From November 2007 *High Frequency Electronics*

UHF RFID Antennas for Printer-Encoders— Part 3: Mobile Equipment

By Boris Y. Tsirline
Zebra Technologies Corporation

The final installment of this series looks at antennas for mobile or portable RFID printer-encoder equipment

Antennas for RFID applications have unique requirements, particularly for the small spaces inside portable or mobile equipment. This final installment of this series of articles looks at antennas for these types of RFID printer-encoders, followed by summary comments for the entire series and an extensive list of references.

UHF Antennas for Mobile Printer-Encoders

Space saving for mobile RFID printer-encoders is the biggest concern. Printers require UHF antennas to be slim, because the space available for their installation is very limited. In addition to the geometric constrains, the antennas must enable the encoding of short labels on a short pitch. Terminated tapered resonant stripline TL antennas are most qualified to meet these stringent requirements of the portable printers. The stripline TL antennas are ultra-compact and conformal. They fit in the space near the printhead and can provide a short transponder placement range. These antennas have received the highest acceptance for transportable and stationary RFID printer-encoders. Antennas are presented by the half-wave stripline (Fig. 10(a)) and a double-conductor stripline (Fig. 10(b)) linear taper width TL.

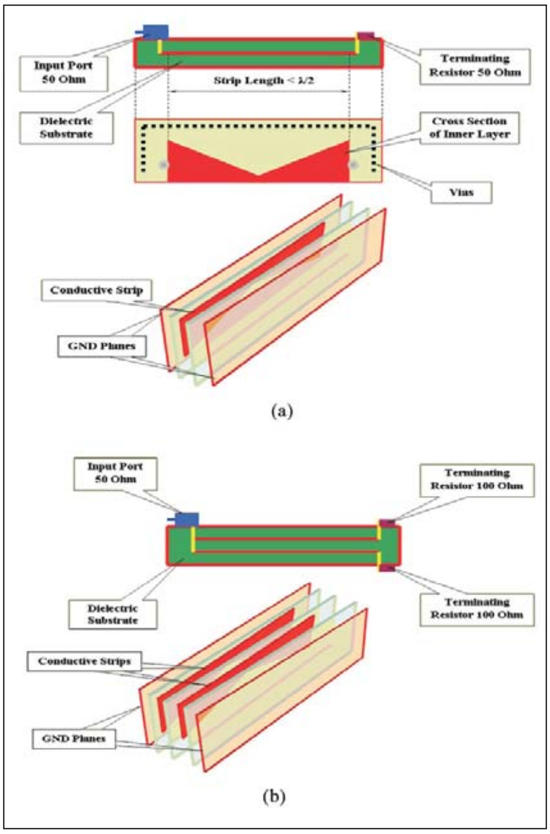


Figure 10 · Structure of terminated tapered stripline TL antennas: (a) single conductor TL antenna; (b) dual-conductor stripline TL antenna.

Antenna Structural Feasibility

Stripline TL antennas, which are arranged in parallel with the transponder in the encoding area, occupy a very small space behind the platen roller (Fig. 11). These antennas allow selective encoding of densely spaced transponders on the liner without activation of adjacent transponders. Examples of a stripline and double-conductor stripline TL antennas are built on PCB substrate and have dimensions of 3.5 × 18 × 100 mm and 6 × 14 × 100 mm, respectively. The internal conductor strip (strips for a double-conductor stripline) is

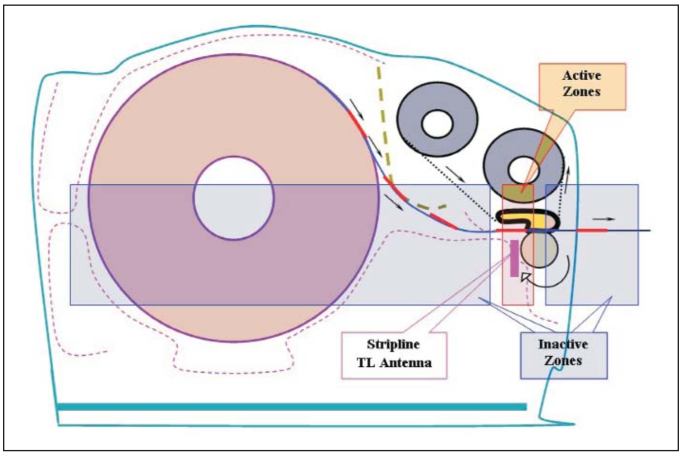


Figure 11 · Printer zones with stripline TL antenna.

