Dallas MTT Chapter

Houston AP/ED/MTT Chapter

Texas Instruments

xtendwave

2012 Mini-Symposium on Wireless and Microwave Circuits and Systems (WMCS)

A Student/Industry Forum

Presentations by Leaders in Wireless and Microwave Research and Technology

Friday, March 23, 2012

1pm – 6:30pm

Baylor University Campus

Waco, TX

Student Research Posters from Texas Universities

www.wmcs2012.com

BAYLOR UNIVERSITY

WIRELESS AND MICROWAVE CIRCUITS AND SYSTEMS

Sponsors

The 2012 Mini-Symposium on Wireless and Microwave Circuits and Systems wishes to gratefully acknowledge our sponsors:

Dallas MTT Chapter

Houston AP/ED/MTT Chapter

Texas Instruments

2012 Mini-Symposium on Wireless and Microwave Circuits and Systems

Baylor University – Mayborn Museum

Friday, March 23, 2012

Agenda

1:00 p.m.	Introduction: Anthony Mendiola (Baylor IEEE Student Branch President), Dr. Charles Baylis (General Chair)
1:10 p.m.	Introduction of Technical Session (part 1): Dr. Oren Eliezer, Technical Program Chair, Xtendwave
1:15 p.m.	Keynote Speaker: Dr. Joseph Guerci, Guerci Consulting, "The Future of RF Systems: Back to the Drawing Board!"
1:40 p.m.	Dr. Jerry Lopez, Texas Tech University and NoiseFigure Research Inc., "Coupled Voltage Controlled Oscillator (VCO) Networks in .18 µm SiGe IC Technology for Phase Control in Array Applications"
2:00 p.m.	Stephen Berger, TEM Consulting, "Challenges of Wireless Coexistence Testing"
2:20 p.m.	Student Research Presentations, Chair: Dr. David Jackson, University of Houston
2:50 p.m.	Break
3:00 p.m.	Introduction of Technical Session (part 2): Dr. Rashaunda Henderson, Technical Program Chair, University of Texas at Dallas
3:05 p.m.	Dr. Hao Ling, University of Texas at Austin, "Radar Signatures of Humans"
3:25 p.m.	Dr. Oren Eliezer, Xtendwave, "A New Broadcasting System and Receivers for USA's Atomic Clock Signal"
3:45 p.m.	Student Research Presentations, Chair: Dr. Alan Davis, University of Texas at Arlington
4:15 p.m.	Session Concludes
4:15 p.m.	Reception and Student Poster Competition
5:00 p.m.	Dinner and Industry Panel Session
6:00 p.m.	Awards and Recognitions: Dr. Charles Baylis (Baylor University), General Chair, Dr. Alan Davis (University of Texas at Arlington), Awards Chair, and Dr. Oren Eliezer (Xtendwave)

Baylor WMCS 2012 Mini Symposium Student Presentations

Determining the Water to Cementitious Material Ratio within Wet Concrete using Guided Microwave Spectrometry

Stuart Gibbs and Josh Daniliuc
Department of Electrical Engineering
Baylor University

Faculty Advisors: Dr. Buford R. Jean, Baylor University
Dr. Robert Marks II, Baylor University

Abstract

Concrete is the second most-used material in the world and with its production comes the need for better quality control. The strength of concrete is heavily influenced by its moisture content when it is formulated, giving rise to a need for an accurate measurement of that moisture content.

This work focuses on the dielectric properties of water between 10MHz and 4 GHz to obtain information about the water content within a sample of wet concrete. A rectangular waveguide is used as a guided microwave spectrometry system to obtain data within this frequency range. In the 500 MHz to 1.5 GHz range the real part of the dielectric constant of water (ε') is dominant and predictably shifts the cutoff frequency of the waveguide lower as water content increases. At frequencies increasing above cutoff the imaginary part of the dielectric constant of water (ε'') increases as well meaning the concrete is more lossy. A principal component analysis is performed on this information and the modified data is run through a neural network to determine the water to cementitious material ratio of the concrete.

Currently, alternative waveguide structures are being investigated and simulated using CST Microwave studio and data is being taken to better train the neural network.

Spectrum Optimization Test Bed for Radar Transmitter Waveforms and Circuitry

Josh Martin
Department of Electrical Engineering
Baylor University

Faculty Advisor: Dr. Charles Baylis, Baylor University
Dr. Robert Marks II, Baylor University
Sponsor: Naval Research Laboratory

Abstract

Radar transmitters must operate with high power efficiency while abiding by increasingly strict spectral requirements. Spectral masks govern the out-of-band leakage that can be produced; this leakage is a byproduct of both the waveform and load impedance terminating the amplifier. Spectral leakage can be minimized to meet spectral mask requirements by increasing the linearity of amplifier operation. Maximizing the power transmitted and the associated power efficiency are critical to preserving the detection capabilities of radar systems. Achieving power efficiency often comes at the cost of linearity, creating a tradeoff between linearity and efficiency in power amplifier design that has been well documented. This presentation focuses on performing load-pull measurements to assess the tradeoff between linearity and efficiency for different chirp waveforms. MATLAB has been used to create and upload two radar-specific chirp waveforms into an arbitrary waveform generator. Spectral spreading was observed in the amplifiers output spectra for the two waveforms as they passed through an amplifier driven into its nonlinear operating region. The optimization consists of selecting the waveform which provides the best compromise between linearity and efficiency through analysis of ACPR load-pull contours. Once the optimal waveform is found, a circuit optimization identifies the load impedance which minimizes unwanted spectral spreading and maximizes device efficiency.

