Signals and systems strand
—DRAFT—

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Contents

1 Overview

1.1 Rationale

One of the major themes in the undergraduate telecommunications engineering program is signals and systems.

Staff have noted student indifference to the subject matter in the stream. They have also observed that students are unprepared to engage with many of the concepts that are presented and seem unable to develop a deep or lasting understanding of the subject matter. These outcomes may be due to some of the following:

- Lack of interest due to perceived lack of relevance to likely employment opportunities. Reinforcement through employer indifference.
- Poor study skills.
- Inappropriate teaching methods.
- Inappropriate dependency structure.
- Unplanned evolution of the program.

This review plans to address these issues and make recommendations that are consistent with the Faculty's practice-based engineering philosophy, the faculty endorsed process of staged development and university encouraged flexible learning approaches. Any proposed subject redevelopment will recognise changes in educational technology, employment patterns of students and budget and resource constraints.

1.2 Scope

While the revision tem will initially look at the whole signal and systems stream subject specific proposals will be limited to :

- 48720 – Introduction to Telecommunications Engineering (half)
- 48541 – Signal Theory
- 48770 – Signal Processing

It will consider these subjects within the new dependency structure shown in Figures 3 and 5. This structure was endorsed at the Telecommunications Retreat of 26th September, 2003.

1.3 Stakeholders

An inexhaustive list of stakeholders includes:

- Review Team (John Reekie, Tim Aubrey)
- Subject coordinators of the subjects involved in the review (Keiko Yasukawa, Martin Evans, Anthony Kadi)

- Telecommunications Program (team led by Kumbesan Sandrasegaran)
- Other programs
- Teaching and Educational Development Committee (Faculty based)
- Faculty Educational Developer
- Students

1.4 Resources available

- Money: nil
- John Reekie
  - Development of proposal documents
  - Co-development of example learning objects
- Tim Aubrey
  - Co-development of learning objects
  - Redevelopment of Introduction to Telecommunications Engineering
- Keiko Yasukawa
  - Redevelopment of Introduction to Telecommunications Engineering
  - (FED advice)
- Other subject coordinators and program members
  - Brainstorming with review team to drive Course Content (Section 3) to a state satisfactory to all Telecommunications staff.
  - Agree to provide concrete course materials when requested by the revision team.
  - Agree to read and comment promptly on further versions of this report.

1.5 Deliverables

- Documents for changing the program structure, including those necessary for the TED approval process and CASS change information. See Section 2 of this report.
- A complete description of topics and learning outcomes agreed upon by Telecoms staff for the signals and systems stream. To be provided as Section 3 of this report.
- Redeveloped and documented Introduction to Telecommunications. As documented in Section **??** of this report, and in the ITE subject documentation.
- Example learning objects for strand components. To be documented in Section **??** of this report, and provided in whatever form is appropriate.
- This report, completed in its second version.

1.6 Program vision

Any development work in the Telecommunications should keep in mind the vision of the Program. This vision was elicited from Telecommunications staff in the Spring 2003 semester.

> The Telecommunications Engineering program views an engineering education as the beginning of a life-long practice that demonstrates ethical and professional conduct in both the workplace and the community. As such, graduates of the program possess a firm telecommunications-specific technical foundation, a grounding in analytical thinking and the ability to abstract and model complexity, and a good understanding of their on-going role as professionals practicing within the broader context of a complex and diversely-skilled society. To this end, the Telecommunications program provides a relevant and stimulating learning program that recognizes and accomodates the diverse backgrounds of its students.

1.7 Qualities

We adopt the notion of *qualities* from software architecture. Qualities are properties of the system under consideration other than the more obvious "functional" properties. For example, reliability, availability, usability, and modifiability are qualities that an architect considers in addition to the production of correct outputs. Satisfying qualities requires prioritizing them and resolving tensions between them.

Analogously, we might consider the "functional" properties of our curriculum to be the material covered (or arguably, the material learnt). Here is the list of qualities that we consider to be the highest priority in the signals and systems stream revision work:

Achievability There is little point in designed a revised course structure if we cannot achieve it. Satisfaction of the *achieveability* quality requires that considerations such as budget, time, staff availability, support for incremental development, and so on be considered.

Longevity This quality is the ability of a subject to "last" a long time without being scrapped and rebuilt. It is a desirable quality because, overall, it reduces the overall cost of subject development. In this revision work, since we are spending additional time over the normal teaching requirements, we should be careful to make sure that anything we implement will last.

Continuity We define this quality to be the continuity of subject content, themes, teaching approaches, and so on, across a series of subjects. Continuity is important, to enable us to properly reinforce and deepen understanding as students progress through a sequence of subjects such as those in the signals and systems stream.

1.8 Abbreviations

The following subject abbreviations are used in this report.

- OOP– Object-oriented programming
- OOD – Object-oriented development
- EfS – Engineering for sustainability
- RTOS – Real-time operating systems
- ITE – Introduction to telecommunications engineering
- ST – Signal theory
- SP – Signal processing
- CT – Communications theory

1.9 About this document

This document is the second in a series related to revision of the "signals and systems" strand of the telecommunications degree program. The first document [1] outlined an initial approach that was largely endorsed by Telecoms staff at the Telecommunications Retreat of 26th September, 2003. This document continues this work with the involvement of additional Telecoms staff.

