IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:	Xiaobo Zhang	
U.S. Patent No.:	11,917,581	Attorney Docket No. 50095-0235IP1
Issue Date:	February 27, 2024	
Appl. Serial No.:	17/950,726	
Filing Date:	September 22, 2022	
Title:	METHOD AND DEVICE IN UE AND BASE STATION USED FOR PAGING	

DECLARATION OF DR. ZHI DING

TABLE OF CONTENTS

I. INTRODUCTION 4
II. QUALIFICATIONS 5
III. DOCUMENTS AND MATERIALS CONSIDERED 11
IV. UNDERSTANDING OF LEGAL STANDARDS 14
A. Earliest Effective Filing Date 14
B. Burden of Proof 14
C. Obviousness Under 35 U.S.C. § 103 15
D. Secondary Considerations of Non-Obviousness 16
V. LEVEL OF ORDINARY SKILL 17
VI. TECHNOLOGY BACKGROUND 18
A. 3rd Generation Partnership Project (3GPP) 18
B. Features of 4G/LTE and Older Networks 18
1. Resource Grid and Frame Structure 18
2. Subcarrier Spacing 20
3. Paging 21
4. Monitoring of Physical Downlink Control Channel (PDCCH) 22
5. Coverage Enhancement (CE) 26
C. 5G/NR Networks 26
1. Configurable Numerology 26
2. Various Frame Structures 28
VII. THE ’581 PATENT 28
A. Summary 28
B. Brief Prosecution History 32
C. Claim Construction 32
D. The Challenged Claims 34
VIII. ANALYSIS OF THE CHALLENGED CLAIMS 43
A. [GROUND 1] *Yeo* and *TS36* render obvious claims 1, 5, 7, 11, 13, 17, 19, and 23 43
1. Effective Filing Date of Yeo 43
2. Yeo 44
3. TS36 49
4. Combining Yeo and TS36 52
5. Independent Claim 1 54
6. Claim 5 68
7. Claim 7 70

8. Claim 11 72
9. Claims 13 and 17 72
10. Claims 19 and 23 76
B. [Ground 2] Claims 2, 3, 7, 8, 12, 13, 17, and 18 Are Obvious over *Yeo*, *TS36*, and *Mallick* 80
1. Overview of *Mallick* 80
2. Combining *Yeo/TS36* with *Mallick* 83
3. Claim 2 85
4. Claim 3 93
5. Claim 4 98
6. Claims 8-10 99
7. Claims 14-16 99
8. Claims 20-22 100

IX. CONCLUSION 100

I, Zhi Ding declare that:

I. INTRODUCTION

1. I have been retained by counsel on behalf of Petitioner Apple Inc. ("Petitioner") to offer technical opinions related to U.S. Patent No 11,917,581 ("the '581 patent") (APPLE-1001). I understand that Apple is requesting that the Patent Trial and Appeal Board ("PTAB" or "Board") to institute an *inter partes* review ("IPR") proceeding of the '581 patent. For the purposes of this Declaration, I have not been asked to opine on any other issues not addressed below.

2. My opinions are based on my years of education, research, and experience, as well as my investigation and study of relevant materials, including those identified in this Declaration. I may rely upon these materials, my knowledge and experience, and/or additional materials in forming my opinions. Further, I may also consider additional documents and information to rebut arguments raised by the Patent Owner Apex Beam Technologies LLC ("Patent Owner" or "Apex"). I reserve any right to supplement this Declaration if further information becomes available or if I am asked to consider additional information. Furthermore, I reserve any right to consider and comment on any additional expert statements or testimony of Apex's expert(s) in this matter.

3. I am not and never have been, an employee of Apple. I received no compensation for this declaration beyond my normal hourly compensation based

on my time actually spent analyzing the ’581 patent, the prior art publications cited below, and issues related thereto, and I will not receive any added compensation based on the outcome of any IPR or other proceeding involving the ’581 patent.

4. My analysis of the materials produced in this investigation is ongoing and I will continue to review any new material as it is provided. This Declaration represents only those opinions I have formed to date. I reserve the right to revise, supplement, and/or amend my opinions stated herein based on new information and on my continuing analysis of the materials already provided.

II. QUALIFICATIONS

5. I am over the age of 18 and am competent to write this declaration. I have personal knowledge, or have developed knowledge of these technologies based upon education, training, or experience, of the matters set forth herein.

6. I presently hold the title of Distinguished Professor in the Department of Electrical and Computer Engineering at the University of California, Davis. Since my appointment on July 1, 2000, I have held the position of professor for the past 25 years at the present university and have served as a faculty member at several US universities for over 30 years. I am also a private technical consultant on various technologies related to information systems. I have more than three decades of research experience on a wide range of topics related data communications and signal processing.

7. I earned my Bachelor of Science degree in 1982 in wireless engineering from the Nanjing Institute of Technology (later renamed as Southeast University) in Nanjing, China. I earned my Master of Science degree in 1987 in electrical engineering from the University of Toronto in Toronto, Canada. I earned my Ph.D. in 1990 in electrical engineering from Cornell University in Ithaca, New York.

8. My responsibilities as a Professor at University of California, Davis, include classroom instruction on various topics of communication systems and signal analysis, as well as mentoring undergraduate students and supervising graduate students in their research and development efforts on various topics related to digital communications. I have directly supervised such research and development works ranging from signal detection to wireless networking. As the chief academic advisor, I have also directly supervised the completion of over 30 Masters theses and 35 Ph.D. dissertations on various topics related to digital communications. I have served full time as a faculty member at three major research universities in the United States over the past 30 years, including Auburn University from 1990 to 1998, University of Iowa from 1999 to 2000, and University of California, Davis, from 2000 to present.

9. Since 1990, I have been selected as the principal investigator of multiple highly competitive federal and local research grants, including more than

twenty major research projects supported by the National Science Foundation and two research projects funded by the U.S. Army Research Office. These competitive research projects focused on developing more efficient and effective digital communication transceivers, networks, and signal processing tools. I have also participated in several large-scale projects supported by the Defense Advanced Research Projects Agency (DARPA) with teams of researchers. I have applied for, and received support from, other federal, state, and industry sponsors.

10. I have published over 250 peer-reviewed research articles in premier international journals, in addition to over 250 refereed technical articles at top international conferences on communications and information technologies. According to Google Scholar, my published works have been cited by over 20,000 times by peers. I also authored two books on communications technologies. My most recent book, coauthored with B.P. Lathi, is entitled, "Modern Digital and Analog Communication Systems," 5th edition, and was published by the Oxford University Press in 2018. The 4th edition of this book (published in 2009) had been widely adopted as an introductory textbook to communication systems.

11. In addition to the over 500 published technical papers that have been cited over 20,000 times according to Google Scholar[1], I am also co-inventor of 7 issued U.S. patents on communication technologies.

12. I am a member of the Institute of Electrical and Electronics Engineers (IEEE) and was elevated to the grade of Fellow in January 2003 for contributions made in signal processing for communication. The IEEE is the world's largest professional society of engineers, with over 400,000 members in more than 160 countries. The IEEE has led the development of many standards for modern digital communications and networking, most notably, the IEEE 802 series of network standards. The IEEE Grade of Fellow is conferred by the Boards of Directors upon a person with an extraordinary record of accomplishments in any of the IEEE fields of interest. The total number selected in any one year does not exceed one-tenth of one percent of the total voting Institute membership.

13. I have served the IEEE in the following capacities:

- Chief Information Officer of the IEEE Communications Society from Jan. 2018 to present.

[1] https://scholar.google.com, as of August 21, 2024.

- Chief Marketing Officer of the IEEE Communications Society from Jan. 2020 to present.
- General Chair of the 2016 IEEE International Conference on Acoustics, Speech, and Signal Processing, the flagship conference of the IEEE Signal Processing Society.
- Chair of the Steering Committee for the IEEE Transactions on Wireless Communications from 2008 to 2010.
- Distinguished Lecturer of the IEEE Communications Society from January 2008 to December 2009.
- Technical Program Chair of the 2006 IEEE Globecom, one of two flagship annual IEEE Communication Society conferences.
- Distinguished Lecturer of the IEEE Circuits and Systems Society from 2004 to 2005.
- Associate Editor of the IEEE Transactions on Signal Processing from 1994 to 1997 and from 2001 to 2004.
- Member of the IEEE Statistical Signal and Array Processing for Communications Technical Committee from 1993 to 1998.
- Member of the IEEE Signal Processing for Communications Technical Committee from 1998 to 2004.

14. In 2012, I received the Wireless Communications Technical Committee Recognition Award from the IEEE Communications Society, an award given to a person with a high degree of visibility and contribution in the field of "Wireless and Mobile Communications Theory, Systems, and Networks." I received the 2020 Education Award from the IEEE Communications Society. According to the Society, this award "recognizes distinguished and significant contributions to education within the Society's technical scope."

15. I have also served as a technical consultant for the telecommunication industry. For example, in 1995 I consulted for Analog Devices, Inc., on the development of the first generation DOCSIS cable modem systems. I have also consulted for other companies, including Nortel Networks and NEC US Laboratories. I worked as a visiting faculty research fellow at NASA Glenn Research Center in 1992 and at U.S. Air Force Wright Laboratory in 1993. I have served on multiple review panels of the National Science Foundation to evaluate competitive research proposals in the field of communication. I have also reviewed a large number of research proposals at the request of the National Science and Engineering Research Council (NSERC) of Canada as an expert panelist from 2010 to 2013, and also at the request of the Research Grant Council (RGC) of Hong Kong as an external reviewer and panelist.

16. I have served as an expert witness or consulting expert on a number of matters related to intellectual property, mostly in the arena of telecommunications, including cellular communications, Wi-Fi technologies, Bluetooth, and optical communications. For example, since 2007, I have been engaged to work on various litigations involving cellular, WiFi, Bluetooth, and optical communication networks.

17. Based on my above-described near three decades of experience in communications technologies, and the acceptance of my publications and professional recognition by societies in my field, I believe that I am qualified to be an expert in wireless communication systems, communication networks, and signal processing.

18. My curriculum vitae, attached as Appendix A, includes a list of publications on which I am a named author. It contains further details regarding my experience, education, publications, and other qualifications provide to an expert opinion in connection with this proceeding.

III. DOCUMENTS AND MATERIALS CONSIDERED

19. In preparing my opinions, I have reviewed the ’581 Patent and its prosecution history and have also reviewed the other documents and materials cited

herein and the materials listed below. When citing from these references, all emphasis is added unless otherwise noted.

Ex.	Description
APPLE-1001	U.S. Patent No. 11,917,581
APPLE-1002	U.S. Patent No. 11,917,581 File History
APPLE-1004	International Patent Publication No. 2018/126401 to Liu et al., filed January 5, 2017, and published July 12, 2018 ("*Liu*")
APPLE-1005	U.S. Patent 10,491,447 to Yeo at al., filed August 22, 2017, and claiming priority to KR applications 10-2016-0106427 (filed August 22, 2016) and 10-2016-0125809 (filed September 29, 2016) ("*Yeo*")
APPLE-1006	Certified translated copy of KR Application 10-2016-0125809 (filed September 29, 2016) ("*Yeo-Priority*")
APPLE-1007	International Patent Publication No. 2017/052199 to You et al., filed September 21, 2016, and published March 30, 2017 ("*You*")
APPLE-1008	International Patent Publication No. 2016/136143 to Mallick et al., filed January 28, 2016, and published September 1, 2016 ("*Mallick*")
APPLE-1009	3GPP TS 36.304 V14.2.0, Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode (Release 14), March 2017, ("*TS36*").
APPLE-1010	U.S. Patent Publication No. 2012/0122495 to Weng et al., filed November 11, 2010, and published May 17, 2012 ("*Weng*")
APPLE-1011	International Patent Publication No. 2017/174469 to Wong et al., filed March 31, 2017, and published October 12, 2017 ("*Wong*")
APPLE-1012	International Patent Publication No. 2017/026983 to Khoryaev et al., filed December 26, 2015, and published February 16, 2017 ("*Khoryaev*")

APPLE-1013	International Patent Publication No. 2015/113664 to Webb et al., filed November 13, 2014, and published August 6, 2015 ("*Webb*")
APPLE-1015	International Patent Publication No. 2016/130175 to Fwu et al., filed August 11, 2015, and published August 18, 2016 ("*Fwu*")
APPLE-1016	U.S. Patent Publication No. 2017/0215170 to Islam et al., filed January 26, 2016, and published July 27, 2017 ("*Islam*").
APPLE-1017	International Patent Publication No. 2017/079530 to Pelletier, filed November 4, 2016, and published May 11, 2017 ("*Pelletier*").
APPLE-1018	International Patent Publication No. 2017/171398 to Yi et al., filed March 29, 2017, and published October 5, 2017 ("*Yi*")
APPLE-1019	U.S. Patent No. 9,225,440 to Swarts et al., filed September 14, 2012, and issued December 29, 2015 ("*Swarts*").
APPLE-1020	U.S. Patent Publication No. 2015/0215944 to Kim et al., filed January 29, 2015, and published July 30, 2015 ("*Kim*").
APPLE-1021	U.S. Patent Publication No. 2011/0038330 to Luo et al., filed July 29, 2010, and published February 17, 2011 ("*Luo*").
APPLE-1022	Declaration of Friedhelm Rodermund
APPLE-1023	First Amended Complaint – filed May 2, 2024; *Apex Beam Technologies LLC, v. Apple Inc.*, Case No. 6:24-cv-00223-ADA-DIG, WDTX.
APPLE-1024	R1-165162, *On Numerology for New Radio Access Technology*, 3GPP TSG RAN WG1 Meeting #85, Nanjing, China, 23th – 27th May 2016.
APPLE-1025	3GPP TS 36.306 V14.1.0, Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio access capabilities (Release 14), December 2016.
APPLE-1026	A. Roessler, J. Schlienz, S. Merkel, M. Kottkamp, "*LTE- Advanced (3GPP Rel.12) Technology Introduction White Paper*"

20. My opinions are also based upon my education, training, research, knowledge, and personal and professional experience. I reserve the right to

supplement or amend this Declaration in the event that I hereafter become aware of additional relevant information.

