Abstract

Globally, governments are building smarter, greener and more sustainable buildings with the help of technological innovations. Deploying embedded WSN in buildings is one of the promising technologies that enables such a vision. However, such sensors face challenges in sourcing long term power, and transmission of wireless signals in and out of building materials. One way to source power is from the ambient RF signals. To harvest such energy, RF energy harvesting antenna is an important component in embedded WSN systems. This antenna can also be responsible for wireless communications. In addition, building materials enclosing the embedded antenna also affects the transmission of RF power that for harvesting and communications.

In this thesis, a study on the concepts of metamaterial and electrically small antennas is performed to combine both concepts in the design of an electrically small antenna, and a scalable antenna array suitable for RF energy harvesting and wireless communications. Another aspect affecting RF energy harvesting and wireless communications indoors is also investigated in this thesis. Analysis into some commonly used admixtures to compare the effects on the embedded arrays and the resulting materials is done.

Combining concepts from metamaterials and electrically small antenna, an electrically small metaresonator is designed. This antenna has a maximum dimension of one-tenth the wavelength of WiFi spectrum at channel 13. Using the stubbed design, the resonant frequency can be tuned to the required centre frequency at channel 7. The resulting antenna has a S_{11} of −25 dB, gain of −16 dB and an efficiency of −9 dB, within expectations of an ESA.

This electrically small metaresonator is then used as an array element to form into an array using DC combiner topology. Due to its geometry and combining the concepts of metamaterials, the

resulting metaresonator array achieves close cell separation distance of 0.0165 λ. The S_{11} of this array is also able to achieve −25 dB, a gain of −4 dB and an efficiency of −6 dB. Furthermore, an analysis of feeding the array at different feed points also demonstrates the flexibility of this array, making it suitable for embedded WSN in buildings.

Next, an investigation into the common building material, cement is done. Comparing admixture pigments typically used in the building industry for colouring of mortar and concrete, the results indicate that cement paste enhanced with 4% micro-sized particles of iron (III) oxide 1) improves the S_{11} of the embedded array by as much as 20 dB, 2) increases its bandwidth while maintaining the overall shape of the S_{11}, and 3) produces a lesser shift in resonant frequency than cement paste alone. Further analysis into S_{21} shows that adding micro-sized iron (III) oxide into cement paste improves the RF power transmission into the material compared to cement paste only sample by as much as 10 dB.

Further investigations into the application of plaster is done to develop an understanding of certain applications in buildings. The results obtained shows that plaster samples are the same or worse than cement paste samples. Furthermore, the findings suggest that embedding the metaresonator array in between a layer of plaster (enhanced or not) and mortar is not suitable for wireless applications as the S_{11} is significantly distorted to an unacceptable range. Analysing S_{21}, it is also observed that plaster enhanced with iron (III) oxide layered on mortar also does not significantly change the RF transmission property of the material. These findings indicate that embedding the metaresonator array in plaster or plaster layer on mortar is not suitable for embedded WSN applications.