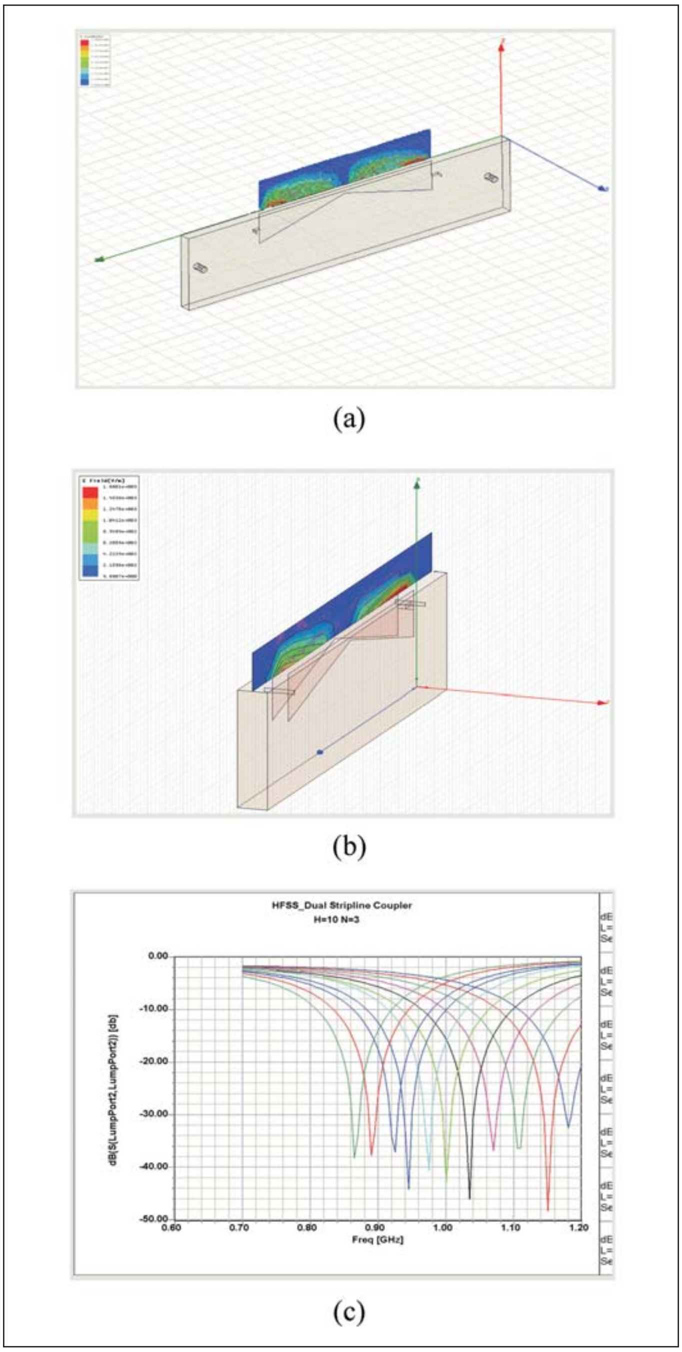


Figure 12 · HFSS simulation of tapered stripline TL. (a) single conductor TL antenna—E field; (b) dual-conductor stripline TL antenna—E field; (c) S_{11} for dual-conductor stripline TL antenna.

