EEM 424
MICROWAVE THEORY

MICROWAVE

INTRODUCTION

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MOTIVATION – 1/2

Elektromanyetik (EM) I dersimizde elektrik ve manyetik alanlarının farklı şekilde ve bağımsız olarak davrandıklarını incelemiş, farklı malzemelerin bulunduğu ortamlardaki davranışlarını matematiksel yöntemlerden faydalanarak tahmin edebilecek düzeye ulaşmıştık.

Elektromanyetik (EM) II dersimizde ise, aslında elektrik ve manyetik alanın aslında çok benzedikleri, belki de farklı açılardan bakıldığında farklı görüntüler oluşturan 'aynı şey' olduğu incelenmişti. EM dalganın davranışını anlayabilmemizde büyük fayda sağlayan Maxwell denklemleri incelenmiş EM dalga frekansının çok geniş olan $[0,\infty)$ aralığında bulunabileceği ifade edilmişti. Gözümüz ile görülebilen dar frekans bandı olan 'ışık' da dahil olmak üzere, tüm bu frekans aralıklarındaki tüm bu gözlemlerimiz eşdeğer şekilde *Elektromanyetik Dalga* olarak adlandırılmıştı. Özellikle düzlemsel EM dalgalar örnek alınarak, farklı dalga davranışları incelenmişti. Bu temel örnek üzerinde, iletken ve yalıtkan malzemelerin bir araya gelmesi halinde, yansıma ve kırılım gibi temel dalga davranışları matematiksel olarak incelenmişti.

MOTIVATION – 2/2

Farklı malzemelerin bir araya gelmesi durumunda gözlenen yansıma ve geçirgenlik özelliklerinin elektronik devreler ile doğrudan ilişkilendirilebileceği incelenmişti. Bir devrede bulunan elektronik devre elemanlarının bağlı oldukları iletim hattının dalga boyu ile karşılaştırılabilecek uzunluklarda olması halinde, eşdeğer empedansın oldukça farklı olabileceği incelenmişti. Bu durumda, devremiz bildiğimiz temel elektronik kurallarına uymayacak ve bizleri şaşırtabilecektir. Tam bu noktada devam edemeden dönemi tamamlamıştık. Mikrodalga kuramı dersi tam bu noktadan itibaren devam etmekte, iletim hatları, dalga kılavuzları, rezonatörler ve mikrodalga elemanları gibi mühendislik hayatınızda karşılaşma olasılığınızın yüksek olduğu konular işlenmektedir.

Günümüzde ‘RF mühendisliği’ olarak adlandırılan özel mühendislik dalının, yakın gelecekte elektronikte yeni teknolojiler ve gelişmeler ile çok yüksek frekanslı uygulamaların daha da artması ile tüm mühendislerin bugüne göre çok daha fazla tecrübe sahibi olmak zorunda kalacakları temel konulardan olması beklenmektedir. Geçmişteki mezunlardan farklı olarak sizler, ‘RF mühendisliği’ ile sınırlandırılmış gibi görülen ancak gelecekte tüm mühendisleri çok daha fazla ilgilendirebilecek temel konuları bu ders kapsamında inceleyeceksiniz.

WEEKLY SCHEDULE

CLASS PERIODS:	17.02.2014 – 23.05.2014
FINAL EXAM WEEK:	24.05.2014 – 04.06.2014
WEEKLY SCHEDULE:	Monday: 15:00 – 15:50 16:00 – 16:50 Thursday: 11:00 – 11:50 12:00 – 12:50 *Office hours*:* Thursday: 14:00 – 16:50 (*) Any other time, please coordinate.

GRADING BASIS

Homework and Test Policy: There will be weekly homework assignments. These will be due one week from the hand-out date (every following Monday), during the class period. Late homework loses 20% of the grade for that homework per 24 hours, beginning immediately following class. There will be one midterm exam, one project (in place of the final exam), and possibly several pop quizes (which would count as an additional homework assignment). There is no planned make-up exams.

%10 Homeworks

%25 Quiz

%35 Midterm

%30 Final

PREREQUISITES (OPTIONAL)

Courses:

MAT 151 Matematiksel Analiz I
MAT 152 Matematiksel Analiz II
EEM 224 Elektromanyetik I
EEM 323 Elektromanyetik II

Skills:

Euclidean geometry
Calculus with complex variables
Linear systems
Programming in Matlab or similar.

