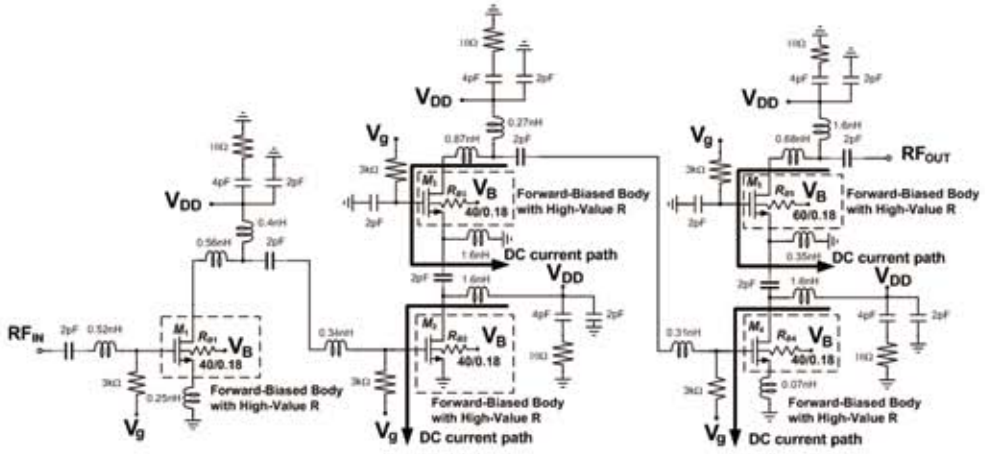
MAJOR RESEARCH ACHIEVEMENTS

MMIC / RFIC

A LOW-VOLTAGE LOW-POWER K-BAND CMOS LNA USING DC-CURRENT-PATH SPLIT TECHNOLOGY

A low-voltage low-power K-band low-noise amplifier (LNA) using 0.18-μm CMOS technology is presented in this letter. By splitting the dc current paths, the supply voltage of the LNA is effectively reduced. Moreover, the forward-biased body is adopted for the LNA to boost the gain. Furthermore, the high-value resistors are utilized between nMOS bodies and forward-body biases (VB) to prevent the signal leakage and noise coupling. The proposed LNA achieved a 13.2-dB gain and 4.1-dB noise figure at 20.5 GHz. The supply voltage and total dc power consumption are 0.6 V and 7.1 mW, respectively. To the author's knowledge, this LNA demonstrates the lowest supply voltage among previously published K-band 0.18-μm CMOS LNA.



DESIGN AND APPLICATION OF Q-ENHANCED INDUCTOR AND ACTIVE BANDPASS FILTER IN STANDARD CMOS

An active bandpass filter consisting of complementary cross-couple pairs to compensate resistive losses of resonators and a shunt-feedback inductor to achieve the transmission zeros has successfully been implemented on a standard CMOS process. By using the proposed topology, the filter provides three transmission zeros to reject the undesired interference while maintaining the desired passband characteristics. Good agreement between measured and simulated results and good electrical characteristics of the low-loss and high-selectivity filter demonstrate the feasibility of the proposed design methodology.

A *Q*-enhanced inductor using tapped-inductor feedback technique is presented. This technique not only compensates resistive losses with low-power consumption but also provides a high-inductance inductor.

The inductor is successfully designed, implemented and verified in a standard 0.18-μm CMOS process. The proposed method improves the *Q* factor as well as power consumption of conventional transformer feedback architectures. Compared with other published works, the proposed design shows advantages in terms of high-*Q* factor, high inductance, and the lowest power consumption.

References

[1] S. Wang, and B.-Z. Huang, "Design of CMOS active bandpass filter with three transmission zeros," *Electron. Lett.*, Vol.47, No. 20, pp. 1030-1031, Sep. 2011.

[2] S. Wang ,and R.-X. Wang, "Q-enhanced CMOS inductor using tapped-inductor feedback," *Electron. Lett.*, Vol.47, No. 16, pp. 921-922, Aug. 2011.

SIGNAL INTEGRITY AND PACKAGING

ENHANCEMENT OF SIGNAL INTEGRITY AND CROSSTALK REDUCTION TECHNIQUES

The signal integrity (SI) in a poor printed circuit board (PCB) layout is affected by noise and may become unstable. Crosstalk is a major source of noise that interferes with SI.