IV. UNDERSTANDING OF LEGAL STANDARDS

21. I am not an attorney and have not been asked to offer an opinion on the law. I understand, however, that certain aspects of the law are relevant to my evaluation and opinions set forth herein. I have therefore been informed of and asked to apply the legal principles summarized below.

A. Earliest Effective Filing Date

22. I understand that the "earliest effective filing date" of a patent is the date of the earliest filing of a patent application in the priority chain of the patent that describes the subject matter of the challenged claims. In this case I understand the '581 Patent claims priority to a Chinese application filed April 19, 2017. While I have not independently evaluated whether the subject matter of the challenged claims of the '581 Patent are described in the Chinese application sufficiently to support the priority claim, I have nonetheless been instructed by Counsel to treat April 19, 2017 as the earliest effective filing date (also referred to herein as the "Critical Date") of the challenged claims for purposes of my analysis in this Declaration. I have done so.

B. Burden of Proof

23. I understand that Apple as the Petitioner bears the burden of establishing by a preponderance of the evidence that the challenged claims are unpatentable. It is my opinion that that prior art and evidence addressed in this Declaration is more than sufficient to meet this burden.

C. Obviousness Under 35 U.S.C. § 103

24. I understand that a claim is invalid if the invention recited in the claim would have been obvious to one of ordinary skill in the art by the earliest effective filing date. I understand this means that even if all the requirements of the claim cannot be found in a single prior art reference that would anticipate the claim, a person of ordinary skill in the field of the invention knowledgeable of the prior art would have come up with the claimed invention. In considering whether a claim is obvious, I have been asked to consider (a) the level of skill in the art at the time of the claimed invention, (b) the scope and content of the prior art, (c) any differences between the prior art and the claims of the patent-in-suit, and (d) any "secondary factors" tending to show non-obviousness of the claimed invention, including commercial success, long-felt but unresolved need, failure of others, copying, praise by others, unexpected results, and simultaneous invention by others.

25. I understand that a claim composed of several elements is not proved obvious merely by demonstrating that each of its elements was independently known in the prior art. I also understand that obviousness should not be analyzed using the

benefit of hindsight. Instead, it must be analyzed from the standpoint of what was known and understood by a POSITA at the time of the claimed invention. I further understand demonstrating that a modification to a reference or the combination of multiple references is obvious requires providing a reason for why a POSITA would modify a reference or combine multiple references and that reason must be supported with some rationale underpinning. Merely pointing out that two references are similar or in the same field of endeavor is not sufficient.

D. Secondary Considerations of Non-Obviousness

26. I understand that in determining whether the claims are obvious I must also consider any evidence bearing on secondary considerations of non-obviousness. These include practical factors such as (1) commercial success, (2) a long-felt need for a solution to the problem facing the inventors, (3) whether others tried and failed to solve the problem, (4) whether others copied the claimed invention, (5) whether the invention achieved unexpected results, (6) whether the prior art teaches away from combining certain known elements, and (7) whether others in the field praised the invention. I also understand that a nexus must be demonstrated between secondary considerations factors and the claimed invention for the factors to be considered.

V. LEVEL OF ORDINARY SKILL

27. I understand there is a concept in patent law known as a person having ordinary skill in the art (POSITA). I understand that this concept refers to a person who is trained in the relevant technical field of a patent without possessing extraordinary or otherwise exceptional skill. I further understand that factors such as the education level of those working in the field, the sophistication of the technology, the types of problems encountered in the art, prior art solutions to those problems, and the speed at which innovations are made may help establish the level of skill in the art.

28. Taking these factors into consideration, in my opinion, with regard to the ’581 Patent, a person of ordinary skill in the art would have a bachelor’s degree in electrical engineering, computer engineering, computer science, or a similar field, along with two years of experience designing or developing wireless networks, including long-term evolution LTE/4G and 5G new radio (NR) cellular technology. Additional years of experience could substitute for an advanced-level degree (and vice versa).

29. Based at least on my educational and work experience, I was at least a person of ordinary skill in the art as of the effective filing date of the ’581 Patent. And while I note that my qualifications and experiences exceed this definition of a person of ordinary skill of the art, in arriving at the conclusions in this Declaration,

I have considered the issues from the perspective of a person of ordinary skill of the art at the relevant time.

30. Unless otherwise stated, I have applied this level of ordinary skill in the art for the purposes of this Declaration.

VI. TECHNOLOGY BACKGROUND

A. 3rd Generation Partnership Project (3GPP)

31. 3GPP is an international partnership of standards-setting organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, and TTC) for developing interoperable global standards for cellular phone systems, including 3rd generation wireless networks (3G), 4th generation wireless networks/Long Term Evolution (4G/LTE), and 5th generation wireless networks/new radio (5G/NR). 3GPP is a de facto international organization for setting standards that govern cellular networks. The 3GPP's Standards are described in Technical Specifications published by 3GPP and its member organizations.

B. Features of 4G/LTE and Older Networks

32. The '581 patent describes several concepts common to both 4G/LTE and 5G/NR technologies. A review of some such concepts is presented below.

1. Resource Grid and Frame Structure

33. In both 4G/LTE and 5G/NR, radio resources for transmission are represented on a time-frequency resource grid. The grid's horizontal axis denotes

time, whereas the vertical axis denotes the frequency domain (APPLE-1010, [0191]-[0196], Fig. 6, below). The smallest unit is called a "resource elements" (RE). Each RE spans one OFDM symbol in time and one subcarrier in the frequency domain (APPLE-1011, 5:27-30). As shown, a resource block (RB) consists of 84 resource elements (REs) spanning 12 contiguous subcarriers and 7 contiguous OFDM symbols..

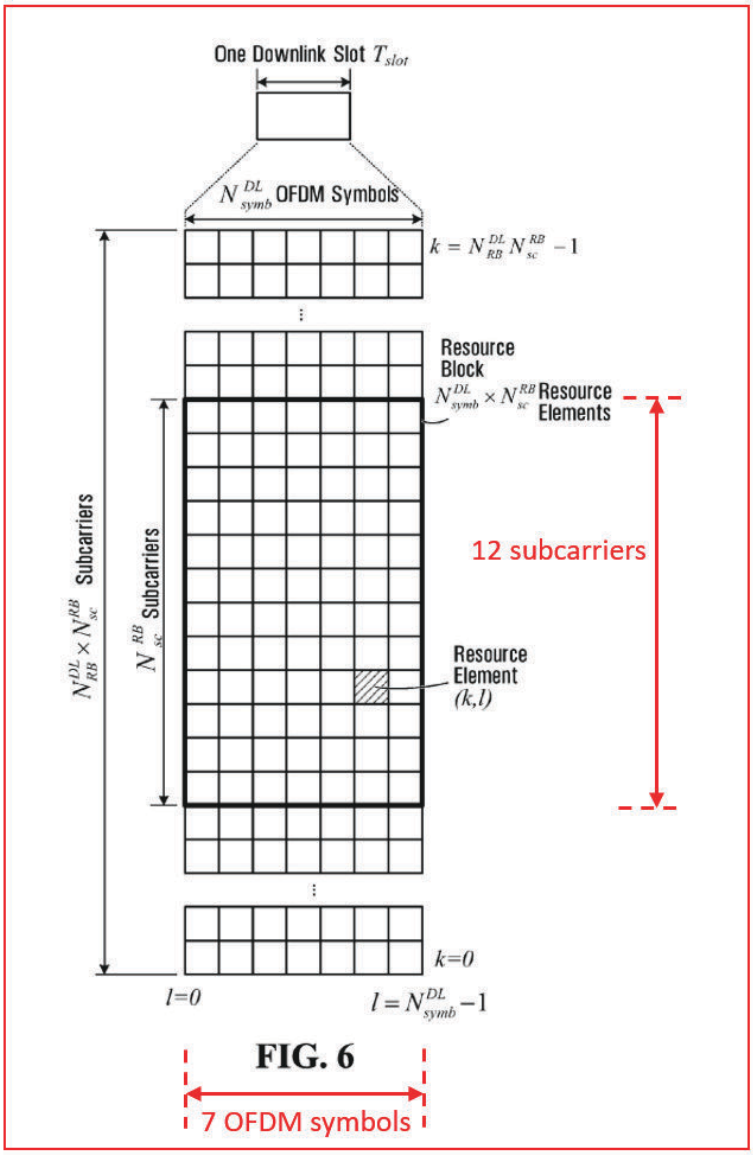
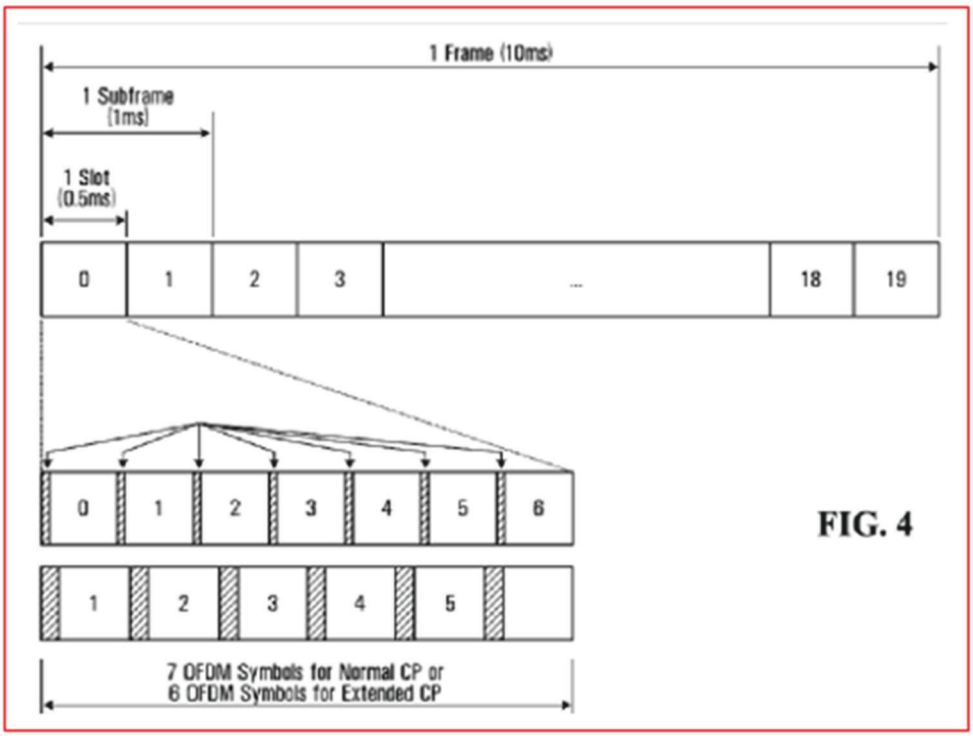


FIG. 6

Weng, Fig. 6, Annotated

34. In the frequency domain, the frequency span of a subcarrier is called "subcarrier spacing." And within the time domain, the radio resources are scheduled using time units such as frame, subframe, slot, and symbol, as shown in the below frame structure.



Weng, Fig. 4.

