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## Mobile Communications Book Reviews

### *Up and Close*

By David Jefferies

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#### INTRODUCTION

There are three books on mobile wireless communications which have come my way recently, and it seemed appropriate to group them and talk about them briefly for readers of *antenneX* online magazine. The topics are slanted towards cellnet phone technology, but make use of what is called the “air interface” or the “physical layer wireless channel”, which is the principal topic of interest to this readership.

Unlike the experiences of most Ham radio aficionados, the professional communication scene has developed under the influence of computer communications, and there is the ubiquitous idea of the “layered protocol” which might best be illustrated using the old-fashioned example of sending someone a hand-written letter. The “physical layer” consists of crafting words on a piece of paper with a pen. The piece of paper is folded up and placed in an envelope, on which is written an address. This is the “next layer up” in the protocol. The envelope is handed to a postman, who conveys it to a sorting office, where it is grouped by destination with many other letters and the whole group of them conveyed to a remote sorting office. The postman is a protocol layer, the sorting algorithms are another and the bulk transport yet another. If we consider the bulk transport layer for a moment, the content of the original message and the precise details of the destination address are of no consequence to the operation. On the other hand, the recipient of the letter has no interest in the precise method by which the letter arrived in his mailbox, but is only interested in the contents.

One of the interesting ideas thrown up by the protocol layer way of looking at communications, is that the behaviours of the various layers interact, even though in our scenario above they seem to be independent. For example, the capacity of a communications link, and its reliability and availability, is perhaps going to be dependent on the antenna technology which is chosen. Thus, the number of times a higher level in the protocol stack has to retry sending a message is dependent on the antenna technology together with the propagation conditions, and on a mobile link this may well be time-dependent.

#### FUNDAMENTALS OF WIRELESS COMMUNICATIONS

The first book is called “Fundamentals of Wireless Communication”, and the authors are David Tse (University of California, Berkeley) and Pramod Viswanath (University of Illinois at Urbana-Champaign). The publishers are Cambridge University Press and the ISBN is 0-521-84527-0. The book is xxi + 564 pages long, hardback, and the publication year is 2005.

- 1 Introduction
- 2 The wireless channel
- 3 Point-to-point communication: detection, diversity, and channel uncertainty  
including 3.3 Antenna diversity
- 4 Cellular systems: multiple access and interference management
- 5 Capacity of wireless channels
- 6 Multiuser capacity and opportunistic communication  
including 6.7.3 “opportunistic beamforming using dumb antennas”

- 7 MIMO I: spatial multiplexing and channel modeling  
 (note, MIMO == multiple input multiple output)  
 including 7.2.3 Antenna arrays with only a line-of-sight path  
 7.2.4 Geographically separated antennas
- 8 MIMO II: capacity and multiplexing architectures
- 9 MIMO III: diversity-multiplexing tradeoff
- 10 MIMO IV: multiuser communication  
 including 10:1 Uplink with multiple receive antennas  
 10:3 Downlink with multiple transmit antennas  
 10:5 Multiple antennas in cellular networks: a systems view

Appendix A Detection and estimation in additive Gaussian noise

Appendix B Information theory from first principles

Each of these chapters is followed by a section helpfully described as “The main plot”.

For those of us used to the idea that communication happens from a single transmit antenna to a single receive antenna, this is an illuminating read as it suggests that the transmit path can be passed from one set of antennas to another in mid-communication, and that many users can simultaneously make use of the same physical antenna installations. Of course, this idea will be “old hat” to Hams who are used to communicating by way of repeaters or satellites. The book explores the technologies that can be used to design appropriate antenna installations and then to make maximally appropriate use of them.



In a digital communications system we can make use of the phenomenon of time translation. Imagine you have a high capacity channel that is only on for 1/10<sup>th</sup> of the time, but during that time will handle 10 times the required data rate. Always providing we can tolerate a little delay on the link (“latency”), we can recover continuous communication by transmitting during the good times at maximum capacity, and then using local memory to pass the signal to the receiver for the 9/10ths of the time that the channel is dead. On a voice channel the tolerable latency may be a few tens of milliseconds.