Basic electrodynamics
Basic wave propagation
Fourier analysis

WEB PAGES

http://moodle.midas.baskent.edu.tr adresinden,

Mühendislik Fakültesi

2014-2015 Bahar Yarıyılı

seçeneklerini takip ediniz.

http://moodle.midas.baskent.edu.tr/course/view.php?id=1286

Ayrıca,

http://www.baskent.edu.tr/~gokhuntanyer/

sayfasında ilave malzeme olduğunda size bilgi verilecektir.

TEXT

Required Text:

[1] D. M. Pozar (2012), Microwave Engineering, John Wiley & Sons, Inc.

[2] R. E. Collin, Foundations for Microwave Engineering.

[3] D. K. Cheng, Field and Wave Electromagnetics.

[4] D. K. Cheng, Fundamentals of Engineering Electromagnetics.

Supplemental Text:

[1] P. Russer (2006), Electromagnetics, Microwave Circuit and Antenna Design for Communications Engineering, Artech House.

[2] A. A. Smith (1998), Radio Frequency Principles and Applications, IEEE Press.

[3] Y. Shmaliy (2006), Continuous-Time Signals, Springer.

[4] K. Kurokawa (1969), An Introduction to the Theory of Microwave Circuits, Academic Press.

Other Supplementary Materials:*

[1] R. M. O'Donnell, 'Radar Systems Engineering', Radar Systems Course, IEEE, 11.1.2009.

[2] N. Kampfer, A. Murk, Lecture Notes, Microwave Physics and Quasioptics: Introduction.

[3] Prof. L. Schachter, Lecture Notes, Microwaves.

[4] F. K. W. Lee, Lecture Notes, Microwave Filters.

[5] S-O. Park, Lecture Notes, Microwave Engineering.

[6] MIT Openware Courses, <Receivers, Antennas and Signals>, <Electromagnetic Wave Theory>, <Electromagnetics>, <Electromagnetics and Applications>, <Electromagnetic Energy: From motors to lasers>

(*) Please check MOODLE for the updated list of references.

OBJECTIVES

When you finish this course you will be able to:

- Understand the physical interpretations of Maxwell's equations
- Get a strong feeling of the meanings of the fundamental electromagnetic equations
- Understand why we really need to know Fourier transform in a lecture of wave propagation
- Realize the practical applications of mathematical approximations and see their importance in simplifying 'nature' so that we (simple minds) could try to understand them
- Describe the similarities and the differences between the governing equations for an electromagnetic wave and planar wave propagation
- Define constructive and destructive interference
- Understand the standing wave mechanism
- Merge your internal understanding of electric and magnetic fields at 0 Hertz to optical waves above ultra-violet at very large frequencies stated in terms of terahertz...
- Understand the duality between wave reflection from a slab of material and transmission lines.
- Start feeling the difference between DC and high frequency AC applications on a conducting wire.
- Enjoy engineering more than others!

TOPICS COVERED

WEEK	TITLE	SUBTOPICS
1	**REVIEW**	**EEM424-DN-0-DIF /2** • Ders İzleme Formu **EEM424-DN-0-HDPD /20** • Haftalık Ders Planlama Dokümanı **EEM424-DN-0-IntroMW /39** • What is 'microwave' • Why 'microwave' **LECTURE: Microwave Physics and Quasioptics: Introduction by N. Kampfer, A. Murk** **EEM424-DN-0-RevEMT /36** • EM I, II, **EEM424-DN-0-RevMW /69** • Review of EEM 424 **EEM424-DN-0-RevMath /25** • Vector algebra, Operators, Coordinate systems • Differential equations for wave analysis
2	**REVIEW**	**Plane Waves:** • Normal and oblique incidence of EM plane waves at planar boundary surfaces • Total reflection, Surface waves •
3	**TRANSMISSION LINES – 1**	**Transmission Lines (Pozar: 48-63):** • **2.1.** The lumped-element circuit model for a TL

