HAWAII CENTER FOR ADVANCED COMMUNICATIONS

High Performance Phased Array Antennas Based on the Ferroelectric and Continuous Transverse Stub Technologies

Ph.D. Dissertation Defense

Presented By: Wayne Kim

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Abstract

Phased array antenna systems are commonly used for radar as well as wireless communications applications. These phased array systems typically require thousands of phase shifters, the amount of which is about 45% of the total system expense. Low cost and simple designs are very important for affordable systems. In this dissertation two aspects in high performance, low cost phased array systems design are investigated. The first is the development of new low cost continuous transverse stub (CTS) antennas while the other includes the development of novel analog ferroelectric phase shifters. The two technologies are then combined in an integrated approach to form a novel antenna array design with linear polarization and electronic beam steering capabilities.

The new CTS antenna employs a coplanar microstrip feed network which makes it a low cost alternative to the traditional waveguide based CTS technology. The newly patented antenna combines the advantages of the parallel plate waveguide and coaxial feed approaches into a compact planar design with a unidirectional beam pattern. Prototypes of a single and three elements coplanar waveguide CTS array is designed and constructed and both the radiation patterns and impedance matching characteristics are experimentally evaluated. Excellent agreement between measured results and simulation data obtained using WIPL-D software is observed.

The analog ferroelectric phase shifter, on the other hand, employs a multi-dielectric substrate and includes a thin layer of silicon dioxide between the signal conductors and the tunable ferroelectric material to reduce the insertion losses and produce good impedance matching. The phase shifter design was evaluated through commercial software as well as by using a spectral domain based analytical approach. It is shown that, unlike earlier designs, the addition of the silicon dioxide layer contributed significantly to enhancing the device performance including the impedance matching, reduction in the insertion loss, and a three fold increase in figure of merit (defined as the phase change/dB) from that of the direct metallization approach. The effect of the anisotropic properties of the ferroelectric material on the device performance was also examined and it is shown that the coplanar geometry allows one to model the ferroelectric using an isotropic representation, thus allowing the use of software packages such as WIPL-D. Furthermore, a novel via-based biasing approach is described and simulation results show its adequate performance in the proposed multilayer phase shifter design.

The integrated coplanar waveguide phased antenna array design with beam steering capabilities is then simulated using WIPL-D software. Simulation results demonstrates linear polarization, superior polarization purity, and up to +/- 20° of beam scanning between the unbiased and biased states of the ferroelectric phase shifter.

Journal Publications:

1. W. Kim, M. Iskander, and C. Tanaka, "High-Performance Low-Cost Phase Shifter Design Based on Ferroelectric Materials Technology", *Electronics Letters*, vol. 40, no. 21, pp. 1345-1347, 2004.
2. W. Kim and M. F. Iskander, "A New Coplanar Waveguide Continuous Transverse Stub (CPW-CTS) Antenna for Wireless Communications," *IEEE Antennas and Wireless Propagation Letters*, vol.4, pp.172-174, 2005.
3. M. Rezk, W. Kim, Z. Yun, and M.F. Iskander, "Performance Comparison of a Novel Hybrid Smart Antenna System versus the Fully Adaptive and Switched Beam Antenna Arrays," *IEEE Antennas and Wireless Propagation Letters*, vol. 4, pp. 285-288, 2005.
4. N. Celik, W. Kim, M. Demirkol, M. F. Iskander, and R.Emrick, "Implementation and Experimental Verification of Hybrid Smart-Antenna Beamforming Algorithm," *IEEE Antennas and Wireless propagation letters*, vol. 5, pp. 280 – 283, 2006.
5. W. Kim and M. Iskander, "Integrated Phased Array Antenna Design Using Ferroelectric Materials and the Continuous Transverse Stub Technology," *IEEE Antennas and Propagation,* Nov., 2006.
6. W. Kim, M. Iskander, and C. Krowne, "Modified Green's Function and Spectral Domain Approach for Analyzing Anisotropic and Multi-Dielectric Layers Coplanar Waveguide Ferroelectric Phase Shifters," *IEEE Microwave Theory and Techniques, Special issue on Ferroelectric Materials Technologies,* Accepted for Publication, 2006.

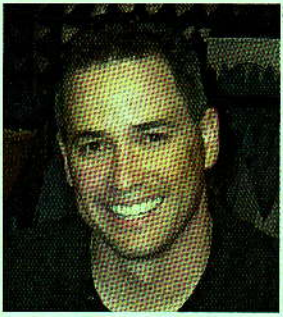
Patent:

1. W. Kim and M. Iskander, "A new coplanar waveguide continuous transverse stub (CPW-CTS) antenna for wireless communications", US Patent, 7,079,082.

Conference Publications:

1. W. Kim and M. Iskander, "Novel High Performance Low Cost Phase Shifters Design Based on the Ferroelectric Materials Technology Using the WIPL-D Code", *Applied Computational Electromagnetics Society*, April 2004, Syracuse, NY.
2. W. Kim, M. Iskander, and C. Tanaka, "Low Cost Phase Shifters and Integrated Phased Antenna Array Designs Based on the Ferroelectric Materials Technology", *IEEE Antennas and Propagation society*, June 2004, Monterey, CA.
3. W. Kim and M. Iskander, "High Performance Low Cost Ferroelectric Phase Shifters Designed for Simple Biasing", *Applied Computational Electromagnetics Society*, April 2005, Honolulu, HI.
4. M. Rezk, W. Kim, Z. Yun, and M. Iskander, "Narrow Beam Adaptive Array for Advanced Wireless Communications", *Applied Computational Electromagnetics Society*, April 2005, Honolulu, HI.
5. W. Kim and M. Iskander, "A Multi-Element Coplanar Waveguide Continuous Transverse Stub (CPW-CTS) Antenna for Wireless Communications", *IEEE Antennas and Propagation Society*, July 2005, Washington DC.
6. W. Kim and M. Iskander, "Integrated Phased Antenna Array Design Using Ferroelectric Materials and the Coplanar Waveguide Continuous Transverse Stub Technologies", *IEEE Antennas and Propagation Society*, July 2006, Albuquerque, NM.

Biography



Wayne Kim received the B.S. degree from the University of Hawaii in 1998 and the M.S. degree from the University of California at Los Angeles in 2001 both in Electrical Engineering. From 1998 to 2001 he was with TRW Space and Electronics (now Northrop Grumman) where he was involved in the development of indium phosphide bipolar transistors as well as MMIC design including high efficient power amplifiers. He is currently working towards the PhD degree at the University of Hawaii where his research interests include developing phased array antennas, smart antenna systems, and associated microwave components for wireless communications. He has several patents. He received a TRW technical award for InP HBT development. He was the second place winner in the student paper contest for the Applied Computational Electromagnetics Society (ACES) conference in 2004. He was a recipient of the Achievement Rewards for College Scientists (ARCS) in 2006.