EE 153. Microwave Circuits and Antennas

12 units (3-2-7); third term. Prerequisite: EE 45.

In the ongoing quest for ever increasing bandwidths and speeds of communication, the frequencies and clock rates of electrical circuits, digital and analog, have continued on their steep ascent, over the past two decades. Computer CPU clocks, at about 100 MegaHertz (MHz) in the early 1990s, are now hovering in the multiple GigaHertz (GHz) range. Cordless phones moved from 400 MHz to 900 MHz, to 2.4 GHz, and finally to 5.8 GHz. Computer wireless local area networks (Wi-Fi), originally at 900 MHz, are now transitioning from 2.4 GHz to 5 GHz. Hard-wired computer network connections now offer "Gigabit Ethernet" options. Cell phones started at 900 MHz, then moved to 1800 – 1900 MHz and now, with 4G, are moving into the 2.5-2.7 GHz band. Automotive collision avoidance radars operate at 77 GHz.

The problem is that, when the frequency of operation becomes so high that the wavelength is comparable to the physical size of an electrical circuit, the traditional circuit analysis techniques that are based on Kirchhoff's voltage and current laws fail. The free-space wavelength of a 5 GHz electrical signal is 6 cm, about the width of a small cell phone. With the continuing trend towards higher frequencies, the specialized design and analysis techniques that apply to this higher frequency domain have found an increasing number of applications. As a Caltech professor once jokingly remarked, even the "digital guys" have had to acknowledge that there is something between 0 and 1!

This course will cover the specialized design and analysis techniques that apply to high-frequency circuits, for wireless communications, radar and broadcasting. The theory of transmission lines, characteristic impedance, maximum power transfer, impedance matching, signal flow graphs, couplers, even and odd mode analyses, filters, noise, amplifiers, mixers and antennas will be covered in the lectures. In the labs, students will design and measure fabricated microwave circuits using sophisticated network analyzers worth well over $100,000. The lab circuits include microstrip filters, directional couplers, low-noise amplifiers and oscillators. Students will be using the commercial microwave Computer-Aided Engineering (CAE) software package *Microwave Office* to design and analyze the circuits. *Microwave Office* is a powerful microwave CAE software package that is actually used by engineers in the field.

GRADING AND COLLABORATION POLICY:

There will be no exams. The student's entire course grade will be based on the homework and labs. Therefore, so that the grades are meaningful, no collaboration of any kind will be allowed on the homework and labs, although students may discuss any aspects of the lectures. Notes or homework solutions from previous years may not be used, but any books may be consulted. Internet sources may not be used. A student's total class percentage score will be calculated at the end of the term by dividing the sum of their homework and lab points by the total number of possible homework and lab points.