Generally, crosstalk can be reduced by adding a guard trace between the victim and aggressor areas of the circuit. A design rule to determine the total length and the horizontal section length of the serpentine guard trace via (SGTV) structure to achieve optimum performance is proposed [1].In addition, the optimal number of grounded vias to prevent crosstalk is also proposed [2].However, a large number of shorting-vias and resistances reduce the flexibility of the circuit routing and increase cost. Using the rectangular-shape resonators (RSR) structure to suppress the far-end crosstalk (FEXT) is proposed [3]. In which, the shorting-via and resistance are not necessary to be used for improving the FEXT, the method can be indeed employed to those products of the high-speed printed circuit board applications

References

[1] W.-T. Huang, C.-H. Lu, and D.-B. Lin, "Suppression Of Crosstalk Using Serpentine Guard Trace Vias," *Progress In Electromagn. Research*, vol. 109, 37-61, 2010.

[2] W.-T. Huang, C.-H. Lu, and D.-B. Lin, "The Optimal Number and Location of Grounded Vias to Reduce Crosstalk," *Progress In Electromagn. Research*, vol. 95, 241-266, 2009.

[3] D.-B. Lin, C.-K. Wang, C.-H. Lu, and W.-T. Huang, "Using Rectangular-Shape Resonators to Improve the Far-End Crosstalk of the Coupled Microstrip Lines," *Progress In Electromagn. Research Symp.*, Marrakech, Morocco, 2011.

ANTENNA

DTV MINIATURIZED ANTENNA AND RFID TAG ANTENNA DESIGN

Digital television (DTV) systems have become very attractive for applications to wireless mobile communication devices. It is desirable to develop new types of DTV systems with receiving antennas that are not only small in size, but are also capable of offering a wide operation bandwidth encompassing the entire DTV band 470–862 MHz. A miniaturized spiral multimode antenna has been proposed [1]. The antenna is especially suited for application in small-sized DTV signal receptions. In addition, A printed chip type antenna using spiral monopole slot structures on system ground for digital video broadcasting-

handheld (DVB-H) signal reception is proposed [2]. The volume of the antenna is only 20 x 20 x 0.8 mm^3.

The interest in radio-frequency identification (RFID) systems has grown tremendously. A novel RFID tag antenna is proposed for the UHF RFID band [3]. The structures of the rectangular patch and microstrip shorted to ground plane. The proposed antenna can work not only in air but also on metallic objects within the UHF RFID band, and the maximum readable distances are over 5 m.

References

[1] D.-B. Lin, P.-C. Tsai, I-T. Tang, and P.-S. Chen, "Spiral and Multimode Antenna Miniaturization for DTV Signal Receptions," *IEEE Antennas Wireless Propag. Lett.*, vol. 9, pp. 902-905 ,2010.

[2] E.-T. Chang, D.-B. Lin, I-T. Tang, and M.-P. Houng, "Novel Chip Antenna with Eight Spiral Monopole Slot Structures for DVB-H Applications," *IEEE Annu. Wireless Microw. Technol. Conf.*, Melbourne,2010.

[3] D.-B. Lin, I-T. Tang, and C.-C. Wang, "UHF RFID H-Shaped Tag Antenna Using Microstrip Feed Design on Metallic Objects," *J. Electromagn. Waves Appl.*, vol. 25, pp. 1828-1839, 2011.

MICROWAVE/MILLIMETER WAVE SYSTEMS

ANALYSIS OF THE LOCAL PULLING IN RF TRANSCEIVERS

A local oscillator (LO) is a crucial component in an RF transceiver subject to interference, which often causes frequency pulling effects to degrade the spectral purity, owing to the nature of oscillators. Generally, the interference comes from various sources including power-amplified signals and spurious signals, and is injected into a VCO of a PLL via a parasitic coupling path [1], [2]. In the early days, Adler [3] and many other authors [4]-[7] studied the behavior of an oscillator under injection of an independent sinusoidal signal. Although a great deal of effort has been made on characterizing the pulling effects, what seems to be lacking, however, is delivering a system frequency response with respect to injection. This research is devoted to a study of injection pulling in a phase-locked oscillator. The preliminary publication of this work [8] provided brief theoretical presentations on the proposed frequency-domain analysis and discrete-time domain calculating method in the prediction of the output spectra of a PLL pulled by injection signals. In addition, a dual-loop model in an expansion of the frequency-domain approach is provided on the phase noise for a pulled PLL [9]. A modulation signal is also considered to imitate the practical interference to pull a PLL. The elimination of the pulling effect was also proposed [10] based on this theoretical work.