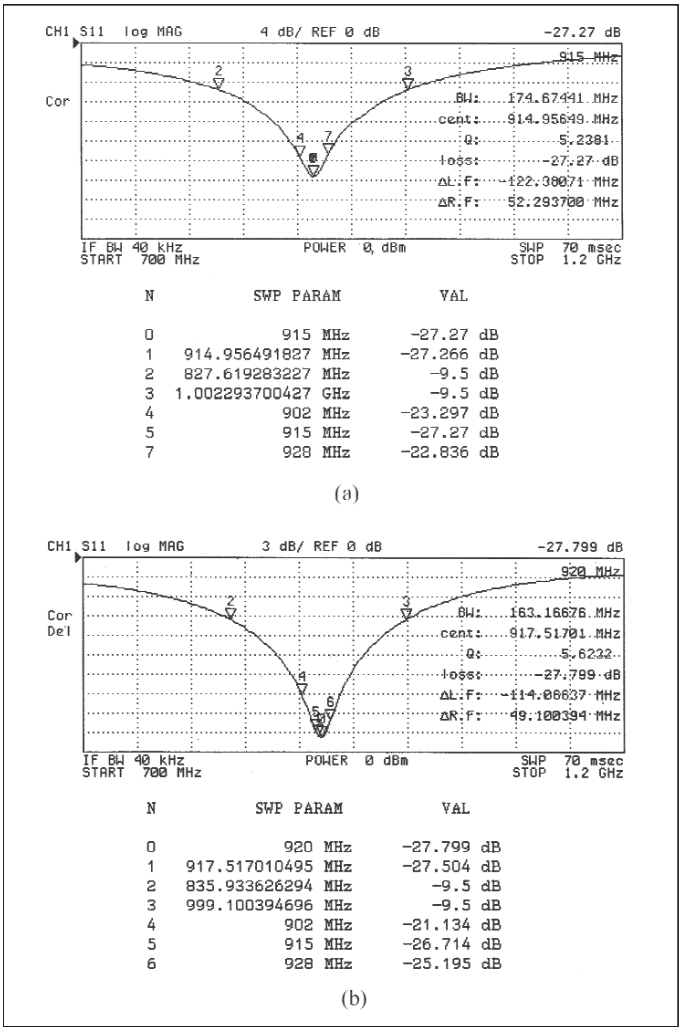
enclosed by two ground planes, stitched by vias along the other three sides of the antennas to organize electric walls and reduce parasitic radiation. The inner layer profile (Fig. 10 (a)) is a modified bow-tie shape with the width linearly varied from 9 to 4.5 and back to 9 mm for the stripline and from 10 to 3 to 10 mm for two strips of the double-conductor TL antenna. The dielectric constant of both substrates is 4.25 and their height is 3.5 and 6 mm accordingly. The length of the single stripline TL is 64 mm and for double-conductor line is 57 mm. The narrow center part of the inner layer is positioned close to the active edge of the TL in order to concentrate magnetic field at the center of this edge. This position of the maximum magnetic field usually corresponds to the center of a targeted for encoding transponder and supports an optimal energy transfer for the symmetrical antenna-transponder alignment.

Transponder Placement Boundaries

The single stripline TL antenna with a thickness of only 3.5 mm improves printer's performance by providing a short transponder *placement starting distance* from the label's leading edge. It enables individual encoding of short Smart Labels with a short pitch comparable to the transponders width (Fig. 1 (d)). The double-conductor stripline TL antenna with a thickness of only 6 mm was developed for specific Smart Labels requiring a longer *transponder placement range* and higher antenna energy efficiency than the single stripline TL antenna.

Encoding Field Intensity

Both antennas are in parallel alignment with targeted transponders and are coupled with them by one open long side edge. The electric field strength distribution simulated using Ansoft HFSS for the single stripline TL antenna (Fig. 12 (a)) and for the double-conductor stripline TL antenna (Fig. 12 (b)) shows optimal shape for coupling with a dipole type transponder antenna (Fig. 2). The capacitive coupling maintained by the stripline TL antenna is relatively weak and permits very close positioning to transponders. The stripline TL antenna is less spatially selective than the microstrip TL antenna but its RF power margin is still about 3 dB without a significant



N	SWP PARAM	VAL
0	915 MHz	-27.27 dB
1	914.956491827 MHz	-27.266 dB
2	827.619283227 MHz	-9.5 dB
3	1.002293700427 GHz	-9.5 dB
4	902 MHz	-23.297 dB
5	915 MHz	-27.27 dB
7	928 MHz	-22.836 dB

(a)

N	SWP PARAM	VAL
0	920 MHz	-27.799 dB
1	917.517010495 MHz	-27.504 dB
2	835.933626294 MHz	-9.5 dB
3	999.100394696 MHz	-9.5 dB
4	902 MHz	-21.134 dB
5	915 MHz	-26.714 dB
6	928 MHz	-25.195 dB

(b)

Figure 13 · Reflection loss S_{11} for stripline TL antenna samples. (a) single conductor TL antenna: 4.5 × 9 × 64 mm; (b) dual-conductor TL antenna: 2× (3 × 10 × 57 mm).

change in the encoding range. The double-conductor stripline TL antenna in comparison with a single strip TL has improved field intensity due to a higher SWR generated by an increased load. Its power efficiency, spatial selectivity and coupling grade with a transponder are also increased due to a larger effective edge area. The double stripline TL antenna has an RF power margin in excess of 6 dB.

