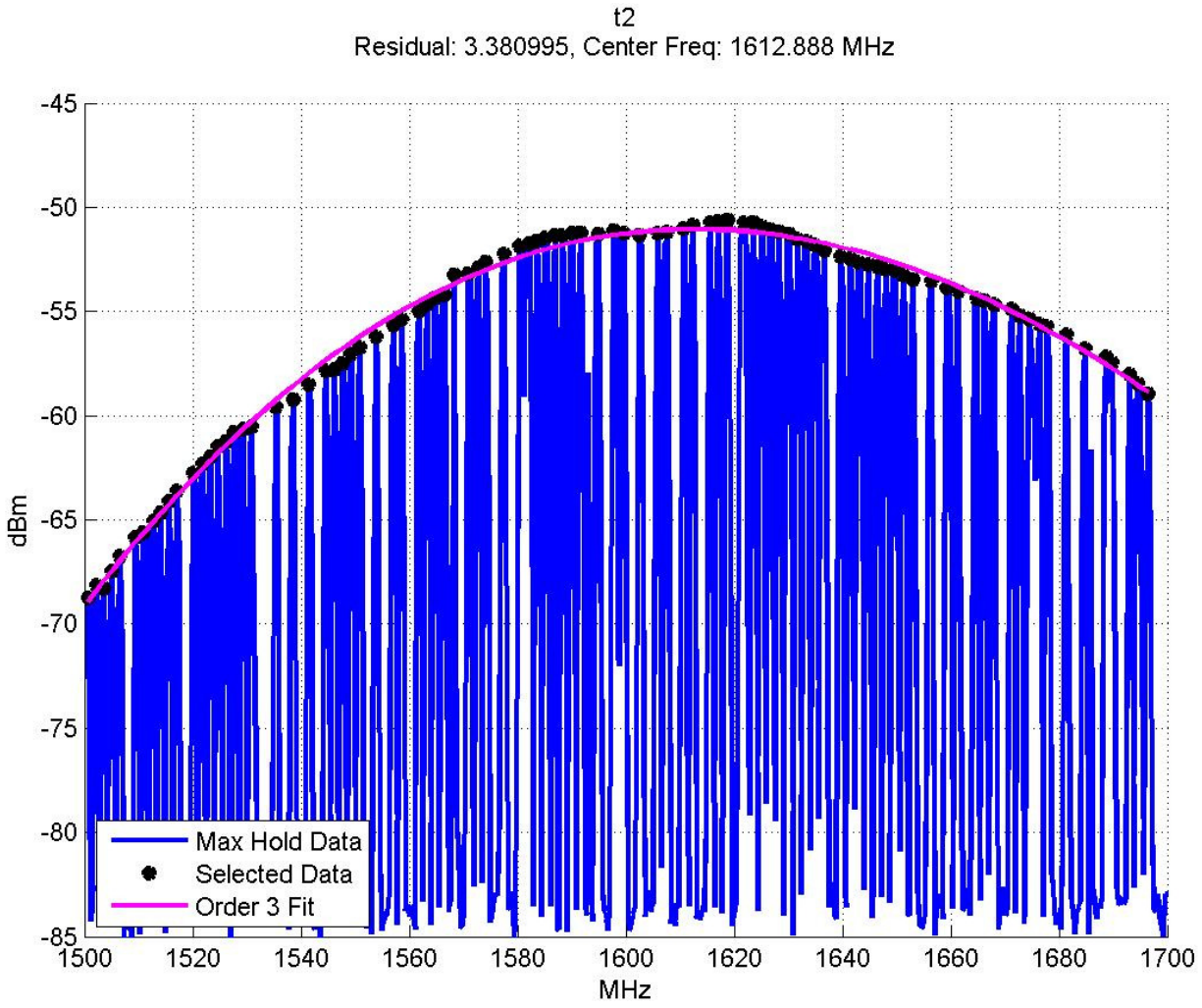
Wireless temperature sensor: testbed showing sensor/heater configuration



