# COMP3310/6331 – Tute/Lab #1 – 2020 Week 3

*As part of the review of 3310, students asked for more 'tute' time to discuss the course content, so we're trying to oblige. For discussions and the cable analysis try work in groups and see if you agree.*

*Note that there is a very limited number of cable samples, so when you get the chance leap to that Activity. For students not yet on-campus, you can do this piece later, it is not assessible.*

*There are more questions here than may fit into the available time. Answers will be posted next week, and you should check your understanding against them. Students not yet on-campus can work through them independently, ask questions in the forum or contact your tutor.*

At the low hardware layers we're currently exploring it's a little tricky to get into too many tools or coding exercises. Soon though!

*At this stage students will have covered:*

- *Signalling and simple informatics, i.e. modulation (AM/FM/PM->ASK/FSK/PSK), multiplexing (TDM, SDM, FDM, WDM), encoding (4b/5b, Manchester), baseband/passband/broadband, and a quick pass by Nyquist and Shannon.*
- *Media: Copper, Fibre and wireless and associated issues*

| Activity | |
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| 1 | **Introductions**:<br>• Who are you? What is your background? What is your interest in computer networking and/or this course?<br>• I don't believe we have any class-reps for 3310 yet, and only one for 6331 – nominations are being sought, see first lecture. |
| 2 | **Discussion of lectures**:<br>• To-date: Any comments on pace, content, style?<br>• Planning ahead: Any particular real-world network systems, technologies, challenges, etc. that you'd like to have a guest lecture on (Weeks 10-12)? Already have one on AARNet (our National Research and Education Network), one on TransACT/NBN, and one on the Wamboin rural fibre network. |
| 3 | **Checking frequency understanding:**<br>• Why do we care about the frequency view of things? Discuss.<br>• *Nature prefers waves, and blocks some! Losing high/low frequencies plays havoc with your nice square signals. Main message is just that underpinning digital signals are real analogue waves across a range and combination of frequencies, that we can take advantage of.*<br>• Why do we use Frequency Division Multiplexing rather than Frequency Shift Keying?<br>• *Because electronics can be tuned to a frequency and use it as a dedicated (multiplexed) channel with ASK/PSK, which is also way more efficient than using a bunch of idle frequencies and jumping between them.* |

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| | <ul><li>A bit of online playing: http://www.falstad.com/fourier/Fourier.html is a very good Fourier Transform visualiser, and you can use it to add a range of signals over the top of each other. Using sound in the lab is a challenge, but visually it's very helpful. You should explore the various built-in waveforms.<ul><li>Switch the Mag/Phase view on, (and maybe Log View to make the scale clearer).</li><li>Hovering over the "magnitudes" shows how the components contribute. You can tweak them individually (click and drag up and down) and see what happens to the resultant (red) curve.</li><li>Increase/decrease the "number of terms" and see what happens, as higher frequencies are excluded (= **low-pass filter,** very common in nature). Imagine you are a receiver interpreting the signals coming in, and only know you are going to get square waves at some rate. When does a square wave not look square?</li><li>The **High-pass** filter excludes the lower frequencies, click more than once to exclude more.</li><li>You can draw an arbitrary (single-valued) function in the top section and it will generate the FT for you. A square pulse train (random selection of 0,+1,-1) with narrow separations shows nicely how quickly the signal degrades as the number of terms are reduced. If you can listen to them, note how the round sine waves individually sound "smooth" but the square wave and triangle wave sound "harsh" due to the many higher frequencies all contributing.</li><li>This last step also visually highlights how the fundamental frequency emerges from a repetitive signal. Just kill all terms but the first (non-constant) one.</li></ul></li></ul> |
| 4 | **The joys of Cables – these will be passed round the room to each group**<ul><li>Copper: You'll have two samples of coaxial ('coax') cables. Look at the thin coax, identify the four main elements (core, dielectric, shield, jacket). Coax gets used in (for example) Cable TV services. Contrast the thin with the thick coax. What's the benefit of the thicker coax, what are the main downsides?</li><li>*Greater shielding/noise protection; greater diameter=less resistance=longer runs; but lots of materials (=expensive) and very stiff (=hard to deploy)*</li><li>Copper: You have samples of Cat5 and Cat7, used in structured cabling to carry data, video, voice (telephone), etc. Identify which is which. What are the main differences between the two? What are the benefits and downsides of each? Note the way the RJ45 plug provides 8 straight wires in a specific order for connecting into a socket. If there's a spare socket in the room, try it out!</li><li>*Cat5 is blue, Cat7 is orange (may be written on some). Cat 7 has foil on each pair, plus a bit of shielding around the whole bundle, plus solid core wires for each pair. All of which go to quality and performance. Also go to materials and manufacturing complexity = higher cost. It's also much stiffer, won't lie down neatly or go round corners easily.*</li><li>Fibre: You have samples of two fibre types, one "multimode" and one "singlemode". The most obvious way to differentiate them (apart from the label) is the diameter of the actual fibre (multimode >> singlemode). Try and see the fibre end, centred in the terminal (perhaps take a photo with your phone if you can and magnify it?). Use a phone torch led to shine a light down one fibre and see it emerge brightly at the other end, regardless of path. Can you see the</li></ul> |

differences? What's the benefit of single-mode over multi-mode? What's the benefit of multi-mode over single-mode?