Impedance Bandwidth

The port impedance of a single conductor stripline TL antenna is 50 ohms. For the double-conductor TL antenna the port impedance of 50 ohms is realized without an additional matching network by connecting in parallel two strips, each loaded by a 100 ohm resistor. Both antennas utilize the same principles for bandwidth improvement as other tapered TL antennas and have a widened bandwidth. They are shorter than $\lambda/2$. A solution for reflection loss S_{11} and geometry calculations for the double-conductor TL antenna are obtained by HFSS simulation (Fig. 12 (c)) and verified empirically. For the above samples the single stripline (Fig. 13 (a)) and double-conductor stripline (Fig. 13 (b)) TL antenna S_{11} parameters demonstrate bandwidths in excess of 150 MHz. By varying individual strip lengths the multi-conductor stripline TL antenna enables further increase in bandwidth, antenna sensitivity, spatial selectivity, power efficiency and transponder placement range.

Conclusions

The article provided a thorough consideration of UHF antennas for stationary and mobile printer-encoders. Terminated TL antennas, while maintaining a considerable system power margin, can selectively interrogate transponders without RF power suppression. Increased available power delivered by the terminated resonant TL antennas to the encoding interval tolerates usage of transponders with large variation of their resonance frequency and activation power threshold. Moreover, enlarged bandwidth of terminated tapered resonant TL antennas allowed using inexpensive RoHS PCB dielectric materials with fairly wide deviations of permittivity, thickness of a substrate and copper cladding.

The proposed miniature stripline TL antennas, with their compressed encoding range, permit portable printer-encoders to work with short, densely spaced Smart Labels. The stripline antennas geometry, their conductive strip dimensions, and bandwidth obtained from Ansoft HFSS modeling for RFID 915 MHz band, have been verified empirically and found to be in a good agreement. Antenna analysis, mostly concentrated on microstrip and stripline terminated TL, imposed no restrictions on the type of TL. Other TL structures, for example, the coplanar waveguide or the slotline, may also be considered as building blocks of antennas for close proximity RFID applications. Conclusively the stripline TL antenna is judged as a vital component for RFID applications involving equipment miniaturization or having spatial constraints for an antenna installation.

Besides RFID printer-encoders, there are many more applications of compact UHF antennas, including access control (Homeland Security market), item-level RFID for conveyors, testing small transponders during their high volume manufacturing, quality validation in the Smart Labels conversion process (Industrial market), and scanners of RFID Smart credit cards (Financial market). It is believed that presented information on UHF antennas will be helpful in selection of UHF Printer-Encoder and as well as a tutorial guide for RFID newcomers. Although the terminated TL antennas have low far-field radiation, they are still a source of UHF electromagnetic energy.

Antenna mounting elements and nearby metal-plastic components can easily create a parasitic wave-guiding structure for this energy transmission, causing excessive unintentional RF radiation that can interfere with the transponder encoding process. UHF terminated TL antennas have relatively low RF power efficiency in exchange for their spatial selectivity and thus, represent an improvement of energy conversion, and can be considered as a subject for further research.

Parts 1 and 2 of this series are available as PDF downloads from the Archives section of this magazine's Web site: www.highfrequencyelectronics.com

Acknowledgements

The author would like to thank Zebra Technologies Corporation and its associates K. Torchalski, Director of RFID, and M. Schwan, System Manager for their helpful and productive discussions regarding UHF RFID Printer-Encoders development, M. Fein, RF Engineer for his HFSS counseling, and R. Gawelczyk, Engineering Technician for his outstanding support and assistance in antenna fabrication, testing and evaluation. The author also would like to thank S. Kovanko, EE Engineer for carefully reading parts of the manuscript.

