Phase Dithered Watermarking for Physical Layer Authentication

By

Nathan West

Bachelor of Science in Electrical Engineering
Oklahoma Christian University
Edmond, OK
2011

Bachelor of Nothing in Foo
Prestigious University
My head, Universe
2012

Submitted to the Faculty of the
Graduate College of
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
Master of Science
May, 2013

Phase Dithered Watermarking for Physical Layer Authentication

Thesis Approved:

George Scheets

Thesis Advisor

Keith Teague

Jim West

ACKNOWLEDGMENTS

I would like to thank....

Name: Nathan West

Date of Degree: May, 2013

Title of Study: Phase Dithered Watermarking for Physical Layer Authentication

Major Field: Electrical Engineering

Abstract will go here. Make sure it remains within the 350 word limit.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

CHAPTER 1

Oklahoma State University ECEN

1.1 A Letter from the Head

Welcome to the School of Electrical and Computer Engineering (ECEN) at Oklahoma State University.

The School boasts 27 faculty members, including several IEEE Fellows and four recent and current NSF CAREER Award winners, along with approximately 300 undergraduate students and 150 graduate students pursuing the B.S., M.S. and Ph.D. degrees on both the Stillwater and Tulsa campuses. Students come to OSU from every state and approximately 120 countries making this a diverse, active, and exciting campus.

OSU offers a friendly and welcoming environment with easy access to faculty who are committed to excellence in the critical areas of teaching, scholarship and research. Our BS degree in Electrical Engineering is fully accredited by ABET. Your success as a student in ECEN is very important to us!

Figure 1.1: Dr. Teague, Professor, Department Head

Over the past three years the School has experienced an unprecedented period of growth. We have been very fortunate to welcome nine new faculty members in the areas of computer engineering, communications, image processing and machine vision, biomedical engineering, and nanotechnology. We strive to emphasize excellence in all area of instruction, scholarship and research, as evidenced by a growing list of faculty and student accomplishments. Research and scholarly activities continue to expand, and thanks to an outstanding faculty annual research funding totals over $3.5 million.

Our programs center around five primary thrust areas: communications, controls, and signal processing; computer engineering; lasers and photonics; electronics and mixed signal VLSI; and power. There are opportunities within these areas to accommodate the goals of almost any student interested in the various specializations within Electrical Engineering and Computer Engineering, as well as several interdisciplinary areas. We are especially excited about a new BS degree in Computer Engineering that we expect to introduce in 2008.

Excellent instruction and research laboratories are located in Engineering South and the Advanced Technology Research Center, a world-class facility located adjacent to Engineering South on the Stillwater campus. In Tulsa, the new Helmerich Advanced Technology Research Center houses a growing program in advanced materials and nanotechnology.

Engineering graduates are in very high demand with over 170 companies actively recruiting at the most recent engineering career fair on campus. Our graduates are recognized as great employees who command high salaries. Our graduates are equally well prepared to study for an advanced degree, and many choose to pursue the M.S. or Ph.D. degree either at OSU or another outstanding university.

Im very excited about our programs and what we have to offer. Please feel free to contact any faculty member or me for further information.

1.1.1 ECE Mission Statement

The School of Electrical and Computer Engineering serving the needs of students, faculty, and those who employ our graduates provides a comprehensive education in electrical or computer engineering. By providing both a breadth of knowledge and depth with design experience in selected areas, graduates are prepared to continue the lifelong process of education needed by active professionals in today's constantly changing global society.

CHAPTER 2

ECEN Graduate Program

Degree programs are offered at the M.S. and Ph.D. levels in Electrical Engineering. Major areas of emphasis in both course offerings and research include communications, speech and image processing, laser applications, computer systems, digital and analog VLSI design, electronics, control theory, real-time system control, renewable energy systems, electric power economics, microwave remote sensing, expert system development, and parallel processing. More details about state-of-the-art research laboratories can be found here.

For more information, contact the School, or Dr. Ramakumar, the ECEN Graduate Coordinator.

2.1 MS Degree Program

Two Master's degree options are available to students in Electrical and Computer Engineering.