Radar Waveform Optimization Using Piecewise Linear Approach

Matthew Moldovan
Department of Electrical and Computer Engineering
Baylor University

Faculty Advisor: Dr. Charles Baylis, Baylor University
Sponsor: Naval Research Laboratory

Abstract

Spectral spreading has become a critical issue in modern radar systems. Due to developing wireless technology, stringent spectral mask requirements imposed by the National Telecommunications Information Administration (NTIA) are requiring radar systems to reduce spectral spreading. The National Broadband Plan in the United States will lead to the re-allocation of radar spectrum for wireless broadband applications; as a result, radars will need to operate in narrower spectra. Cognitive radar systems and adaptive waveform optimization have been suggested as the radar protocol of the future. This research discusses a piecewise linear radar waveform optimization method that maximizes energy and flatness inside the pass band while meeting spectral mask requirements. A grid of points on a frequency-versus-time plot is defined. These points are connected by lines to form a piecewise linear chirp and an exhaustive search is performed in MATLAB to determine the frequency-versus-time profile that yields the optimum spectrum. In addition, pulsed chirping is explored and measurements are performed. Simulated and measurement results are compared.

A 0.18-µm CMOS Resistive Shunt Feedback Low-Noise Amplifier for 3.1-10.6-GHz UWB Receivers

Xin Guan[1], Cuong Huynh[2]

[1]Broadcom Inc., Irvine, California, U.S.A
[2]Department of Electrical and Computer Engineering
Texas A&M University

Faculty Advisor: Dr. Cam Nguyen, Texas A&M University
Sponsor: U.S. Air Force Office of Scientific Research and U.S. National Institute of Justice

Abstract

A 0.18-µm CMOS low-noise amplifier (LNA) employing resistive shunt feedback, operating over the entire ultra-wideband (UWB) frequency range of 3.1-10.6 GHz, has been designed, fabricated and tested. The UWB LNA achieves measured power gain of 7.5±2.5 dB, minimum input matching of -8 dB, noise figure from 3.9 to 6.3 dB, and IIP3 from -8 to -1.9 dBm, while consuming only 9 mW over 3-10 GHz. It occupies only 0.55×0.4 mm^2 without RF and DC pads. With its simple design, miniature size, and competitive performance, this LNA is expected to be valuable for many wireless CMOS UWB receivers.

An Ultra-Broadband 0.18-μm BiCMOS Active Balun

Cuong Huynh
Department of Electrical and Computer Engineering
Texas A&M University

Faculty Advisor: Dr. Cam Nguyen, Texas A&M University
Sponsor: U.S. Air Force Office of Scientific Research and U.S. National Institute of Justice

Abstract

A new RF active balun is proposed, analyzed and designed using a 0.18-μm BiCMOS technology, showing its distinguished characteristic of good balance across ultra-wide frequency ranges. The active balun provides a high differential-mode gain and extremely low common-mode gain; hence, ultra-high common-mode signal suppression. The designed 0.18-μm BiCMOS active balun exhibits an ultra-broadband performance from 2 to 40 GHz differential-mode gain from 1 to 5.2 dB and common-mode signal suppression from 25 to 71 dB. Good matching at its input and output are obtained at the 35-GHz design frequency. The RF active balun consumes a dc current of 8.2 mA from a 1.8 V source.

An Ultra-High-Isolation, Ultra-Wide-Band Microwave and Millimeter-Wave BiCMOS Switch

Cuong Huynh

Department of Electrical and Computer Engineering
Texas A&M University

Faculty Advisor: Dr. Cam Nguyen, Texas A&M University
Sponsor: U.S. Air Force Office of Scientific Research and U.S. National Institute of Justice

Abstract

A new RF switch architecture with ultra-high isolation and possible gain is proposed, analyzed and demonstrated using 0.18-μm BiCMOS technology. The new RF switch architecture achieves an ultra-high isolation - substantially higher than that produced by a conventional switch topology. The newly designed 0.18-μm BiCMOS RF switch exhibits an ultra-broadband performance from 10 to 38 GHz with -2.6-dB loss to 0.4-dB gain, isolation from 40 to about 70 dB, and input return loss from 8 to 20 dB under small signal conditions. Within 35.5-38.5 GHz, its isolation reaches extremely high values, with the highest isolation around 70 dB at 36 GHz, approaching the measurable limit of the vector network analyzer. Measured insertion loss and isolation under large-signal conditions at 35 GHz show around 1-2 dB and 51.5 dB, respectively. The RF switch consumes a dc current of only 8 mA from a 1.8 V source. The extremely high isolation achievable by the new RF switch demonstrates the possibility of pushing RF system performance limited by switch isolation to a next level.

