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Young and David J. Goodman ☐ ☐ ☐

Single Carrier FDMA

A New Air Interface for Long Term Evolution



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SINGLE CARRIER FDMA

A NEW AIR INTERFACE FOR LONG TERM EVOLUTION

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- root-raised cosine pulse 129
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- RS, *see* reference signal
- SC/FDE, *see* single carrier with frequency domain equalization
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- wireless local area network 6
- wireless metropolitan area network 7
- WLAN, *see* wireless local area network
- WMAN, *see* wireless metropolitan area network
- WSSUS, *see* wide-sense stationary uncorrelated scattering

Appendix C

Deciphering the 3GPP LTE Specifications

Unless you are really familiar with the LTE standardization process, it is rather difficult to understand how things actually work just by reading through the specifications. Since a technical specification is merely a description of a guideline for interoperability, it does not necessarily explain any rationale or background information for choice of the specific methodologies or parameters.

One way to find a more detailed description of the specific methodology or parameter in the specification is to go through the contribution papers (called technical documents, or tdocs) that 3GPP uploads on their meeting website. 3GPP has different work groups working on different aspects of the radio interface and network architecture. The Technical Specification Group Radio Access Networks (TSG RAN) is where all the radio air interface specifications are handled and it has five working groups (WG) as described in Table C.1.

Table C.2 highlights the LTE specifications and their corresponding working groups.

Most of the physical layer and MAC layer components are discussed in RAN1 meetings and the meeting information is at <http://www.3gpp.org/ftp/Specs/html-info/Meetings-R1.htm>. Figure C.1 is a screenshot of the website.

If you go to this site, there is a column called "First & Last tdoc" (tdoc = technical document) as shown in Figure C.1. This is the paper number that identifies each contribution paper. If you click on the link, it directs you to the ftp site where you can access all the tdocs of the particular meeting.

Table C.1 TSG RAN work groups

RAN WG1 (RAN1)	Layer 1 (Physical layer) specification
RAN WG2 (RAN2)	Layer 2 (MAC, RLC) and layer 3 specification
RAN WG3 (RAN3)	Overall UTRAN architecture.
RAN WG4 (RAN4)	Radio performance and protocol aspects
RAN WG5 (RAN5)	Mobile terminal conformance testing

Since the tdocs are uploaded in zip files without any title (only the tdoc numbers are specified in the file name), you would have to look at the excel spreadsheet of the tdoc list (provided at the bottom of the list) to know which is which. Tdoc numbers are in the form of Rx-yyzzzz where *x* is the RAN work group number, *yy* is the year of the meeting, and *zzzz* is the cumulative number assigned to the document. For example, R1-081165 refers to the document 1165 of RAN1 meeting in the year 2008.

It may be daunting to go through each tdoc list spreadsheet for each meeting because the list is usually very long list (300 ~ 400) and not organized by subject. What you can do is first read the meeting summary report that summarizes the discussions and decisions from the meeting by subject. You can find the meeting report by following “Files” link and then “Report” link. From the meeting report, you can find out about the decisions made and the relevant tdocs. Once you know the tdoc number, you can locate the link from the “First & last tdoc” column and access it from there.

Table C.2 LTE specifications and their corresponding working groups

Document number	Working group
36.1xx	RAN4
36.2xx	RAN1
36.3xx	RAN2
36.4xx	RAN3
36.5xx	RAN5
36.8xx	RAN4
36.902	RAN3
36.913	RAN
36.938	RAN4
36.942	RAN4
36.956	RAN4

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the meeting by
" link and then
about the deci-
c number, you
access it from