2. Subcarrier Spacing

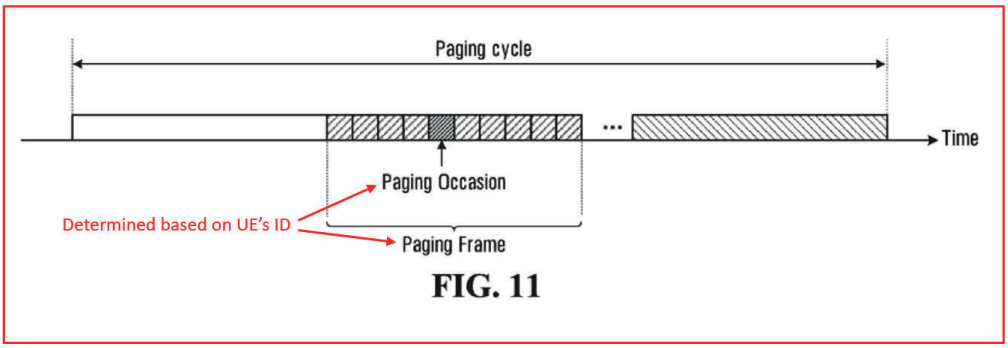
35. In a network, subcarrier spacing may correlate with the duration of a symbol or slot. For example, in 4G/LTE, a radio frame is 10 ms long, with 10

subframes per radio frame. Each subframe contains two slots and typically 14 OFDM symbols (APPLE-1010, [0178]-[0180]). The standard subcarrier spacing is 15 kHz, corresponding to a symbol duration of 66.7 µs, though other spacings like 7.5 kHz may also used, resulting in different frame structures (APPLE-1012, 9:19-31).

3. Paging

36. Paging in wireless networks allows UEs to conserve battery power by entering an idle mode when no data is exchanged with the base station for a while (APPLE-1010, [0003]). While in idle mode, the UE periodically checks for paging messages from the base station which pages the UE when it has downlink messages/data from the network that should be delivered to the UE. If a paging message is detected, the UE switches back to active mode to exchange data. These checks occur during specified "paging occasions," (or POs) within a "paging cycle". *Id*. The paging occasion may be a subframe within a "paging frame," with cycle durations ranging from a few subframes to many radio frames, determined by the UE's ID (APPLE-1010, [0228]-[0229], [0235]-[0236]). This mode of operation, where the UE needs to monitor only the POs within paging cycles to conserve energy, is referred to as discontinuous reception (DRX), and the time

interval between monitoring POs by a specific UE is referred to as a discontinuous reception (DRX) cycle. APPLE-1009, p.8-10, 39



Weng, Fig. 11, Annotated.

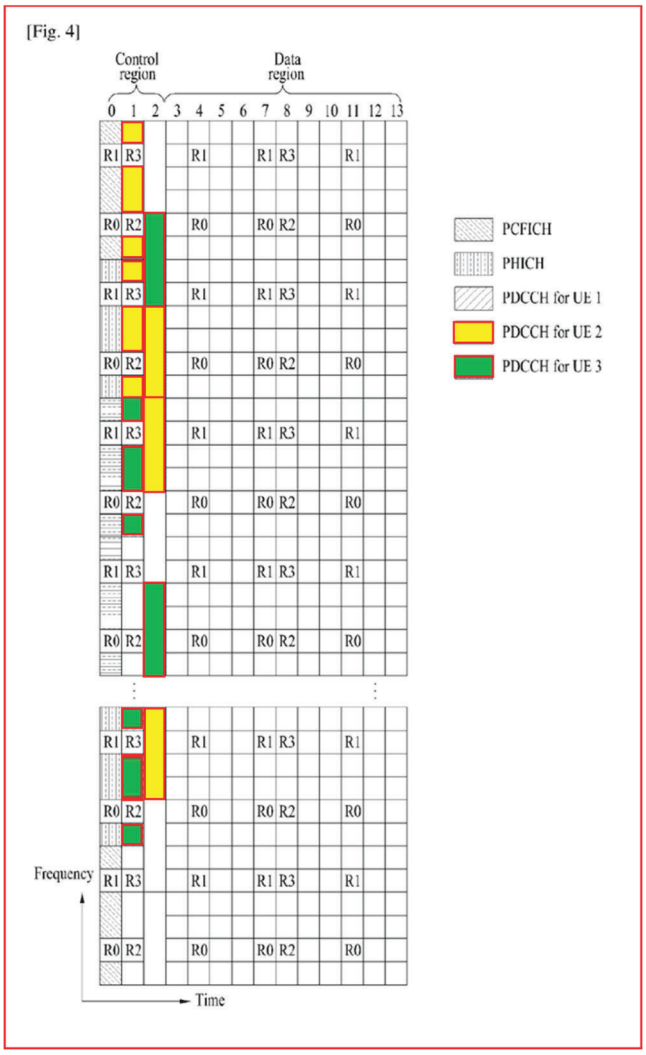
4. Monitoring of Physical Downlink Control Channel (PDCCH)

37. The resource grid is divided into a control region for transmitting and receiving control information (e.g., paging scheduling information) and a data region for transmitting and receiving data (e.g., paging messages). In the time domain, a subframe can be split into these regions, with the control region typically residing in the first 1-4 symbols, (APPLE-1007, [144]).

38. The control region may contain physical downlink control channels (PDCCHs) for transmitting downlink control information (DCI), which helps locate and decode resources on subsequent physical downlink shared channels (PDSCHs) (APPLE-1010, [0226]; APPLE-1007, [104]). In paging, the PDCCH

carries paging scheduling information, and the PDSCH carries paging messages (APPLE-1007, [105]).

39. A UE typically does not know where its PDCCH resides within the control region, as different PDCCHs in the control region may be directed to different UEs (APPLE-1007, [121]). Each PDCCH occupies different resource elements in the grid (APPLE-1007, Fig. 4).



You, Fig. 4, Annotated.

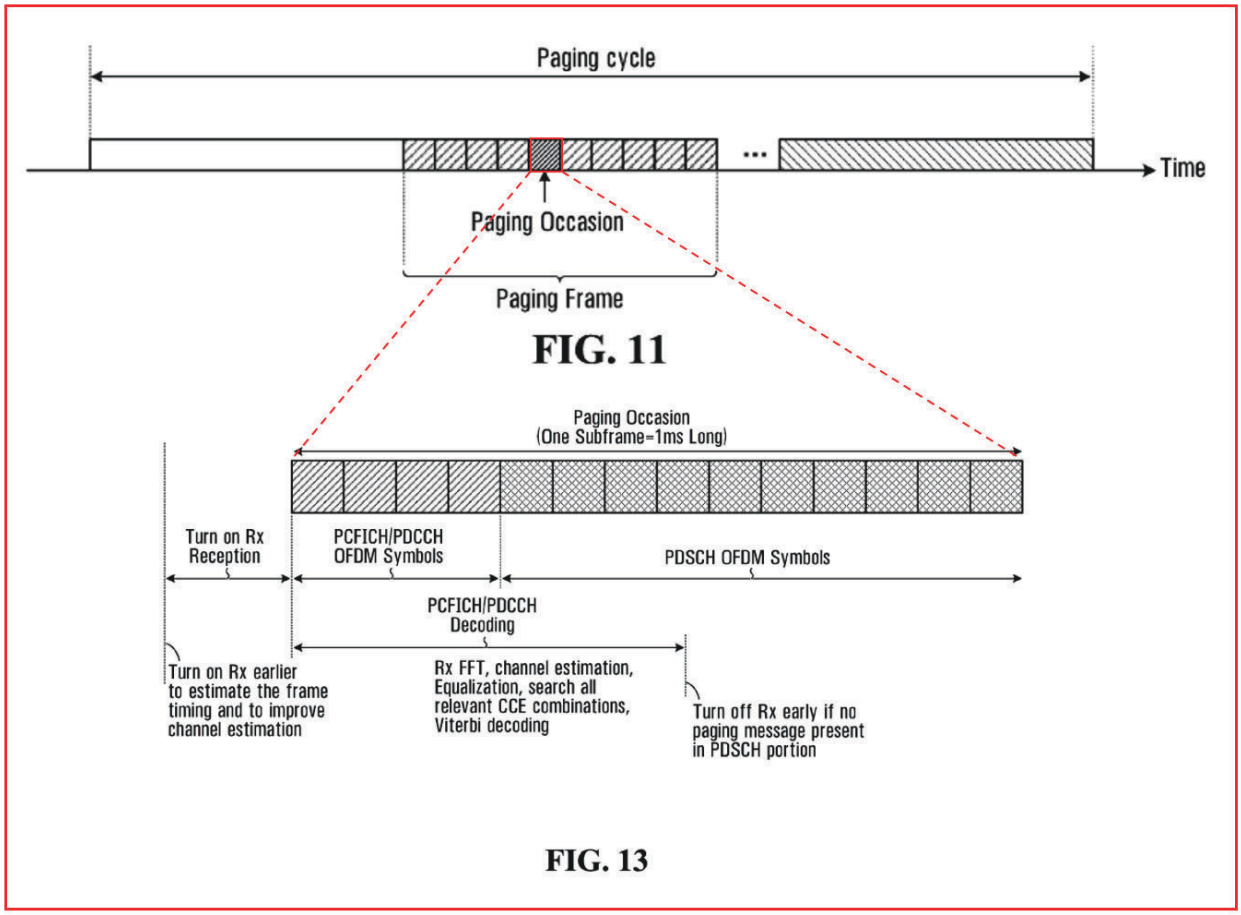
40. The UE must search for its PDCCH through the control region, known as the "PDCCH search space," by decoding each possible PDCCH space to determine if any are encoded with its identifier. APPLE-1007, ¶117. These possible PDCCH spaces are called "PDCCH candidates," suggesting any may contain DCI for the UE. Different PDCCH search spaces can be defined, either for all UEs in a cell ("common search space" or "CSS") or for specific UEs ("UE-specific search space" or "USS"). APPLE-1007, ¶¶117, 119 (Table 9).

41. The UE monitors the PDCCH search space to find DCI intended for it by attempting to decode each PDCCH. This process, known as blind detection, continues until a PDCCH passes an error check with the cyclic redundancy check (CRC) code scrambled by the UE's identifier. If none are found, the UE continues to monitor the next subframe's control region. APPLE-1007, ¶121.

42. The UE monitors for its identifier information referenced as Radio Network Temporary Identity (RNTI), which is "the information indicating the UE to which the Downlink Control Information (DCI) transmitted on PDCCH is addressed." APPLE-1020, ¶¶[0010], [0213]. The specific type of RNTI that is used for paging is referred to as P-RNTI, which indicates to a UE whether or

not a DCI message on the PDCCH is intended for paging. APPLE-1020, ¶[0213].

43. During paging, the UE initiates a reception (Rx) process to monitor (i.e., blindly decode) the PDCCH search space at a paging occasion (PO). If no paging indicator is found in the control region, the UE turns off the Rx process and waits for the next paging occasion. If DCI is detected, the UE decodes the corresponding PDSCH to obtain the paging message. APPLE-1010, ¶¶257-260.



Weng, Figs. 11, 13, Annotated

5. Coverage Enhancement (CE)

44. Conventional 4G/LTE includes a coverage enhancement (CE) mode where a base station may repeat signal transmissions, allowing a UE to attempt repeated receptions to improve decoding success. APPLE-1013, 13:22-24, 14:3-15:11, 15:23-16:8, Fig. 6. This is beneficial for weak signal reception, such as at the cell edge. In CE mode for paging, the same PDCCH may be repeatedly transmitted in multiple common search spaces (CSSs) across several subframes, enabling a UE to monitor these CSSs during paging occasions. APPLE-1007, ¶¶186-200.

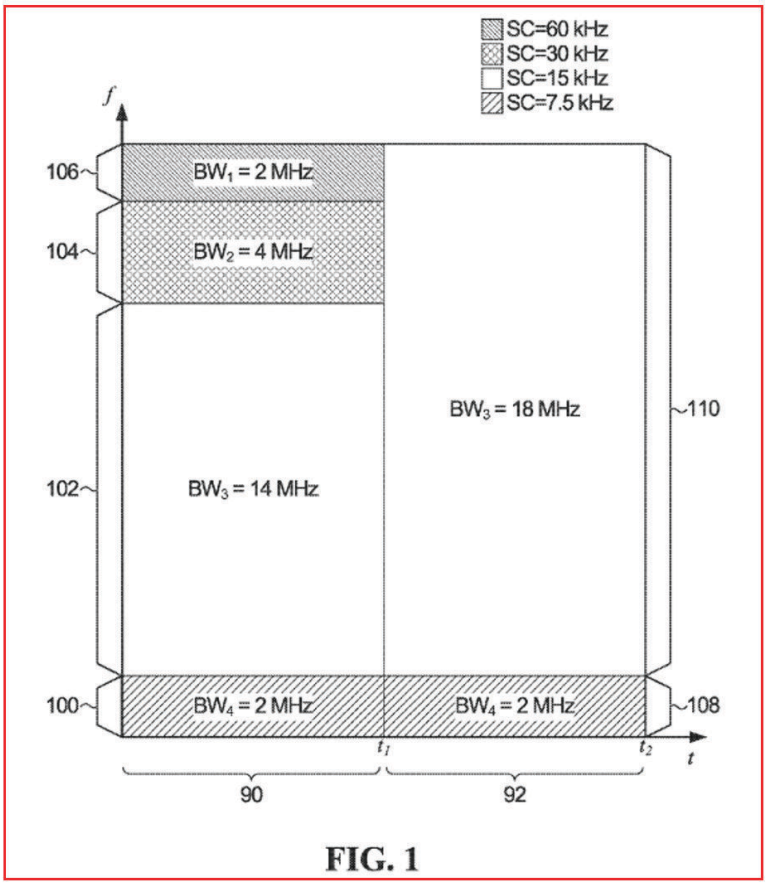
You, Fig. 8, Annotated.