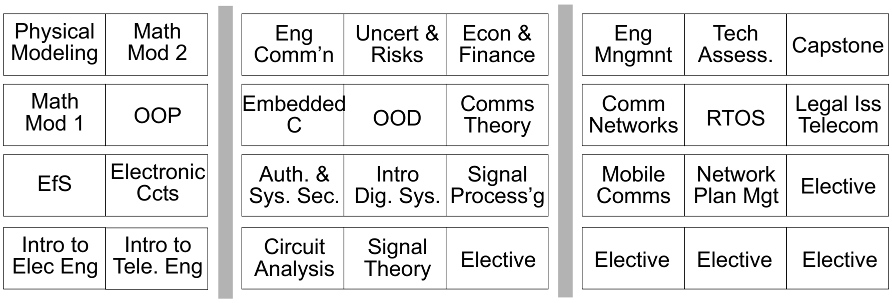

Figure 1: Timetable view of the current program

2 Program Structure

This section describes the current and proposed structure of the Telecommunications program. The proposed structure is based on:

1. A proposal for changes to the signals and systems strand accepted at the retreat in September 2003.

2. Ongoing revision work on the networking strand, led by Kumbesan Sadrasegaran.

2.1 Timetable view of the program

Figure 1 shows the current Telecommunications program in a standard timetabling format. This view is the current Course Template, but with prerequisite dependencies left out. For simplicity, I have left out Software Engineering, which is an alternate choice to OOD, and Telecommunications Channels, which is an alternate choice to Mobile Communications.

Figure 2 is the same view, but with some of the prerequisite dependencies overlaid on it. The subjects shaded grey are the signals and systems-related subjects; those in very light grey are the networking stream subjects (with which this report is not concerned, except insofar as changes in the timetable structure need to work together with concurrent work on this stream).

Figure 3 is the proposed new structure. The main changes are as follows:

1. The dependency of Signal Theory on Circuit Theory is removed.

2. Signal Theory is made dependent on Math Modeling 2.

3. Signal Processing is "inserted" between Signal Theory and Communications Theory.

4. The order of Communications Networks and Authentication and Systems Security is swapped (networking strand).

In order to achieve this change, the timetable must be altered slightly by moving Communications Theory (and any following subjects) back one semester.