References

1. "Item-Level Visibility in the Pharmaceutical Supply Chain: a Comparison of HF and UHF RFID Technologies," White Paper, Philips Semiconductors, TAGSYS, Texas Instruments Inc., July 2004. http://www.tagsysrfid.com/modules/tagsys/upload/news/TAGSYS-TI-Philips-White-Paper.pdf

2. M.C. O'Connor, "Study Shows Big Growth for RFID Printer-Encoders," *RFID Journal, Inc.,* July 25, 2006. http://www.rfidjournal.com/article/articleprint/2515/-1/1/

3. M.C. O'Connor, "RFID Changing Buying Behavior," *RFID Journal, Inc.,* July 21, 2006. http://www.rfidjournal.com/article/articleprint/2508/-1/1/

4. L.G. Maloratsky, *Passive RF & Microwave Integrated Circuits,* Newnes, 2003.

5. K.V.S. Rao, P.V. Nikitin, S.F. Lam, "Antenna Design for UHF RFID Tags: A Review and a Practical Application" *IEEE Transactions on Antennas and Propagation,* Vol. 53, No. 12, pp. 3870-3876, December 2005.

6. "Texas Instruments Gen 2 Inlay," RI-UHF-00C02 - Product Bulletin, 2006. http://www.ti.com/rfid/docs/manuals/pdfspecs/ri-uhf-00c02_prodbulletin.pdf

7. D.M. Dobkin, S.M. Weigand, "UHF RFID and Tag Antenna Scattering, Part I: Experimental Results," *Microwave Journal,* Vol. 49, No. 5, pp. 170-190, May 2006.

8. D.M. Dobkin, T. Wandinger, "A Radio-Oriented Introduction to RFID—Protocols, Tags and Applications," *High Frequency Electronics,* Vol. 4, No. 8, pp. 32-46, August 2005.

9. D.M. Dobkin, S.M. Weigand, "UHF RFID and Tag Antenna Scattering, Part II: Theory," *Microwave Journal,* Vol. 49, No. 6, pp. 86-96, June 2006.

10. (284) T. Breahna, D. Johns, "Simulation Spices RFID Read Rates," *Microwaves and RF,* pp.66-76, March 2006.

11. P.V. Nikitin, K.V.S. Rao, S.F. Lam, V. Pillai, R. Martinez, H. Heinrich, "Power Reflection Coefficient Analysis for Complex Impedances in RFID Tag Design," *IEEE Transactions on Microwave Theory and Techniques,* Vol. 53, No. 9, pp. 2721-2725, September 2005.

12. C.A. Balanis, *Antenna Theory: Analysis and Design,* 2nd Edition, John Wiley & Sons, 1996.

13. C. Capps, "Near field or far field?," *EDN Magazine,* pp. 95-102, August 16, 2001.

14. I. Straus, "Loops and Whips, Oh My!," *Conformity,* pp. 22-28, August 2002.

15. I. Straus, "Near and Far Fields—From Statics to Radiation," *Conformity,* pp. 18-23, February 2001.

16. B.Y. Tsirline, "Spatially Selective Antenna for Very Close Proximity HF RFID Applications-Part 1," *High Frequency Electronics,* Vol. 6, No. 2, pp. 18-28, February, 2007.

17. J.D. Griffin, "A Radio Assay for the Study of Radio Frequency Tag Antenna Performance," MSEE Thesis, Georgia Institute of Technology, August 2005. http://etd.gatech.edu/theses/available/etd-05022005-142356/unrestricted/griffin_joshua_d_200508_mast.pdf

18. S.G. Downs, "Why Antennas Radiate," *QEX Magazine,* pp. 38-42, January/February 2005.

19. R. Schmitt, "Understanding Electromagnetic Fields and Antenna Radiation Takes (Almost) No Math," *EDN,* pp. 77-88, March 2, 2000.

20. G. Kumar, K. P. Ray, *Broadband Microstrip Antennas,* Artech House, 2003.

21. J.F. Feltz, J.A. McCurdy, L.D. Neuhard, "RFID printer and antennas," U.S. Patent Application 20050280537, December 22, 2005.

22. T.A. Chapman, R.E. Schumaker, A. W. Edwards, S.S. Morris, J.P. Harkins, B.S. Jarvis, "RFID tag and printer system," U.S. Patent 7,066,667 B2, June 22, 2006.