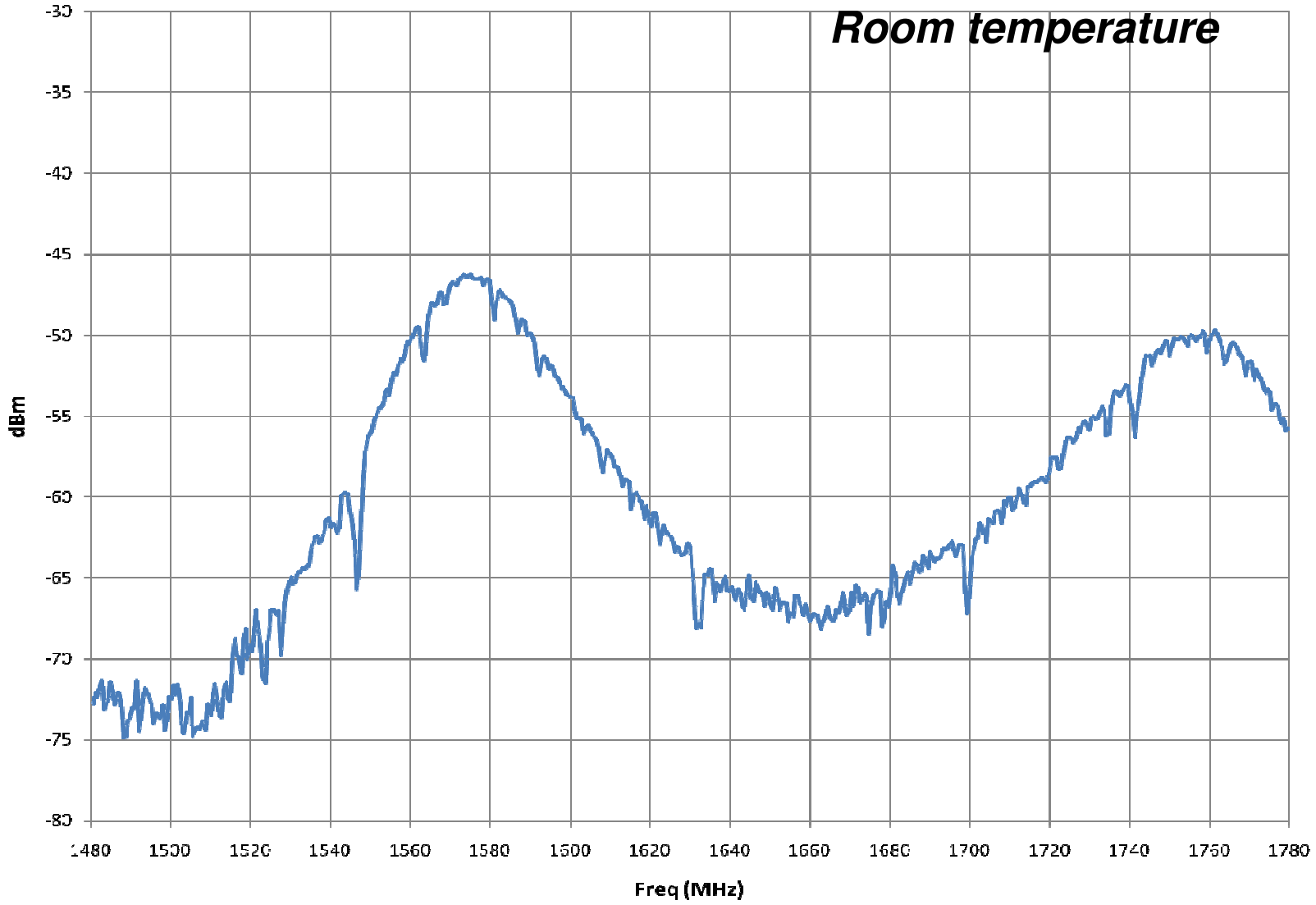
Wireless Temperature Sensor: Test Apparatus