- *SMF is labelled as such, the MMF is much longer and matches the bag label. Quite hard to see the fibre entrance in the terminals, but becomes clearer when shining a light through. With the wider MMF core you get a 'brighter' and 'broader' light out the other end, and it's easy to line up with the led source. SMF is quite a bit fiddlier.*
- *SMF much narrower core than MMF, only allows for a (largely) direct light ray to get through. Removes modal distortion (i.e. all the reflected longer paths are avoided). Gives you **much** greater range and higher data rates. Costs a lot more, since it's harder to terminate and you light it up with lasers instead of LEDs.*

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1. Draw an Amplitude-Shift-Keyed wave with four different levels, that represents 01.00.11.00.10.00.01.00
   *It's just the reverse order of the one in the T1 lecture slide*
2. Explain how a 16-position constellation (QAM) diagram works, with amplitude and phase axes, to represent bit patterns. Which bit pattern (maybe) goes where, and why? Could you have a 35-position QAM? And what would it look like? If yes, would it be efficient? If no, what values are better suited?
   *Each position represents a unique phase shift and amplitude shift of a signal wave. With 16 unique positions you can encode four bits per symbol. Students can arbitrarily allocate patterns to points. There are some arguments for various layouts, e.g. to make small single-bit changes in bit patterns, like 0100 and 0101, look like large changes in phase/amplitude.*
   *You can have any QAM arrangement you like, 5*7 is fine, even 1*35 is fine - but it gets harder to separate 35 levels of ASK or PSK, and you are wasting space. The efficiency is about how many bits you can encode per symbol. 35 = 8.3 bits, which wastes space. Better off with QAM patterns that are a power of 2 to encode an integer number of bits.*
3. Nyquist: Given a 1MHz wave, amplitude modulated to 8 levels, what's the potential datarate achievable?
   *2*1MHz*log2(8)=6Mb/s – students may struggle why they can fit two bits into a single wave, you need to look at it like a 180degree phase-shift-key*
4. Media question: Why does copper become less useful over longer distances? What causes those problems? How can we fix them?
   *Too much attenuation (energy loss) and too much noise (energy gain).*
   a. *Energy loss, wire is resistive, and especially at higher frequencies.*
   b. *Noise, wire is an antenna.*
   c. *Fix it with shielding, twisting, differential signalling, better connectors, ...*
5. Encoding question: why is 'encoding' bits into a modulated signal so important? What problems are you solving?
   *Make the signal clearer overall, by ensuring a higher rate of transitions (easier to detect), to avoid the 100000…000…000 vs "are-you-dead" problem.*
   *AND provide a mechanism for clock-recovery, so you know how wide a bit is, i.e. what the data rate actually is, and where the bit boundaries are (clock sync).*

6. Explain what dB, dBm and dBi mean, how are they different?
   a. *dB is just a ratio, e.g. of signal/noise energy. Expressed on log scale, and times 10, e.g. 20dB = 2B = $10^2$ =100. -20dB = -2B = $10^{-2}$ = 0.01*
   b. *dBm is also just a ratio, but the zero point is 1mW (0dBm = 1mW, 20dBm = 100mW, -20dBm=0.01mW)*

c. *dBi is also just a ratio, used to measure gain of an antenna relative to an ‘isotropic’ antenna (transmitter or receiver). Could be higher-gain antenna due to design, e.g. more directional, or larger, or … e.g. wifi AP antennas you can buy a 3-18dBi antenna to replace/augment the built-in.*

7. What can you do to make wireless transmission better?
    a. *(slide) Be clearer: shout louder or slower. Be smarter: avoid noise (frequency hopping), or focus (beam-shaping) or terrain (higher/taller antennas)*
8. How can I make signals over copper/fibre/wireless go further? What are the challenges that brings?
    a. *Repeaters (regenerate the signal cleanly) and amplifiers (amplify both the signal and the noise). They cost money, and need their own power. Can introduce significant delays to unpack/repack the signal.*
9. Can I build a wireless transmitter of any power at any frequency? What might stop me?
    a. *Yes you can, but you shouldn’t without some consideration of your neighbours*
    b. *Regulations. ACMA.*
    c. *Fellow transmitters will beat you up.*
10. Looking a little ahead. If you have an Android phone please help those who don’t. Install “wifi-analyzer” on your Android phone from the google play store. (Seems like there’s still no Apple version). The name is not unique; I recommend the version by ‘farproc’/Kevin Yuan, as it seems to perform best.
    a. There are a variety of screens you can drag through left-to-right.
    b. How many (wifi) signals or access points can you see? How strong are they (in mW)? (interpret the dBm figures) Which one is the strongest/weakest from your location? Can you find a wifi-access point using the signal indicator? (somebody could fire up a hotspot on their phone as a target)

11. Have a look at https://eyes.nasa.gov/dsn/dsn.html to see the spacecraft being supported by the three tracking stations around the world. If you click on an antenna that is receiving (RX)/sending(TX) a signal you’ll get info about what it is communicating with. On the right side click on **‘more detail’** to get information about the signal being sent/received. The antenna picture shows if it is TX/RX, and if there is a modulated signal (data) or just a ‘carrier wave’ (like a heartbeat)
    a. A standard microwave oven uses about 1kW of power to cook. An LED bulb can be 1W. How does that compare to the signal being transmitted to the spacecraft?
    b. How strong is the signal coming back, compared to the wifi signals you measured with your phone? How many powers of ten different?
    c. If you look at different antennas/spacecraft you’ll notice their distance, time-delay and signal strength vary significantly. What’s the furthest spacecraft you can find here, and what data-rate is it achieving? For reference, the Moon is 400,000km away (about 1.3 light-seconds), the Sun is about 150 million km away (about 8 light-minutes). Around Mars several spacecraft can be contacted in parallel by the one dish, so you may see multiple selectable options there.