SiGe BiCMOS Concurrent Dual-band LNAs with Integrated Notch Filter

Jaeyoung Lee
Department of Electrical and Computer Engineering
Texas A&M University

Faculty Advisor: Dr. Cam Nguyen, Texas A&M University
Sponsor: The Air Force Office of Scientific Research

Abstract

Two concurrent dual-band low-noise amplifiers (DBLNA) for K- and Ka-band radar applications are presented. Both DBLNAs are based on the conventional wide-band LNA with two-stage cascode configuration. In order to implement the dual-band transfer characteristic, the first DBLNA (DBLNA1) uses two active notch filters connected to the collector node of common-emitter (CE) device at each stage. Since the active notch filter can compensate the loss of an on-chip inductor by providing negative resistance, the implemented active notch filter achieves very high quality factor compare to the low quality factor of conventional passive notch filter. Thus, the DBLNA1 exhibits high stop-band performance at 29 GHz between two desired RF bands (24.5/35 GHz). However, for the DBLNA1, the additional power consumption and increase of noise figure (NF) are unavoidable due to the active notch devices. In order to resolve these disadvantages of the DBLNA1, the second DBLNA (DBLNA2) is designed by integrating one passive notch with feedback scheme. The passive notch is fed-back from the collector of CE transistor at the second stage to the tapped inductor load of the first stage. This feedback notch configuration indeed forms a dual-band load network of the first stage, and also provides large stop-band attenuation without additional power consumption. Most importantly, removal of active notch filter at the first stage results in the lower NF performance compare to the DBLNA1.

The DBLNAs are designed with 0.18-µm SiGe BiCMOS process (SBC18H2) of TowerJazz. The post-layout simulation results of DBLNA1 show the power gain of 25.1/23.8 dB and NF of 3.76/3.93 dB at 24.5/35 GHz, respectively. The power consumption of DBLNA1 is 29.5 mW. The DBLNA1 excluding pads occupies 705×450 μm^2. The DBLNA2 achieves the power gain of 19.6/19.5 dB and NF of 3.62/3.64 dB at 24.5/35 GHz, respectively. The power consumption of DBLNA1 is 25.2 mW. The area of DBLNA2 excluding pads is 780×405 μm^2. The input and output return losses of both DBLNAs remain larger than 10 dB over desired bands.

A 0.18-μm BiCMOS Divide-by-3 Injection-Locked Frequency Divider Implementing Phase Tuning for Enhanced Locking Range

Sanghun Lee
Department of Electrical and Computer Engineering
Texas A&M University

Faculty Advisor: Prof. Cam Nguyen, Texas A&M University
Sponsor: U.S. Air Force Office of Science Research and U.S. National Institute of Justice

Abstract

A fully integrated 3.5 GHz divide-by-3 (1/3) injection-locked frequency divider (ILFD) is developed. It consists of an internal 10.5-GHz Voltage Controlled Oscillator (VCO) functioning as an injection source, 1/3 ILFD core, and output inverter buffer. A phase tuner implemented on an asymmetric inductor is proposed to increase the locking range. With an internal injection signal power of only -18 dBm, a 25% enhancement in the locking range from 12 to 15 MHz is achieved with the proposed phase tuning. The integrated 1/3 ILFD has a frequency tuning range of 3.3 – 4.2 GHz. It is realized using a 0.18-μm BiCMOS process, occupies 0.6 × 0.7 mm^2, and consumes 19.1 mW.

Low-Power Wide-Locking-Range Dual-Injection-Locked 0.18-µm BiCMOS 1/2 Divider with Simultaneous Optimization of VCO Loaded *Q* and Current

Sanghun Lee
Department of Electrical and Computer Engineering
Texas A&M University

*Faculty Advisor***:** Prof. Cam Nguyen, Texas A&M University
Sponsor: U.S. Air Force Office of Science Research and U.S. National Institute of Justice

Abstract

A new 1/2 dual-injection locked frequency divider (dual-ILFD) with wide locking range and low-power consumption is proposed, analyzed, and developed together with a divide-by-2 current mode logic (CML) divider. The chip was fabricated using a 0.18-µm BiCMOS process. The 1/2 dual-ILFD enhances the locking range with low-power consumption through optimized load quality factor (Q_L) and output current amplitude (i_{OSC}) simultaneously. The relationship between i_{OSC} and Q_L, and hence the locking range, is explained analytically. The designed 1/2 dual-ILFD also works as a free-running oscillator between 3.592 GHz and 4.102 GHz without injection signals. The 1/2 dual-ILFD achieves a locking range of 692 MHz between 7.512 and 8.204 GHz. The current consumption of the designed core 1/2 dual-ILFD is 2.93 mA with 1.5 V supply. The designed 1/2 dual-ILFD increases the locking range by 9.9 times over a single-injection counterpart. The new 1/2 dual-ILFD is especially attractive for microwave phase-locked loops and frequency synthesizers requiring low power and wide locking range.

A Self-Injection-Locked 0.18-μm BiCMOS 1/3 Frequency Divider with Improved Locking Range, Phase Noise and Sensitivity

Sanghun Lee
Department of Electrical Engineering
Texas A&M University

Faculty Advisor: Prof. Cam Nguyen, Texas A&M University
Sponsor: U.S. Air Force Office of Science Research and U.S. National Institute of Justice

Abstract

A new divide-by-3 injection-locked frequency divider (ILFD) utilizing self-injection technique is developed. The self-injection is realized with an odd-to-even harmonic converter through a feedback-amplifier that increases the injection efficiency of the 1/3 ILFD with boosted self-injection signal. The self-injection technique substantially enhances the locking range and phase noise, and reduces the minimum power of the injection signal needed for the 1/3 ILFD. The locking range is increased by 47.8 % and the phase noise is reduced by 14.77 dBc/Hz at 1-MHz offset. The required minimum injection signal power is only -30 dBm. The 1/3 ILFD is realized in CMOS technology with Jazz 0.18-μm BiCMOS process. The core 1/3 ILFD occupies 0.048 mm^2 with power consumption of 18.2 mW from a 1.8 V power supply.

