Welcome to ENGN4545/ENGN4565: RF Engineering

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ENGN4545/ENGN4565: Weekly Timetable

- Monday 11.00 am - 12.00 pm Chem T2
  Tuesday 9.00-10.00 am Chem T2
- Practical Group 1 Tuesdays 2.00-5.00 pm
  Room R103 (Digital Lab, Ian Ross Building)
- Tutorial Group 1 Tuesdays 11.00 am - 12.00 pm
  Chem G51A

ENGN4545/ENGN4565: Syllabus

1 Introduction to radiofrequency
2 EM1 Vector fields. Charge, EM Fields
3 EM2 Maxwells Equations
4 EM3 Wave Motion
5 EM4 Impedance, skin effect
6 Fourier analysis, networks, S,Y-parameters
7 Filters and matching networks
8 Transmission lines
9 Characterising transmission line networks
10 Shielding and measurement principles

ENGN4545/ENGN4565: Syllabus (Ctd.)

11	Transistors at radiofrequency, amplifiers, oscillators
12	Noise, distortion, SINAD, phase noise
13	Mixers, modulators, demodulators, up/down conversion
14	Transformers, directional couplers, baluns, phase hybrids
15	Frequency Synthesis, Phase Lock Loops, Direct Digital Synthesis, CORDICS
16	Wireless Communications Systems
17	Radio frequency measurements. Analysers
18	Antennas, aperture, gain, impedance, reciprocity
19	Satellite links
20	Radio wave propagation

Textbooks

- Most is available in lecture notes and on the web

  http://engnet.anu.edu.au/DEcourses/engn4545/introduction.html

- But there are some good books too as listed on the web.

What will you learn?

- Fundamentals of the theory... get a feeling for how things work.
- How to design and build simple Radiofrequency circuits. (Build a radiofrequency transceiver)
- How to do radio measurements. How to use spectrum analysers and vector network analysers
- How some highly specific radiofrequency devices work
- How radiowaves propagate. How to compute link budgets
- Legal issues of radio emission.

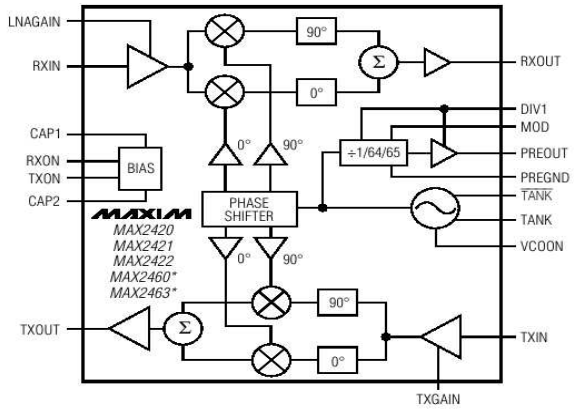
Assessment

- Exam 40 %: Based largely on the lecture material.
- Project 40 %: Choice of two similar projects involving design, construction and testing.
- Labs 20 %: Partly test and measurement exercises with some questions contained in supplementary material on the web.

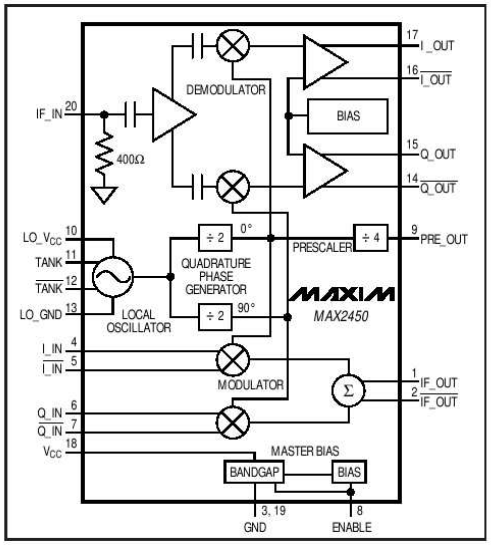
Project 1: Hardware

Choice of two...