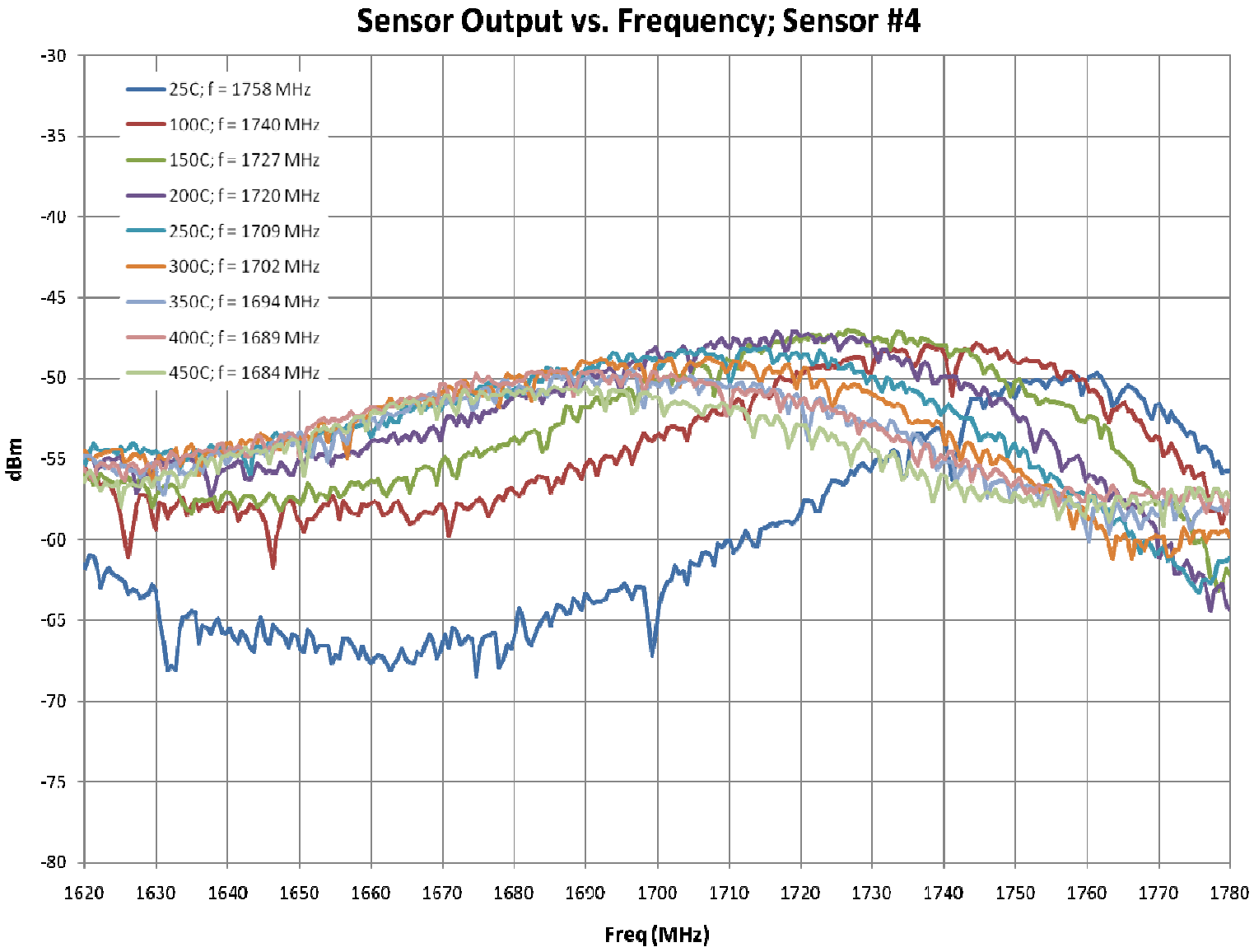
Typical Wireless Sensor Peak Response



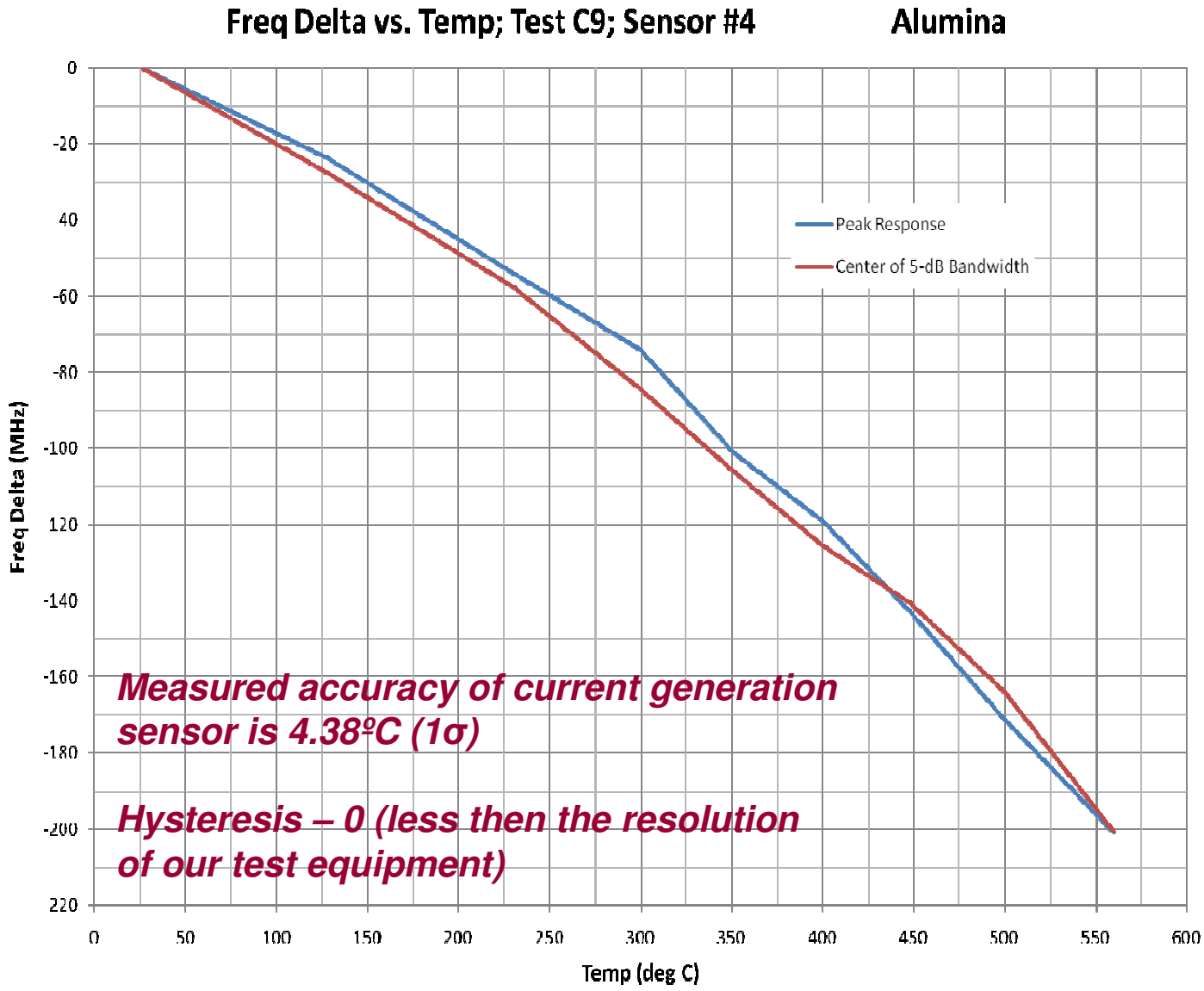
Typical Two Sensor Peak Response



Wireless Temperature Sensor Response: Sensor Output as a Function of Temperature and Frequency