		○ Wave propagation on a TL ○ Propagation constant, Impedance, Power flow for the lossless coaxial line • **2.2.** Field analysis of TL ○ The telegrapher equations for coaxial line • **2.3.** The terminated lossless TL ○ Voltage Standing Wave Ratio (VSWR) ○ Open circuit termination ○ A TL of Zo feeding a TL of Z1 ○ Short circuit termination ○ Desibel and Neper ○ TL as circuit elements ○ Transients on TL, ○ Reflection diagrams, ○ Pulse excitation
4	**TRANSMISSION LINES – 2**	**Transmission Lines (Pozar: 63-):** • **2.4.** Smith chart ○ Basic Smith Chart operations ○ The combined impedance-admittance Smith chart ○ The slotted line and impedance measurement • **2.5.** The quarter-wave transformer, the frequency response of • **2.6.** The generator and load mismatches ○ Impedance matching, Conjugate matching • **2.7.** Lossy TL ○ Low loss, Distortionless, Terminated, Perturbation method • **2.8.** Transients on TL ○ Reflection of pulses ○ Bounce diagrams Basic Smith chart operations (Pozar)

		ZY Smith chart (Pozar) Lossy lines Impedance measurement with a slotted line (Pozar)
5	**SMITH CHART – 1**	Smith Chart, Impedance matching, Smith Chart, Quarter-wave transformer (Pozar, Cheng) Generator and load mismatches (Pozar) Conjugate matching
6	**SMITH CHART – 2**	Smith Chart,Double-stub matching
7	**WAVEGUIDES – 1**	Waveguides General solutions for; (Pozar, Cheng) Transverse electromagnetic (TEM) waves Transverse electric (TE) and transverse magnetic (TM) waves
8		**MIDTERM EXAM**
9		Wave impedances Parallel-plate waveguide – TE waves Energy, power, attenuation
10		Parallel-plate waveguide – TM waves Rectangular waveguides – TM waves Rectangular waveguides – TE waves Attenuation Partially loaded waveguide (Pozar) Waveguide flanges (Pozar) Circular waveguides – TM and TE waves Dielectric waveguides /Dielectric slab – TM and TE waves
11		Coaxial lines Surface waves on a grounded dielectric sheet Stripline Microstrip transmission line Wave velocities and dispersion

		Group velocity Power capacity of TL
12		Microwave network analysis (Pozar) Impedance and equivalent V and I Impedance and admittance matrices The scattering matrix The transmission (ABCD) matrix Signal flow graphs Modal analysis Excitation of waveguides
13		Cavity resonators – Rectangular TEmnp modes Quality factor of a resonator Circular cavity resonator
14		Microwave components Resonators, power dividers, Directional couplers, Microwave filters, Ferrimagnetic components
15		**FINAL EXAM**

MEETINGS

You can stop by my office for a cup of coffee if you had arrived early.

Class room: A – 307 (I have the key)

My office: A – 404

Phone (office): (312) 246-66-66 Ext: 1221

- Coffee, tea and snacks are allowed in class room
  (as long as you share them with your friends)
- Personal breaks (any time if necessary, please sign if you are leaving).
- Definitely no phones, no messaging and no labtops !..

ADDITIONAL NOTES

The information in this lecture has been obtained from sources believed to be reliable. The author does not guarantee the accuracy or completeness of any information presented herein, and shall not be responsible for any errors, omissions or damages as a result of the use of this information.

All materials are cited. The list of such references are given in the course outline documentation.

INFORMATION ABOUT THE INSTRUCTOR

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Active research: *Statistical signal processing*:

- Test statistics
- Q-RNG with 'exact statistics'
- Web portal for T-RNG.

Signal processing:

- Time and freq. resolution optimizations.

Antenna design and optimization

Music theory:

- Just-37 interval system for the Turkish Maqam music
- Al-Jurjani's 1,000 year old problem
- Struggle between the octaves and the fifths.

Related Publications:

URL: http://www.baskent.edu.tr/~gokhuntanyer/
https://www.researchgate.net/profile/Gokhun_Tanyer

Working Books:

1. 'Nature of music – Sound of mathematics' (in English).
2. 'Müziğin doğası – Matematiğin sesi' (in Turkish).

Working Papers:

3. 'Adaptive desirability function for multi objective design of 2D circular array antennas'.