- MSEE (Traditional Thesis Path) Plan I:* 30 Hours
- MSEE (Professional Path) Plan III:* 33 Hours

*Plan I, Plan III, etc., refers to Graduate College designation. Students in the Professional Path (Plan III) are required to take courses in at least four areas of ECEN at the 5000 level (designated by second digit of course number). Students in the Traditional Thesis Path (Plan I) are required to take courses in at least two

Table 2.1: The credit requirements for an MS in ECEN at OSU. Depending on desired path different classes are required in different areas. In the end you get to pick whatever you want!

	Traditional Path	Professional Path
Technical Elective	3 hours	3 hours
ECEN Graduate Level Courses	18 hours	21 hours
Additional Courses		6 hours
Thesis	6 hours	
ECEN 5070	3 hours	
Creative Component		3 hours
	30 hours	33 hours

areas of ECEN at the 5000 level (designated by the second digit of course number). A summary of the two degree program requirements is given in the following table:

For Professional Path option (Plan III), a 3-hour ECEN 5000+ course (with a term project) is designated as the creative component. Or, a 3 hour ECEN 5070 may be completed, under the supervision of an ECEN professor. For the Traditional Path option (Plan I), the optional 3 hours of ECEN 5070 should be completed with the thesis advisor.

Additional Master's degree requirements are:

1. Professional Path students MUST take 6 hours from ECEN 5513, 5613, 5713 and any remedial courses at the first enrollment opportunity after entrance into the MS program.

2. Traditional Path students MUST take 3 hours from ECEN 5513, 5613 and any remedial courses at the first enrollment opportunity after entrance into the MS program.

3. Up to two (2) 4000 level ECEN courses that have been approved for graduate

credit within the ECEN program may be included on the Master's plan of study. The list of approved courses is included at the end of this bulletin.

4. No course required for the BSEE degree at OSU may appear on a study plan for the Master's degree.

5. No course that was applied to BSEE credit may be included on a graduate plan of study.

6. The minimum requirement of 18 hours of graduate-level courses in ECEN MAY NOT include the following courses: ECEN 5000, 5030 and 6050.

7. CS 4113 IS NOT appropriate for M.S. Plans of Study in this department.

8. Graduate College regulations REQUIRE a minimum of 21 hours of 5000-level courses on all Master's plans.

9. Students who do not have a BSEE degree CAN include only one "outside" course on their Master's Plan of Study. All students MUST have at least one course "outside" ECEN.

10. For the technical elective (3 hours), courses that are cross-listed with ECEN must be approved by the student's advisor.

2.1.1 Entrance Requirements

3.0 GPA in an accredited BSEE program is the usual standard for admission to the MSEE program. However, applicants with lower GPA, to about 2.7, may be granted probationary admission. Students who have BS degrees in other engineering fields may be admitted to the MSEE program, subject to the same GPA requirements. These candidates will be expected to take enough prerequisite courses (from undergraduate ECEN courses, and perhaps some Math, CS and Physics) to accomplish two

ends: (a) to assure a reasonable basis for success in the graduate courses to be taken for the MSEE degree; and, (b) to assure that when the candidate goes into practice with the MSEE degree, there will be no potentially "embarrassing holes" in the candidate's technical background. This may well require some prerequisite courses in areas of study in which the student has little interest and in which he/she has no intention of practicing after graduation. Students are sometimes admitted to an MSEE program with a grade of "C" in one or two junior or senior courses. Students may be required, as a condition of admission to the MSEE program; to repeat such courses, or take another undergraduate -level course in the same or closely-related area of study. A grade of "B" MUST be attained in such prescribed prerequisites. Students admitted unconditionally to the program are assumed competent to take the required M.S. courses. If the student feels unprepared for one of the required classes, he/she may enroll in the appropriate prerequisites. Students admitted conditionally should enroll in the necessary undergraduate prerequisites as a first priority. Graduate courses may be taken concurrently with prerequisite courses in other areas. The student need not necessarily complete all prerequisite courses before taking the first 5000-level courses. GRADUATE RECORD EXAMINATION: Scores for the Graduate Record Examination (GRE) general exam must be submitted with the application.

