Embedding Antennas into Concrete for Sensing Applications: A Packaging Adventure

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The nation's civil transportation infrastructure of structural concrete bridges is aging and deteriorating – principally as a result of the corrosion of the steel reinforcement that gives these structures their tensile strength. State Departments of Transportation officials are faced with the challenge of determining which structures need to be rehabilitated or replaced and when to do so. Assessing the condition of the steel reinforcement is not simple, since the steel is typically buried beneath 1 to 2 inches or more of concrete. Currently, these assessments are based primarily on qualitative visual inspections and anticipated design lives. This subjective and empirical information has proven insufficient for developing cost-effective asset management and operating strategies. In the hands of decision-makers, advanced, accurate information about the internal condition of steel reinforcement and the effectiveness of new materials and rehabilitation methods could save the nation billions of dollars annually.

Certainly, the industrial and academic communities have already moved to address this nationwide problem. Several non-destructive external sensing methods have been developed to assess the condition of the hidden steel. Unfortunately, none of these solutions has been integrated into a useful, viable system, since they often require prohibitive effort and expense to install and maintain. Moreover, the data collected from embedded sensors often fail to provide a quantitative description of deterioration such as extent of loss in bond or reduction in the cross-sectional area of the tendon.

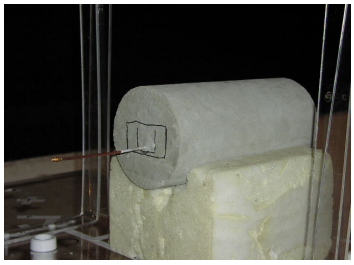

Figure 1: Antenna embedded in concrete cylinder.

As part of a multi-disciplinary effort to develop a wireless embedded sensor system to examine corrosion of tendons in prestressed concrete girders, we have designed, fabricated, and tested antennas operating in the 2.4 GHz and 5.8 GHz ISM frequency bands embedded in concrete samples. The antenna is intended strictly for communication purposes while the actual sensing mechanism will use ultrasonics. The presentation will detail the electromagnetic characterization of a number of concrete mixes considered for bridge girders and the implementation of this data into the antenna design procedure. The antenna design, based on a U-slot microstrip patch antenna (S. Weigand et al., *IEEE Trans. on Antennas and Propagat.*, **2**, 2003) takes several factors into account. One set of factors is the anticipated range of conductivity and permittivity of the surrounding concrete as its water content changes over time and with seasons. Another consideration is the size limitation of the antenna/radio/sensor system imposed by the desire to maintain the girder's structural integrity. Measurements and simulations of antenna behavior in a number of embedded scenarios (one depicted in Fig. 1 above) will be presented and discussed in the context of the anticipated communication link budget for the "girder network."