References

[1] B. Razavi, "Challenges in portable RF transceiver design," *IEEE Circuits Devices Mag.*, vol. 12, no. 5, pp. 12–25, Sep. 1996.

[2] B. Razavi, "RF transmitter architectures and circuits," in *Proc. IEEE Custom Integrated Circuits Conf.*, San Diego, CA, 1999, pp. 197–204.

[3] R. Adler, "A study of locking phenomena in oscillators," *Proc. IRE*, vol. 34, no. 6, pp. 351–357, June 1946.

[4] R.-D. Huntoon, and A. Weiss, "Synchronization of oscillators," *Proc. IRE*, vol. 35, no. 12, pp. 1415–1423, Dec. 1947.

[5] R.-C. Mackey, "Injection locking of klystron oscillators," *IRE Trans. Microw. Theory Tech.*, vol. 10, no. 4, pp. 228–235, July 1962.

[6] L.-J. Paciorek, "Injection locking of oscillators," *Proc. IEEE*, vol. 53, no. 11, pp. 1723–1727, Nov. 1965.

[7] K. Kurokawa, "Injection locking of microwave solid-state oscillators," *Proc. IEEE*, vol. 61, no. 10, pp. 1386–1410, Oct. 1973.

[8] C.-J. Li, C.-H. Hsiao, F.-K. Wang, T.-S. Horng, and K.-C. Peng, "A rigorous analysis of local oscillators pulling in frequency and discrete-time domain," *2009 IEEE Radio Freq. Integr. Circuits Symp. Dig.*, pp. 409–412.

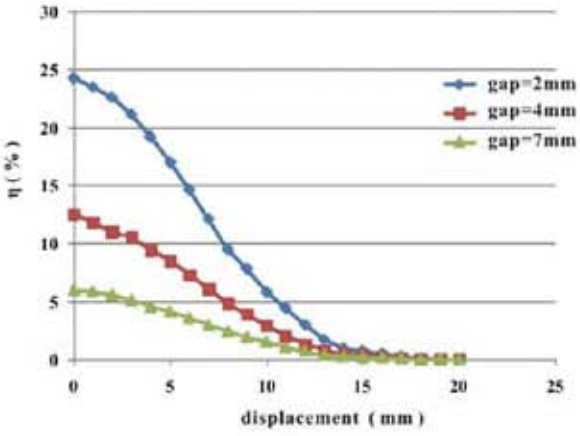
[9] C.-J. Li, C.-H. Hsiao, F.-K. Wang, T.-S. Horng, and K.-C. Peng, "A rigorous analysis of a phase-locked oscillator under injection," *IEEE Trans. Microw. Theory Tech.*, vol. 58, pp. 1391–1400, May 2010.

[10] C.-H. Hsiao, C.-J. Li, F.-K. Wang, T.-S. Horng, and K.-C. Peng, "Analysis and improvement of direct-conversion transmitter pulling effects in constant envelope modulation systems," *IEEE Trans. Microw. Theory Tech.*, vol. 58, no. 12, pp. 4137–4146, Dec. 2010

STUDY OF CONTACTLESS CHARGING PLATFORM FOR MOBILE DEVICES

This work proposes a universal contactless charging platform, which allowed two mobile devices placed and charged simultaneously. The size of charging platform is 114mm x 110mm x 22mm. By using electromagnetic induction, it could achieve wireless power transmission between charging platform and mobile device. The induction coil of the contactless charging platform is made of printed circuit board coil with minified coil size and circuit volume. The reed switch is used to achieve zero standby power consumption in the charging system. The experimental results show that the output regulated dc voltage of the secondary-side circuit is 5V, when the induction coil gap is 2mm and displacement is 0mm. The secondary-side circuit has a maximum output power of 1W and a maximum transmission efficiency of 24.2%, with a load impedance of 25Ω. The transmission efficiency maintained above 20%, when the secondary coil displacement less than 4mm. By designing appropriate secondary-side circuits to meet the charging requirements of different types of mobile device.

