Title (maximum of 20 words):
Patch-Based FSS for Bridge Girder Vehicular Impact Strain Sensing

Abstract (minimum of 300 words):
Frequency-selective surfaces (FSSs) are planar arrays of patch- or aperture-based conducting elements with a specific frequency-dependent transmissive or reflective response when illuminated with incident electromagnetic energy. The specific frequency response is determined by the element size, shape, and relative spacing between adjacent elements (commonly referred to as a unit cell). The electromagnetic and physical properties of the dielectric substrate upon which the unit cells are located (and superstrate, if applicable) also play a role. For patch-based FSSs, a conductive backplane mounted opposite to the unit cells on a dielectric substrate is commonly used as it facilitates a reflection response. This allows for passive, one-sided, and remote (non-contact) inspections using such a sensor. This can be particularly useful in inspection scenarios where access to both sides of a structure is unavailable. To this end, in recent years, FSSs have been extended from wide use as radomes and filters (amongst other applications) to include sensors. Regarding sensing, in particular, the specific frequency response of FSS is also affected by the surrounding geometry and environment within which it is located. This makes such sensors uniquely well-suited for structural health monitoring (SHM) and nondestructive evaluation (NDE) applications, including strain sensing. In this case, when the sensor is surface mounted on or integrated within a structure, (physical) geometric changes in the structure will also similarly change the sensor geometry. As such, these geometric changes produce a change in the sensor's frequency response. Therefore, in this work, a (patch-based) dipole FSS sensor was designed to resonate in the X-band (8.2 – 12.4 GHz) with a strain measurement capability range on the order of 5% (50,000 μstrain). Six FSS sensors were fabricated and adhered to a prestressed concrete bridge girder to measure the strain before and after large-scale impact testing. Transportation agencies acknowledge the challenges posed by collisions between overheight vehicles and bridges, yet few have established clear countermeasures. Measurements were performed on the sensors before and after the impact to quantify the change in the frequency response of the sensors. The measured change in frequency response of the sensors was used to quantify the strain experienced by the girder at select locations. A finite element strain simulation was conducted in tandem to validate the accuracy of the measured stain values. The comparison between the simulated and measured values revealed that 5 of the 6 sensors accurately measured the strain at select locations while one of the sensors overestimated the strain experienced by the girder.

Mini Abstract (maximum of 50 words):
Six FSS-based sensors featuring a dipole element were fabricated to detect a strain range on the order of 5% (50,000 μstrain). The sensors were attached at multiple points on a concrete girder to evaluate the strain experienced across the girder due to an impact.

Bio (maximum of 100 words):
Alexander Hook is a graduate research assistant in the Microwave Sensing (μSense) Laboratory at Missouri University of Science and Technology (Missouri S&T). Alexander’s research focuses on frequency selective surfaces (FSSs) with a particular interest in additive manufacturing processes and techniques for FSS sensors. Alexander is a recipient of the Graduate Assistance in Areas of National Need (GAANN) fellowship.