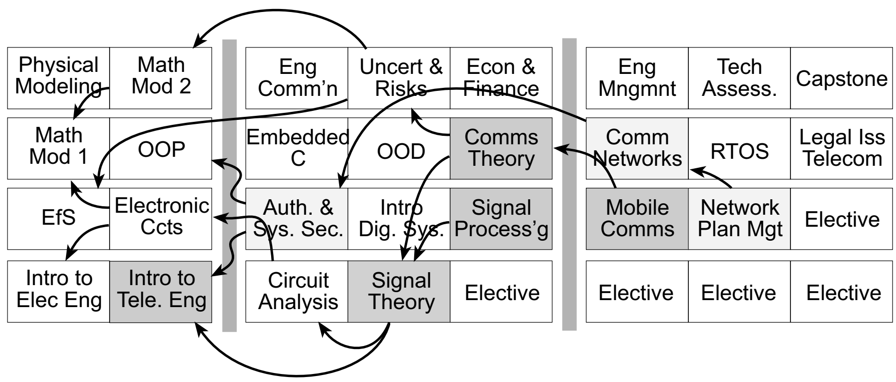

Figure 2: Timetable view with a partial dependency view overlaid

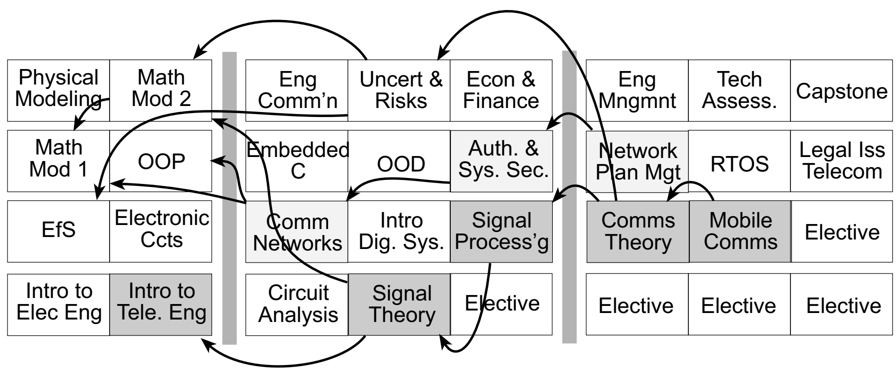

Figure 3: Timetable and partial dependency view of the proposed program

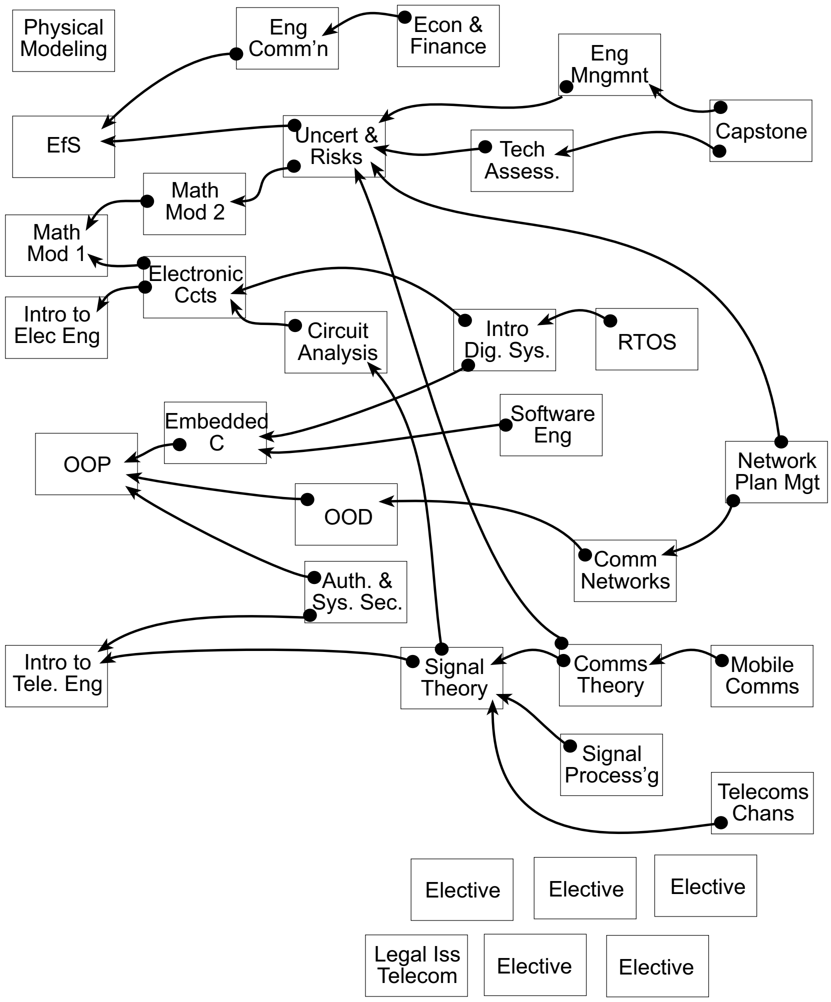

Figure 4: Dependency graph of the current program

2.2 Dependency view

Figure 4 explicitly shows all dependencies in the current program. This view highlights that there are two "bottleneck" subjects in the program—that is, subject which depend on multiple subjects and have multiple subjects depending on them. The two subjects are Uncertainties and Risks, and Signal Theory.

After revising the dependencies as discussed above, the program is as shown in Figure 5. Signal Theory is no longer a bottleneck. Uncertainties and Risks is, and we recommend that the Telecoms team examine further why these dependencies exist and whether they are really valid.

The structure of the signals and systems subjects in Figure 5 is now much cleaner, and this is apparent from the diagram. We could consider this structure to be an instance of a more general pattern. We might label this a "tree" pattern, as shown in Figure 6—the "trunk" consists of a strong sequence of

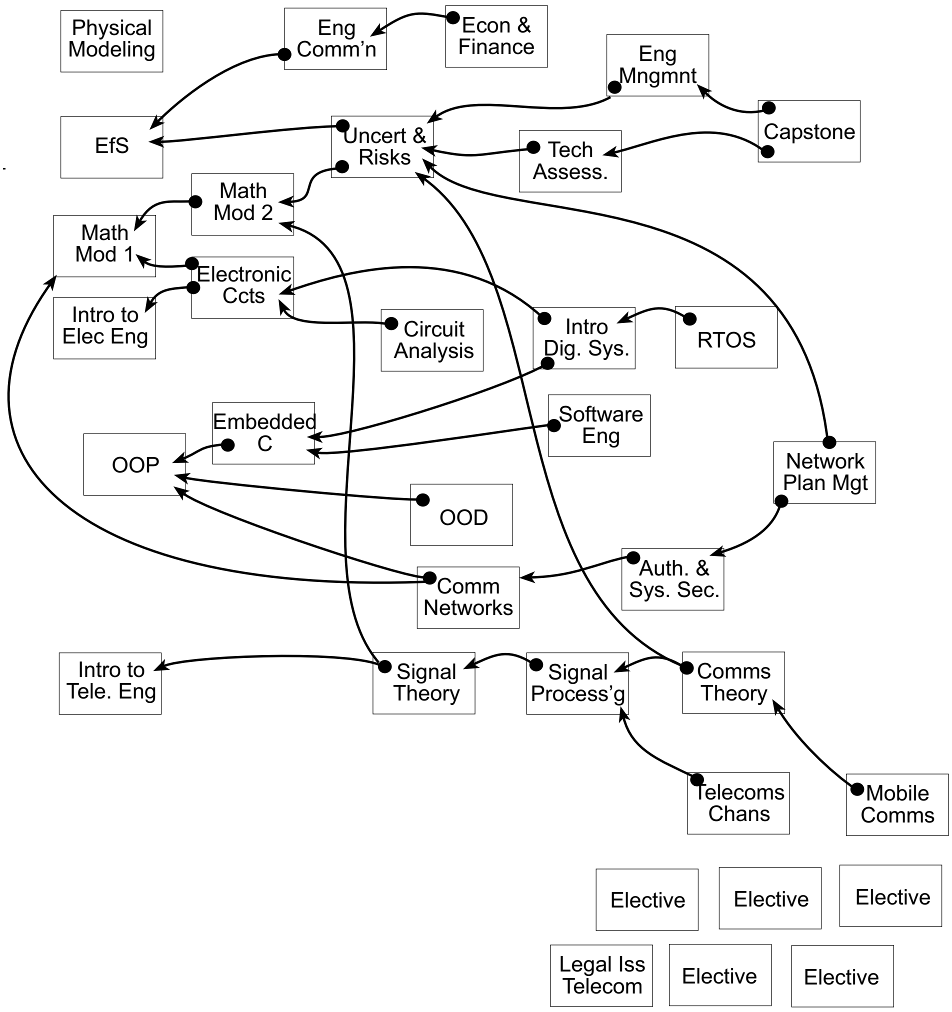

Figure 5: Dependency graph of the proposed program

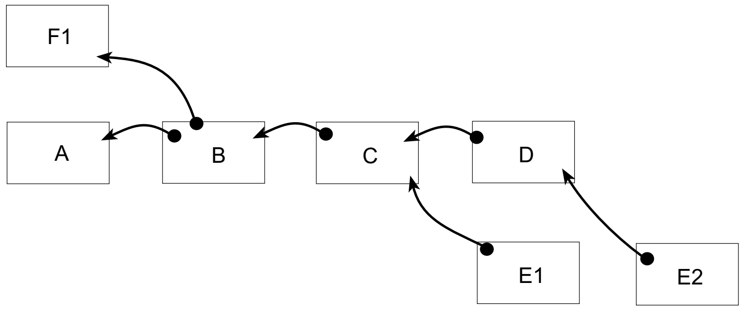

Figure 6: A general pattern of subject dependencies

field-of-practice-specific subjects (*A–D*); the "roots" are foundation subjects typically applicable to more than field of practice (F_n); and the "branches" are in-depth explorations in the field of practice (E_n).

