Course #26

Radio System Design - Theory and Practice

INSTRUCTOR
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TECHNOLOGY FOCUS
In order to design cost effective radios, designers must understand the whole system. Only then can the various interactions and trade-offs be appreciated and the design optimised for a particular application. Fortunately, understanding the whole system does not require detailed knowledge of each circuit. By isolating key parameters it is possible to relate the system specification to block level requirements and appreciate the whole picture.

The advent of 5G and the technology spin-offs along the way have re-invigorated developments in all radio systems. They have produced new levels of sophistication as well as RF ICs for complex functions which amalgamate analogue/digital circuit ideas as well as sophisticated signalling and protocol layers. This comprehensive course gives designers a thorough view of all key elements, from circuit blocks through the system level to network concepts.

COURSE OBJECTIVES AND WHO SHOULD ATTEND
Objective of this course is to explain the basics of system performance from constituent component block characteristics, block interaction and the relation to the top-level system specifications. Various tools are used to provide accurate initial estimates of component performance while others show the relative contribution of different elements. Together they help isolate critical performance parameters, giving designers tools of cost effective solutions with an understanding of the interrelated aspects.

This is an intermediate level course suitable for system designers wishing to better understand component level implications or practicing component design engineers interested in managing more complex sub-assemblies and systems. The course is suitable for those working in radio as well as in the mobile phone industry, handset or base station, satellite communications, radar, EW/ECM and IoT.

Monday Signal Integrity
The first day introduces key behavioural performance characteristics of two port blocks in the system. There is a refresher on standard concepts such as sources of noise, noise figure and temperature definitions. The origin of intermodulation signals and prediction of levels are discussed, leading on to compression and dynamic range to illustrate the often conflicting requirements of sensitivity and strong signal handling. Methods to extend simple cascade analysis to multi-stage systems are described along with practical tips to better understand how the cascade builds up and how to evaluate the relative contribution of each stage. An approach to the analysis of signal compression is described, using a tried and tested method not found in textbooks.

Tuesday Signal Translation

The second day describes the issues associated with frequency translation of signals. Continuing from the IM discussions of the previous day, mixer operation is described in terms of the small signal translation of modulated signals up or down in frequency. Then the large signal behaviour in terms of undesired spurious signal responses is described. The important distinction between spurii generated by the mixing process and those due to susceptibility from other inputs is highlighted, as well as how digital concepts in mixing alter the traditional analogue view of mixers. Prediction of spurious signal frequencies and estimation of the levels is demonstrated using design charts and computer simulation. Then the important concept of IQ mixing is discussed for both transmitters and receivers.

Filters are an essential part of any system, restricting the input bandwidth, isolating wanted from unwanted signals and defining the detected noise bandwidth. Without complicated mathematics, design examples are used to illustrate key design criteria and the importance of unloaded Q discussed. System passband and stopband performance estimation is illustrated with innovative spreadsheets that supplement traditional charts and tables. They also include prediction of performance of generalised transfer functions that are not possible with older methods.

Wednesday System Architecture

Bringing together the concepts so far, the third day focuses on system design. The architecture of radio systems is described with discussions on gain and frequency planning with illustrations of typical system requirements that also highlight the main differences in the design of transmitters and receivers.

All systems require considerable gain and key trade offs are discussed. Similarly all systems translate the frequency where there are important choices on where to put the LO, and IF frequencies. Various design options such as single conversion, near zero IF and direct conversion or zero IF schemes are shown. The expanding role of DSP is discussed, drawing both parallels and differences to analogue schemes. Some ideas on quite different architecture that exploit DSP are also discussed.

Thursday Signal Transport

Reliable radio communication requires transport of information through a highly variable channel. In this section the key details of the radio link performance is analysed, showing how to relate transmitter performance to the receiver via the link budget calculation. Various signal channel impairments are described with reference to link calculations with implications to signal quality in terms of power, frequency, and time.

Then relating back to the key link impairment mechanisms of different modulation schemes are described, starting from AM and FM, progressing through various digital phase and frequency modulation concepts culminating in OFDM. The relative merits of different modulation types are illustrated with reference to system performance criteria such as SNR, BER and channel capacity.

Friday Radio Layer Standards
The final day describes various system approaches to radio communication finishing with a summary of key concepts that will be used in next generation systems.

The radio system level is extended to the network level showing how multiple access methods allow the sharing of the communication channel between many signals and places. Drawing on the examples from earlier topics, the evolution of FDMA, TDMA, CDMA and OFDM are described. Then the implementation of these concepts in modern systems such as W-CDMA, broadcast standards such as DAB, other OFDM systems such as IEEE802.11 and LTE are described

The final section introduces key concepts that will be used in next generation systems such as 5G and New Radio. Such innovations will rely on progress on a number of fronts, analogue and digital as well as circuit and system innovations. Topics discussed are MIMO / massive MIMO, Ad Hoc Networks, Cognitive Radio, Full Duplex, Software Defined Radio and the expanding role of DSP.

Throughout the lectures, various practical tools including spreadsheets are used to illustrate key issues and to provide information for future analysis and design.
A copy of all the Excel examples, many useful application notes, and alphabetic list of abbreviations and other material is provided to each student on a memory stick This is made more accessible via an innovative wiki based hypertext structure that allows easy access using a standard web browser.