An Energy Harvesting and Link Monitoring System using a 3 Stage Voltage Multiplier and Multi Phase Charge Pump on AMI06 process

Ravindranath Shrivastava
Electrical and Computer Engineering
Texas Tech University

Faculty Advisor: Dr. Richard Gale, Dr. Changzhi Li, Texas Tech University

Abstract

The reliability and the efficiency of the wireless link between the TX/RX for wireless sensors devices depends on the environmental conditions such as change in the physical distance or changes in the orientation between transmitter and receiver. So the need arises to monitor and the ability to adjust the wireless link between TX/RX without interrupting the operation of the wireless sensor. Also the ambient wireless energy can also be harvested to power the wireless sensor circuitry. We propose an N-Stage Voltage Multiplier/Rectifier built in AMI06 process using a PMOS diode to convert the ambient RF Energy into DC voltage which can be measured to evaluate the strength of the Wireless link. The proposed system can be used to monitoring and vary the wireless link parameters such as the resonant matching condition between TX/RX antenna coil and physical alignment without interrupting the operation of the wireless sensor. Also the DC energy harvested can be boosted further by our proposed multiphase charge pump to a higher DC Level which can be used by the wireless sensor circuitry. The DC power harvested can also be used alongside the on board battery which will lead to increase in battery efficiency. The voltage multiplier/rectifier and charge pump involving the power stage and the feedback circuitry can be built on the same die as the wireless sensor circuitry which can lead to less bulky system.

A Wireless Smart Sensor Network based on Multi-function Interferometric Radar Sensors for Structural Health Monitoring

Bozorgmehr Vosooghi
Department of Electrical Engineering
University of Texas Tech

Faculty Advisor: Dr. Changzhi Li, University of Texas Tech
Sponsor: National Science Foundation

Abstract

This work presents a wireless smart sensor network for structural health monitoring (SHM). Structural health monitoring is the dynamic process of monitoring the safety and functionality of infrastructures. Several existing approaches have been used for SHM. Linear variable differential transformer has been commonly used for sensing the displacement. However, it requires fixed reference point, which makes it very difficult to be installed on the long span bridge. Laser Doppler Vibrometer is very expensive and bulky, therefore impractical for extended SHM systems. Compact radar systems which are low-cost, low-power, and easy-installation can be used for healthcare applications. In this work, we proposed the use of radar sensor for structural health monitoring. We have designed a miniature radar sensor (2.4 GHz) for SHM. The radar sensor is a software-defined multifunctional device with a built-in ZigBee module for wireless data transmission and easy mesh networking. It has a small size of about 5cm x 7cm. The radar sensor works in a low power mode that allows the whole WSSN to be powered by a single battery pack. Furthermore, the radar sensor works in the arctangent-demodulated interferometric mode to monitor the structure's displacement with an accuracy of sub-millimeter.

As a demonstration, we implemented a WSSN of two radar sensors on a two-storey building model to monitor the model's fundamental frequencies. We compared the WSSN results with the reference accelerometer records. From the experimental result, it can be found that the WSSN based on multi-function radar sensors is a good alternative for SHM.

Wideband Conductor Loss Analysis for Transmission Line with Arbitrary Cross-section and Periodic Surface Roughness

Xichen Guo
Department of Electrical Engineering
University of Houston

Faculty Advisors: Dr. Ji Chen and Dr. David R. Jackson, University of Houston
Sponsor: Huawei Technologies Co., Ltd.

Abstract

The analysis of conductor loss for a transmission line with an arbitrary cross-section and a periodic surface roughness along the propagation direction is presented in this work. The frequency dependent skin-effect and proximity are both considered in the analysis. The per-unit-length impedance is first extracted by assuming a smooth metal surface. A modified surface impedance that accounts for the periodic metal surface roughness is then incorporated to provide a high-frequency correction.

The first step is to extract a series per-unit-length impedance as a function of frequency without considering the skin-depth and current-crowding effects. A compact 2D-FDTD solver is used to model the entire cross-sectional geometry (possibly inhomogeneous) assuming the metals are perfect electric conductors. To analyze the skin-depth as well as the current-crowding effects, the electromagnetic field distribution on the surface obtained from the previous perfect conductor analysis is then used as a boundary condition to analyze the current distribution inside the conductor; the conductor-only model is built in the 2D-FDTD solver with finer meshes to capture the current redistribution as a result of the finite conductivity. The equivalent surface impedance of the conductor is therefore obtained with a scale factor extracted as a function of the location on the circumference of the conductor.

Once the series per-unit-length impedance is solved, the fine features of the metal surface roughness are modeled as periodic protrusions. The reflection coefficient obtained from a plane-wave reflection from the periodic surface is used to obtain the surface impedance for the rough metal, which is used in a high-frequency calculation of the attenuation.

Wireless Power Transmission for Geophysical Applications

Xiyao Xin
Department of Electrical and Computer Engineering
University of Houston

Faculty Advisors: Dr. Ji Chen and Dr. David R. Jackson, University of Houston
Sponsor: Tubel Energy, Inc.