Wireless Temperature Sensor Response: Sensor Output as a Function of Temperature

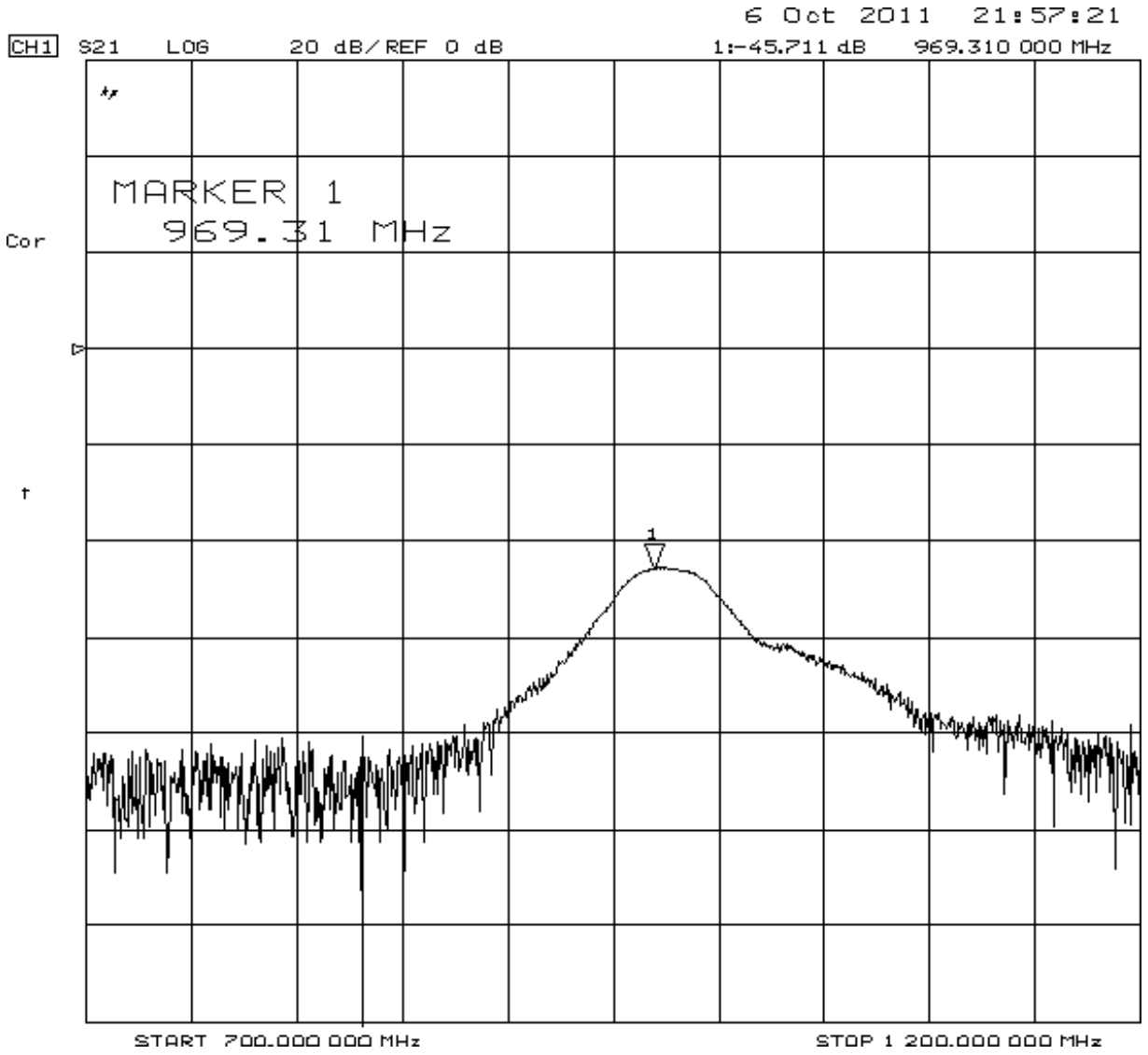


Signal Processing and Turbine Section Propagation Measurements

- 3rd order polynomial curve fit
- Calibration table……onetime calibration per sensor geometry
- Temperature estimation algorithm….noise/multipath/ doppler….signal strength variation due to environment
- Propagation measurements taken on 10/7/11 at Honeywell
- Usable signal from sensor over about +/- 30 deg sector from probe antenna location.