Optical / Infrared (IR) bands:

4. S. G. Tanyer, C. B. Erol, 'Calibration of the simulation models using limited samples of measured data for the maritime infrared background radiance', Communications Fac. Sci. Univ. Ank. Series A2-A3, 4. 2012.
5. A. Altıntaş, S. G. Tanyer, 'An examination of the effect of polarization on the radiation losses of bent optical fibres,' Optical and Quantum Elect., Vol.25, pp.105–112, 1993.
6. A. Altıntaş, S. G. Tanyer, 'An examination of the effect of polarization on the radiation losses of bent optical fibres,' BILCON'90, Ankara Turkey, Editor:Erdal Arikan, Vol.I, Elsevier, pp.481–487, July 1990.
7. N. Saldi, M. S. Tokay, M. Kucuk, Z. G. Figen, S. G. Tanyer, 'Evaluation of a target recognition algorithm using the sensor model – Sensör modeli kullanılarak bir hedef tanıma algoritmasının başarımının değerlendirilmesi,' 2011 IEEE 19th Signal Processing and Communications Applications Conference (SIU 2011), pp. 706–709, 2011.
8. B. Akyüz, C. B. Erol, S. G. Tanyer, 'Infrared Terrestrial Background Modeling Using MODIS Vegetation Index', International IR Target and Background Modeling & Simulation Workshop, ITBMS'2009, Toulouse, France, 2009.
9. E. Yurdanur, C. B. Erol, S. G. Tanyer, 'Modeling Errors on Maritime IR Background Radiance', International IR Target and Background Modeling & Simulation Workshop, ITBMS'2009, Toulouse, France, 2009.
10. A. Altıntaş, S. G. Tanyer, 'Optik fiberlerde bükülme kayıplarının hesaplanması,' Elektrik Müh. 3. Ulusal Kongresi, Istanbul, Turkey, pp.362–369, Sept. 25-30, 1989.

Radio frequency (RF) band:

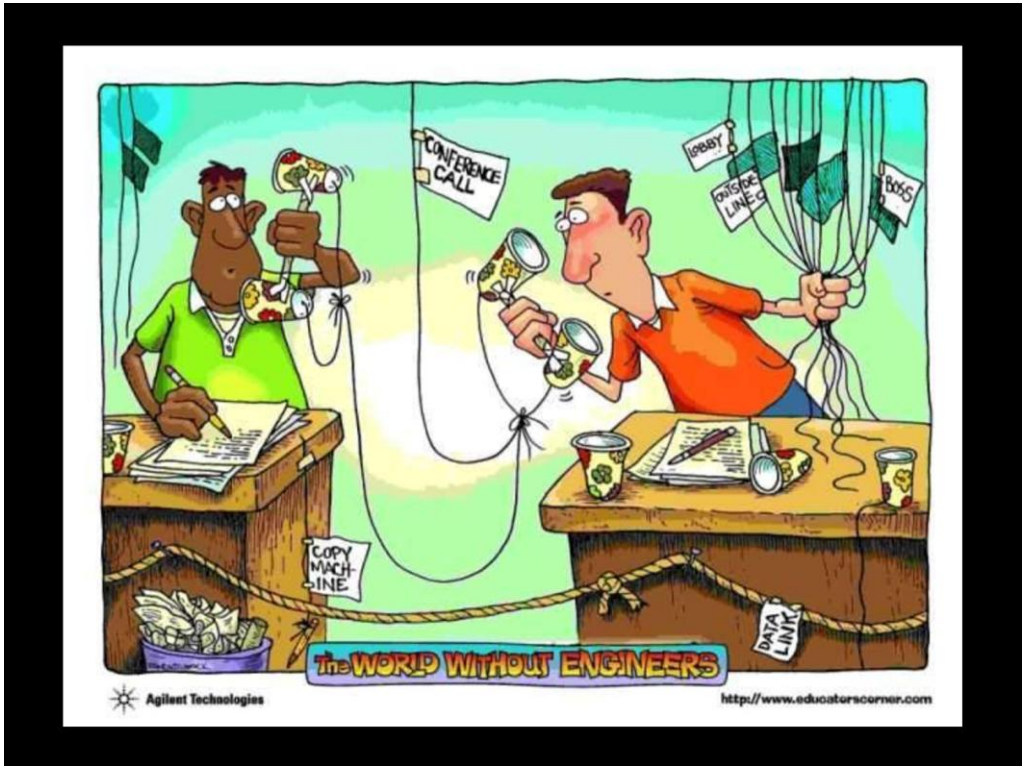
11. S. G. Tanyer, A. E. Yilmaz, F. Yaman, 'Adaptive desirability function for multi objective design of thinned array antennas', Journal of Electromagnetic Waves and Applications 01/2012; Vol. 26, No. 17-18, pp. 2410-2417, 2012.
12. O. T. Altinoz, S. G. Tanyer, A. E. Yilmaz, 'A comparative study of fuzzy-PSO and chaos-PSO', Electroteh. Versnik, (79) (1-2): pp. 68–72, 2012.
13. S. G. Tanyer, C. B. Erol, 'Broadcast analysis and prediction in the HF band', IEEE Transactions on Broadcasting, vol.44, no.2, pp.226–232, June 1998.
14. S. G. Tanyer, Taha Yücel, Selim Şeker, 'Topography based design of the T-DAB SFN for a mountainous area,' IEEE Trans. on Broadcast, Vol.43, No 3, pp.309–316, Sept. 1997.
15. S. G. Tanyer, R. G. Olsen, 'High frequency scattering by a conducting circular cylinder coated with a dielectric of non uniform thickness,' IEEE Trans. on Antennas and Propagat., Vol.45 No.4, pp.689–697, April 1997.
16. A. Altıntaş, O. Ocalı, S. Topçu, S. G. Tanyer, H. Köymen, 'Computer Aided Frequency Planning for the Radio and TV Broadcasts,' IEEE Trans.