2.1.2 Retention Standards

The Graduate College bulletin sets forth certain minimum grade standards for retention: The School of Electrical and Computer Engineering expects all candidates to attain grades of "B" in all courses taken as graduate students, whether prerequisite courses or courses listed as part of the Plan of Study. A grade below "B" in a prerequisite course is cause for suspension. A 3.0 or above GPA in graduate courses must be maintained. A grade below "C", or more than two (2) "C's" in graduate courses

will result in suspension.

2.1.3 Master of Science Degree

Graduate College credit requirements for the Master of Science degree may be satisfied by one of the following alternatives:

A thesis of NOT MORE than 9 credit hours, plus 21 (or more) hours of course work for a total of 30 hours. (Graduate College Plan I) 33 hours of approved course work which MUST include a three-hour creative component (course or independent study). (Graduate college Plan III). Note that Graduate College Plan II, the report option IS NOT available to ECEN students.

A preliminary Plan of Study for the Master's Degree should be worked out by the student and his/her advisor. This plan should include a listing of course work contemplated, and an estimate of the time schedule. All Master of Science degree students must satisfy the creative component requirement of the Graduate College. For students electing the Plan III option, at least 3 hours must be designated with the advisor's approval, as the creative component (which may include independent study). The initiative for proposing a plan of study lies with the student; the student should note the Graduate College requirement that a Master's plan be filed BEFORE the student registers for his/her 17th hour of graduate credit. A creative component proposal MUST ALSO BE approved and filed.

The approval of the student's advisor and two other faculty members as well as that of the Dean of the Graduate College is required on all Master's Plans of Study. The student should work out his proposed plan of study with his advisor and arrange for typing and submission of the final version to the graduate college.

Study plans may be revised from time to time; the revision is accomplished by submitting a new plan as outlined above. The Graduate College REQUIRES that the final plan be filed before registration for the semester in which the necessary work

for the degree will be completed.

The School of Electrical and Computer Engineering waives the foreign-language requirement for Master's Degree.

2.2 PhD Degree Program

The PhD Degree has different requirements. When they become relevant to me next year I'll look at them!

2.3 Other Graduate Degree Options

There's apparently some other degrees. I don't care really care about them.

2.4 Department Forms

There are a variety of forms.

- Graduate Memorandum
- Plans of Study Forms
- Masters
- Ph.D.
- Graduation Clearance Form
- Assistantship
- Assistantship Applications
- International Teaching Assistant Program

BIBLIOGRAPHY

[1] D. J. G. Roy D. Yates, *Probability and Stochastic Processes : a friendly introduction for electrical & computer engineers*. John Wiley & Sons, 1999.

[2] B. Sklar, *Digital Communications: Fundamentals and Applications*. Prentice Hall, second ed., 2001.

[3] B. Lebold, "Physical layer watermarking of binary phase-shift keyed signals using standard gnu radio blocks," Master's thesis, Oklahoma State University, 2009.

[4] P. L. Yu and B. M. Sadler, "Mimo authentication via deliberate fingerprinting at the physical layer," *IEEE Transactions on Information Forensics and Security*, vol. 6, September 2011.

[5] A. O. Hero, "Secure space-time communication," *IEEE Transactions on Information Theory*, vol. 49, December 2003.

[6] M. Bloch, B. Joao, M. R. D. Rodrigues, and S. W. McLaughlin, "Wireless information-theoretic security," *IEEE Transactions on Information Theory*, vol. 54, June 2008.

[7] N. Borisov, I. Goldberg, and D. Wagner, "Intercepting mobile communications: the insecurity of 802.11," in *Proceedings of the 7th annual international conference on Mobile computing and networking*, MobiCom '01, (New York, NY, USA), pp. 180–189, ACM, 2001.

[8] P. Judge, "Obsolete wep wi-fi gets new security shield," *Network World*, September 2007. http://www.networkworld.com/news/2007/091907-wep-wi-fi-security-shield.html.

[9] L. Xiao, L. Greenstein, N. Mandayam, and W. Trappe, "Fingerprints in the ether: Using the physical layer for wireless authentication," in *Communications, 2007. ICC '07. IEEE International Conference on*, pp. 4646 –4651, june 2007.

[10] N. Goergen, T. Clancy, and T. Newman, "Physical layer authentication watermarks through synthetic channel emulation," in *New Frontiers in Dynamic Spectrum, 2010 IEEE Symposium on*, pp. 1 –7, april 2010.