非接觸式充電平台對行動裝置充電之實體圖



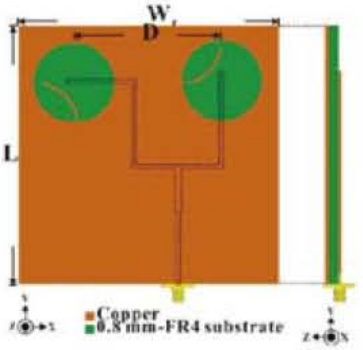
線圈間隙和位移改變之傳輸效率關係圖

DESIGN OF CIRCULARLY POLARIZED ARRAY RECTENNA FOR THE APPLICATIONS OF WIRELESS POWER TRANSMISSION

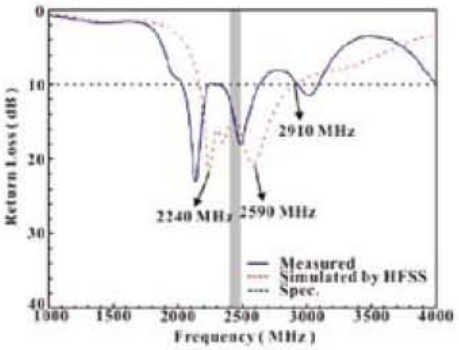
In this work, circularly polarized array rectenna for the applications of wireless power transmission has been studied. The proposed array antenna is operating at Microwave Frequency which intercepts and receives the RF energy of any polarization wave in free space. Low-pass filter, matching network and voltage-doubler rectifier are designed for impedance matching after the receiver antenna as well as to suppress the high order harmonics efficiently and minify the circuit size. It also solved the problem of traditional electric products battery charging. The technology of wireless power transmission for a rectenna by using the electromagnetic power as a charging resource, combine with the circular polarized array rectenna to achieve self-sufficiency application.

The proposed design of circular polarized slot array antenna, Low-pass filter, matching network and the

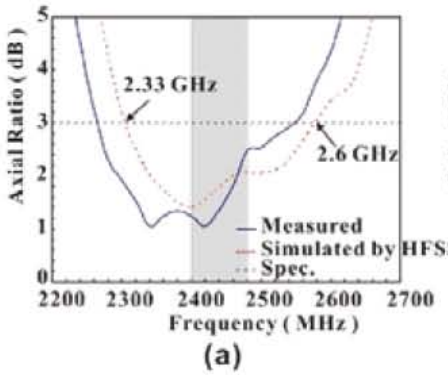
voltage-doubler rectifier which exhibit bandwidth and axial ratio bandwidth are following the specification of IEEE 802.11b (2.4~2.485 GHz). The result of the antenna gain is about 6~7.2 dBi. With the present design, a maximum voltage of 6.5 V and a conversion efficiency of 70 % colud be attainable.



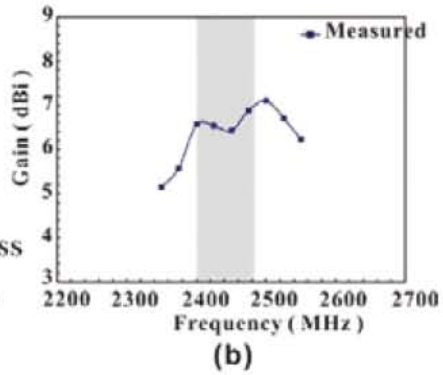
應用於 2.45 Ghz 微帶線饋入圓極化槽孔陣列天線之結構圖



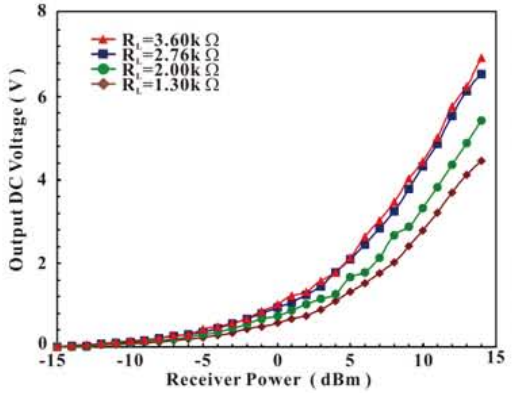
應用於 2.45 Ghz 微帶線饋入圓極化槽孔陣列天線之饋入網路示意圖.