on Broadcast, Vol.42, No.2, pp.144–148, June 1996.
17. F. Yaman, A. E. Yilmaz, S. G. Tanyer, 'Analysis of the design of the thinned antenna array pattern using the desired function', 2012 IEEE 20th Signal Processing and Communications Applications Conference (SIU 2011), Antalya, Turkey.
18. M. A. Şahin, K. Leblebicioglu, S. G. Tanyer, 'Performance Optimization of Monopulse Target Tracking Radar', 13th Signal Processing and Communications Applications Conference, Proceedings of the IEEE, SİU'05, pp. 49–52, 16-18 May, 2005.
19. C. B. Erol, S. G. Tanyer, 'Estimation of the daily mean ionospheric total electron content using global ionospheric maps', Geoscience and Remote Sensing Symposium, 2002. IGARSS'02. 2002 IEEE International , Vol. 2, pp. 1287–1289, 24-28 June, 2002.
20. C. B. Erol, ; S. G. Tanyer, 'Improved method for the estimation of the ionospheric irregularities by site dependent total electron content (TEC) amplitude fluctuation index', Geoscience and Remote Sensing Symposium, 2002. IGARSS '02. 2002 IEEE International , vol.2, pp. 1290–1292 vol.2, 24-28, June 2002.
21. S. G. Tanyer, B. Baykal, C. B. Erol, "On the use of blind equalization in the HF communication" Proceedings of the IEEE-EURASIP Workshop on Nonlinear Signal and Image Processing, NSIP-99, Vol. 1, pp.159–162, June 1999.
22. S. G. Tanyer, 'High-resolution radar in inhomogeneous media', Signal Processing Proceedings, 1998. ICSP '98. 1998 Fourth International Conference on , vol., pp.381–384 vol.1, 1998.
23. S. G. Tanyer, C. B. Erol, 'Comparison of the current methods for coverage area prediction for communication in the HF band', Antennas and Propagation Society International Symposium, 1998 IEEE, vol.4, no., pp.1888-1891 vol.4, pp.21–26, June 1998.
24. S. G. Tanyer, M. Karaman, I. Öztürk, 'Analysis of wave propagation in inhomogeneous media using FDTD method and its applications', Mathematical Methods in Electromagnetic Theory, 1998. MMET 98. 1998 International Conference on , vol.2, pp.629–631, June 2-5 1998.
25. S. G. Tanyer, M. Karaman, I. Öztürk, 'FDTD analysis for the ultrasonic imaging in the inhomogeneous media - Ultrason görüntüleme sisteminin homojen olmayan ortamda FDTD yöntemi ile incelenmesi,' SIU-98, 6. Sinyal İşleme ve Uygulamaları Kurultayı, Kızılcahaman, May 1998.
26. A. Altıntaş, H. Köymen, S. Topçu, S. G. Tanyer, O. Ocalı, 'Topography and demography based spectrum utilization in the VHF and UHF terrestrial broadcast bands,' URSI, Lille, France, Aug. 1995.
27. A. Altıntaş, O. Ocalı, S. Topçu, S. G. Tanyer, H. Köymen, 'Computer Aided Frequency Planning for the Radio and TV Broadcasts', NATO AGARD, Digital Communications systems: propagation effects, technical solutions, system design, Athens, Greece, Sept. 1995.
28. S. G. Tanyer, R. G. Olsen , 'High frequency scattering by a conducting circular cylinder coated with a dielectric of non uniform thickness-TE Case', ACES 10'th Annual Review of Progress in Applied Computational Electromagnetics, Monterey CA, Mar, 1994.
29. S. G. Tanyer, R. G. Olsen, 'High frequency scattering by a conducting circular cylinder coated with a dielectric of non uniform thickness', URSI Radio Science Meeting, Ann Arbor MI, June 1993.
30. S. G. Tanyer, 'Elektronik Harp Teknik ve Taktikleri', 6. Savunma Teknolojileri Konferansı (SAVTEK-12), C3 Oturumu, June 20–22, 2012.
31. F. Yaman, A. E. Yılmaz, S. G. Tanyer, 'Analysis of the design of the thinned antenna array pattern using the desired function', 20. IEEE Signal Processing, Communications and Applications Conference, April 18 – 20, 2012.