C. 5G/NR Networks

1. Configurable Numerology

45. Due to various factors, including a wide range of available frequency bands (APPLE-1015, ¶¶33, 40), the 5G system supports configurable numerology, including variable subcarrier spacing and symbol duration. *Id.*, ¶57; APPLE-1016,

p. 1. For example, during time period 90 in the figure below, bandwidth is divided into four subbands with 7.5, 15, 30, and 60 kHz subcarrier spacings, respectively. During time period 92, a new division creates two subbands with different subcarrier spacings. APPLE-1016, ¶35, Fig. 1. Each subcarrier spacing corresponds to a different symbol and/or slot duration because different subcarrier spacings lead to different symbol durations. APPLE-1017, ¶72; APPLE-1024, Table 2 (reproduced below); APPLE-1022, ¶21.



Islam, Fig. 1.

Table 2. Candidate numerology sets

Subcarrier-spacing	15 KHz	60 KHz	75 KHz	120 KHz	240 KHz	375 KHz
OFDM symbol length (μs) (w/o CP)	66.67	16.67	13.33	8.33	4.17	2.67
CP Length (ns)	4687	1172	938	586	293	188

R1-165162, (APPLE-1024), Table 2

2. Various Frame Structures

46. As discussed above, different subcarrier spacings (i.e., numerologies) result in different frame structures. Thus, 5G's flexible numerology allows for multiple frame structures to schedule DCI transmission/monitoring, such as paging scheduling information. APPLE-1018, ¶¶155-163 (Tables 1-3). The ’581 patent's portrayal of this flexibility as inventive is unfounded, as it already existed in prior art, including *Yeo*, *Liu*, *Fwu*, and *Pelletier*. For instance, *Yeo* describes “acquiring system information using numerology associated with the control channel among a plurality of numerologies that the terminal supports,” as well as using different frame structures resulting from different subcarrier spacings. APPLE-1005, 4:67-5:3, FIGs. 2B-2D; APPLE-1006, FIGs. 3b-3d, [0474].

VII. THE ’581 PATENT

A. Summary

47. The ’581 patent describes a method and device for paging transmission in a communication system with multiple numerologies, which include various

subcarrier spacings and symbol time lengths (APPLE-1001, 1:20-25, 41-48). It outlines a process for determining paging transmission opportunities based on the numerology used (*Id*., 2:8-16). Specifically, it claims: (i) using a first signaling to schedule a paging message; (ii) monitoring the first signaling in X time intervals; and (iii) using location of a subband associated with the first signaling to determine the X time intervals. *Id*., 23:15-29.

48. As to the first aspect (i), annotated FIG. 8 below shows that the first signaling determines scheduling information for the first radio signal (APPLE-1001, 19:54-64). This signaling can be physical layer signaling, like DCI (downlink control information), transmitted via a PDCCH (*Id*., 20:8-14). The first radio signal carrying the paging message may be sent on a PDSCH (*Id*., 20:18-19). The "second radio signal [can be] transmitted on a Physical Broadcast channel (PBCH)" and carry either "Master Information Block Information (MIB) information" or "System Information Block Information (SIB) information." *Id.*, 5:45-52.

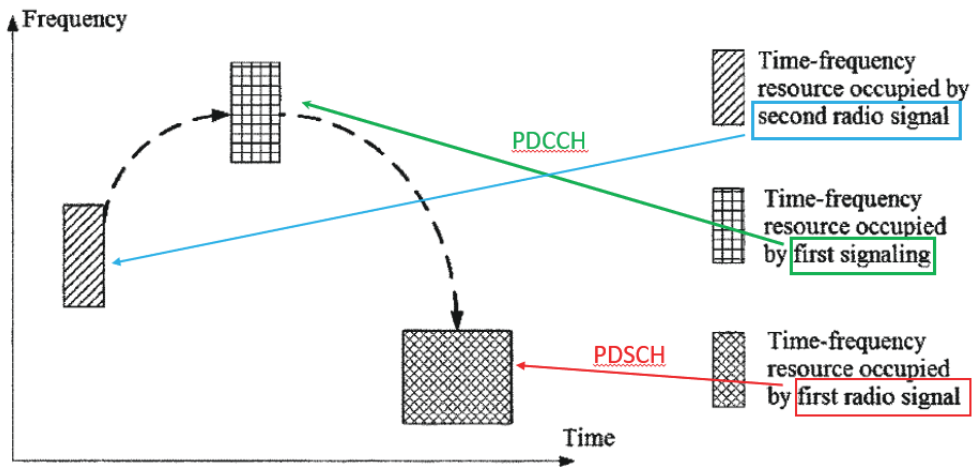


FIG. 8

49. Second concept (ii) is depicted below in annotated FIG. 6 (below), where each filled rectangle signifies a paging time interval monitored by a specific UE within a particular time window. For instance, UE#2 monitors a first signaling in X2 time intervals, which are part of time window #b. APPLE-1001, 17:66-18:1.

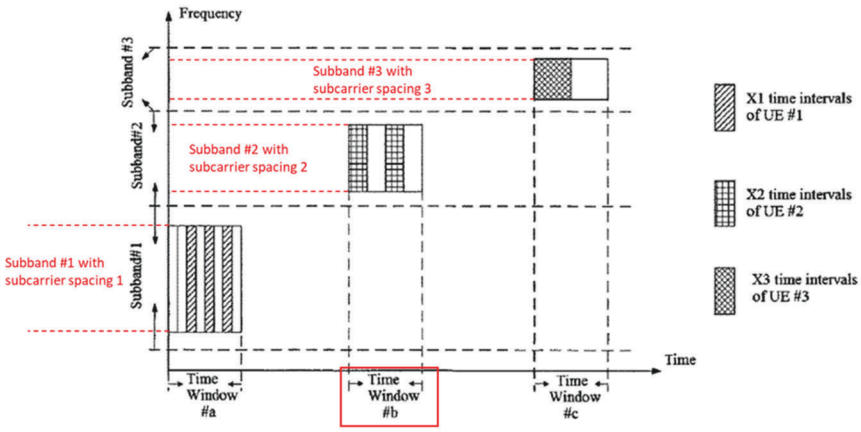


FIG. 6

50. Regarding concept (iii), although the ’581 Patent claims that the location of a subband is used for determining X, the patent does not explicitly describe how the determination is made based on the location of the subband. Rather, the ’581 patent states that, for each UE, the subband of the frequency domain resource used for transmitting the first signaling “includes a positive integer number of consecutive subcarriers in frequency domain.” APPLE-1001, 18:7-8. Annotated FIG 7 illustrates a special case (X=1) for using the subcarrier spacing to determine the X time intervals. *Id*., 18:49-54. Specifically, each UE (UE_a, UE_b, UE_c, or UE_d) is associated with a respective time window. *Id*., 18:55-64, Fig. 7. The subcarrier spacing associated with each UE affects how to divide the respective time window into Y time intervals, and the feature ID of the UE is used to determine which one of the Y time intervals includes the X=1 time interval. *Id*. The ’581 patent further clarifies that the time length of each X time interval is correlated with the subcarrier spacing. *Id*., 19:7-10. Thus, subcarrier spacing determines both the time-domain location (i.e., which Y time interval) and the duration (i.e., time length) of each X time interval.

	Index of X=1 time interval in the first time window			
	Feature ID=a	Feature ID=b	Feature ID=c	Feature ID=d
Y=1	0	0	0	0
Y=2	0	1	0	1
Y=4	0	1	2	3
Y=8	1	3	5	7
Y=16	2	6	10	14

This table illustrates, for example, that for a UE with Feature ID=b, if the time window is divided into Y=16 time intervals, the X=1 paging occasion is at interval no. 6 of the time window spanned by the 16 intervals numbered 0, 1,...,15.

FIG. 7

B. Brief Prosecution History

51. During prosecution, the application received an allowance after a single Office Action that set forth only a double-patenting rejection over a parent application. APPLE-1002, pp.145-152. A published application associated with *Yeo*, *Mallick*, and an earlier version of *TS36* were cited during prosecution, but I did not see any substantive discussion on these references.

C. Claim Construction

52. I understand that the words of a claim are generally given their ordinary and customary meaning, which I understand is the meaning that the term would have to a person of ordinary skill in the art in question at the time of the invention, *i.e.*, as of the effective filing date of the patent application. I understand the person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the

entire patent, including the specification and prosecution history. Additionally, I understand other extrinsic evidence external to the patent and prosecution history, such as dictionaries and treatises, may also be useful in determining the meaning that the term would have to a person of ordinary skill in the art in question at the time of the invention. I understand that such extrinsic evidence, however, is generally afforded less weight than intrinsic evidence in determining the meaning of claim terms, and overall is unlikely to result in a reliable interpretation of a patent claim scope unless considered in the context of the intrinsic evidence.

53. I have been instructed that the "intrinsic record" includes the patent itself, including the claims, description, and figures (APPLE-1001, '581 Patent), and the patent's prosecution history—*i.e.*, the record of proceedings at the U.S. Patent and Trademark Office ("Patent Office") concerning the patent (APPLE-1002, Prosecution History). I understand that, like the claims and written description, the prosecution history provides evidence to a person of ordinary skill in the art of how the inventor intended his patent to be understood, and how the Patent Office understood the patent. I understand that the inventor is permitted to apply a special definition to the terms or to limit the scope of claim terms in his patent claims, which may differ from the term's plain and ordinary meaning. That special definition or limitation on scope may be provided in the patent's written description, the patent's prosecution history, or both. I understand that claim interpretation may also be

informed by "extrinsic evidence" (that is, evidence outside of the patent record itself). I have been informed that extrinsic evidence may include dictionaries, technical treatises, and other materials evidencing the meaning of a claim term and the understanding held by a POSITA in the relevant time period.

54. I have been asked for purposes of this declaration to apply the plain and ordinary meaning of the claim terms as they would have been understood by a person of ordinary skill in the art at the earliest effective filing date of the '581 Patent.

55. I understand that no claim term's construction is in dispute at this time. Based on my review of these materials and my personal knowledge and experience, I have considered each term of the '581 Patent as it would have been understood by a person of ordinary skill in the art at the earliest effective filing date of April 19, 2017. I also understand that I am to interpret each claim term by its plain and ordinary meaning when applying the prior art, which I have done here. In my opinion, claims 1-5, 7-11, 12-17, and 19-23 ("Challenged Claims"), under their plain and ordinary meaning, are unpatentable for at least the reasons I address below in Grounds 1 and 2.

D. The Challenged Claims

56. I understand that claims 1-5, 7-11, 12-17, and 19-23 of the '581 patent are being challenged in this proceeding. The claims are arranged as

follows:

- Claims 1-5: Method for UE
- Claims 7-11: Method for base station
- Claims 13-17: UE device
- Claims 19-23: Base station device

57. Both independent claim 1 and independent claim 13 are directed at the UE device for paging reception. In my opinion, independent claim 13 is substantially similar to claim 1, except it is an apparatus claim directed to "[a] UE for paging," and requires (1) "a first receiver" to monitor a first radio signaling in X time intervals, and (2) "a second receiver" to receive a first radio signal. In addition, claims 2-5 and claims 14-17 are also substantially identical.

58. Both independent claim 7 and independent claim 19 are directed at the base station for paging transmission. Independent claim 19 is substantially similar to claim 7, except it is an apparatus claim directed to a base station for paging, and requires (1) "a first transmitter" to transmit a first signaling in a positive integer number of time intervals of X time intervals, and (2) "a second transmitter" to transmit a first radio signal.