Abstract

Wireless power transmission is needed whenever it is difficult to implement a wired connection between a power source and an electrical load. One such situation arises in the geophysical area. It is desired to wirelessly power sensors along a pipe inside of an oil-producing well that is drilled horizontally, as there might be a production packer on the pipe so that cables cannot reach the device behind it. Creating an electrical power connection between a vertical and a lateral oil pipe also needs a wireless power transfer method. This investigation will focus on optimizing the achievable range and power transfer efficiency for the system of two coils wrapped along metallic pipes in the presence of a lossy environment.

A CAD model is used to describe the wireless power transfer system, in which each coil is modeled as an inductor in series with a resistor, along with a shunt capacitance placed across the circuit to model the stray capacitance of the coil and a shunt resistor placed across the inductor to model the eddy current losses in the lossy environment. This shunt resistor accounts for eddy current loss inside the pipe as well as in the external environment. The coil interaction is accounted for by a mutual inductance between the two coils.

Based on the CAD model, the power transfer efficiency is calculated and measured. Simple approximate formulas are also derived (in the weak-coupling limit) that directly show in a simple way the effects of the various coil parameters on the power transfer efficiency. The effects of adding a ferrite layer between the coils and the pipe is also explored in an effort to increase the power transfer efficiency. Also, the effect of encapsulating the coils with a layer of insulating material is explored for the purpose of improving the stability of the power transfer efficiency in a variable underground environment.

Reconfigurable Transformation Optics Based Surface Plasmon Polariton Wave Adapter

Bayaner Arigong
Department of Electrical Engineering
University of North Texas

Faculty Advisor: Dr. Hualiang Zhang and Dr. Hyoung Soo Kim, University of North Texas

Abstract

In this paper, we propose the design of a reconfigurable surface plasmon polariton (SPP) wave adapter designed by transformation optics, which can control the confinement of SPP waves on un-even metal surfaces. The proposed plasmonic device is constructed using homogeneously tunable materials (i.e. liquid crystals) so that the corresponding SPP wave transmission can be reconfigured by applying different voltages. Different types of modified design are investigated. Their performance is verified by full-wave simulations. The proposed devices will pave the way towards developing tunable plasmonic devices.

Design of Tunable Metamaterial Based On-Chip Spiral Inductors

Bayaner Arigong
Department of Electrical Engineering
University of North Texas

Faculty Advisor: Dr. Hualiang Zhang and Dr. Hyoung Soo Kim, University of North Texas

Abstract

This paper presents an innovative and practical architecture for a tunable spiral inductor with high quality factor (Q) on standard CMOS technology. Metamaterial based winding ring structures are employed to achieve the proposed high performance inductor. Specifically, the proposed structure is realized by utilizing the multiple metal-layers and vias available in a CMOS process. It is found that, by controlling the number of additional metamaterial ring structure applied to the original spiral inductor, the total inductance can be tuned. Using full-wave electromagnetic simulator, 20% and 40% increase are achieved in inductance when adding single-turn and two-turn metamaterial winding rings respectively. Moreover, the resultant Q of the metamaterial based tunable inductor is also increased from 2.75 to 3.75 at 17GHz (i.e. 36% increment).

Design of Dual-band Planar Microstrip Butler Matrix

Jin Shao
Department of Electrical Engineering
University of North Texas

Faculty Advisor: Dr. Hualiang Zhang, University of North Texas

Abstract

A novel planar 4×4 butler matrix working at two separate frequency bands is introduced. The proposed dual-band butler matrix consists of four dual-band 90 degree hybrids, two dual-band crossovers, two dual-band 45 degrees delay lines, and several dual-band impedance transformers. All of these dual-band components are designed to operate at 2.4 and 5.8 GHz to ensure the butler matrix can function at these two frequency bands.

Butler Matrices are widely used in antenna array systems. They can provide the feeding networks for switched beams antennas. Up to now, many microwave components have been designed to achieve dual-band operations. However, only very few dual-band butler matrix designs have been reported so far. In a recent paper (J.K. Lee and K. Chang, Electronics Letters, vol. 47, issue 21, 1164-1165, 2011), researchers introduced a dual-band butler matrix without crossovers. Since a novel planar dual-band crossover is also introduced in this paper, the entire dual-band butler matrix can be built on a uniplanar way. In this paper, a novel planar 4×4 butler matrix consists of four dual-band 90 degrees hybrids, two dual-band crossovers, two dual-band 45 degrees delay lines, and several dual-band impedance transformers are presented. These dual-band components are designed by using T-shape, modified T shape, or step-impedance structures.

Dual-Band Radio-Frequency Device for Sensing Dielectric Property Changes in Microfluidic Channel

Jin Shao
Department of Electrical Engineering
University of North Texas

Faculty Advisor: Dr. Hualiang Zhang, University of North Texas

Abstract

This work presents a dual-band RF device to detect the dielectric changes in polydimethylsiloxane (PDMS) microfluidic channel. Such a device, which consists of two dual-band Wilkinson power dividers (working at 2Ghz and 5GHz) and two 90^o dual-band microstrip lines (providing 180^o phase difference at two working frequencies), is very sensitive for identifying dielectric material changes. Moreover, by operating at two frequencies simultaneously, it can improve the measurement stability/robustness. Compared with the recently reported RF microfluidic sensor [Yang et al, Lab Chip, 10, 553, (2010)], the proposed device features enhanced measurement stability with the same level of measurement sensitivity (-80dB cancellation level).