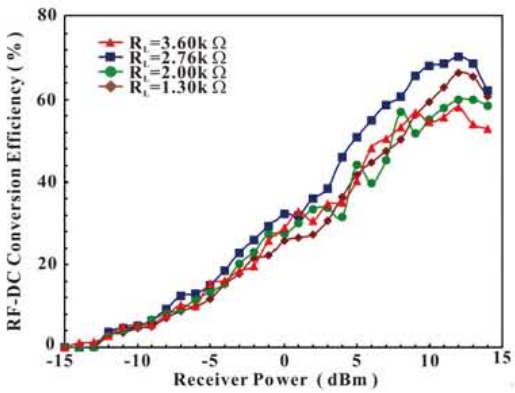
(a)應用於 2.45 Ghz 微帶線饋入圓極化槽孔陣列天線之模擬與實測軸比圖.



(b)應用於 2.45 Ghz 微帶線饋入圓極化槽孔陣列天線之與實測增益



應用於 2.45GHz 無線功率傳輸之整流陣列天線隨負載電阻 RL 變化,實測輸出直流電壓與接收功率間響應曲線圖.



應用於 2.45 GHz 無線功率傳輸之整流陣列天線隨負載電阻 RL 變化時,實測系統轉換效率與接收功率間響應曲線圖.

WIRELESS POWER CHARGING SYSTEM FOR MOBILE HANDSET

This topic aims at the development of three functional block circuits for high-frequency wireless energy transfer system, including transmission, propagation, and reception. First, a Metamaterial cavity consisting of the periodic Metamaterial surfaces is developed. The electromagnetic coupling characteristics between the transmitter and the receiver inside the Metamaterial cavity are investigated by using Couple Mode Theory and Perturbation Theory. Compared to the conventional metal cavity, the proposed Metamaterial cavity possesses broad bandwidth, strong coupling and EMI-free characteristics. Second, the power amplifier, antenna switch module and rectifier will be implemented by the most challenging CMOS IC process. For the receiving path, this proposed solution uses the original handset antenna without the need of extra bulky spiral antenna as the conventional low-frequency wireless energy transfer system, which benefits the commercialization of the proposed system in the compact multi-mode and multi-band handset wireless charging application. Finally, novel cubic, cylindrical, and spherical cavity resonators and the power amplifier, antenna switch module and RF-to-DC rectifier based on CMOS process are designed and implemented. The validity and usefulness of the proposed wireless energy transfer system is verified through simulation and measurement.

References

[1] C.-Y. Liou, C.-J. Kuo, M.-L. Lee and S.-G. Mao, "Coupling Enhancement Between Monopole-Type Resonators Using Metamaterial Cavity," *Applied Physics Lett.*.

[2] C.-Y. Liou, C.-J. Kuo, M.-L. Lee, and S.-G . Mao, "Wireless Charging System of Mobile Handset Using Metamaterial-Based Cavity Resonator," *IEEE MTT-S Int. Microw. Symp,*. June 2012.

[3] C.-Y. Liou, C.-J. Kuo, J.-C. Yeh, Y.-Z. Chueh, and S.-G. Mao, "Broadband and strong coupling metamaterial-based cavity resonator using artificial magnetic surfaces," *2011 IEEE MTT-S Int. Microw. Workshop Series on Innovative Wireless Power Transmission: Technol., Syst., Appl.(IMWS)*, pp.119-121, May 2011.

[4] C.-Y. Liou, C.-J. Kuo, J.-C. Yeh, Y.-Z. Chueh, and S.-G. Mao, "Broadband and strong coupling metamaterial-based cavity resonator using artificial magnetic surfaces," *2011 IEEE MTT-S Int. Microw. Workshop Series on Innovative Wireless Power Transmission: Technol., Syst., Appl. (IMWS)*, pp.119-121, May 2011.