3 Collaborative outcomes

This section describes the results of collaborative work on the signal and systems strand and in the broader Telecoms group.

3.1 Concept map

Figure 7 is the concept map for the signals and systems strand. The concept map is a concise view of the knowledge that we believe we are imparting. We have shaded dark grey topics that should be covered in some depth, and in light grey topics that will be covered only at an introductory level.

This set of concepts was discovered by a meeting of Telecommunications staff, including Warren Yates, Sam Reisenfeld, Kumbesan Sandrasagaran, John Reekie, and Johnson Agbinya. Tim Aubrey and John Reekie decided on which topics to include for the purposes of this revision.

As this revision proceeds, we expect to increasingly be concerned with the type of understanding achieved in each topic. For that purpose, we will talk about the following types of understanding.

- Intuitive

  An intuitive understanding of telecommunications concepts. Intuitive understanding provides a basis for deeper work such as mathematics or simulation.

- Mathematical

  Ability to perform and understand the necessary mathematical manipulations in signal and communications theory.

- Applicability

  An understanding of how particular telecommunications concepts are applied in real systems.

In the concept map, a "deep" understanding includes all three of the above, whereas an introductory understanding includes only one or perhaps two.

3.2 Complementary Skills

This section lists the skills that Telecommunications staff have identified for the signals and systems stream. These skills are those that are tpyically not covered by the course material itself, but are essential for properly grasping and being able to exercise the material. We groups these skills into the following:

- Problem-solving skills

  Understanding how to approach solving unknown problems at various levels of complexity.

- Simulation skills

  Knowledge of how to use Matlab (or a related language) to perform simulations of telecommunications concepts and systems.

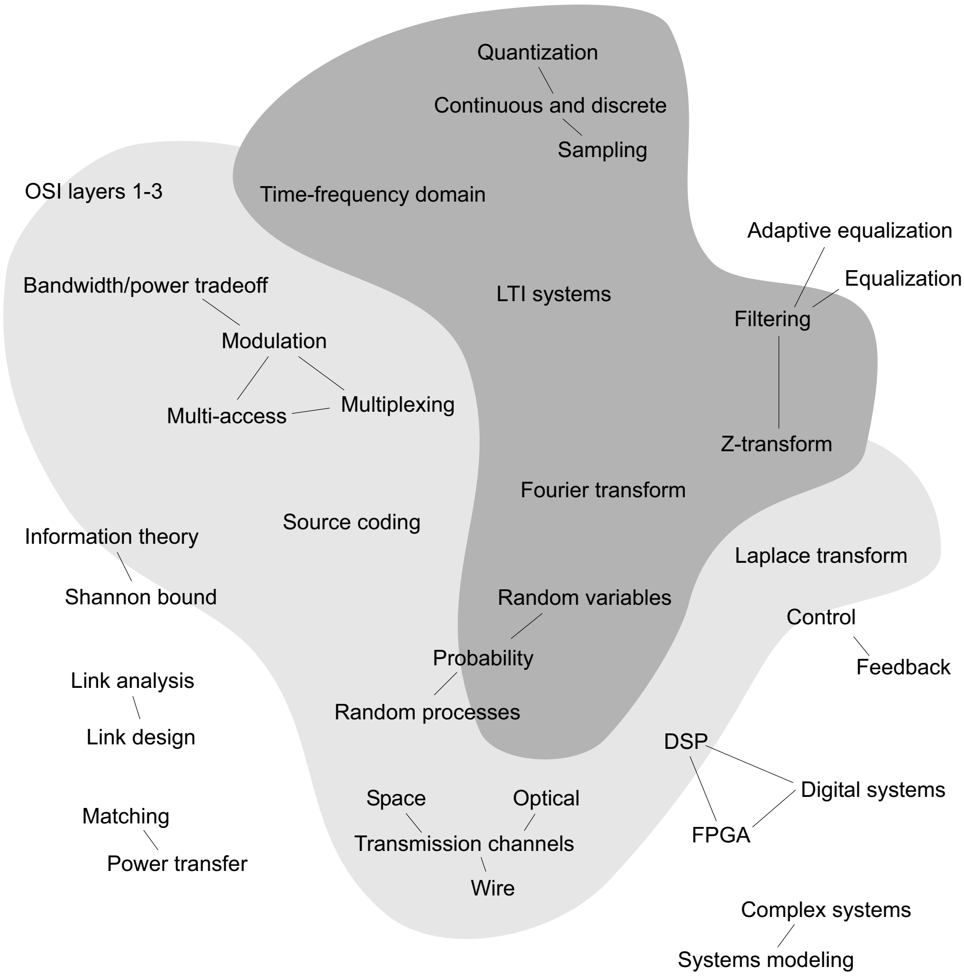

Figure 7: Concept Map of the signals and systems strand. The shaded dark grey area indicates the topics that will be covered in depth in the introductory subjects; the shaded light grey area indicate the topics that will covered to a lesser depth.

- Programming skills

  Knowledge of how to implement telecommunications modules and systems in a conventional programming language such as Java or C, culminating in ability to implement on real-time platforms.

Below, this view is illustrated by specific problems that students can solve. The problems are formulated in the "assessment" capability view—that is, if students were assessed on these tasks the distribution would roughly equal the mark distribution for a subject. For each the stage of the program is noted (early, mid, or late). The information in this section was obtained by consultation with Telecoms staff. Clearly, we need a great deal more input.

3.2.1 Problem-solving skills

...