59. The following tables demonstrate the similarity among the claims, with identical language italicized.

Claim 1	**Claim 7**
[1pre] A method in a User Equipment (UE) *for paging, comprising:*	[7pre] A method in a base station *for paging, comprising:*
[1a] monitoring *a first signaling in X time intervals; and*	[7a] transmitting *a first signaling in* a positive integer number of time intervals of *X time intervals; and*
[1b] receiving *a first radio signal;*	[7b] transmitting *a first radio signal;*
[1c] *wherein X is a positive integer;*	*wherein X is a positive integer;*
[1d] *the first signaling is used for determining scheduling information for the first radio signal;*	*the first signaling is used for determining scheduling information for the first radio signal;*
[1e] *the scheduling information comprises occupied time-frequency resource, adopted* Modulation Coding Scheme (*MCS*), *and subcarrier spacing of subcarriers in occupied frequency domain resource;*	*the scheduling information comprises occupied time-frequency resource, adopted MCS, and subcarrier spacing of subcarriers in occupied frequency domain resource;*
[1f] *the first radio signal carries a paging message;*	*the first radio signal carries a paging message;*
[1g] *the frequency domain resource used for transmitting the first signaling belongs to a first subband;*	*the frequency domain resource used for transmitting the first signaling belongs to a first subband;*
[1h] *the first subband comprises a positive integer number of consecutive subcarriers in frequency domain; and*	*the first subband comprises a positive integer number of consecutive subcarriers in frequency domain; and*
[1i] *location of the first subband in frequency domain is used for determining the X time intervals.*	*location of the first subband in frequency domain is used for determining the X time intervals.*

Claim 1	**Claim 13**
[1pre] A method in a User Equipment (UE) *for paging, comprising:*	A UE *for paging, comprising:*
[1a] monitoring *a first signaling in X time intervals; and*	a first receiver, to monitor *a first signaling in X time intervals; and*
[1b] receiving *a first radio signal;*	a second receiver, to receive *a first radio signal;*
[1c] *wherein X is a positive integer;*	*wherein X is a positive integer;*

[1d] *the first signaling is used for determining scheduling information for the first radio signal;*	*the first signaling is used for determining scheduling information for the first radio signal;*
[1e] *the scheduling information comprises occupied time-frequency resource, adopted* Modulation Coding Scheme (*MCS*), *and subcarrier spacing of subcarriers in occupied frequency domain resource;*	*the scheduling information comprises occupied time-frequency resource, adopted MCS, and subcarrier spacing of subcarriers in occupied frequency domain resource;*
[1f] *the first radio signal carries a paging message;*	*the first radio signal carries a paging message;*
[1g] *the frequency domain resource used for transmitting the first signaling belongs to a first subband;*	*the frequency domain resource used for transmitting the first signaling belongs to a first subband;*
[1h] *the first subband comprises a positive integer number of consecutive subcarriers in frequency domain; and*	*the first subband comprises a positive integer number of consecutive subcarriers in frequency domain; and*
[1i] *location of the first subband in frequency domain is used for determining the X time intervals.*	*location of the first subband in frequency domain is used for determining the X time intervals.*

Claim 1	**Claim 19**
[1pre] A method in a User Equipment (UE) *for paging, comprising:*	A base station *for paging, comprising:*
[1a] monitoring *a first signaling in X time intervals; and*	a first transmitter, to transmit *a first signaling in* a positive integer number of time intervals of *X time intervals; and*
[1b] receiving *a first radio signal;*	a second transmitter, to transmit *a first radio signal;*
[1c] *wherein X is a positive integer;*	*wherein X is a positive integer;*
[1d] *the first signaling is used for determining scheduling information for the first radio signal;*	*the first signaling is used for determining scheduling information for the first radio signal;*
[1e] *the scheduling information comprises occupied time-frequency resource, adopted* Modulation Coding Scheme (*MCS*), *and subcarrier spacing*	*the scheduling information comprises* at least one of *occupied time-frequency resource, adopted MCS, and subcarrier spacing of subcarriers in occupied frequency domain resource;*

of subcarriers in occupied frequency domain resource;	
[1f] *the first radio signal carries a paging message;*	*the first radio signal carries a paging message;*
[1g] *the frequency domain resource used for transmitting the first signaling belongs to a first subband;*	*the frequency domain resource used for transmitting the first signaling belongs to a first subband;*
[1h] *the first subband comprises a positive integer number of consecutive subcarriers in frequency domain; and*	*the first subband comprises a positive integer number of consecutive subcarriers in frequency domain; and*
[1i] *location of the first subband in frequency domain is used for determining the X time intervals.*	subcarrier spacing of subcarriers included in the first subband *location of the first subband in frequency domain is used for determining the X time intervals.*

Claim 2	Claim 8
[2a] The method according to claim 1, *wherein any one of the X time intervals belongs to a first time window in time domain;*	The method according to claim 7, *wherein any one of the X time intervals belongs to a first time window in time domain;*
[2b] *the time length of the first time window is predefined;*	*the time length of the first time window is predefined;*
[2c] *the first time window is divided into Y time intervals;*	*the first time window is divided into Y time intervals;*
[2d] *the X time intervals are X time intervals of the Y time intervals, Y being a positive integer not smaller than X;*	*the X time intervals are X time intervals of the Y time intervals, Y being a positive integer not smaller than X;*
[2e] *the subcarrier spacing of subcarriers included in the first subband is used for determining Y; and*	*the subcarrier spacing of subcarriers included in the first subband is used for determining Y; and*
[2f] *a feature ID of a monitor of the first signaling is used for determining the X time intervals in the Y time intervals.*	*a feature ID of a monitor of the first signaling is used for determining the X time intervals in the Y time intervals,*
[2g] *the feature ID refers to a remainder when an International*	*the feature ID refers to a remainder when an International Mobile*

Mobile Subscriber Identification Number (IMSI) is divided by 1024.	*Subscriber Identification Number (IMSI) is divided by 1024.*

Claim 2	Claim 14
[2a] The method according to claim 1, *wherein any one of the X time intervals belongs to a first time window in time domain;*	The UE according to claim 13, *wherein any one of the X time intervals belongs to a first time window in time domain;*
[2b] *the time length of the first time window is predefined;*	*the time length of the first time window is predefined;*
[2c] *the first time window is divided into Y time intervals;*	*the first time window is divided into Y time intervals;*
[2d] *the X time intervals are X time intervals of the Y time intervals, Y being a positive integer not smaller than X;*	*the X time intervals are X time intervals of the Y time intervals, Y being a positive integer not smaller than X;*
[2e] *the subcarrier spacing of subcarriers included in the first subband is used for determining Y; and*	*the subcarrier spacing of subcarriers included in the first subband is used for determining Y; and*
[2f] *a feature ID of a monitor of the first signaling is used for determining the X time intervals in the Y time intervals*.	*a feature ID of a monitor of the first signaling is used for determining the X time intervals in the Y time intervals*,
[2g] *the feature ID refers to a remainder when an International Mobile Subscriber Identification Number (IMSI) is divided by 1024.*	*the feature ID refers to a remainder when an International Mobile Subscriber Identification Number (IMSI) is divided by 1024.*

Claim 2	Claim 20
[2a] The method according to claim 1, *wherein any one of the X time intervals belongs to a first time window in time domain;*	The base station according to claim 19, *wherein any one of the X time intervals belongs to a first time window in time domain;*
[2b] *the time length of the first time window is predefined;*	*the time length of the first time window is predefined;*
[2c] *the first time window is divided into Y time intervals;*	*the first time window is divided into Y time intervals;*
[2d] *the X time intervals are X time intervals of the Y time intervals, Y*	*the X time intervals are X time intervals of the Y time intervals, Y*

being a positive integer not smaller than X;	*being a positive integer not smaller than X;*
[2e] *the subcarrier spacing of subcarriers included in the first subband is used for determining Y; and*	*the subcarrier spacing of subcarriers included in the first subband is used for determining Y; and*
[2f] *a feature ID of a monitor of the first signaling is used for determining the X time intervals in the Y time intervals.*	*a feature ID of a monitor of the first signaling is used for determining the X time intervals in the Y time intervals*,
[2g] *the feature ID refers to a remainder when an International Mobile Subscriber Identification Number (IMSI) is divided by 1024.*	*the feature ID refers to a remainder when an International Mobile Subscriber Identification Number (IMSI) is divided by 1024.*

Claim 3	Claim 9
[3a] The method according to claim 2, *wherein the first time window belongs to one of Z time windows, Z being an integer greater than 1;*	The method according to claim 8, *wherein the first time window belongs to one of Z time windows, Z being an integer greater than 1;*
[3b] *Z is predefined, or Z is configurable;*	*Z is predefined, or Z is configurable;*
[3c*] any two of the Z time windows have an equal time length,*	*any two of the Z time windows have an equal time length,*
[3d] *any two of the Z time windows are orthogonal in time domain,*	*any two of the Z time windows are orthogonal in time domain,*
[3e] *any one of the Z time windows is a radio frame,*	*any one of the Z time windows is a radio frame,*
[3f] *Z is equal to the number of radio frames included in a Discontinuous Reception (DRX) cycle; and*	*Z is equal to the number of radio frames included in a Discontinuous Reception (DRX) cycle; and*
[3g] *the feature ID of the monitor of the first signaling is used for determining the first time window in the Z time windows.*	*the feature ID of the monitor of the first signaling is used for determining the first time window in the Z time windows.*

Claim 3	Claim 15
[3a] The method according to claim 2, *wherein the first time window belongs*	The UE according to claim 14, *wherein the first time window belongs to one of*

to one of Z time windows, Z being an integer greater than 1;	*Z time windows, Z being an integer greater than 1;*
[3b] *Z is predefined, or Z is configurable;*	*Z is predefined, or Z is configurable;*
[3c] *any two of the Z time windows have an equal time length,*	*any two of the Z time windows have an equal time length,*
[3d] *any two of the Z time windows are orthogonal in time domain,*	*any two of the Z time windows are orthogonal in time domain,*
[3e] *any one of the Z time windows is a radio frame,*	*any one of the Z time windows is a radio frame,*
[3f] *Z is equal to the number of radio frames included in a Discontinuous Reception (DRX) cycle; and*	*Z is equal to the number of radio frames included in a Discontinuous Reception (DRX) cycle; and*
[3g] *the feature ID of the monitor of the first signaling is used for determining the first time window in the Z time windows.*	*the feature ID of the monitor of the first signaling is used for determining the first time window in the Z time windows.*

Claim 3	**Claim 21**
[3a] The method according to claim 2, *wherein the first time window belongs to one of Z time windows, Z being an integer greater than 1;*	The base station according to claim 20, *wherein the first time window belongs to one of Z time windows, Z being an integer greater than 1;*
[3b] *Z is predefined, or Z is configurable;*	*Z is predefined, or Z is configurable;*
[3c] *any two of the Z time windows have an equal time length,*	*any two of the Z time windows have an equal time length,*
[3d] *any two of the Z time windows are orthogonal in time domain,*	*any two of the Z time windows are orthogonal in time domain,*
[3e] *any one of the Z time windows is a radio frame,*	*any one of the Z time windows is a radio frame,*
[3f] *Z is equal to the number of radio frames included in a Discontinuous Reception (DRX) cycle; and*	*Z is equal to the number of radio frames included in a Discontinuous Reception (DRX) cycle; and*
[3g] *the feature ID of the monitor of the first signaling is used for determining the first time window in the Z time windows.*	*the feature ID of the monitor of the first signaling is used for determining the first time window in the Z time windows.*

Claim 4	Claim 10
The method according to claim 3*, further comprising:*	*The method according to claim* 9*, further comprising:*
receiving *a third signaling*;	receiving *a third signaling;*
wherein, the third signaling is used for configuring Z.	*wherein, the third signaling is used for configuring Z.*

Claim 4	Claim 16
The method according to claim 3, further comprising:	The method according to claim 15, wherein the second receiver further
receiving *a third signaling*;	receives *a third signaling*,
wherein, *the third signaling is used for configuring Z.*	*the third signaling is used for configuring Z.*

Claim 4	Claim 22
The method according to claim 3, further comprising:	The method according to claim 21, wherein the second transmitter further
receiving *a third signaling;*	transmits *a third signaling,*
wherein, *the third signaling is used for configuring Z.*	*the third signaling is used for configuring Z.*

Claim 5	Claim 11
[5a] The method according to claim 1, *further comprising:* receiving *a second radio signal;*	The method according to claim 7, *further comprising:* transmitting *a second radio signal;*
[5b] *wherein the second radio signal is used for determining at least one of location of the first subband in frequency domain, or subcarrier spacing of subcarriers included in the first subband;*	*wherein the second radio signal is used for determining at least one of location of the first subband in frequency domain, or subcarrier spacing of subcarriers included in the first subband;*
[5c] *the second radio signal carries Master Information Block (MIB) information, or the second radio signal carries System Information Block (SIB) information;*	*the second radio signal carries Master Information Block (MIB) information, or the second radio signal carries System Information Block (SIB) information.*

Claim 5	Claim 17

[5a] The method according to claim 1, further comprising: receiving *a second radio signal;*	The UE according to claim 13, wherein the first receiver further receives *a second radio signal;*
[5b] wherein *the second radio signal is used for determining at least one of location of the first subband in frequency domain, or subcarrier spacing of subcarriers included in the first subband;*	*the second radio signal is for determining at least one of location of the first subband in frequency domain, or subcarrier spacing of subcarriers included in the first subband;*
[5c] *the second radio signal carries Master Information Block (MIB) information, or the second radio signal carries System Information Block (SIB) information;*	*the second radio signal carries Master Information Block (MIB) information, or the second radio signal carries System Information Block (SIB) information.*

Claim 5	Claim 23
[5a] The method according to claim 1, further comprising: receiving *a second radio signal;*	The base station according to claim 19, wherein the first transmitter further transmits *a second radio signal;*
[5b] wherein *the second radio signal is used for determining at least one of location of the first subband in frequency domain, or subcarrier spacing of subcarriers included in the first subband;*	*the second radio signal is for determining at least one of location of the first subband in frequency domain, or subcarrier spacing of subcarriers included in the first subband;*
[5c] *the second radio signal carries Master Information Block (MIB) information, or the second radio signal carries System Information Block (SIB) information;*	*the second radio signal carries Master Information Block (MIB) information, or the second radio signal carries System Information Block (SIB) information.*