32. S. G. Tanyer, Davetli Konuşmacı, 'Ülke Bekasında Saklı Kalmış Kuvvet Çarpanlarının Önemi ve Elektronik Harp'in Türkiye'deki Yeri', Savunma Teknolojileri Konferansi (SAVTEK-2010), June 24, 2010.
33. M. Ş. Arslan, S. G. Tanyer, A. Saranlı, B. Baykal, 'Ağ Merkezli Elektronik Harp Kapsamında Veri Tümleştirmeli Radar Ağ Sistemi', 3. Savunma Teknolojileri Konferansı (SAVTEK), C3, June 30, 2006.
34. C. B. Erol, S. G. Tanyer, 'Yer Bağımlı Toplam Elektron Miktarı (TEC) Genlik Dalgalanma İndisi ile İyonosferik Bozan Etkenlerin Kestirimi'', 1. Ulusal Kongresi, URSI - Union Radio Science International, Sept. 18-20, 2002.
35. C. B. Erol, S. G. Tanyer, 'Küresel İyonosferik Haritalar Kullanılarak Günlük Ortanca İyonosferik Toplam Elektron Miktarının Tahmin Edilmesi', 1. Ulusal Kongresi, URSI - Union Radio Science International, Sept. 18-20, 2002.
36. Ö. Özgün, S. G. Tanyer, 'Troposferdeki Elektromanyetik Yayılımının Hesaplanmasında Fourier Adımlama Yönteminin Başarımının İncelenmesi', 1. Ulusal Kongresi, URSI - Union Radio Science International, Sept. 18-20, 2002.
37. S. G. Tanyer, B. Baykal, C. B. Erol, 'Yüksek frekans bandında geniş bandlı PSK iletişimi ve kanal denkleştirilmesi,' SIU-99, Proceedings of 7th IEEE Signal Processing and Communications Applications Conference, Ankara, May 1999.
38. Elektromanyetik Enterferans (EMI) ve Elektromanyetik Uyumluluk (EMC), Broadcast Magazine, pp.54–57.

Acoustics:

39. S. G. Tanyer, T. E. Tuncer, 'Kapalı ve yarı kapalı mekanların akustik özelliklerinin bilgisayar ortamında simüle edilerek incelenmesi,' 2. Ulusal Akustik ve Gürültü Kongresi, Turk Akustik Dernegi, Antalya, Oct. 23-25, 1996.



The capacity to learn is a gift;
The ability to learn is a skill;
The willingness to learn is a choice.

- Frank Herbert, *Dune*

Good luck !...