3.2.2 Simulation skills

1. Use Matlab to reinforce mathematical analyses. (Stage: Mid)

2. Use Matlab to simulate a multi-user communications system end-to-end. (Stage: Late)

   The program would include simulation of source coding and decoding, the channel, and so on. A compelte program is required, although a GUI front-end is not. The result of the program would be a series of performance graphs.

3.2.3 Programming skills

1. Able to use network-based simulation tools. (Stage: Mid)

   This implies a general proficiency in Java (and C++ is also desired), and in particular the ability to read and modify existing code.

2. Write a java application to securely obtain a ticket price from the Qantas website. (Stage: Mid)

3. Read and understand a real Java application. (Stage: Mid)

4. Write a requirements document for a protocol simulator. (Stage: Mid)

5. Write a Java-based distributed program for sensing, control, analysis, and management.

3.3 Learning outcomes

For each major area in the darker-shaded section of the Concept Map, the signals and systems team produced a mindmap of the learning outcomes. These maps were determined at meetings in May and June, 2004, attended by Tim Aubrey, Subhash Challa, Martin Evans, Anthony Kadi, John Reekie, and Keiko Yasukawa.

Figures 8 to 13 show the outcomes discovered for each of these key areas.

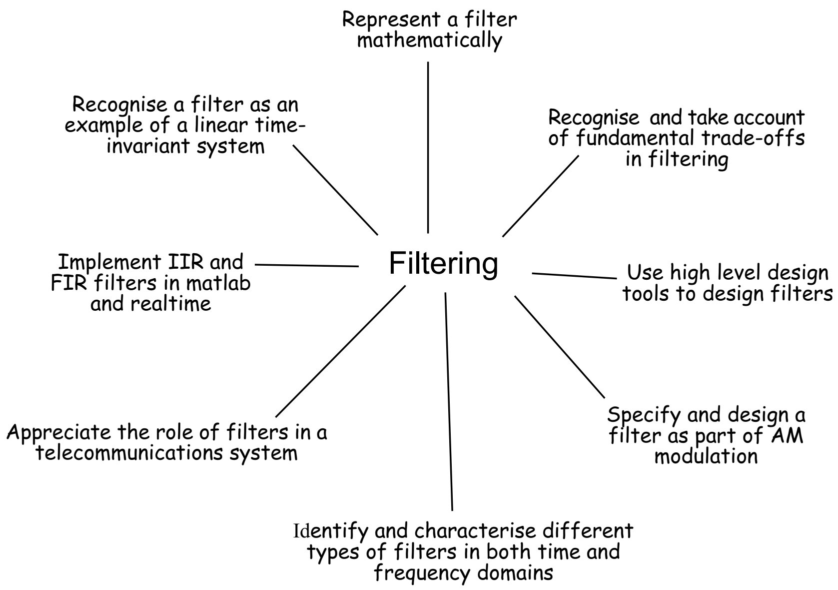

Figure 8: Outcomes for filtering

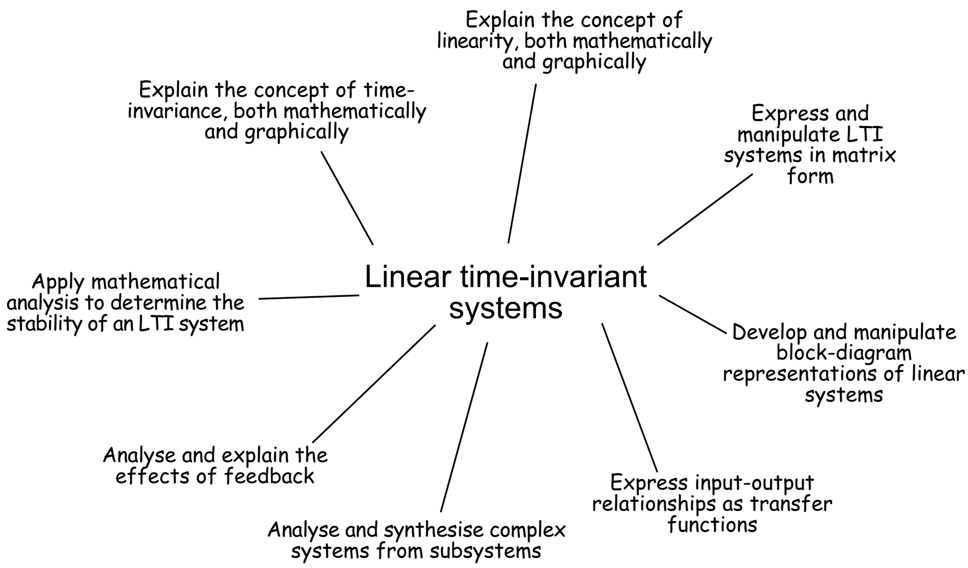

Figure 9: Outcomes for linear time-invariant systems

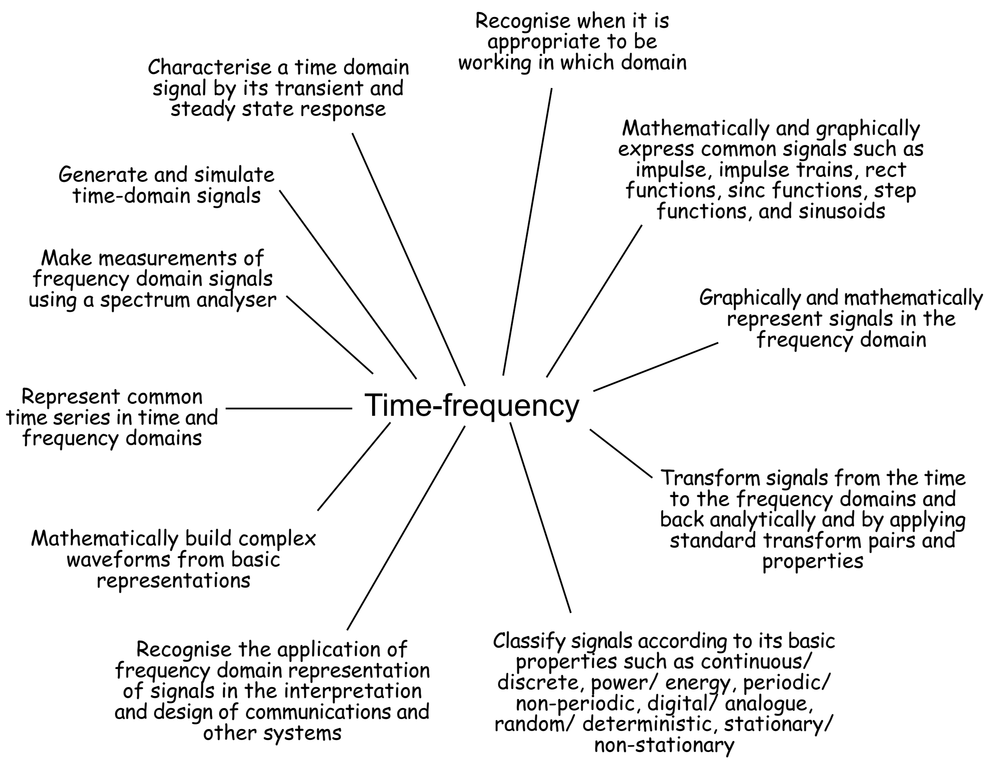

Figure 10: Outcomes for time-frequency domain signals and their representations

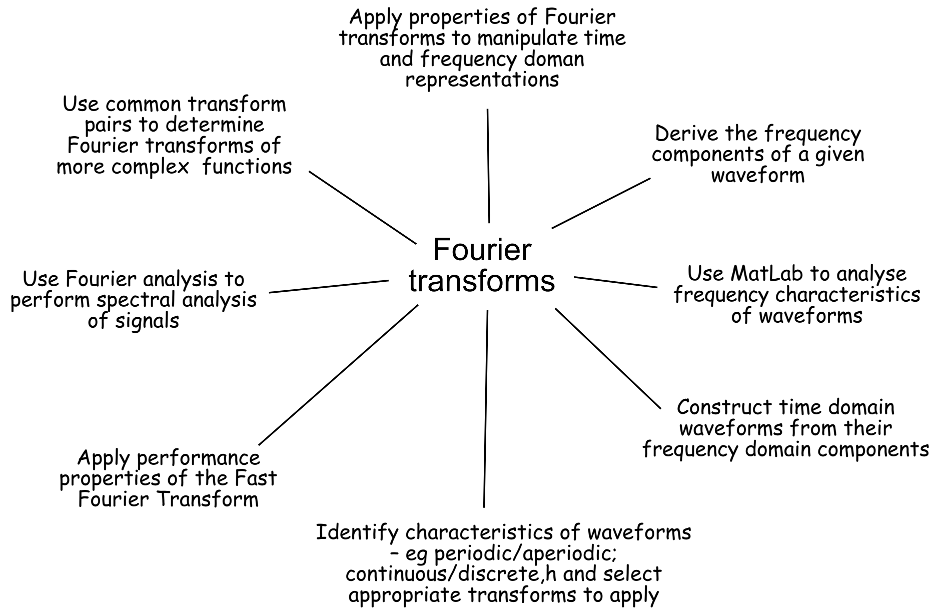

Figure 11: Outcomes for Fourier transforms

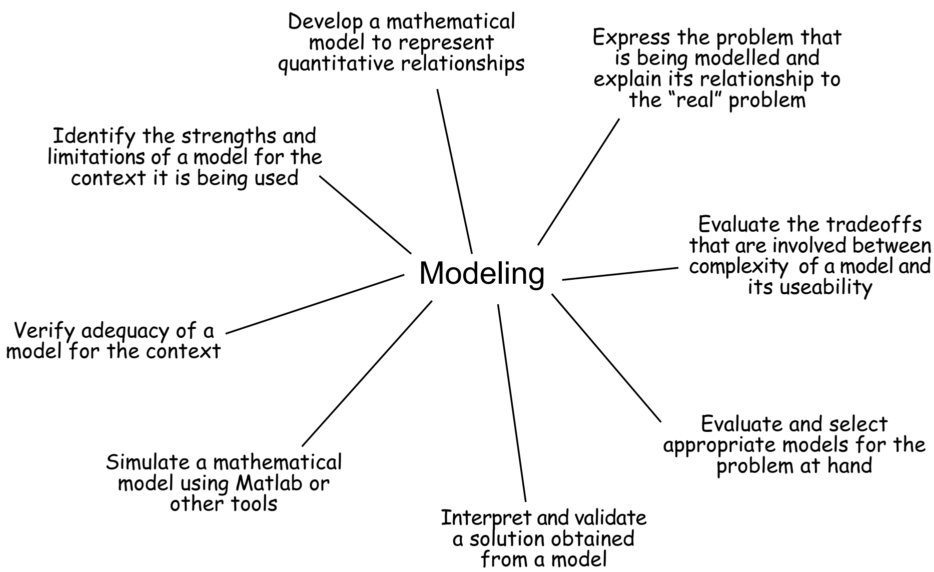

Figure 12: Outcomes for modeling