23. L. Beauvillier, M.J. Brady, D-W. Duan, D.J. Friedman, P.A. Moskowitz, P. Murphy, "Method and apparatus for testing RFID tags," U.S. Patent 6,104,291, August 2000.

24. R.E. Collin, *Foundations for Microwave Engineering,* 2nd Edition. Wiley-IEEE Press, 2001.

25. G.B. Barrus, R.E. Schumaker, , A.W. Edwards, K.M. Smith, D.C. Gibbs, R.Jr. Concepcion, "RFID tag, antenna, and printer system," U.S. Patent 7,037,009 B2, May 2, 2006.

26. G.B. Barrus, R.E. Schumaker, A.W. Edwards, D.C. Gibbs, K.M. Smith, R. Concepcion Jr. , "RFID tag, antenna, and printer system," U.S. Patent 6,929,412 B1, August

16, 2005.

27. D.M. Pozar, *Microwave Engineering,* 2nd Edition, John Wiley & Sons, 1998.

28. K.C. Gupta, R. Garg, I. Bahl, P. Bhartia, *Microstrip Lines and Slotlines,* Artech House, 1996.

29. L. Young, "The Quarter-Wave Transformer Prototype Circuit," *IRE Transactions on Microwave Theory and Techniques,* pp. 483-489, September 1960.

30. G. Matthaei, L. Young, E.M.T. Jones, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures,* Artech House, pp. 255-354, 1980.

31. R. W. Klopfenstein, "A Transmission Line Taper of Improved Design," *Proceedings of the IRE,* Vol. 44, pp. 31-35, January 1956.

32. R.P. Hecken, "A Near-Optimum Matching Section Without Discontinuities," *IEEE Transactions on Microwave Theory and Techniques,* Vol. MTT-20, No. 11, pp. 734-739, November 1972.

33. J.-T. Kuo, "Riccati Matrix Differential Equation Formulation for the Analysis of Nonuniform Multiple Coupled Microstrip Lines," *IEEE Transactions on Microwave Theory and Techniques,* Vol. 44, No. 6, pp. 880-886, June 1996.

34. K. Lu, "An Efficient Method for Analysis of Arbitrary Nonuniform Transmission Lines," *IEEE Transactions on Microwave Theory and Techniques,* Vol. 45, No. 1, pp. 9-14, January 1997.

35. "3D Electromagnetic-Field Simulation for High-Performance Electronic Design," Ansoft Corp.

Author Information

Boris Y. Tsirline is the Principal Engineer at Zebra Technologies Corporation. He received a BS and MS degrees in RF & Microwave Engineering from Moscow Aviation University, Russia in 1973 and a PhD in EE from Moscow State University in 1986. Before moving to the US in 1992, he served as a Director of R&D at Automotive Electronics and Equipment Corp., Russia, developing military and aerospace electronic systems. He has been in the Automatic Identification and Data Capture industry since 1995. He managed the development of Zebra's first HF RFID printer-encoder and established the design methodology for HF and UHF spatially selective transponder encoding modules used throughout the corporation divisions for RFID labels and cards printers. Dr. Tsirline holds three non-classified Russian and two US patents and has numerous pending patents for RFID enhancements. He can be reached by e-mail at BTsirline@zebra.com.

射 频 和 天 线 设 计 培 训 课 程 推 荐

易迪拓培训(www.edatop.com)由数名来自于研发第一线的资深工程师发起成立，致力并专注于微波、射频、天线设计研发人才的培养；我们于 2006 年整合合并微波 EDA 网(www.mweda.com)，现已发展成为国内最大的微波射频和天线设计人才培养基地，成功推出多套微波射频以及天线设计经典培训课程和 ADS、HFSS 等专业软件使用培训课程，广受客户好评；并先后与人民邮电出版社、电子工业出版社合作出版了多本专业图书，帮助数万名工程师提升了专业技术能力。客户遍布中兴通讯、研通高频、埃威航电、国人通信等多家国内知名公司，以及台湾工业技术研究院、永业科技、全一电子等多家台湾地区企业。