VIII. ANALYSIS OF THE CHALLENGED CLAIMS

A. [GROUND 1] *Yeo* and *TS36* render obvious claims 1, 5, 7, 11, 13, 17, 19, and 23

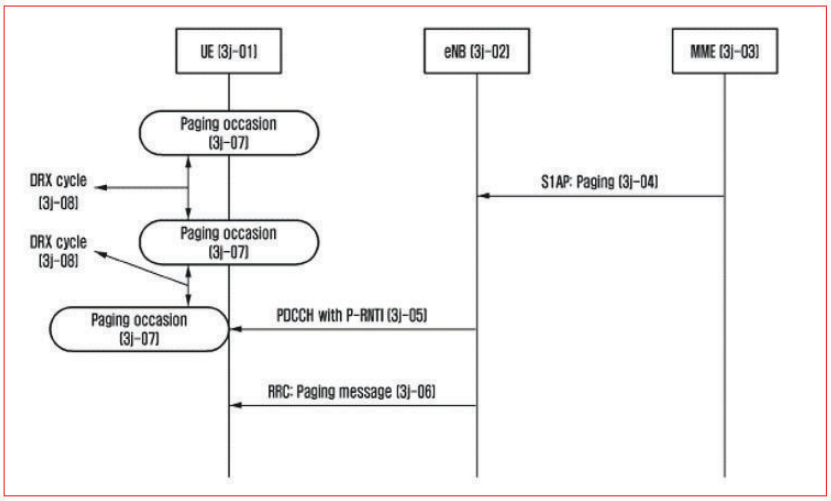
1. Effective Filing Date of Yeo

60. I understand that *Yeo* (APPLE-1005) claims priority to KR Application 10-2016-0125809 filed on September 29, 2016 (APPLE-1006-*Yeo-Priority*). For my review below, I have provided citations to *Yeo* (APPLE-1005) and also to the corresponding portions in *Yeo-Priority* (APPLE-1006). *Yeo* also claims priority to KR applications 10-2016-0106427 (filed August 22, 2016), but I have not relied on this document for my analysis.

2. Yeo

61. *Yeo* is directed to, among other things, "paging in wireless cellular communication system" – and is therefore in the same technology area as the '581 Patent. APPLE-1005, Title; APPLE-1006, [0013]. Like the '581 Patent, *Yeo* addresses, in the relevant portions, paging transmission in a "5G communication system… for supporting a plurality of numerologies or subcarrier spacings in one system. APPLE-1005, 3:12-16, APPLE-1006, [0014]. As background information, *Yeo* describes the paging procedure employed in 4G LTE systems, and then extends the concept to adapt to variable numerologies available in 5G NR systems. For example, with reference to FIG. 3J, reproduced below with annotations, *Yeo* describes that in an efficient paging procedure, a terminal (or user equipment (UE)) wakes up for "a little while in a predetermined time interval… to observe the paging information from the network, allowing the terminal…to be…idle…for

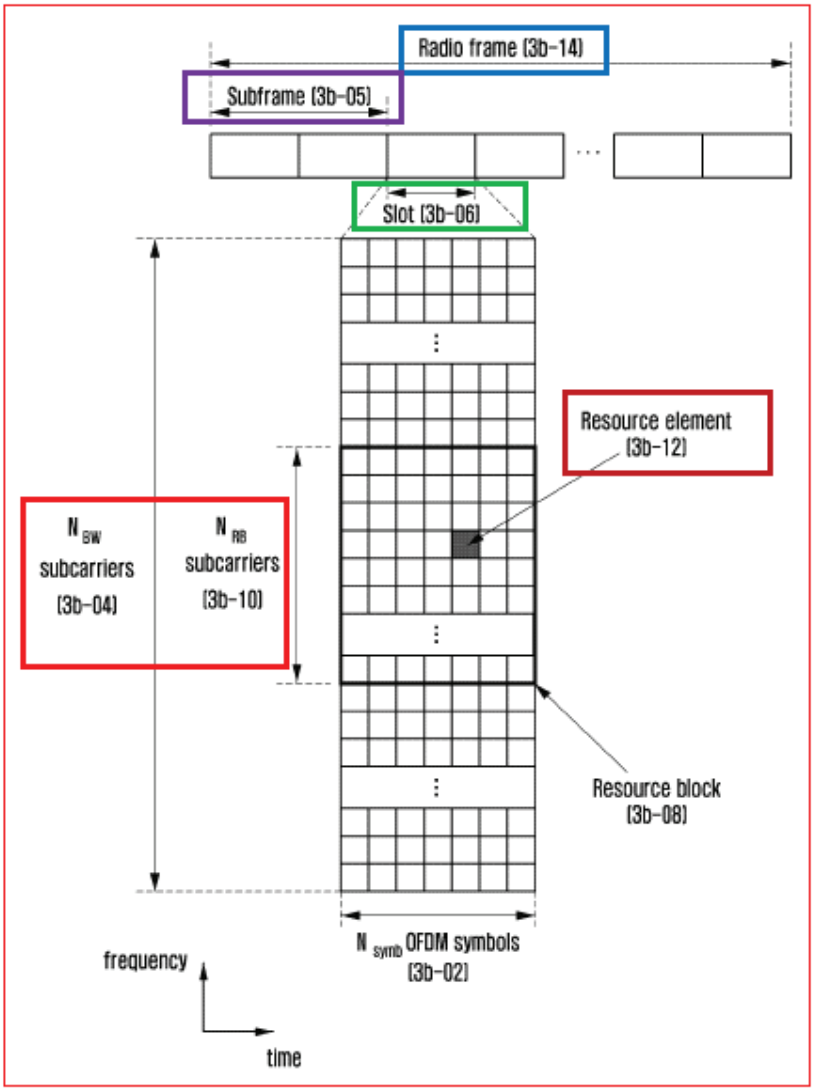
most of the time." APPLE-1005, 53:8-12; APPLE-1006, [0455]. For this, *Yeo*, adopts the basic paging structure of LTE, noting that a paging occasion (PO) is "a subframe in which the PDCCH [is] configured [to transmit information that] a paging message exists," and a paging frame (PF) is "one radio frame including one or more POs." The UE is described as being able to "observe one PO per discontinuous reception (DRX) period." APPLE-1005, 53:12-20; APPLE-1006, [0455].



Yeo, Fig. 3J.

62. The structure of the paging frame and PO subframe generally adheres to the basic structure used in LTE with each radio frame including multiple subframes and each subframe including two slots, each of which includes multiple OFDM symbols. APPLE-1005, FIG. 3B (annotated below); APPLE-1006, FIG. 1a. Each OFDM symbol includes multiple resource elements that each having a

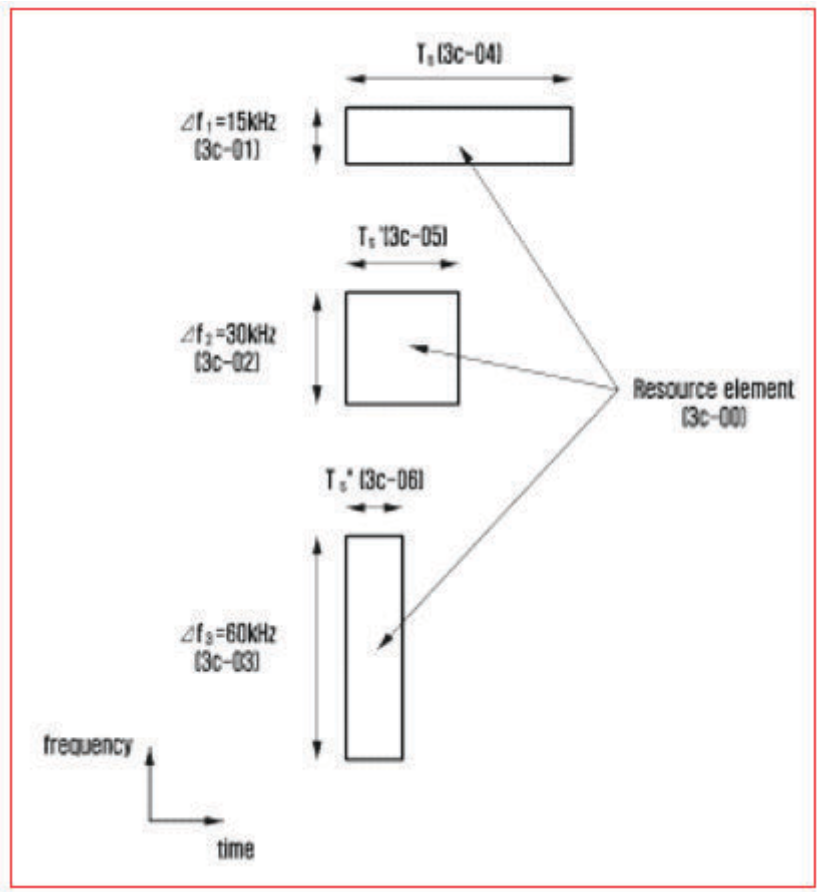
different frequency range. The frequency range corresponding to each resource element in an OFDM symbol is referred to as a subcarrier, and the width of the frequency range is referred to as subcarrier spacing.



Yeo, FIG. 3B, Annotated

63. *Yeo* extends the above frame structure to the variable numerology concept in 5G, where the length or duration of each OFDM symbol varies with

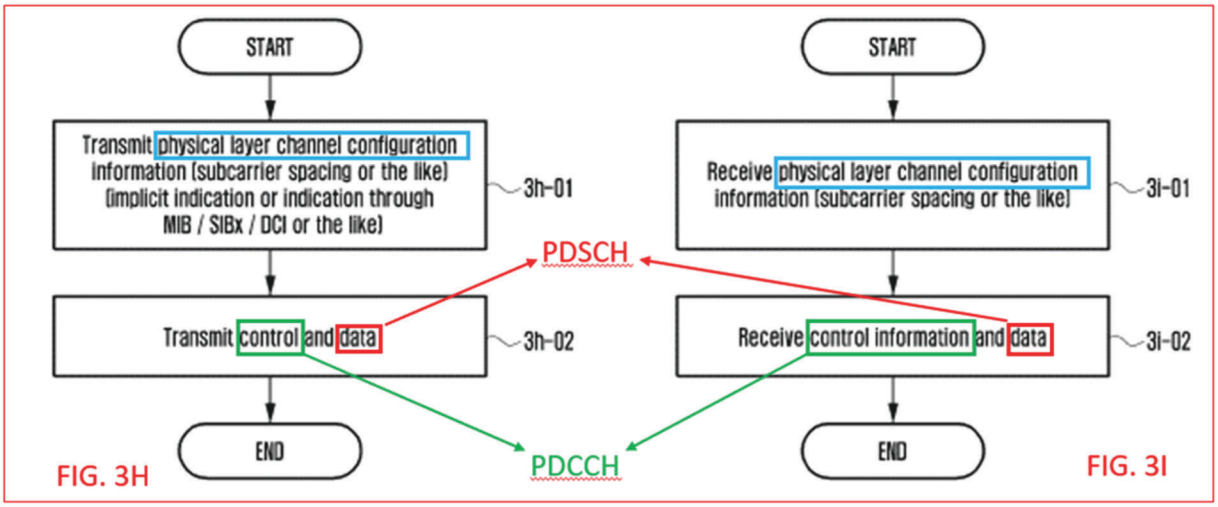
subcarrier spacing. Specifically, FIG. 3C (annotated below) shows resource elements for subcarrier spacings 15KHz, 30 KHz, and 60Khz, and it is noted that "the subcarrier spacing and the length of the OFDM symbol have a reciprocal relationship with each other." APPLE-1005, 43:49-62; APPLE-1006, [0383].



Yeo, FIG. 3C

64. Because the OFDM symbol durations are different for different subcarrier spacings, a UE needs to know the numerology information to decode the information received during paging occasions. More specifically, with reference to

its FIG. 3H and 3I (annotated below) as well as FIGs. 3L and 3M, *Yeo* describes that a base station "transmits information on numerology (e.g., subcarrier spacing, etc.) for the physical layer channel used for paging," prior to transmitting any "control information and data for paging." The information on numerology can include a Master Information Block (MIB) or a system information block (SIBx). A terminal (or user equipment UE) receives the "information on the physical layer numerology" and upon determining that the terminal supports the numerology, proceeds to receive "the control information and data reception." APPLE-1005, 56:12-27; APPLE-1006, [0452]. The data for paging or "paging message" is transmitted on the PDSCH, and scheduling information on the PDSCH can be acquired from the PDCCH. APPLE-1005, 3:48-50; APPLE-1006, [0013].