- MAX2450: 35 - 80 MHz VHF design.
- MAX2420: 900 MHz transceiver design



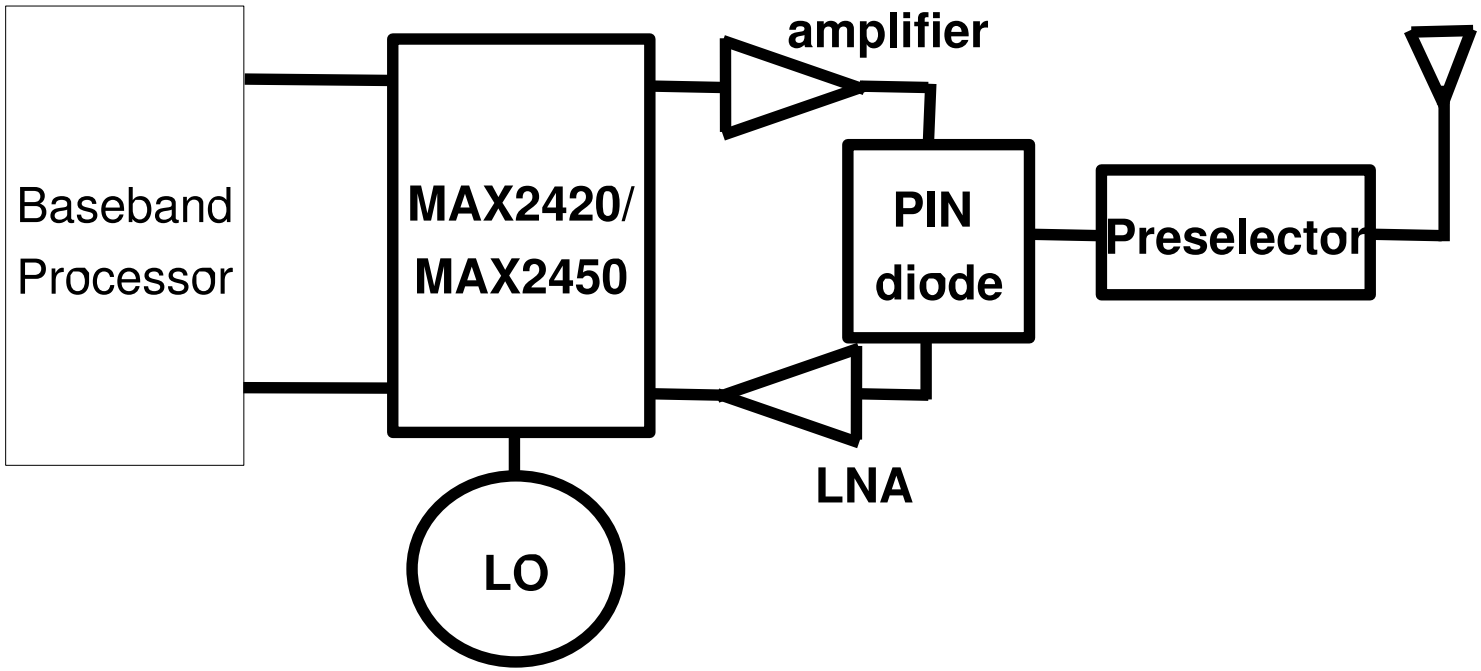
MAX2420



MAX2450

Project 2: IQ Radio Transceiver

- Radiofrequency design for voltage spec (baseband processor), sensitivity (link budget), phase noise, distortion products, antenna gain and engineering...