[11] H. Wen, P.-H. Ho, C. Qi, and G. Gong, "Physical layer assisted authentication for distributed ad hoc wireless sensor networks," *Information Security, IET*, vol. 4, pp. 390 –396, december 2010.

[12] S. Jain and J. Baras, "Preventing wormhole attacks using physical layer authentication," in *Wireless Communications and Networking Conference (WCNC), 2012 IEEE*, pp. 2712 –2717, april 2012.

[13] R. Spector, *Listening to the enemy: key documents on the role of communications intelligence in the war with Japan.* G - Reference, Information and Interdisciplinary Subjects Series, Scholarly Resources Inc., 1988.

[14] D. E. Newton, *Encyclopedia of Cryptology.* ABC-CLIO, 1997.

[15] L. Xiao, L. J. Greenstein, N. B. Mandayam, and W. Trappe, "Channel-based detection of sybil attacks in wireless networks," *IEEE Transactions on Information Forensics and Security*, vol. 4, September 2009.

[16] B. S. Paul Yu, John Baras, "An implementation of physical layer authentication using software radios," Tech. Rep. ARL-TR-4888, Army Research Laboratory, 2009.

[17] J. E. Kleider, S. Gifford, S. Chuprun, and B. Fette, "Radio frequency watermarking for ofdm wireless watermarking," in *International Conference on Acoustics, Speech, and Signal Processing*, May 2004.

[18] P. L. Yu, J. S. Baras, and B. M. Sadler, "Physical-layer authentication," *IEEE Transactions on Information Forensics and Security*, vol. 3, March 2008.

[19] P. K. Vitthaladevuni and M.-S. Alouini, "Exact ber computation of generalized hierarchical psk constellations," *IEEE Transactions on Communications*, vol. 51, December 2003.

[20] P. Yu, J. Baras, and B. Sadler, "Multicarrier authentication at the physical layer," in *IEEE International Symposium on A World of Wireless, Mobile and Multimedia Networks*, june 2008.

[21] P. Yu, *Physical Layer Authentication*. PhD thesis, University of Maryland, 2008.

[22] P. L. Yu, J. S. Baras, and B. M. Sadler, "Physical-layer authentication," *IEEE Transactions on Information Forensics and Security*, vol. 3, March 2008.

[23] D. Goodin, "Android, nokia smartphone security toppled by near field communication hack," *Ars Technica*, July 2012. http://arstechnica.com/security/2012/07/android-nokia-smartphone-hack/.

[24] S. Knight, "Gsm security vulnerability affects 80 percent of mobile phones worldwide," *Techspot*, December 2011. http://www.techspot.com/news/46810-gsm-security-vulnerability-affects-80-percent-of-mobile-phones-worldwide.html.

[25] G. Radio, "Decrypting gsm phone calls." https://srlabs.de/decrypting_gsm/.

[26] G. Radio, "Gnuradio openbts network architecture," 2010. http://gnuradio.org/redmine/projects/gnuradio/wiki/OpenBTSNetwork_Architecture.

APPENDIX A

IMPORTANT TABLE

Appendix A goes here. Table A.1 is copied from Chapter **??**.

Table A.1: Sample multicolumn table

Parameter	Column 1		Column 2	
	Subcolumn 1	Subcolumn 2	Subcolumn 1	Subcolumn 2
Parameter 1	Element 11	Element 12	Element 13	Element 14
Parameter 2	Element 21	Element 22	Element 23	Element 24
Parameter 3	Element 31	Element 32	Element 33	Element 34

APPENDIX B

MORE DATA

Appendix B data goes here

VITA

Nathan West

Candidate for the Degree of

Master of Science

Thesis: Phase Dithered Watermarking for Physical Layer Authentication

Major Field: Electrical Engineering

Biographical:

Personal Data: Born in New Brunswick, New Jersey on March 16, 1989

Education:

Received the B.S. degree from Oklahoma Christian University, Edmond, OK 2011

Completed the requirements for the degree of Master of Science with a major in Electrical Engineering at Oklahoma State University in May, 2013.

Experience:

Tons of experience doing very cool things!