Yeo, Figs. 3H and 3I, Annotated

65. *Yeo* further describes various types of UEs that are served by the wireless network, including UE type that supports massive machine type communication (mMTC), UE type that supports MIMO (multiple-input-multiple-output), UE type that supports enhanced mobile broadband (eMBB), and UE type that supports ultra-reliable and low-latency communications (URLLC). APPLE-1005, 2:13-23, 10:10-14; APPLE-1006, [0004], [0027]. Massive MTC (mMTC) is a type of MTC that supports mass communications among connected devices. APPLE-1005, 29:5-7; APPLE-1006, [0211]. The frequency subband in use for a UE can vary with the type of devices/communications and associated requirements, and thus be allocated accordingly. See, for example, APPLE-1005, FIG. 1D, 9:60-10:21; APPLE-1006, FIG. 1d, [0027].

66. Yeo is analogous art to the ’581 Patent. Indeed, comparison of Yeo’s FIGs. 3H and 3I with FIG. 8 from the ’581 Patent (supra) reveals that Yeo describes the overall solution that the ’581 purports to solve – determining “transmission opportunities of paging according to the numerology employed by the paging.” APPLE-1001, 2:1-5.

3. TS36

67. *TS36* is a Technical Specification document published by the 3GPP and pertains to Evolved Universal Terrestrial Radio Access (E-UTRA) UE procedures in idle mode. E-UTRA technology is well-known to be associated with

4G/LTE. APPLE-1019, 1:25-31. In the relevant portions, *TS36* specifically describes details of paging procedures, in particular, details of the DRX mode referred to in *Yeo*. APPLE-1009, p.39. For example, *TS36* specifically covers details of implementations where a paging frame (PF) contains "one or multiple Paging Occasion(s)" and the UE "needs only to monitor one PO per DRX cycle" – as also described in *Yeo* with respect to FIG. 3J. APPLE-1009, p.39; APPLE-1005, 53:12-20; APPLE-1006, [0455]. Monitoring the PO includes monitoring PDCCH within the PO for the identifier P-RNTI - which indicates to a UE whether or not paging is scheduled in the PO for the UE. The UE performs the paging message reception in a Paging Narrowband (PNB) that is within the subband assigned to the UE. APPLE-1009, p.39. The subband can be assigned depending on the type of services of services—such as enhanced mobile broadband (eMBB), mMTC, ultra-reliable and low-latency communications (URLLC), etc.—provided by the UE. APPLE-1005, FIG. 1D, 9:60-10:21; APPLE-1006, FIG. 1d, [0027].

68. *TS36* provides the formulae that are used for determining PF and PO in implementing paging in DRX – based on DRX parameters provided as portions of System Information (SI). Specifically, the system frame number (SFN) of the radio frame corresponding to PF is determined as:

SFN mod T= (T div N)*(UE_ID mod N)

An index i_s that points to the PO within the PF is determined as:

i_s = floor(UE_ID /N) mod Ns

Notably, the determination of the PF and PO depends explicitly on an identifier (UE_ID) of the UE – signifying that each UE has a designated PF and PO in a paging cycle. APPLE-1009, p.39.

69. *TS36* also shows how the determination of PO is affected by the location of the system bandwidth. For example, *TS36* describes that "if P-RNTI is transmitted on MPDCCH with system bandwidth > 3MHz", the paging occasions can be determined as per the following table (APPLE-1009, page 40, annotated):

UE-specific Paging Occasions

Number of UEs that can be paged using a paging frame

Ns	PO when i_s=0	PO when i_s=1	PO when i_s=2	PO when i_s=3
1	9	N/A	N/A	N/A
2	4	9	N/A	N/A
4	0	4	5	9

Paging occasions for a given UE depending on whether 1, 2, or 4 UEs are paged using a paging subframe

70. *TS36* further describes that "if P-RNTI is transmitted on MPDCCH with system bandwidth of 1.4MHz and 3MHz", i.e., for system bandwidths narrower than the previous case of bandwidth greater than 3 MHz, the corresponding paging occasions can be determined as per the following table (APPLE-1009, page 41, annotated):

UE-specific Paging Occasions

Number of UEs that can be paged using a paging frame

Ns	PO when i_s=0	PO when i_s=1	PO when i_s=2	PO when i_s=3
1	5	N/A	N/A	N/A
2	5	5	N/A	N/A
4	5	5	5	5

Paging occasions for the same UE depending on whether 1, 2, or 4 UEs are paged using a paging subframe

71. Thus, *TS36* describes that determination of the time intervals corresponding to the POs depends on the system bandwidth. It was also well-known to a POSITA as of the Critical Date that different system bandwidths could be allocated to different locations in the frequency domain (with the allocation varying over time). *See* for example, FIG. 1 of *Islam* (reproduced above), which shows that allocations change from one time period to another. APPLE-1016, FIG. 1. As such, *TS36* makes it clear that the determination of paging occasions depends explicitly on the width (and hence location) of the system bandwidth.

4. Combining Yeo and TS36

72. Although *Yeo* describes that a "PF is defined as one radio frame including one or more POs," and that a UE "can observe one PO per discontinuous reception (DRX) period," *Yeo* leaves out some implementation details – e.g., how a UE identifies the one or more POs in a PF. APPLE-1005, 53:14-17; APPLE-1006, [0455]. Yet, to implement the technology described in *Yeo*—for example, to have a UE monitor a PO where PDCCH is encoded with P-RNTI (as described with

respect to FIG. 3J)—a POSITA would look for such implementation details. However, such details were well-known by the Critical Date, for example, through technical specifications published by 3GPP working groups in the relevant technical areas. *Yeo* specifically mentions "long term evolution (LTE) or evolved universal terrestrial radio access (E-UTRA) of the 3GPP," (APPLE-1005, 11:48-49; APPLE-1006, [0036]) as well as paging operations of a UE in an idle mode (APPLE-1005, 3:39-59; APPLE-1006, [0013]), and a POSITA would have turned to *TS36* to implement these feature sets at least because *TS36* specifically provides the requisite technical specifications for the paging operations described in *Yeo*.

73. A POSITA would have known that the 3GPP Technical Specification Group (TSG) has already approved standardization that "specifies the Access Stratum (AS) part of the Idle Mode procedures applicable to a UE", which provides the paging details of UE in idle mode compatible with other aspects of the 3GPP cellular standard. APPLE-1009, p.6. Indeed, *TS36* bears the title "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode" and supplies details of the implementations that are missing from *Yeo*.

74. For example, while *Yeo* (i) describes the exact same equation for determining a PF as *TS36*, and (ii) notes that a PF includes "one or more POs," *Yeo* does not specifically describe how those "one or more POs" are determined by

a UE (*compare Yeo*'s "equation 3" in column 53 to the equation "SFN mod T= (T div N)*(UE_ID mod N)" on page 39 in *TS36*). *TS36* fills in this gap by describing that the index "i_s pointing to PO" is given by the equation "i_s = floor(UE_ID/N) mod Ns." A POSITA would have had a reasonable expectation of success in combining *Yeo* with *TS36* at least because the combination leads to the predictable result of determining the UE-specific POs within the PF of *Yeo*.

75. Overall, a POSITA would have referred to the equations and tables described in *TS36* to determine the implementations details associated with implementing the paging procedure described in *Yeo*. APPLE-1009, p.39-40. The combination would yield predictable results by allowing for different UE-specific POs within PFs of *Yeo*'s system as a function of the location of the paging subband.

5. Independent Claim 1

[1pre]: "A method in a User Equipment (UE) for paging, comprising:"

76. As shown in FIG. 3I and 3J (reproduced above), *Yeo* describes a method in a UE for paging, for example, to monitor a PDCCH in a paging occasion. APPLE-1005, FIGs. 3I and 3J, 52:50-54; APPLE-1006, FIGs. 5h and 5i, [0452]. The combination of *Yeo* with *TS36* at least renders this feature obvious.

[1a]:"monitoring a first signaling in X time intervals; and"

77. *Yeo* describes that a terminal or UE "[i]n order to observe the paging information, the terminal wakes up for a little while at a predetermined time interval to observe control signaling." APPLE-1005, 3:40-43; APPLE-1006, [0013]. *Yeo*'s "PDCCH configured as P-RNTI" constitutes or at least renders obvious the claimed "first signaling" because *Yeo* describes that in order to receive paging messages, "specific mapping location in the frequency domain, the modulation scheme, or the like may be determined based on the DCI transmitted through the PDCCH." APPLE-1005, 14:5-8, APPLE-1006, [0055]. The combination of *Yeo* with *TS36* at least renders this feature obvious.

78. *Yeo* defines each paging occasion "as a subframe in which the PDCCH [is] configured as the P-RNTI," and a paging frame as "one radio frame including one or more POs." APPLE-1005, 53:14-17; APPLE-1006, [0455]. As such, the time intervals associated with the POs in *Yeo* constitutes or at least render obvious the "X time intervals."

79. In the Complaint filed against Apple in the Western District of Texas, Patent Owner explicitly equates "first signaling" to"paging DCI" and "P-RNTI," and the "X time intervals" to "PDCCH monitoring occasions" – which, as described above, are described by *Yeo*. APPLE-1023, ¶¶81, 83, 85, 257. The combination of *Yeo* with *TS36* at least renders this feature obvious.

[1b]: "receiving a first radio signal;"

80. *Yeo* describes this limitation by disclosing that "[t]he paging message is transmitted through the PDSCH, and scheduling information on the PDSCH can be acquired from the PDCCH configured as P-RNTI." APPLE-1005, 53:48-51; APPLE-1006, [0013]. Here, the PDSCH containing the paging message constitutes or at least renders obvious the claimed "first radio signal" because *Yeo* describes that "downlink data may be transmitted on a physical downlink shared channel (PDSCH) that is a physical channel for downlink data transmission." APPLE-1005, 14:1-3; APPLE-1006, [0055]. From at least this description, a POSITA would have understood that the PDSCH is a radio signal. Indeed, this is also consistent with the position adopted by the Patent Owner in pending litigation. APPLE-1023, ¶¶81, 83, 84 (equating "first radio signal" to paging messages on PDSCH). The combination of *Yeo* with *TS36* at least renders this feature obvious.

[1c]: "wherein X is a positive integer;"

81. As discussed for [1a], *Yeo* describes a paging frame to include "one or more POs." APPLE-1005, 53:14-17; APPLE-1006, [0455]. A POSITA would have understood that the number of POs can only be positive

integers. The combination of *Yeo* with *TS36* at least renders this feature obvious.

[1d]: "the first signaling is used for determining scheduling information for the first radio signal;"

82. *Yeo* describes that "[t]he paging message is transmitted through the PDSCH, and scheduling information on the PDSCH can be acquired from the PDCCH configured as P-RNTI." APPLE-1005, 53:48-51; APPLE-1006, [0013]. As described with respect to limitations [1a] and [1b], *Yeo*'s "PDCCH configured as P-RNTI" constitutes or at least renders obvious the claimed "first signaling," and the PDSCH constitutes or at least renders obvious the claimed "first radio signal." As such, the foregoing portion of *Yeo* describes limitation [1d]. This is identical to what Patent Owner alleges in the pending litigation – noting that in the "Accused Products," "the first signaling (e.g., paging DCI, P-RNTI) is used for determining scheduling information for the first radio signal." APPLE-1023, ¶83, 258. The combination of *Yeo* with *TS36* at least renders this feature obvious.

[1e]: "the scheduling information comprises occupied time-frequency resource, adopted Modulation Coding Scheme (MCS), and subcarrier spacing of subcarriers in occupied frequency domain resource;"

Yeo describes using all three of the above parameters as portions of the scheduling information. *Yeo* describes that the "the scheduling

information…is transmitted…through downlink control information (DCI)," and in "DCI format 1" includes "at least one of the following control information":

- "Resource allocation type 0/1 flag:…The type 0 applies a bitmap scheme to allocate a resource in a resource block group (RBG) unit. In the LTE system, a basic unit of the scheduling is the resource block (RB) represented by a time-frequency domain resource and the RBG includes a plurality of RBs and thus becomes a basic unit of the scheduling in the type 0 scheme. The type 1 allocates a specific RB within the RBG."…
- "Modulation and coding scheme (MCS)"

APPLE-1005, 13:21-40; APPLE-1006, [0046]-[0048].

83. *Yeo* also describes embodiments in which the scheduling information includes "subcarrier spacing of subcarriers in occupied frequency domain resource." For example, *Yeo* describes that "the base station…can include information on the subcarrier spacing of the PDSCH…to which the contention resolution message is transmitted in the DCI transmitted to the PDCCH." This description is generic and not specific to or exclusive of paging messages. And

while the PDCCH described above is configured with C-RNTI, a POSITA would have readily understood that it is straightforward to extend the concept to other RNTI transmissions including DCI transmitted over PDCCH configured with P-RNTI such that the UE can detect and receive paging. APPLE-1005, 52:10-14, 38-40; APPLE-1006, [0450], [0228]. The combination of *Yeo* with *TS36* at least renders this feature obvious.