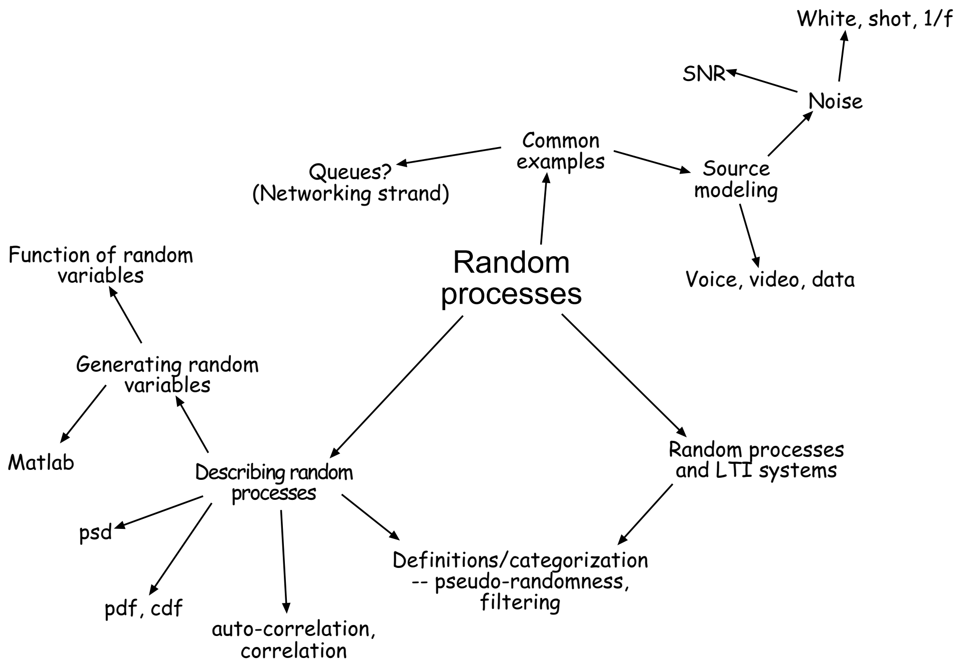

Figure 13: Outcomes for random processes

	Foundational	**Field of practice**
University	**Academic**	**Theoretical**
Practice	**Professional**	**Applied**

Figure 14: Outcomes mappings framework

3.4 Outcomes mappings

Acording to the Yasukawa outcomes mapping framework, we divide the outcomes into the four areas indicated in Figure 14. These are listed below.

Note: this doesn't currently include random processes.

3.4.1 Academic

1. recognise and express the concept of linearity mathematically
2. recogniser and express the concept of tim-invariance mathematically
3. test for linearity of a system
4. test for time-invariance of a system
5. apply appropriate mathematical transform operations to express functions in time and/ or frequency/ z-domains
6. use matrix representations to represent linearity input-output systems
7. apply basic matrix operations
8. recognise and express linearity of an input output system
9. recognise and express time-invariance of an input output system
10. identify waveforms characteristics as periodic/ aperiodic; continuous/ discrete
11. discuss the power and limitations of models in understanding "real world" processes and systems
12. recognise different classes of mathematical models eg discrete/continuous; deterministic/probabilistic; linear/nonlinear; dynamic/ static
13. identify critical steps in a modelling process - eg problem clarification, selection of model type, derivation of the model, model verification, solution validation

3.4.2 Theoretical

1. appreciate the role of filters in a telecommunications system
2. recognise filters as an example of a linear time-invariant system
3. represent filters mathematically in time, frequency and z-domains
