METARESONATOR ARRAY IN BUILDING ELEMENTS

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ABSTRACT

Electrically small antennas and metaresonators share a similar disadvantage of narrow bandwidth when the concept of resonance is applied. In this project, a type of planar metaresonator array that is built on complementary split ring resonators is shown to exhibit narrow fractional bandwidth characteristic of 3%. One way to overcome this limitation is to modify the surrounding dielectric. In the context of RF energy harvesting in green buildings, where this type of planar metaresonators can be embedded in the façade and partitions, the change in surrounding dielectric due to this embedment is beneficial to the return loss and radiation pattern. However, it is well-known that the available power in concrete is reduced due to attenuation of RF signals. To overcome the reduced power in concrete, a study into five common magnetic and/or metallic particles that are added to enhanced concrete is done. Focusing on the effects on this metaresonator, it is shown that 0.5% iron oxide in concrete shows the enhancement by improving the S_{11} by 15 times, the fractional bandwidth by 5 times, 12 dB increase in S_{12}, and an omni directional radiation pattern from a directional one.

METHOD

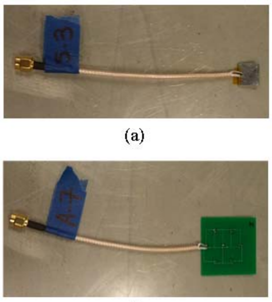

Fig. 1 Samples of proposed metaresonators in particle enhanced concrete (a) Single unit element/cell (b) 7-cell array

TABLE I
Sample types and labels

Sample type	Label
Mortar only (Control)	CON-N, CON-S, CON-A
Mortar with magnetite particles <5μm	MAG-M-N, MAG-M-S, MAG-M-A
Mortar with magnetite particles 50-100nm	MAG-N-N, MAG-N-S, MAG-N-A
Mortar with iron oxide particles <5μm	IOX-M-N, IOX-M-S, IOX-M-A
Mortar with iron oxide particles <5nm	IOX-N-N, IOX-N-S, IOX-N-A
Mortar with nickel particles <50nm	NIC-N-N, NIC-N-S, NIC-N-A

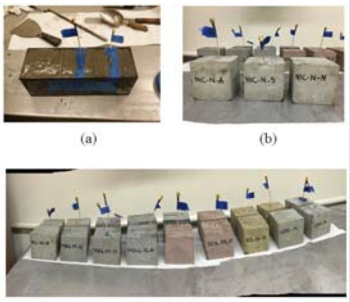

Fig. 2 Samples of proposed metaresonators in particle enhanced concrete

TABLE II
Types of particles, size and percentage by weight used

Sample type	Size	Percentage
Magnetite	< 5 μm	0.5%
Magnetite	50 – 100 nm	0.5%
Iron oxide	< 5 μm	0.5%
Iron oxide	< 5 nm	0.5%
Nickel	< 50 nm	0.5%

Remarks:

1. 18 samples produced including control, single unit cell, and array.
2. Following common materials found in literature for concrete

RESULTS

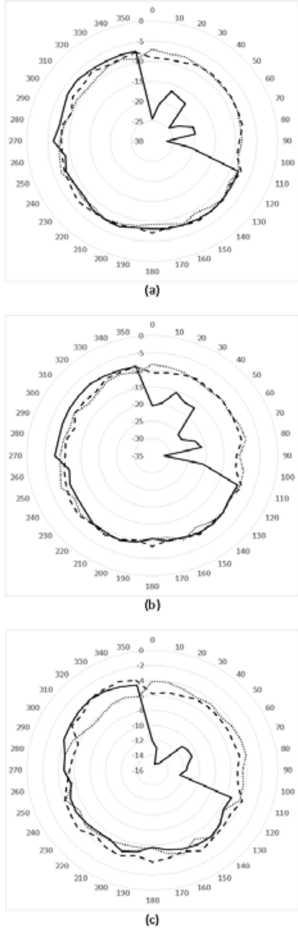

Fig.5 In air (solid line), control CON-A (dotted line), and iron oxide IOX-M-A radiation patterns of proposed antenna (unit: dBi) (a) Channel 1 (b) Channel 7 (c) Channel 13

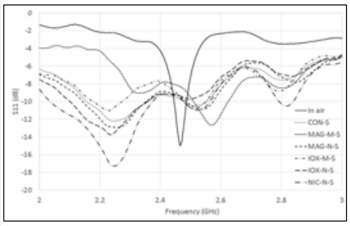

Fig.3 Comparison of S11 of single unit element/cell in air, and other mortar enhanced particles from 2 to 3 GHz

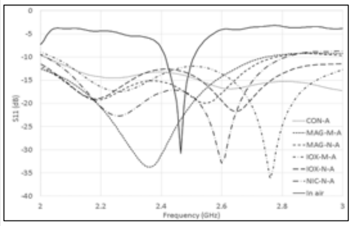

Fig.4 Comparison of S11 of 7 element/cell array in air, and other mortar enhanced particles from 2 to 3 GHz

TABLE III
EFFECTS OF MEDIA ON RETURN LOSS AND RESONANT FREQUENCY

Sample type	S_{11} Improvement	Frequency shift
Mortar only (Control)	1.7x improved	-23.2%
Mortar with magnetite particles <5μm	11.9x improved	2.04%
Mortar with magnetite particles 50-100nm	3.8x improved	12.2%
Mortar with iron oxide particles <5μm	15.4x improved	-12.40%
Mortar with iron oxide particles <5nm	7.4x improved	-8.35%
Mortar with nickel particles <50nm	7.8x improved	-5.45%

FINAL REMARKS

Iron oxide of micro size has the greatest positive effect on the performance of the metaresonator in terms of return loss compared to air, transmission coefficient compared to mortar alone, and change the radiation pattern into an omni-directional one without significant impact on the antenna gain.

REFERENCES

[1] Y.L. Sum, V. Rheinheimer, B.H. Soong, P.J.M. Monteiro, "Antenna Embedded Into Concrete and Method for Embedding Antenna Into Concrete ", US Provisional Patent Application No. 62/430,172, 5th December 2016. Filed
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[2] Y.L. Sum, V. Rheinheimer, B.H. Soong, P.J.M. Monteiro, "Effects of Cement Paste Enhanced with Iron-Based Magnetic Particles on an Embedded Small Resonator Antenna," Nature Scientific Report, 7, Article number: 15185, 2017.

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