The dual-band technology is combined with the RF dielectric measurement device to provide two-frequency-band microfluidic detections. The proposed device is able to catch the dielectric change (lead to frequency shift) in the PDMS channel at 2GHz and 5GHz, simultaneously. The direction of the resonant frequency shift at the two working frequencies is consistent. This consistency can be employed to minimize the influence of incorrect testing data (which may be caused by background noise or operational error) to the measurement. In this way, stability improvement of the microfluidic RF dielectric measurement device can be achieved by using the proposed dual-band devices.

Thermal Circuit Analysis of High Frequency Microwave Devices

Ardasheir Rahman
Department of Electrical Engineering
University of Texas at Arlington

Faculty Advisors: Dr. Ronald Carter, Dr. Alan Davis and Dr. Howard Russell University of Texas at Arlington

Abstract

High frequency semiconductor devices require careful modeling of the thermal network. In the microelectronic, microwave, and RF components, the levels of integration and device density on the chips as well as frequency of operation has been increasing to meet the demands of the market. In most RF systems, the power amplifier stage produces the most critical heat. The output stage of the power amplifier generally uses high gain semiconductor devices like Bipolar Junction Transistors (BJTs) or Heterojunction Bipolar Transistors (HBTs).

The thermal design is aimed to prevent the thermal induced physical failure through reduction of the temperature rise above ambient and minimization of temperature variation with the packaging structure. Modeling of the thermal components into its electrical analogy is done so that designer can incorporate the thermal effects of the devices in the designer simulations. This study concentrated on the thermal modeling aspects of the high frequency device using TCAD 3-dimensional thermal simulation. The thermal characterization of HBTs has been presented. The effects of the isolation oxide and thermal impedance dependence on the dimensions of vertical and horizontal isolation oxide have been explored. A thermal model has been developed for packaging schemes with a solder bump connection to ambient temperature and compared with a bottom wafer ambient temperature connection. The electrical analogy developed from the thermal analysis can be used in VBIC, HICUM and MEXTRAM compact transistor models which are used to characterize the behavior of HBTs.

Thermal Characterization of SiGe HBTs using HICUM model

Valay Shah
Department of Electrical Engineering
University of Texas at Arlington

Faculty Advisors: Dr. Ronald Carter, Dr. Alan Davis and Dr. Howard Russell University of Texas at Arlington

Abstract

At microwave frequencies transistors are the most widely used solid-state devices. At very high microwave frequencies, high frequency effects limit the usefulness of transistors and also the other solid state devices. The primary limitations to higher frequency are emitter and base resistance, capacitance and the transit time. These parameters can be controlled by reducing the area of the transistor without reducing the periphery and still maintaining high transistor gain. The other obstruction to this solution is the requirement of high current and power capability for microwave applications. Heterojunction Bipolar Transistors (HBTs) have been designed to operate at much higher frequencies than silicon BJTs. They also out-perform their CMOS counterparts by having superior flicker noise, broad-band noise, Early voltage, transconductance and better tracking of V_{be} relative to the V_t of the MOSFET. All these benefits come at the cost of self heating of the transistor. Self heating can be modeled by taking into account the increase in thermal resistance and thermal capacitance of the device increasing the power dissipation of the device. In order to precisely monitor the increase in the thermal parameters of the device couple of SPICE compact models are available in the market. Among these various models VBIC, HICUM and MEXTRAM compact models are widely used to characterize the thermal behavior of HBTs.

The HICUM model is used to characterize the thermal parameters of SiGe HBTs. Along with the thermal parameters other device model parameters are also optimized in order to get the best fit of theoretical values with the measured data. Forward Gummel and output characteristic setups have been used to measure the device data.

Reference Timing Circuit

Farah Vandrevala
Department of Electrical Engineering
University of Texas at Arlington

Faculty Advisors: Dr. Ronald Carter, Dr. Alan Davis and Dr. Howard Russell,
University of Texas at Arlington

Abstract

The detector to be used in the Large Hadron Collider requires very low jitter clock signal to measure the time difference between two outgoing protons. The reference timing circuit is stabilized through the use of a phase locked loop feedback mechanism that first multiplies and converts a 40 MHz signal to 480 MHz, which is sent down a coaxial cable to a receiver circuit, which reflects it back to the transmitter until the jitter is less than 10 ps. The stabilized output signal at the receiver end is then converted to a 40 MHz square wave.

Here we focus on converting the 40 MHz pulse signal into a 480 MHz signal which is stabilized through an analog phase locked loop circuit. The stabilized output signal is then converted back to a 40 MHz pulse wave. The purpose of this circuit is to observe the changes in the signal characteristics as the frequency is changed. Since the original pulse signal passes through filters, mixers and a host of other RF components, it gets converted into a sine wave, which then must be converted back to a pulse form while still preserving the signal integrity.

Microwave Applications of ε-Near-Zero Metamaterials

Jason C. Soric
Department of Electrical Engineering
University of Texas at Austin

Faculty Advisor: Dr. Andrea Alù, University of Texas at Austin

Abstract

With the large interest in metamaterials, experimental findings have recently shown that this new technology is more than a theoretical curiosity. Devices based on metamaterials have shown significant advantages compared to those based on conventional materials in a variety of applications, including antennas, phased-arrays, circuits and other components, spanning frequencies from radio to the optical range. In this work, we present several of our recent efforts in theoretically exploring and experimentally verifying the anomalous properties and applications of ε-near-zero (ENZ) and low- or negative-permittivity metamaterials for matching, antenna design and cloaking.