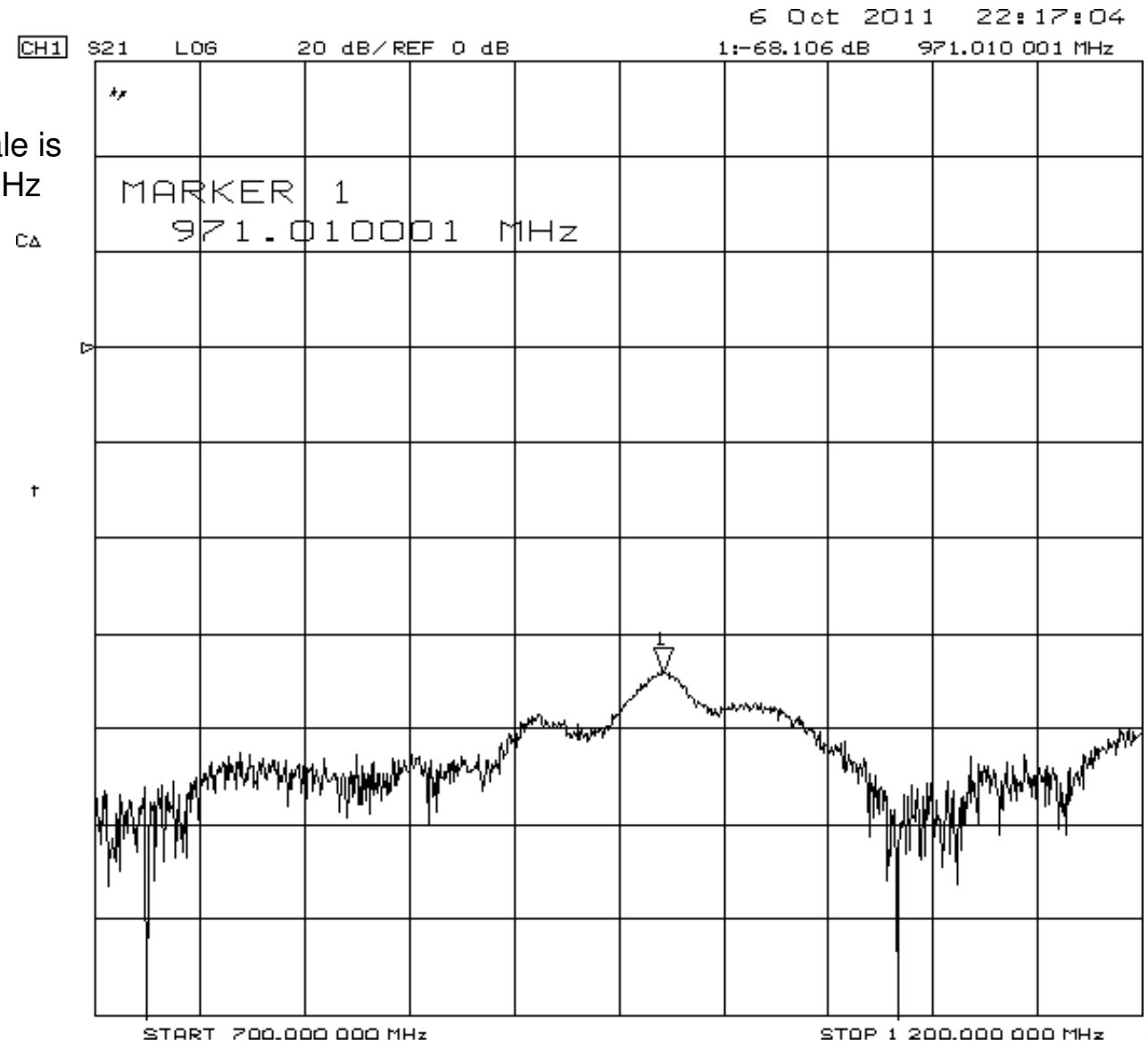
Coupling Between Probe Antenna and Sensor; Antenna Sensor on Blade Directly Over Probe

