Extreme Environment SiC Wireless Sensor Suites for Nuclear Thermal Propulsion Engines. S. E. Minden[1] , J. R. Fraley[2] P.I., Bryon Western[3] and Lauren Kegley[4]; [1] REU Intern/Design (1406 E. Mission Blvd. Fayetteville, AR 72701, sminden@apei.net), [2] Lead Engineer, Principle Investigator for project (jfraley@apei.net), [3]Design Engineer (bwester@apei.net), [4]Design Engineer (lkegley@apei.net)

Introduction:

[1]Nuclear Thermal Propulsion(NTP) systems for space exploration have been studied for several decades. However, there has been a renewed interest in solid core NTP systems in recent years, because of their ability to achieve space mission performance objectives that are well beyond foreseen chemical propulsion system capabilities.

In a solid core NTP system, liquid propellant, hydrogen in this case, is pumped through the propellant line which is housed in the outer shell of the nozzle and reactor core. This serves as a coolant as well as to preheat the propellant. The liquid hydrogen is then directed into the reactor core to create a high temperature, high pressure gas. The gas is then expanded through the nozzle. This system creates a high thrust and high specific impulse which will enable longer and deeper space missions to be realized. The temperatures in this system, on the lower scale, will be able to reach upwards of 450C.

[1]There are a number of critical telemetry measurements to be monitored under continuous field operation. Real time monitoring of this system will greatly increase operational safety and performance and reduce operation and maintenance costs. Currently, the data transmission and power delivery for these extreme environment sensors are delivered via wire line. These not only limit the placement of the sensors, but also adds significant weight to the vehicle.

Resonant Structures:

The solution proposed by APEI, Inc is to use a suite of extreme environment sensors that are embedded within the NTP system and interface those sensors with a high temperature wireless transmitter to broadcast the data to a health monitoring system. To power the devices, an ability to wirelessly transfer power in extreme environments is necessary. We have used the well-known phenomenon of inductive coupling to answer this need. A common method to increase the power delivered to a remote locations is the introduction of a parallel capacitor to create resonant structures. By placing the capacitor on both the transmitting and receiving coils, we can drastically increase transfer range as well as the efficiency of power transfer.

Minimizing Weight:

When dealing with space flight, weight is a major concern. Weight is directly proportional to the money required to break out of the Earth’s atmosphere. Hence, when looking at where the sensors suites will be placed, it would be in the interest of those funding the mission to minimize weight where ever possible.

Due to the transmission coil being large and bulky in relation to the sensor suites themselves, it would be beneficial to be able to transfer power to all of the wireless receivers via a single transmission coil. This sort of thing has been tested in experimental settings and has proven to be an acceptable means of powering multiple receivers. However, therein lies a problem related to the orientation of the receiver/transmitter magnetic fields.

3 Dimensional Solution:

It's been proven that stationary, mono-directional power transfer to multiple devices can be facilitated by a single transmission coil. But what if the sensors aren't stationary? What if they're facing different directions? What if they're rotating? If, at any time, the orientation of the receiver is such that magnetic flux from the transmitter does not intersect the receiver coils, magnetic coupling goes to zero and power is no longer transferred.

The need for a drop-in 3 dimensional solution to this problem is needed. We have devised a solution wherein an extreme environment 3-dimensional receiver is formed by placing three(or more) magnetically coupled inductor pairs within a harsh environment substrate. The inductor pairs will be printed directly to the substrate, low temperature co-fire ceramic, and then electrically connected to the various other components. This will provide strength and structure to the receiver which will allow it to survive in extremely harsh, high temperature environments. The 3 dimensionality of the receiver will ensure that no matter what the orientation of the receiver there will always be some sort of intersection of the magnetic field of the transmitter and receiver coils.

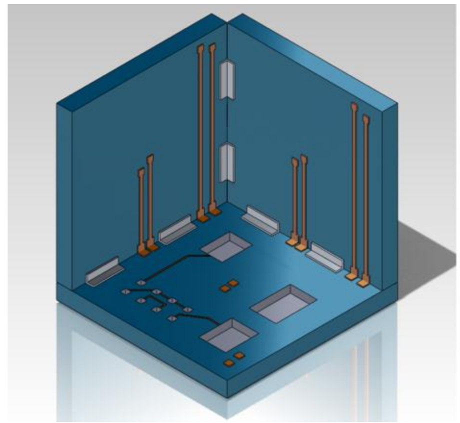

Fig. 1: 3Dimensional Wireless Power Receiver (inside)

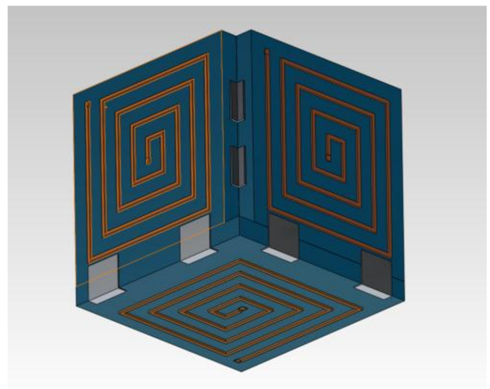

Fig. 2: 3Dimensional Wireless Power Receiver (outside)

Acknowledgements:

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References:

[1] John R. Fraley, Bryon Western, APEI, International,