3GPP meetings for group R1									
Click here to go to the Liaisons page.									
Meeting	Title	Town	Start	End	First & Last tdoc	Register	Participants	Files	ICal
R1-59	3GPPRAN1#59	South Korea	2009-11-09	2009-11-13	-	Register	Participants	-	ICS
R1-58b	3GPPRAN1#58-BIS		2009-10-12	2009-10-16	-	Register	Participants	-	ICS
R1-58	3GPPRAN1#58		2009-08-24	2009-08-28	-	Register	Participants	-	ICS
R1-57b	3GPPRAN1#57-BIS		2009-06-29	2009-07-03	-	Register	Participants	-	ICS
R1-57	3GPPRAN1#57		2009-05-04	2009-05-08	-	Register	Participants	-	ICS
R1-56b	3GPPRAN1#56-BIS		2009-03-23	2009-03-27	-	Register	Participants	-	ICS
R1-56	3GPPRAN1#56	EU	2009-02-09	2009-02-13	-	Register	Participants	-	ICS
R1-55b	3GPPRAN1#55-BIS	EU	2009-01-12	2009-01-16	-	Register	Participants	-	ICS
R1-55	3GPPRAN1#55	Prague	2008-11-10	2008-11-14	-	Register	Participants	-	ICS
R1-54b	3GPPRAN1#54-BIS	Prague	2008-09-29	2008-10-03	-	Register	Participants	-	ICS
R1-54	3GPPRAN1#54	Jeju Island	2008-08-18	2008-08-22	- *	Register	Participants	Files	ICS
R1-53b	3GPPRAN1#53-BIS	Warsaw	2008-06-30	2008-07-04	-	Register	Participants	-	ICS
R1-53	3GPPRAN1#53	Kansas City	2008-05-05	2008-05-09	- *	Register	Participants	Files	ICS
R1-ah-27107	Workshop on IMT-Advanced	Shenzhen	2008-04-07	2008-04-08	REV-080001 - REV-080058 *	-	Participants	Files	-
R1-52b	3GPPRAN1#52-BIS	Shenzhen	2008-03-31	2008-04-04	R1-081155 - R1-081900 *	-	Participants	Files	-
R1-52	3GPPRAN1#52	Sorrento	2008-02-11	2008-02-15	R1-081048 - R1-081152 *	-	Participants	Files	-
R1-51b	3GPPRAN1#51-BIS	Sevilla	2008-01-14	2008-01-18	R1-080001 - R1-080619 *	-	Participants	Files	-
R1-51	3GPPRAN1#51	Jeju	2007-11-05	2007-11-09	R1-074525 - R1-075102 *	-	Participants	Files	-
R1-50b	3GPPRAN1#50-BIS	Shanghai	2007-10-08	2007-10-12	R1-073895 - R1-074520 *	-	Participants	Files	-
R1-50	3GPPRAN1#50	Athens	2007-08-20	2007-08-24	R1-073240 - R1-073988 *	-	Participants	Files	-

Figure C.1 Screenshot of the 3GPP RAN1 meeting information website at <http://www.3gpp.org/ftp/Specs/html-info/Meetings-R1.htm>

For example, the channel coding scheme specified in TS 36.212 uses quadratic permutation polynomial (QPP) interleaver. Let's say we want to find more details of the QPP interleaver. By searching through the meeting reports, we can find that there was a decision to adopt the QPP interleaver in RAN1 meeting #47b. The document that proposes this method is R1-070483 and other related documents are listed as well in the meeting report. By looking at the listed documents, we can understand more about the QPP interleaver that is new in LTE channel coding.



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Single Carrier FDMA

A New Air Interface for Long Term Evolution

☐ **Hyung G. Myung**, *Qualcomm/Flarion Technologies, USA*
David J. Goodman, *Polytechnic University, USA*

Single Carrier Frequency Division Multiple Access (SC-FDMA) is a novel method of radio transmission under consideration for deployment in future cellular systems; specifically, in 3rd Generation Partnership Project Long Term Evolution (3GPP LTE) systems. SC-FDMA has drawn great attention from the communications industry as an attractive alternative to Orthogonal Frequency Division Multiple Access (OFDMA).

Single Carrier FDMA places SC-FDMA in the wider context of wireless communications, providing the reader with an in-depth tutorial on SC-FDMA technology. The book introduces the reader to this new multiple access technique that utilizes single carrier modulation along with orthogonal frequency multiplexing and frequency domain equalization, plus its applications in communications settings. It considers the similarities with and differences from orthogonal frequency division modulation, multiplexing, and multiple access used extensively in cellular, broadcasting, and digital subscriber loop applications. Particular reference is made to the peak power characteristics of an SC-FDMA signal as an added advantage over OFDMA.

Key features:

- ☐ Provides an extensive overview of the principles of SC-FDMA and its relation to other transmission techniques.
- ☐ Explains how the details of a specific implementation influence the tradeoffs among various figures of merit.
- ☐ Describes in detail the configuration of the SC-FDMA uplink transmission scheme published by 3GPP.
- ☐ Features link level simulation of an uplink SC-FDMA system using MATLAB®.

This is an essential text for industry engineers who are researching and developing 3GPP LTE systems. It is suitable for engineers designing wireless network equipment, handsets, data cards, modules, chipsets, and test equipment as well as those involved in designing LTE infrastructure. It would also be of interest to academics, graduate students, and industry researchers involved in advanced wireless communications, as well as business analysts who follow the cellular market.

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