Project 3: Expectations

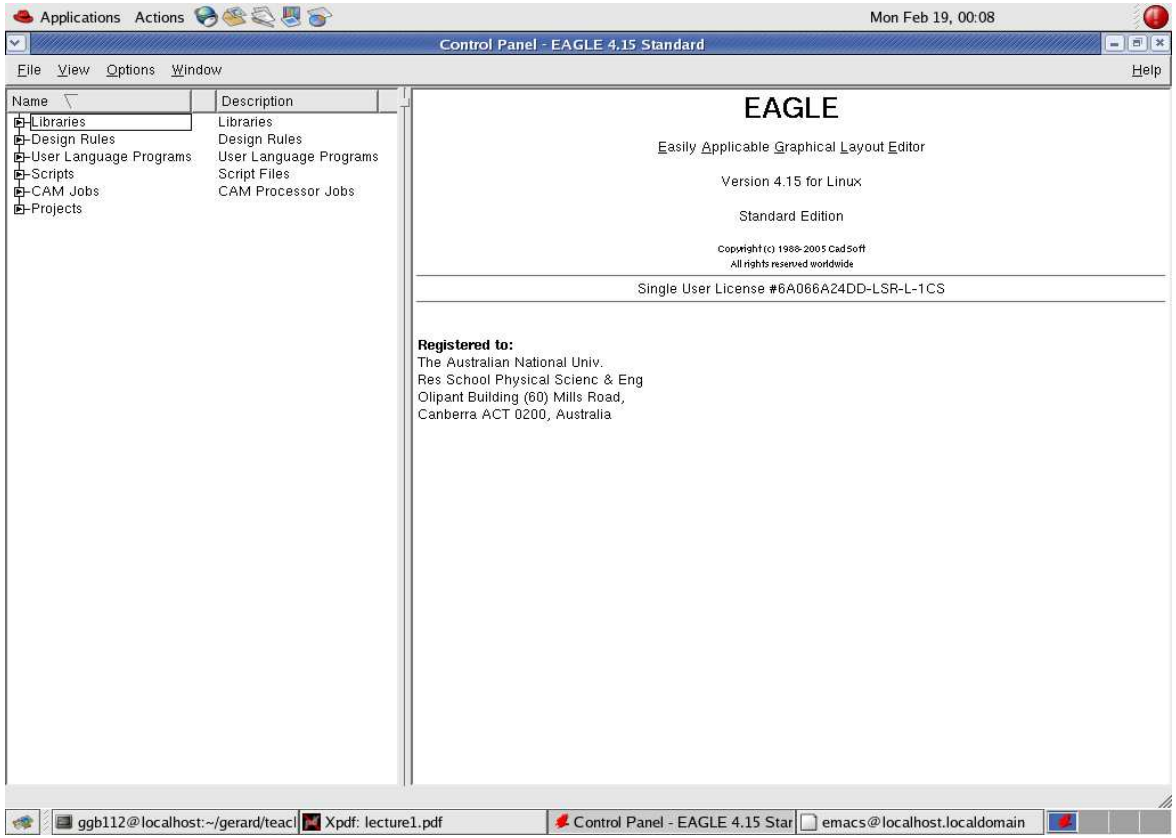
- Aim to design, build and test the circuit of your choice.
- Ostensibly apply the knowledge that you have learned in the course.
- Each student build their own project and each student is marked individually on their own work.
- You can collaborate.
- Assessment consists of a midterm progress report (2 pages, due 5 April) and final report (30 pages) and demonstration due at the end of semester (31 May)

Project 4: Design Criteria

- Design of MAX2420/2450 layout. There is much information.. even an eval. kit. I leave it up to you.
- Design of a power amplifier to bring up to 100 mW EIRP.
- Design of PIN diode T/R switch.
- Design of circuit board mounted antenna.
- Design or purchase of the local oscillator ... MAX2420 has an internal oscillator but probably too much phase noise.
- Meet sensitivity spec of -100 dBm for 12 dB SINAD (?). May need a Low Noise Amplifier or an AGC amplifier (?)

Project 5: PCB Design

- Eagle: http://www.cadsoftusa.com. For both WINDOWS and LINUX. Ver 4.16.