4. identify and characterise different types of filters in time, frequency and z-domains
5. recognise fundmantal trade-offs in filtering
6. use transfer functions and block diagrams to represent input output systems
7. manipulate block diagrams to analyse linear systems

8. analyse and synthesise complex systems from basic subsystems
9. explain the effects of feedback
10. perform discretisation of continuous systems using methods including impulse invariance and bilinear transforms
11. reconstruct continuos signals from discrete time signals
12. apply sampling theorem in the conversion of signals from continuous to discrete
13. use common Fourier transform pairs to derive Fourier transforms of more complex functions
14. apply Fourier transform properties to manipulate time and frequency representations
15. derive frequency components of a given waveform
16. construct a time domain waveform from its frequency domain components
17. apply performance properties of the Fast Fourier transform in analysing waveforms
18. apply mathematical modelling for the analysis and design of telecommunications systems
19. evaluate the performance of different types of models
20. use Matlab and other tools for simulating models

3.4.3 Professional

1. apply a systems approach to the analysis and design of complex systems

3.4.4 Applied

1. select and use appropriate design tools for the design of filters
2. make decisions about trade-offs in filter design
3. implement IIR and FIR filters in Matlab and realtime
4. verify correct implementation of a filter within a communications system
5. use Matlab facilities for the analysis of frequency components of waveforms
6. identify waveform characteristics and select appropriate transforms for the analysis of the waveforms
7. use Fourier analysis for spectral analysis of signals