A simple matching technique based on an ultra-narrow ENZ channel is presented and experimentally verified, which allows matching arbitrarily-shaped waveguide structures independent of their length, shape or discontinuities. Based on this unique physical mechanism, we show that a feeding element may be efficiently matched to free-space when connected to such an ENZ channel, independent of its longitudinal position. Compact multiband ENZ antenna designs are presented based on this concept, providing highly efficient isotropic radiation from small antennas without the need of complex matching circuits. Experiments and full-wave simulations support the exciting properties of ENZ metamaterials for microwave waveguiding and radiation.

Cloaking has received a large amount of attention over the last decade. We present our recent experimental validation of cloaking based on ENZ metamaterials, using the scattering cancellation technique: *plasmonic cloaking*. We have designed, realized and tested a low-permittivity metamaterial cover aimed at strongly suppressing the total scattering cross-section (SCS) of a 3D, finite-length, moderately sized dielectric cylinder in free-space over a moderate bandwidth in the microwave range. This cloaking effect is validated by conventional azimuthal, elevation, and out-of-plane monostatic and bistatic far-field measurements. In addition, experimental near-field measurements demonstrate the cloaking effect around the cloak. These near-field images explicitly show the scattering cancellation effect, fully consistent with our far-field measurements. Our experimental validation represents the first effective application of the cloaking technique to a free-standing 3D object, with exciting venues for super-stealth, non-invasive testing and measurements, and improved biosensing.

Design of a Leaky Wave Antenna for Two-Dimensional Tracking of Moving Targets

Shang-Te Yang
Department of Electrical and Computer Engineering
The University of Texas at Austin

Faculty Advisor: Dr. Hao Ling, The University of Texas at Austin

Abstract

A microstrip leaky wave antenna (MLWA) is a simple and elegant antenna structure for achieving a frequency-scanned beam with high gain. In this work, two back-to-back microstrip leaky wave antennas are designed to acquire a two-dimensional azimuth-elevation radar image of moving targets in a scene. The concept entails the use of the frequency-scanned pattern of the MLWA to detect the azimuth bearing of individual targets. Two such MLWAs are then packed closely together to work as an interferometer to derive the corresponding elevation bearing. A single half-width MLWA is designed first using the transverse resonance method. In order to pack two antennas for applying interferometry, two MLWA elements are placed in a back-to-back configuration. The MLWA elements consist of two thin metal fins with a center metal block serving as the vertical shorting plane for both elements. This design results in good isolation and more symmetrical element patterns. The designed half-width MLWA is verified with the full-wave solver FEKO and built for measurement. The simulation and measurement results agree well and the main beam is scanned by sweeping the operating frequency. Acoustic subwoofers driven with constant audio tones are then used as test Doppler targets. It is shown that an azimuth-elevation radar image of multiple subwoofers can be generated by the proposed antenna structure. Simulation is also carried out using a narrower beam MLWA and human animation data to illustrate the potential of using the MLWA to gather a frontal image of a moving human.

Realizing Efficient Wireless Power Transfer in the Near-Field Region Using Electrically Small Antennas

Ick-Jae Yoon
Department of Electrical and Computer Engineering
University of Texas at Austin

Faculty Advisor: Dr. Hao Ling, University of Texas at Austin

Abstract

Non-radiative wireless power transfer using the coupled mode resonance phenomenon has been widely reported in the literature. However, the distance over which such phenomenon exists is very short when measured in terms of wavelength. In this work, we investigate how efficient wireless power transfer can be realized in the radiating near-field region beyond the coupled mode resonance region.

First, electrically small folded cylindrical helix (FCH) dipole antennas are designed to achieve efficient near-field power transfer. Measurements show that a 40% power transfer efficiency (PTE) can be realized at the distance of 0.25λ between two antennas in the co-linear configuration. These values come very close to the theoretical upper bound derived by the spherical mode theory. The results also highlight the importance of antenna radiation efficiency and impedance matching in achieving efficient wireless power transfer.

Next, antenna diversity and antenna directivity are explored to further extend the range or efficiency of the power transfer. For transmitter diversity, it is found that a stable PTE region can be created when multiple transmitters are employed at sufficiently close spacing. For receiver diversity, it is found that the overall PTE can be improved as the number of the receivers is increased. Small directive antennas based on the FCH design are also implemented to enhance the PTE. It is shown that the far-field realized gain is a good surrogate for designing small directive antennas for near-field power transfer.

Finally, to examine the effects of surrounding environments on the near-field coupling, we derive an analytic upper bound for near-field wireless power transfer when the transmitter is surrounded by a spherical material shell. The derived formulas for both TM and TE mode radiators show good agreement with full-wave simulation results. Lossy dielectric material effects on wireless power transfer are studied using the derived theory. Power transfer measurements through an exterior concrete wall are conducted and the results are compared with the theory.

Investigation of FR4 Laminates for Millimeter-Wave Packaging

Supreetha Aroor
Department of Electrical Engineering
University of Texas at Dallas

Faculty Advisor: Dr. Rashaunda Henderson, University of Texas at Dallas

Abstract

Emerging millimeter-wave circuits for commercial applications require low manufacturing costs, high performance and a high level of integration. CMOS has been identified as an important technology for the realization of low-cost millimeter-wave consumer products. As a result, there is an increased emphasis on the packaging of millimeter-wave circuits. Antennas fabricated in laminate packages are being considered as a low-cost alternative to system-on-chip solutions.

