MAJOR RESEARCH ACHIEVEMENTS

MMIC / RFIC

DEVICE MODELING AND CIRCUIT DESIGN FOR RF APPLICATIONS

In our research results, the device modeling of the microwave transistors including the metal oxide semiconductor field effect transistors (MOSFETs) and pseudomorphic high electron mobility transistors (pHEMTs) has been carried out. In addition, the circuit design and system implementation for the radio frequency (RF) applications are realized. In the device modeling, the four-port on-wafer de-embedding technique is proposed for the MOSFET characterization. Only two dummies, including an open and a through, are used so that the advantages of simplicity and chip area reduction is achieved. For the III-V transistor characterization, the first RF current-voltage (I-V) curve for a GaAs (Gallium Arsenide) pHEMT is presented. This RF I-V curve is implemented from the high frequency extracted transconductance and output conductance. The difference between the direct current (DC) I-V and RF I-V of the pHEMT is observed due to the surface state effect and slow deep level traps effect. This RF I-V curve can be utilized to predict the performance of the RF circuit more precisely. For the MOSFET device, the breakdown small-signal equivalent circuit is proposed to describe the anomalous inductive S22 for the first time. A novel and physical breakdown network is utilized to remove the low-frequency dispersion of the channel resistance determined by the conventional method. Good agreement between simulated and measured S-parameters of the MOSFET operated in the breakdown region is obtained.

In the circuit design, the high-linearity and low-power silicon germanium (SiGe) low noise amplifier (LNA) is presented. The third-order intermodulation (IM3) cancellation is realized by using the series-shunt feedback capacitance such that the high linearity can be achieved. The presented cascode LNA for 5.7 GHz wireless local area network (WLAN) band applications has the 2.79 dB NF, 16.25 dB power gain, 3.69 dBm IIP3, and 4 mW DC power consumption. The state-of-the-art figure of merit (FOM) of the presented LNA is demonstrated.

In the system implementation, the low power consumption vital sign detection system is realized based on the power management technique with pulse bias. The direct-conversion non-quadrature architecture is employed to implement the sensor for human respiration and heartbeat detection. The tunable phase shifter is utilized to reduce the null point and DC offset problem. In addition, the pulse bias with the switching noise considered is applied to the presented sensor for the green energy application. Thus, the front-end circuits can save 44 % power dissipation when compared with the conventional circuits without power management.

SIGNAL INTEGRITY AND PACKAGING

RF AND SI INTEGRATED DESIGN TECHNIQUES FOR THE CHIP CARRIER IN A WIRELESS 3D SYSTEM-IN-PACKAGE

This work is devoted to the advanced and novel RF and signal integrity (SI) designs for the chip carrier in a 3D system-in-package (3D-SiP). The research targets include active device carriers, passive integrated devices, stacked dies in package, antennas in package, embedded passive substrate, 3D interconnects, etc. Electromagnetic simulation and equivalent-circuit modeling for individual devices and interconnects are particularly emphasized for the convenience of system integration and development.

There is a main project with two subprojects in this work. The main project takes up the wireless 3D-SiP technology planning, develops the test vehicle based on IEEE 802.11n standard, and transfers the technology to the industry. In addition, the main project carries out the designs of integrated and embedded passives, the modeling of 3D passives and interconnects, and then the codesigns of RFICs and chip carriers in a wireless 3D-SiP. Subproject 1 studies the electrical characteristics of crucial interconnects such as through silicon vias (TSVs) and micro-bumps and their influence on signal and power integrity. The subproject 1 also extends to a novel integrated design of RF chips, integrated passive devices, and antennas in a 3D-SiP for MIMO system applications. Subproject 2 is focused on the miniaturized antennas in package with the use of metamaterial and electromagnetic bandgap structures to improve the arising electromagnetic compatibility (EMC) problems. In the meanwhile, the subproject 2 develops the isolator to reduce the coupling between antennas for MIMO system applications.

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ANTENNA

MULTIBAND COUPLED-FED MONOPOLE ANTENNAS FOR MOBILE COMMUNICATION DEVICES

In this work, a variety of multiband communication device antennas using the coupling-feed mechanism are presented. The coupling feed contributes additional capacitance to the antenna's input impedance which shows a high inductive component for the traditional case of using a direct feed. In the first and second antenna designs, with the coupling feed, the high input inductance of the antenna is effectively compensated. This behavior leads to a dual-resonance excitation for the lower band of the antenna. Two wide operating bands are achieved, allowing the antenna's lower and upper bands to easily cover GSM850/900 and GSM1800/1900/UMTS operation. For the last two antenna designs, owing to the coupling feed, the very large input impedance seen at antenna's lower band is greatly decreased and results in successful excitation of the one-eighth wavelength (λ/8) mode of the antenna. The specific absorption rate and hearing aid compatibility results for these mobile phone antennas are also analyzed. The effects of presence of the user's hand on the laptop computer antenna performance are also studied in this work.