Background

- Radio waves form the low frequency part of the electromagnetic spectrum. (30 Hz - 300 GHz)
- Radiofrequency engineering refers to the applications of devices and processes that exploit radio waves.
- Radio Engineering is quite a diverse subject because there are **many applications** of radio: not just wireless comms and radar.
- Old subject, having its modern roots in Maxwell's equations (1865) and the famous experiments of Heinrich Hertz (1886).
- Moor's law and the ever increasing capabilities of digital devices in the last thirty years has led to the disappearance of radiofrequency from the curricula of most universities worldwide.
- The present wireless revolution is turning this around.

Electromagnetic Spectrum

SLF	30-300 Hz	Submarine communications
ULF	300-3000 Hz	Telephone
VLF	3-30 kHz	Avalanche beacons,wireless heart rate monitors
LF	30-300 kHz	Navigation, time signals, AM longwave broadcast
MF	300-3000 kHz	AM (Medium-wave) broadcast
HF	3-30 MHz	Industrial processing, International broadcasts (shortwave)
VHF	30-300 MHz	FM and TV broadcasts
UHF	300-3000 MHz	TV broadcasts, cell phones, wireless LAN
SHF	3-30 GHz	microwave devices, Most radar systems (e.g. Police radar)
EHF	30-300 GHz	Plasma Fusion ECRH, Synthetic Aperture Radar

Industrial Scientific Medical Bands

- There are a number of bands in which are free to transmit. These are the **Low Interference Potential Device bands** and the **Industrial Scientific and Medical bands**
- 13.553 MHz - 13.567 MHz (100 mW), 26.957 MHz - 27.283 MHz (1 Watt), 40.66 MHz - 40.70 MHz (1 Watt), 918 MHz -926 MHz (1 Watt) , 2400 MHz - 2450 MHz(1 Watt), 5725 MHz - 5875 MHz (1 Watt) and 24000 MHz -24250 MHz (1 Watt).
- All values are EIRP (Equivalent Isotropic Radiated Power).

The History of Radio

1844	Samuel Morse invents telegraphy
1864	James Clark Maxwell publishes the theory of electromagnetism
1876	Alexander Graham Bell develops the telephone
1886	Heinrich Hertz discovers electromagnetic waves
1901	Marconi sends wireless signals across the Atlantic
1905	Einstein publishes the special theory of relativity
1906	Lee deForest develops the 3 element (Triode) vacuum tube
1908	Amateur radio emerges
1912	The Titanic disaster points to the need for radio regulation
1913	Edwin Armstrong develops the regenerative receiver. CW is born
1918	Edwin Armstrong develops the superheterodyne receiver
1918	C.W. is used by the military during the war
1926	Crystal control of transmitters developed
1926	Baird and Jenkins demonstrate television
1927	Heisenberg publishes the Uncertainty Principle

The History of Radio

1935 The invention of radar
1946 Accidental discovery of microwave cooking
1946 Felix Bloch and Edward Purcell discover Nuclear Magnetic Resonance
1948 Single Sideband is fully described in the amateur publications
1948 The FCC creates Class A and Class B CB radio between 460-470 MHz
1955 Technicians are given 6 meter privileges
1956 Transistors widespread, but most radio equipment still all tubes
1957 Sputnik, the first artificial satellite is launched
1958 First integrated circuits
1960 SSB catches up on AM in popularity
1961 OSCAR I, the first amateur satellite, is launched.
1963 Penzias and Wilson discover the cosmic microwave background
1964 Fairchild produce the 702,704 and 741 op-amps
1985 The first FPGA is on the market

Radiofrequency Waves

Radio waves are electromagnetic waves and therefore propagate at the speed of light $c = 3 \times 10^8 m/s$.

$$\lambda = \frac{c}{frequency} \tag{1}$$

Band	Frequency range
160 m	1.815 to 1.89 MHz
80 m	3.5 to 3.8 MHz
40 m	7 to 7.1 MHz
30 m	10.1 to 10.15 MHz
20 m	14 to 14.35 MHz
15 m	21 to 21.45 MHz
12 m	24.89 to 24.99 MHz
10 m	28.0 to 29.7 MHz
6 m	50.08 to 51 MHz
2 m	144 to 146 MHz
70 cm	430 to 440 MHz
23 cm	1240 to 1300 MHz