Flame Resistant 4 (FR4) is an inexpensive material typically used as a substrate for printed circuit boards in low frequency applications. Here, we investigate FR4 laminates as possible packaging solutions up to 67 GHz. We present measurement results for coplanar waveguide transmission lines on three different FR4 laminates with varying substrate heights and metallization thicknesses, namely, FR406, FR408 and a multi-layer FR4 material. The impedance, effective permittivity and attenuation constant of these lines is calculated from S-parameter data. A comparison of the attenuation constants shows that FR408 laminate by Isola Global has the lowest attenuation. Measurement data for microstrip lines on a multi-layer FR4 stack-up is also presented. These lines can be used to facilitate flip-chip packaging of future integrated circuit (IC) chip sets on the FR408 material which will rely on short interconnects that do not degrade overall system performance as demonstrated by this work.

Millimeter-wave Properties of Silicon Substrates

Wen Shu
Department of Electrical Engineering
University of Texas at Dallas

Faculty Advisor: Dr. Rashaunda Henderson, University of Texas at Dallas
Dr. Sam Shichijo, University of Texas at Dallas
Sponsor: Semiconductor Research Corporation (SRC)

Abstract

Millimeter-wave CMOS circuits have emerged because of technology scaling. While the properties of silicon substrate at frequencies below 100 GHz are widely researched, the substrate effects above 100 GHz are little studied. At these high frequencies, the effects of plasma oscillation and carrier damping start to become noticeable. In addition, the permittivity and conductivity of silicon become complex and affect the loss mechanisms of the substrate. The Drude model can be used to describe the carrier dynamics of electrons and holes; which treats the free carriers in a solid, subject to random collisions. Passive devices measured up to sub-millimeter wave frequencies can provide information about the silicon substrate properties. This work studies how substrate properties influence the performance of passive devices.

Coplanar waveguide transmission lines are the initial structures used in this study. The line dimensions are calculated using analytical expressions and simulated with Ansoft HFSS to be compared with the fabrication. A design of experiments has been developed as a function of substrate resistivity and impedance, for characterizing material properties up to 325 GHz. The lines are fabricated with different process methods – blanket substrate processing at UT Dallas or standard 65nm CMOS processing at a member company fabrication facility. Material parameters (conductivity and permittivity) are extracted from the measured scattering parameters of the fabricated lines by using multiline thru-reflect-line calibration and de-embedding techniques.

Post-CMOS Interconnect Performance at Millimeter-Wave Frequencies

Rownak Islam
Department of Electrical Engineering
University of Texas at Dallas

Faculty Advisor: Dr. Rashaunda Henderson, University of Texas at Dallas
Sponsor: Semiconductor Research Corporation (SRC)

Abstract

The performance of interconnects for use in on-chip antenna integration systems will be presented at millimeter-wave (mm-wave) frequencies. Benzocyclobutene (BCB) is an excellent candidate for high frequency post-CMOS integration because of its low dielectric constant (2.65), low loss tangent and simple processing. The material is photo definable and can be deposited similarly to photoresist. Coplanar waveguide (CPW), microstrip and grounded CPW (GCPW) simulations up to 300 GHz have been performed in HFSS and transmission line characteristics are compared. Measurement results of three interconnect up to 67 GHz shown that GCPW possesses less loss (dB/mm) compared to microstrip and CPW interconnects.

In particular, an extensive study of CPW interconnects on 10 ohms-cm CMOS substrates has been conducted. Dielectric loss is minimized in CPW with BCB thicknesses no greater than 32 microns. To the authors' knowledge, the loss (dB/mm) of measured CPW interconnects on 8 and 24 microns of BCB is compared for the first time up to 220 GHz. A 60 Ohm CPW on 24 microns of BCB has an attenuation of 0.55 dB/mm at 60 GHz whereas a 50 ohm CPW interconnect on standard CMOS without a P+well layer has an attenuation constant of 1 dB/mm at the same frequency.

A High-Isolation 70-90 GHz SPST Switch in 45nm CMOS

Tabassum Mahzabeen
Department of Electrical Engineering
University of Texas at Dallas

Faculty Advisor: Dr. Bhaskar Banerjee, University of Texas at Dallas
Sponsor: Semiconductor Research Corporation

Abstract

CMOS has emerged as the technology of choice for radio frequency (RF) and millimeter wave (mmW) integrated circuits (IC). The seamless integration of CMOS transceiver with digital CMOS process enhances the on-chip testability thus reducing the production and testing cost. Built-in-self-test (BIST) using loopback is one of the cost-effective methods of testing the transceiver and is a challenging problem at millimeter wave frequencies. One of the critical blocks for loopback is the switch closing the loop between the transmitter and the receiver. For this application, the switch requires to have very high isolation such that the switch does not impede the regular operation of the transceiver. Additionally, the switch also needs to have high impedance during OFF time such that the signal through the switch is minimal. The insertion loss is not crucial to the loopback operation as the signal level transmitted from the baseband processor can be adjusted for precise loopback operation.

We present an SPST switch that was fabricated in TI45nm bulk CMOS process with five thin metal layers and 2.4 μm thick top metal layer. The measured switch exhibits 12 dB of insertion loss at center frequency of 80 GHz, peak isolation of 42 dB, and return loss of 14 dB. The isolation is below 31 dB from 70-90 GHz. When the switch is not operating, the measured impedance is 192 Ω, reasonably high impedance for the incoming signal so as to have minimal effect on the normal operation of the receiver.