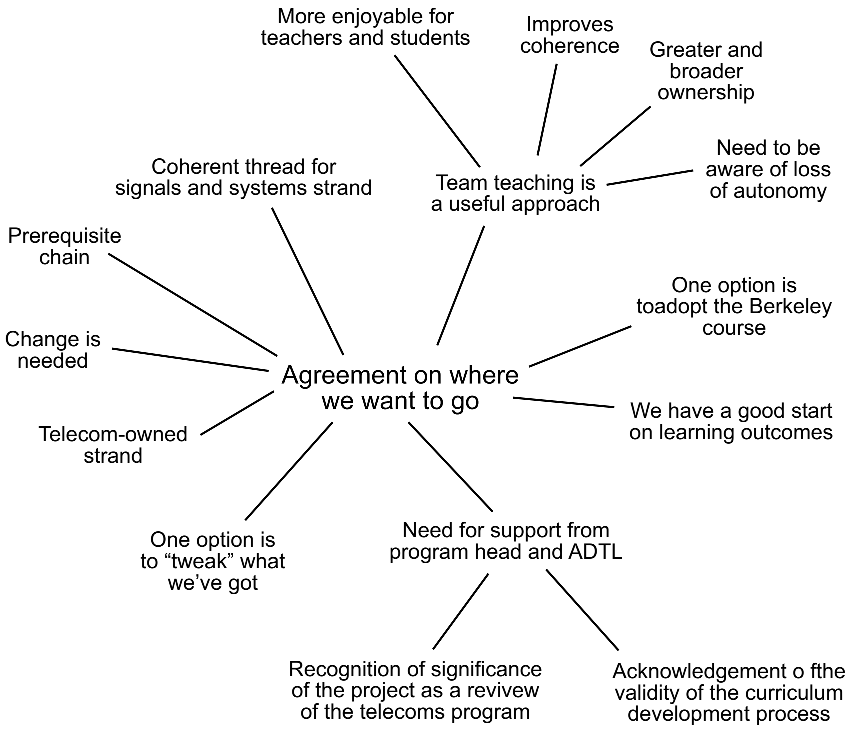

Figure 15: Mindmap of the points of strong agreement between members of the signals and systems team.

3.5 Other maps

On June 28th 2004, the signals and systems strand met to determine the current status of our thinking process. Present were Tim Aubrey, Martin Evans, John Reekie, and Keiko Yasukawa. Anthony Kadi gave his apologies, and Tim Aubrey summarized Anthony’s position.

Figure 15 is a summary of what the members of the signals and systems strand currently is in unanimous agreement on.

Figure 16 highlights the main issues perceived by team member around the two main options being considered. The two options are:

- Adopt the “Berkeley course.”

  This course is the Structure and Interpretation of Signals and Systems, also known as EECS20, developed at UC Berkeley during the period 1996 to 2002. All are in agreement that adopting the course is a reasonable option and that doing so would require some adaption; the amount and type of adaption is, though, still under discussion.

  The course and its impact on the signals and systems strand is summarized in [2].

- “Build” our own course.

Also known as the "tweak option," this option means developing a new set of subject from "scratch," albeit including use and reuse of existing materials, in particular those that have already been developed for signals and systems subjects. The extent of reuse vs new development is still under discussion.

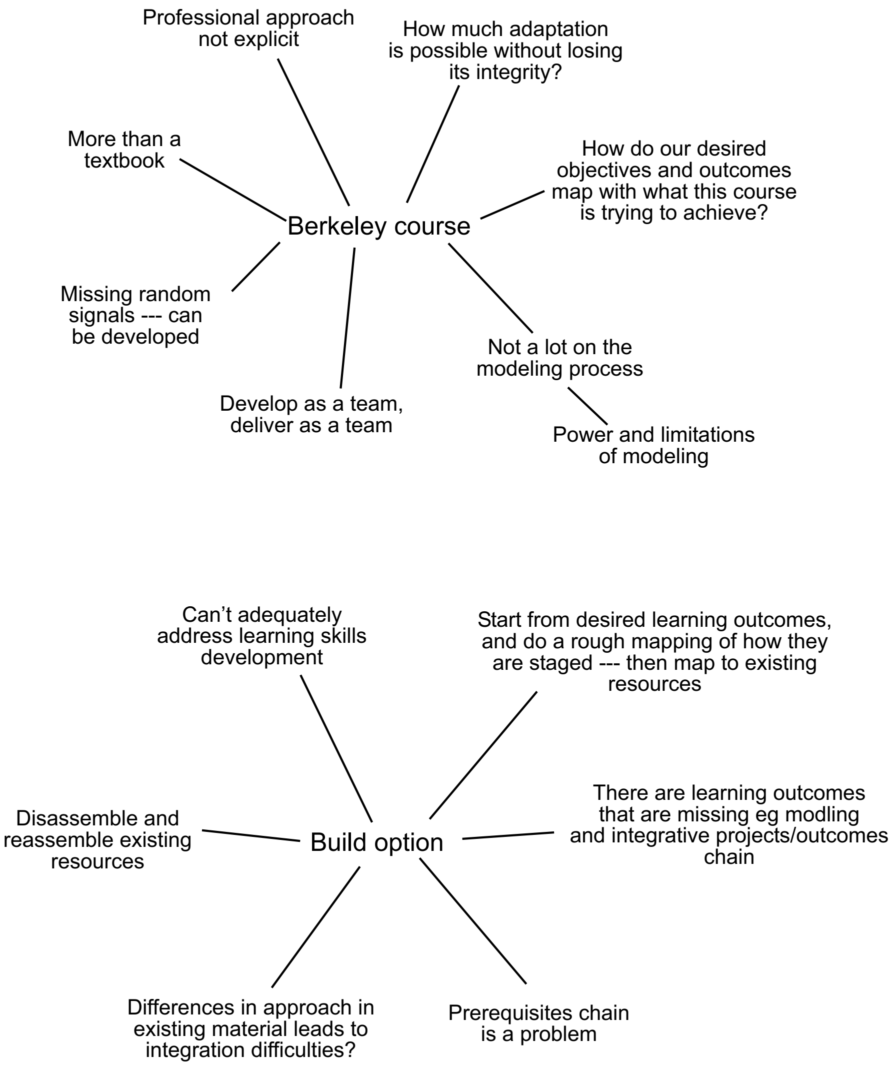

Figure 16: Mindmap of the perceived issues with the two main options being considered by the signals and systems team.

4 Moving forward

Section 2 of this report is essentially complete. It is vital that we complete Section 3 next, and we can do this only with the help of all Telecoms staff.

References

[1] John Reekie. Re-architecting the telecommunications program – initial proposal. Online at http://www.eng.uts.edu.au/ johnr/pdf/telco-revision-1.pdf, September 2003.

[2] John Reekie. The case for EECS20: The structure and interpretation of signals and systems. Online at http://www.eng.uts.edu.au/ johnr/pdf/eecs20.pdf, April 2004.