A Study of Absorption and Scattering of Microwaves by Dielectric Scatterers such as Insects

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With Application to MIMO Radar for Imaging Termites and UAV Imaging MIMO Radar

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An Investigation of Modes without Cutoff, Open Waveguides and Artificial Dielectrics

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To Kymberly and Paris

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Abstract

The application of radar to the detection of termites and the imaging of their activity in-situ poses many challenges. Insects such as termites and ants are dielectric scatterers with large values of refractive index and absorption at microwave and millimeter wave frequencies, and radar sensing in-situ is performed through building materials which have widely varying losses and anisotropies.

The research presented in this thesis seeks to understand the phenomena of absorption and scattering from dielectric scatterers such as termites, and to design a Multiple Input Multiple Output (MIMO) imaging radar for detecting and imaging termite activity based on that understanding. The investigation undertaken here comprises theoretical, numerical and experimental studies, and demonstrates the possibility of not only the detection and imaging of termite activity, but also the possibility of the provocation and control of termites using suitable millimeter and sub-millimeter waves wave emissions.

This thesis also presents the design and experimental testing of a novel wave guiding structure consisting of an open waveguide with an artificial dielectric coating supporting the HE_{11} mode, a mode which is inherently broadband, and which could be used to provide a millimeter wave stimulus directly to a termite. This guiding structure has the potential to deliver millimeter waves through the skin more efficiently than other techniques, and has possible applications to millimeter wave therapeutic treatments including acupuncture.

Finally, this thesis presents research on the design of an imaging MIMO radar for Unmanned Aerial Vehicles (UAVs), where target and platform velocities are very much greater than those observed in detecting and imaging termite activity. This investigation shows that small Kasami, Kamaletdinov construction 2 and Moreno-Tirkel Family B sequence families have

properties which make them suitable candidates for the sequences for high resolution imaging MIMO radar, though the Kamaletdinov construction 2 and Moreno-Tirkel Family B sequence families are the superior of the three. These results have application to a wide range of problems in imaging radar such as through-the-wall radar, medical imaging, security screening and non-destructive testing.

Declaration of Originality

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Publications of Author's original research contributions arising from this Thesis

The following is a list of peer reviewed conference publications and a granted patent of the Author's original research contributions which arose from the research conducted in this Thesis.

G. A. Rankin, and A. Z. Tirkel, "Sequences for MIMO Imaging Radar", submitted to the Australian Microwave Symposium 2016, Adelaide, Australia, 2016.

G. A. Rankin, and A. Z. Tirkel, "Sequence Families for MIMO Imaging Radar", presented at the Progress in Radar Research Workshop, Adelaide, Australia, 2015.

G. A. Rankin, A. Z. Tirkel, and A. N. Leukhin, "Millimeter Wave Array for UAV Imaging MIMO Radar," presented at the International Radar Symposium 2015, Dresden, Germany, 2015.

G. A. Rankin, and A. Z. Tirkel, "Excitation of Low Loss HE_{11} Modes on an Acupuncture-Like Needle," presented at the 39th International Conference on Infrared, Millimeter, and Terahertz Waves, Tucson, AZ, U.S.A., 2014.

G. A. Rankin, A. Z. Tirkel, L. Q. Bui, and N. W. D. Le Marshall, "Radar Imaging: Conventional and MIMO", presented at the Fourth International Conference on Communications and Electronics, Hue, Vietnam, pp. 171-176, 2012.

G. A. Rankin, N. W. D. Le Marshall, and A. Z. Tirkel, "MIMO Array for Radar Imaging Applications," presented at the Progress in Radar Research Workshop, Adelaide, Australia, 2012.

A. Z. Tirkel, J. C. S. Lai, T. A. Evans, and G. A. Rankin, "Effects of Millimeter Wave Exposure on Termite Behavior," presented at the Progress in Electromagnetics Research Symposium, Marrakesh, Morocco, pp. 1581-1585, 2011.

A. Z. Tirkel, J. C. S. Lai, T. A. Evans, and G. A. Rankin, "Heating and Provocation of Termites Using Millimeter Waves," presented at the Progress in Electromagnetics Research Symposium, Marrakesh, Morocco, pp. 1586-1589, 2011.

G. A. Rankin, and A. Z. Tirkel, "Hybrid Modes on a Single Conductor Waveguide," presented at the Progress in Radar Research Workshop, Adelaide, Australia, 2011.

N. W. D. Le Marshall, G. A. Rankin, and A. Z. Tirkel, "High Resolution, Wide Coverage Termite Imager," presented at the Progress in Electromagnetics Research Symposium, Xi'an, China, pp. 663-667, 2010.

N. W. D. Le Marshall, G. A. Rankin, and A. Z. Tirkel, "Hybrid Array for the Detection and Imaging of Termites," presented at the IEEE Radio and Wireless Symposium, Orlando, FL, U.S.A., pp. 288-291, 2010.

Patent: A. Z. Tirkel, N. W. D. Le Marshall, and G. A. Rankin, "Wide Area Detection of Insects Using Reflected Microwaves," WO 2011047426, 2009.

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