Microstrip Antennas Utilizing Yttria-Stabilized Zirconia for Extreme Environments

Aleks Mertvyy, Md. Samiul I. Sagar, Abu H. Hridhon, Praveen Sekhar, and Tutku Karacolak

School of Engineering and Computer Science, Washington State University Vancouver
Vancouver, WA 98686, USA

There is a great military, space, and industry need for wireless systems that can operate under extreme conditions such as high temperatures and harsh chemical environments. Some of the applications include planetary rovers for space exploration missions, wireless systems for mining and oil drilling applications, monitoring combustion turbines, and wireless environmental monitoring of first responders. Since antennas are the most critical components of a wireless system, design of antennas capable of surviving harsh environments is significant for overall system reliability and efficient communication. Yttria-Stabilized Zirconia (YSZ) is a ceramic, which has been recently used in a wide variety of gas sensing, biomedical, and thermal applications. YSZ has properties of high temperature tolerance, moisture resistance, high strength and corrosion resistance, and structural stability. One of the recent applications of YSZ is its utilization as a substrate material in the design of patch antennas. The electrical properties of YSZ allows for designing antennas with compact form factor and high efficiency due to high relative permittivity and low loss tangent.

In this work, the main aim is to evaluate microstrip patch antennas utilizing YSZ substrates and assess YSZ as a potential dielectric material for extreme environment sensing applications. First, dielectric property measurements are conducted using T-resonator and transmission line methods to determine relative permittivity and loss tangent. Then, using the measured values sample microstrip monopole patch antennas operating at 2.4 GHz ISM and S bands are designed to demonstrate the feasibility of the proposed objective. Various antenna feeding methods are investigated such as microstrip line feeding (radiator and ground plane on separate layers) and co-planar waveguide feeding (radiator and ground plane on a single layer). After the simulations, the designed antennas are manufactured on a 0.15 mm thick YSZ substrate using two fabrication methods including ink-jet printing and cleanroom sputtering process. Reflection coefficient and radiation pattern measurements are performed to compare with the simulations. Good agreement is obtained between the measured and simulated results at the band of operation. Results regarding antenna parameters such as impedance matching, gain, and efficiency will be presented. The steps for fabrication process of the antennas will also be shown in details. Following the single antenna design, a multiple input multiple output (MIMO) implementation of the proposed design is analyzed to evaluate the antenna performance against propagation issues such as the high multipath loss in working conditions of first responders. A parametric study is carried out on the antenna topology and ground plane structure to reduce mutual coupling between the elements. MIMO specific antenna parameters will be characterized such as envelope correlation coefficient, diversity gain, mean effective gain, and total active reflection coefficient.

Acknowledgement: This work was supported by the National Science Foundation (NSF) under Grant No. ECCS-2104513.