Now, if you have an antenna installation which has to transmit to a large number of geographically separated users on different bearings, you can electronically steer a narrow beam to each of them in turn, providing you revisit each user within the latency time. We have met this idea in the technology of the lighthouse, which rotates a highly collimated beam of light around the horizon, revealing its presence to the various navigating ships every so often. In the case of the lighthouse, the speed of rotation and beam configuration can also serve as its identification signal.

You don't even need the information about where the individual receivers may be located if you flash the beam randomly around the landscape, providing the receivers have a method of returning information to the transmitter about when they are illuminated. As the transmitter beam passes over a particular receiver, it identifies itself and tells the transmitter to download the specific chunk of information intended for it.

Further, if you have a mobile communications scenario, it is well known that the signal strength on the link suffers fading (Rayleigh, Rician) which may lead to signal outages longer than the desired latency time. The use of a channel to transmit at high data rate when it is available is known in this case as “opportunistic communication”, for one cannot predict precisely when this will be. The effect of sweeping the transmitter beam randomly around the landscape can be to put up the fading rate, as perceived by the receiver, so that the time between illuminations falls below the tolerated latency time.

And even further, you can engineer diversity into the path lengths by having multiple transmit antennas arranged in an array, and so you then arrange for them to be fed in random phases so that the fading happens faster than nature herself dictates, and using the opportunistic communications during the strong channel connect times. The end user then perceives uninterrupted and reliable communications, wherever he or she may be located, and however he or she may be moving.

This simple illustration shows how antenna technology may be worked into a communications system that on the face of it might seem a rather hit-and-miss or unreliable matter.

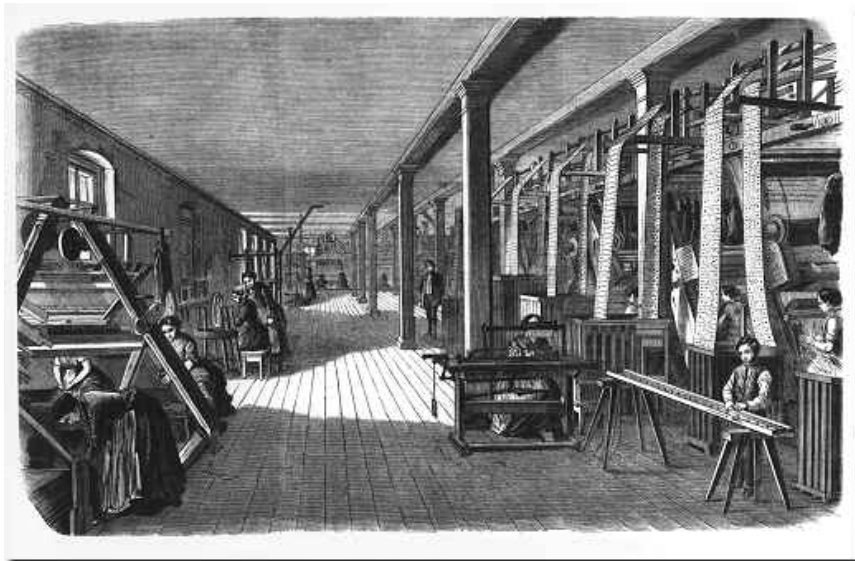
The book is fairly technical mathematically, and the appendix on information theory is compressed and principally of use to those people who have already met the ideas elsewhere. The preface remarks on “the huge surge of research activities in physical-layer wireless communication theory” and it may well be that these advances will proved a fertile ground for ingenious amateurs over the coming decades.

## **MOBILE WIRELESS COMMUNICATIONS**

The second book that is discussed may be summarized as “where we are now with cell phone technology”. It is called “Mobile wireless communications” and the author is Mischa Schwartz, of Columbia University. The publishers are Cambridge University Press and the ISBN is 0-521-84347-2. The book has xi + 457 pages, and is hardback; the publication year is 2005.