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MOBILE COMMUNICATION DEVICE ANTENNAS FOR LTE/WWAN AND LTE MIMO OPERATIONS

In this work, not only the antenna and antenna array design techniques for fourth-generation mobile communication system are proposed, but also the specifications related to antenna bio-compatibility are studied. At first, two dual-wideband design techniques suitable to be applied for laptop computer applications for LTE/WWAN and LTE MIMO operations are proposed. The techniques can also be applied to internal tablet computer antennas. The isolation issues of MIMO antenna array of different mobile communication devices, such as laptop computer, tablet computer, and mobile phone, are then discussed. Finally, an analysis of body SAR for tablet computer applications are given and discussed.

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DESIGN OF MINIATURIZED PRINTED CIRCUIT BOARD ANTENNAS FOR 802.11N MIMO APPLICATIONS

MIMO antennas were designed for 802.11n wireless standards with maximum transfer rates of up to 300 Mbps. First, we designed two small single antennas, which were applied later in MIMO antenna designs. The size of our MIMO antenna designs was only 19 mm × 30.3 mm. In MIMO antenna designs, we employed two methods to increase the isolation between the two MIMO antennas: one manipulated the ground plane size, in which the isolation reached 18.9 dB; the other utilized a decoupling metal, where the overall isolation reached 24.6 dB in all of the operating frequencies, with the best isolation being 31.4 dB. The frequency of the coupling/decoupling for the decoupling metal can be adjusted independently; thus not affecting the original resonant frequency and the return loss of the two MIMO antennas. Actual measurements conducted in the microwave chamber (Reverberation Chamber) have verified the channel capacity were effectively increased, the total radiation efficiencies were about 60%, and the effective diversity gain was about 7dB. The MIMO antenna designs can practically and easily applied in the USB dongles.

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MEASUREMENT AND ANTENNA DESIGN OF RFID TAGS FOR METALLIC OBJECTS

A measurement method for characterizing RFID chip has been proposed that can measure the approximate Read/Write threshold power and impedance of RFID strap with minimum operating procedures; furthermore, the complicated RF facilities are not required. Obtaining the specifications of RFID strap allows designers to estimate maximum read range of designed RFID tag in advance. Therefore, the implemented cost and design cycle times can be reduced substantially. For the verification of the final match condition of assembled RFID tag, a direct measurement technique has been developed, which not only can verify the final impedance match condition of the assembled RFID tags, but can also be used to identify the resistance and reactance mismatch condition between the RFID chip and antenna. The measurement data obtained from the verification method can also be used to estimate the assembly error introduced by different mounting methods. The use of the corrected circuit model of the RFID chip impedance, which includes the assembly error, helps improve the accuracy of the RFID tag design. In the RFID metal tag design, a series of low profile and miniature RFID tags, which is directly attached on metallic objects, has been developed. A series of low cost and easily produced RFID tag antenna structures also has been realized for RFID application on hanging metallic tag, which makes the RFID solution well suited for metallic tag of labeling system that requires integration of RFID technology. The attached RFID metal tag and the metallic RFID hanging tag cover most of the RFID application on steel products in the steel industry.

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COMPUTATIONAL ELECTROMAGNECTICS

THE ANALYSIS AND SIMULATION OF MICROSTRIP-FED DIELECTRIC RESONATOR ANTENNA USING FDTD METHOD

Dielectric resonator antennas (DRAs) offer some attractive characteristics over conventional microstrip antennas, such as small size, low profile, light weight, ease of excitation, and high radiation efficiency at higher frequency bands. Since DRAs attract more and more attention, theoretical analysis has been insufficient to simulate various configurations of dielectric resonator antennas. Therefore some researchers introduce numerical methods to analyze DRAs, such as Finite Difference Time Domain (FDTD) method, Method of Moment (MoM), Finite Element Method (FEM). In this work, we apply two kinds of methods including FDTD and MoM to analyze a DRA and compare the results using these two methods. Then we simulate various configurations of DRAs using FDTD method. In designing the DRAs, we applied an equivalent approach to solve approximate dimensions of DRAs, and then we obtain accurate dimensions using FDTD method. In this work, a DRA at 5.8 GHz has been designed with an L-shaped patch to increase impedance bandwidth. Above all, we hope to build a fast and accurate procedure to find the resonant frequency, bandwidth, and far field patterns of DRAs, and to reduce computation time in designing DRAs.

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