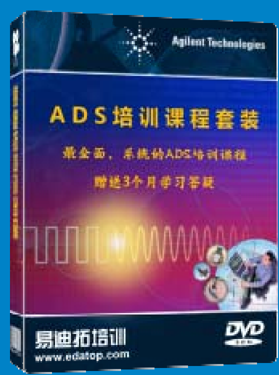
易迪拓培训课程列表：http://www.edatop.com/peixun/rfe/129.html

射频工程师养成培训课程套装

该套装精选了射频专业基础培训课程、射频仿真设计培训课程和射频电路测量培训课程三个类别共 30 门视频培训课程和 3 本图书教材；旨在引领学员全面学习一个射频工程师需要熟悉、理解和掌握的专业知识和研发设计能力。通过套装的学习，能够让学员完全达到和胜任一个合格的射频工程师的要求…

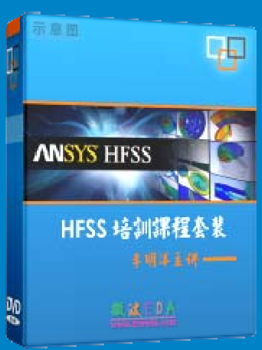
课程网址：http://www.edatop.com/peixun/rfe/110.html

ADS 学习培训课程套装



该套装是迄今国内最全面、最权威的 ADS 培训教程，共包含 10 门 ADS 学习培训课程。课程是由具有多年 ADS 使用经验的微波射频与通信系统设计领域资深专家讲解，并多结合设计实例，由浅入深、详细而又全面地讲解了 ADS 在微波射频电路设计、通信系统设计和电磁仿真设计方面的内容。能让您在最短的时间内学会使用 ADS，迅速提升个人技术能力，把 ADS 真正应用到实际研发工作中去，成为 ADS 设计专家...

课程网址： http://www.edatop.com/peixun/ads/13.html



HFSS 学习培训课程套装

该套课程套装包含了本站全部 HFSS 培训课程，是迄今国内最全面、最专业的 HFSS 培训教程套装，可以帮助您从零开始，全面深入学习 HFSS 的各项功能和在多个方面的工程应用。购买套装，更可超值赠送 3 个月免费学习答疑，随时解答您学习过程中遇到的棘手问题，让您的 HFSS 学习更加轻松顺畅…

课程网址：http://www.edatop.com/peixun/hfss/11.html

CST 学习培训课程套装

该培训套装由易迪拓培训联合微波 EDA 网共同推出，是最全面、系统、专业的 CST 微波工作室培训课程套装，所有课程都由经验丰富的专家授课，视频教学，可以帮助您从零开始，全面系统地学习 CST 微波工作的各项功能及其在微波射频、天线设计等领域的设计应用。且购买该套装，还可超值赠送 3 个月免费学习答疑…

课程网址：http://www.edatop.com/peixun/cst/24.html

HFSS 天线设计培训课程套装

套装包含 6 门视频课程和 1 本图书，课程从基础讲起，内容由浅入深，理论介绍和实际操作讲解相结合，全面系统的讲解了 HFSS 天线设计的全过程。是国内最全面、最专业的 HFSS 天线设计课程，可以帮助您快速学习掌握如何使用 HFSS 设计天线，让天线设计不再难…

课程网址：http://www.edatop.com/peixun/hfss/122.html

13.56MHz NFC/RFID 线圈天线设计培训课程套装

套装包含 4 门视频培训课程，培训将 13.56MHz 线圈天线设计原理和仿真设计实践相结合，全面系统地讲解了 13.56MHz 线圈天线的工作原理、设计方法、设计考量以及使用 HFSS 和 CST 仿真分析线圈天线的具体操作，同时还介绍了 13.56MHz 线圈天线匹配电路的设计和调试。通过该套课程的学习，可以帮助您快速学习掌握 13.56MHz 线圈天线及其匹配电路的原理、设计和调试…

详情浏览：http://www.edatop.com/peixun/antenna/116.html

我们的课程优势：

※ 成立于 2004 年，10 多年丰富的行业经验，

※ 一直致力并专注于微波射频和天线设计工程师的培养，更了解该行业对人才的要求

※ 经验丰富的一线资深工程师讲授，结合实际工程案例，直观、实用、易学

联系我们：

※ 易迪拓培训官网：http://www.edatop.com

※ 微波 EDA 网：http://www.mweda.com

※ 官方淘宝店：http://shop36920890.taobao.com