- 1 Introduction and overview
  - 2 Characteristics of the mobile radio environment-propagation phenomena
  - 3 Cellular concepts and channel allocation
  - 4 Dynamic channel allocation and power control
  - 5 Modulation techniques
  - 6 Multiple access techniques: FDMA TDMA CDMA, system capacity comparisons
  - 7 Coding for error detection and correction
  - 8 Second generation digital wireless systems
  - 9 Performance analysis: admission control and handoffs
  - 10 2.5G/3G Mobile wireless systems: packet switched data
  - 11 Access and scheduling techniques in cellular systems
  - 12 Wireless LANs and personal-area networks
- References  
Index

Antennas get only a few pages of mention in this digital communications systems engineering book, which is aimed at University students who are at the interface between undergraduate and postgraduate study. In fact, the term “wireless” in the title is more a description of an application, and electromagnetics and diversity engineering such as were discussed in the book above, do not feature. I found it an interesting read, as it seems to indicate that there will be a new generation of telecommunications engineers coming out of the Universities who have only the smattering of knowledge of the Physics that underlies their discipline. Another striking point that may be observed is that very little of the subject matter of this book is science-based. Rather, everything is man-made, and if history had turned out differently the systems to achieve the same results might have been designed very differently.



I am reminded of the intricate machinery on display in museums around Nottingham, for the automated production of lace using Jacquard looms. Historically, a very large number of highly skilled workers were replaced within a human generation by the mechanization of lace-making. Modern cellular communications would appear to be the same kind of social phenomenon. Communications technology will be cheap, reliable, easily available to all irrespective of their technical competence and level of education, and irrespective of a large antenna and ungainly “shack” in the back yard. But I digress...

Chapter 4 of “Mobile wireless communications” deals with the important topic of optimizing the use of resources in a cellular system to enhanced desired communications and reduce the amount of interference between channels. One important method used to help with this task is to adopt directional antennas to reduce the number of interfering signals with which a desired signal has to contend. These antennas have been described as “dumb”, “smart”, and “smarter” depending on their steerability under signal control. In addition, the segmentation of the receive space into cells doesn't have to be done at constant cell size. In downtown areas and populated buildings one can have much smaller cell regions (“picocells”) whereas in the open countryside one aims for “macrocells” and in intermediately populated regions one has the intermediate size “microcells”. Bearing in mind that highly collimated beam antennas have large Rayleigh distances from the array to the far field region, it is clear that the antenna technology (at a given operating frequency) may be different for the small picocells than for the others.

## ANTENNA DISCUSSIONS

The *antenneX* Antenna Discussion list has touched on the subject of power control. One attempts to make reliable contact, in a multi-channel environment, using the minimum power necessary to establish the desired data rate on the link. Again, in order to do this it is necessary to have a feedback mechanism that can return channel performance data to the transmitter control electronics.

We may take encouragement from the fact that Hams are custodians of lore and technology that is no longer central to electronic communication on this planet. This is a valuable resource of knowledge, and should not be squandered or allowed to die out for reasons of commerce.



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## WCDMA DESIGN HANDBOOK

The third and last book that is discussed may be summarized as “where we are going next with cellular communications technology”. It is altogether a more technical book, less pedagogical in intent and aimed more at the people who need a handbook. The title is “WCDMA design handbook” and the author is Andrew Richardson, a consultant in the UK on telecommunications technology. The publishers are again Cambridge University Press and the ISBN is 0-521-82815-5.

The book was first published in 2005, and it has xxv + 565 pages, including ten pages for the list of abbreviations used in the book. This abbreviation list tells us that WCDMA means “wideband code division multiple access”.

- 1 Introduction
- 2 WCDMA in a nutshell
- 3 Spreading codes and modulation
- 4 Physical layer
- 5 RF aspects
- 6 Chip rate processing functions
- 7 Symbol rate processing functions
- 8 Layer 2 – medium access control (MAC)
- 9 Layer 2 – RLC
- 10 PDCP and BMC protocols
- 11 Layer 3 – RRC
- 12 Measurements
- 13 NAS
- 14 Idle mode functions

appendix  
references  
index

W-CDMA is a technology that uses available channel bandwidth in small chunks across a large number of users. It is basically a spread spectrum technology, with the individual channels or users identified not by their precise frequency (FDMA) or by the time slot in which they transmit (TDMA), but with an identifying code which is chosen from a large

number of “orthogonal” codes that do not in principle interfere with each other. Again, the technology relies on breaking up the continuous voice or data communication into small packets, which are then reassembled in sequence at the receiver to create the illusion of continuous communication. This process is known as “packet switching” (PS), whereas ham operators will be more used to the concept of “circuit switching” (CS) where two way communication is established on a continuous channel, which may be defined by frequency, geography, or which of a bundle of wires (in a terrestrial telephone system) may be excited.