horizontal scale is
700 – 1200 MHz



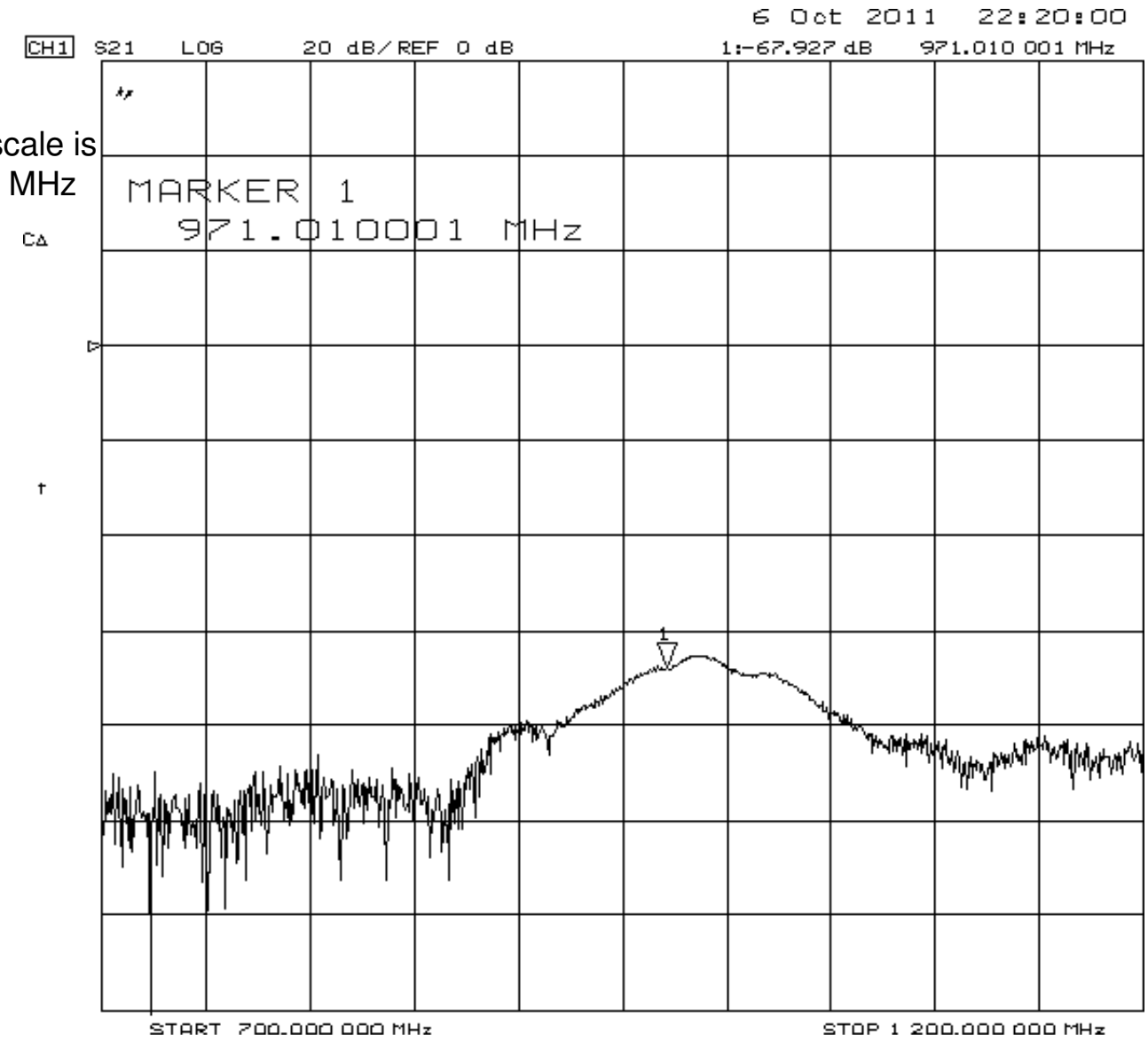
Coupling Between Probe Antenna and Sensor; Antenna Sensor 4 Blades from Probe

horizontal scale is 700 – 1200 MHz



Coupling Between Probe Antenna and Sensor; Antenna Sensor 12 Blades from Probe

horizontal scale is 700 – 1200 MHz



Summary

A passive wireless thin film sensor has been demonstrated to 560ºC that requires no power to operate and…… exhibits ideal characteristics for remote temperature sensing

The wireless temperature sensor was designed to withstand the harsh environment of the hot section in turbine engines; robust diodes, antennae, interconnects and dielectric

The sensor frequency changes as a function of temperature and shows no hysteresis upon heating and cooling

WTS is particularly useful in applications where the surface temperature of rotating components is desired and where the routing of wires to a data acquisition system to complete the measurement is too difficult or complex.

Acknowledgements

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Thank You!