The packet switched concept immediately allows communication of data as well as audio signals. There is no distinction to the system as to “what is put in the envelopes”...it can be voice, pictures, pointers to URLs and so-on. In fact, it is this idea that is borrowed from wired terrestrial computer communications, and the only difference is that part of the channel is arranged to be wireless, making use of various kinds of diversity which includes the spatially segregated cellular concept and the directional antenna technologies discussed above.

One of the other advantages of spread spectrum communication techniques such as W-CDMA is that they are robust to attempts to intercept and jam the signals, and run at continuous micropower transmit levels rather than having short periods of high power transmission interspersed with long periods of silence. If we apply this kind of technology to a single channel, or even a rather small number of channels, we can bury the “fact of communication” deeply into the random system noise that is floating around in the airwaves. This is of great interest to those people who specialise in secure communications, for, if it cannot be identified that communication is happening at all (using scanners or listening devices) then no one is going to go to the trouble to try to intercept the content or to try to listen in.

## **THE CODE**

Now, coming to the content of this specialized book, I had to take several weeks of reading time to penetrate to its substance. It must be said that the use of abbreviations and acronyms is a major impediment to the book's utility. I have written about this on a website

<http://www.ee.surrey.ac.uk/Personal/D.Jefferies/mobiletelephony.html>

where I also include a listing of the acronyms used. To quote from this web page

"For instance, who would have thought that an ordinary mobile phone handset is commonly referred to as the UE ("User Equipment")?"

And this kind of thing rapidly leads to people writing passages such as

PMM-connected

In this state, the location of the UE is known in the SGSN to an RNC, the UE has previously established a GMM context (or is about to do so) and there is an active PS signalling connection between the UE and the PS CN. The location of the UE is tracked by the UTRAN, but the UE still needs to perform RAUs whenever the UE identifies that the RA has changed. With an active PS signalling connection, the UE has an active RRC connection, and so the UE is notified of changes in the RAI either through broadcast messages (CELL\_FACH, CELL\_PCH or URA\_PCH states) or through the RRC mobility signalling messages (CELL\_DCH state). The UE does not need to perform periodic RAUs while in the PMM-CONNECTED state.

Even with the aid of the glossary included in the book from which this extract is taken, or with the aid of the meta-links of this section, such writing has to be agreed to be pretty much impenetrable, and of doubtful utility to people who do not happen to know the subject matter so well (to start with) that they have no need to read the book. "

That said, this book is about the third generation mobile communications technology that is soon to be released on us. It is included in this book review for completeness, and to let people be aware of just where communications technology may be taking us all. Perhaps when I too become one of the "inner circle cognoscenti" I shall be able to slot the information contained in this book into my personal body of knowledge. Until then, I feel it is best left to the experts.



To summarize, the three books reviewed lightly, but up close in this short article all have in common means of communication which have the characteristics that

- There are a great many geographically dispersed users all trying to communicate at the same moment
- The communication channel itself is erratic, being subject to unpredictable fading and outage time
- The users, unlike hams, expect instantaneous reliable communication all (or most) of the time
- The system implementation standards need to be agreed by all interested parties across the planet so that there are no regional compatibility problems. (This is particularly important with mobile communications technology).

Your reviewer thinks it is most impressive how these conflicting requirements have been simultaneously met by the appropriate use of technology. A recent comment seen in the press is that the development seems to have happened so far in three main regions; Europe, Japan, and the USA where there are a number of competing and largely incompatible systems ("freedom of choice and competition"). The comment goes on to say that what we should expect is that future mobile comms technology may well be driven by the Chinese, who have a very large tied home market and who will be able to impose their communication standards

on the world scene, particularly as they are not tied down by ideas of “freedom to compete in an unregulated way”. What is an over-arching need in mobile technology is for uniform global standards, rather than choice for the consumer. –30–

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