[1f]: "the first radio signal carries a paging message;"

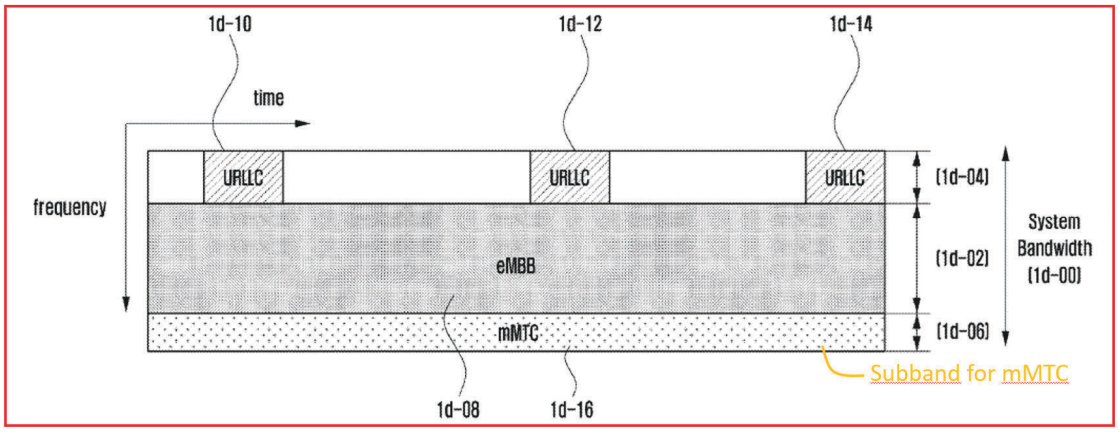
84. As discussed in [1b], *Yeo* describes that "[t]he paging message is transmitted through the PDSCH." APPLE-1005, 3:48-49; APPLE-1006, [0464]. The combination of *Yeo* with *TS36* at least renders this feature obvious.

[1g]: "the frequency domain resource used for transmitting the first signaling belongs to a first subband;"

85. *Yeo* in combination with *TS36* render obvious this feature. As described with respect to limitation [1a], *Yeo*'s "PDCCH configured as P-RNTI" constitutes or at least renders obvious the claimed "first signaling." *Yeo* further describes "mapping location in the frequency domain of the PDCCH maybe…transmitted over the entire system transmission bandwidth." APPLE-1005, 13:64-67; APPLE-1006, [0054]. As such, a POSITA would have readily

understood from this disclosure that the bandwidth for transmitting the PDCCH constitutes or at least renders obvious "the frequency domain resource."

86. Further, as discussed above, *Yeo* describes various types of UEs that are served by the wireless network, including UE type that supports massive machine type communication (mMTC), UE type that supports MIMO, UE type that supports enhanced mobile broadband (eMBB), and UE type that supports ultra-reliable and low-latency communications (URLLC). APPLE-1005, 2:13-23; APPLE-1006, [0004]. Massive MTC (mMTC) is a type of MTC that supports mass communications among connected devices. APPLE-1005, 29:5-7; APPLE-1006, [0211]. The frequency bands in use can vary with the type of devices/communications and associated requirements, and thus be allocated accordingly. APPLE-1005, FIG. 1D, 9:60-10:21; APPLE-1006, FIG. 1d, [0027]. *Yeo* describes—with reference to FIG. 1D (annotated below)—"the subband 1d-06…for mMTC data transmission." APPLE-1005, 16:24-36.; APPLE-1006, [0168].



Yeo, FIG. 1D, Annotated

87. It was well known to a POSITA as of the Critical Date that "a downlink (DL) means a radio transmission path of a signal transmitted from a base station to a terminal," and a "Master information block (MIB)…includes…[i]nformation on downlink cell bandwidth." APPLE-1005, 18:56-57, 45:29-35; APPLE-1006, [0182], [0391]-[0394]. It was also well-known as of the Critical Date that downlink information is transmitted over DL transport channels which could include "a Broadcast Channel (BCH), Downlink Shared Data Channel (DL-SDCH) and a Paging Channel (PCH)." APPLE-1021, [0043].

88. A POSITA would have understood from the description of *Yeo* alone that because the mMTC transmissions occur within the subband 1d-06, the subband 1d-06 would include the associated DL transport channels including the associated PCH, and the paging transmissions and receptions for mMTC would

also take place within the subband 1d-06. Further, *TS36* describes that for MTC (which mMTC is a type of), the PDCCH (referred to as MPDCCH) is monitored in a narrower band (referred to as the paging narrowband PNB) within the subband 1d-06. As such, a subband for a specific service – such as the subband 1d-06 for mMTC constitutes or at least renders obvious the claimed "first subband." APPLE-1009, p.39-40.

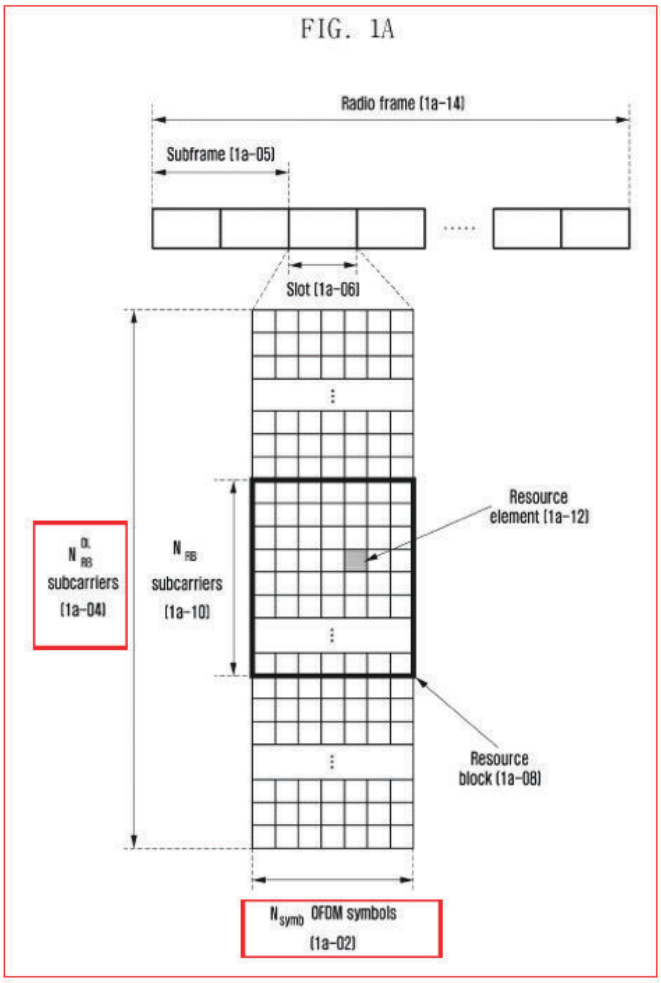
89. As discussed above, although *Yeo* describes paging mechanism in general, as well as a different subband for mMTC services, *Yeo* leaves out some implementation details, e.g., those specific to the mMTC services. For example, while *Yeo* describes—in the context of paging—that a paging frame "PF is defined as one radio frame including one or more [paging occasions] POs," and that a UE "can observe one PO per discontinuous reception (DRX) period," *Yeo* does not specifically describe how a paging channel is determined for particular services such as mMTC. *TS36* provides these details and fills the gap for mMTC paging by describing that "[i]f P-RNTI is monitored on MPDCCH, the PNB is determined by the following equation: PNB = floor(UE_ID/(N*Ns)) mod Nn." A POSITA would have understood that the PNB refers to the band associated with the paging channel, and as such, would have had a reasonable expectation of success in combining *Yeo* with *TS36* a least because a POSITA would have recognized that

the combination leads to the predictable result of implementing the paging channels in mMTC as described in *Yeo*. As such, *Yeo* in view of *TS36* renders obvious the foregoing feature.

[1h]: "the first subband comprises a positive integer number of consecutive subcarriers in frequency domain; and"

90. *Yeo* describes that information in a "data or a control channel is transmitted" using "a basic structure of a time-frequency domain that is a radio resource region" as shown in FIG. 1D (annotated below) – which shows the arrangement of OFDM symbols within a slot of a subframe, and that each OFDM symbol includes a positive integer number of consecutive subcarriers. APPLE-1005, 12:20-34; APPLE-1006, [0039]-[0040]. *Yeo* also describes that "[the DCI] may be transmitted within first N OFDM symbols within the subframe." Because *Yeo* describes that DCI is "transmitted through the PDCCH," (*see* APPLE-1005, 14:1-8; APPLE-1006, [0055]), and the PDCCH is transmitted in a service-specific subband (*see* discussion related to limitation [1g]), a POSITA would have readily understood that the service-specific subband would include the subcarriers associated with the corresponding OFDM symbols – the subcarriers constituting "a positive integer number of consecutive subcarriers in frequency domain." APPLE-1005, FIG. 1A, 12:35-41; APPLE-1006, FIG. 1a, [0060]. The combination of *Yeo* with *TS36* at least renders this feature obvious.

91.



[1i]: "location of the first subband in frequency domain is used for determining the X time intervals."

92. As described with respect to limitation [1a], the time intervals associated with the paging occasions (POs) in *Yeo* constitutes or at least render obvious the "X time intervals." However, although *Yeo* describes that a "PF is defined as one radio frame including one or more POs," and that a UE "can observe one PO per discontinuous reception (DRX) period," *Yeo* does not

explicitly specify how a UE identifies the one or more POs. APPLE-1005, 53:14-17; APPLE-1006, [0455]. Specifically, while *Yeo* (i) describes the exact same equation for determining a PF as *TS36*, and (ii) notes that a PF includes "one or more POs," *Yeo* does not specifically describe how those "one or more POs" are determined by a UE. *TS36* fills in this gap by describing that the index "i_s pointing to PO" is given by the equation "i_s = floor(UE_ID/N) mod Ns.".

93. Further, *Yeo* also describes that the above 4G concepts can be extended to support various types of services such as enhanced mobile broadband (eMBB), mMTC, ultra-reliable and low-latency communications (URLLC), etc.—as supported by 5G NR—and the requirements for such services can vary. APPLE-1005, 10:10-21; APPLE-1006, [0027]. Indeed, *Yeo* also describes—with reference to its FIG. 1D (reproduced above)—dividing the system frequency bands into corresponding subbands for different services, with mMTC occupying subband 1d-06, for example. APPLE-1005, 16:24-37; APPLE-1006, [0168].

94. To the extent *Yeo* does not describe the details of how the time intervals associated with the one or more POs are determined for the individual subbands, such details were well-known to a POSITA as of the Critical Date, and the details make it clear that the location of the corresponding subband is used in

determining the time intervals associated with the one or more POs. Specifically, *TS36* covers implementation details that specify locations of "one or multiple Paging Occasion(s)" within a paging frame, and shows how the location of the one or more POs vary depending on the location of the subband. APPLE-1009, p.39-40. For example, and as discussed in **V.2** *supra*, *TS36* shows that for otherwise-same operating parameters, the POs are different in a subband in the 1.4MHz-3MHz range as compared to the POs in a subband that is above 3MHz. APPLE-1009, p.39-40. Specifically, *TS36* describes that "if P-RNTI is transmitted on MPDCCH with system bandwidth > 3MHz" (i.e., system bandwidth greater than 3MHz), the paging occasions can be determined as per the following table:

UE-specific Paging Occasions

Number of UEs that can be paged using a paging frame

Ns	PO when i_s=0	PO when i_s=1	PO when i_s=2	PO when i_s=3
1	9	N/A	N/A	N/A
2	4	9	N/A	N/A
4	0	4	5	9

Paging occasions for a given UE depending on whether 1, 2, or 4 UEs are paged using a paging subframe

On the other hand, "if P-RNTI is transmitted on MPDCCH with system bandwidth of 1.4MHz and 3MHz" (i.e., system bandwidth smaller than or equal to 3MHz), the corresponding paging occasions can be determined as per the following table:

UE-specific Paging Occasions

Number of UEs that can be paged using a paging frame

Ns	PO when i_s=0	PO when i_s=1	PO when i_s=2	PO when i_s=3
1	5	N/A	N/A	N/A
2	5	5	N/A	N/A
4	5	5	5	5

Paging occasions for the same UE depending on whether 1, 2, or 4 UEs are paged using a paging subframe

APPLE-1009, p.40-41, annotated.

As such, *Yeo* in view of *TS36* renders obvious that the determination of one or more POs—depends explicitly on the system bandwidth. A POSITA would have readily understood that a change in system bandwidth necessarily results in a change in one or both boundaries of the corresponding frequency band, and hence, in a change of location of the system band. Further, a POSITA would have also understood that the designated band for a specific type of device/service (e.g., mMTC) would be the subband allocated to that type of device/service (e.g., the subband 1d-06 discussed with reference to feature [1g]) *Id*. For at least these reasons, a POSITA would have readily understood from the teachings of *Yeo* in view of *TS36*, that the determination of one or more POs depends on a location of the system band corresponding to the type of device/service (e.g., mMTC), and as such, the combination of the references renders obvious using a "location of the first subband in frequency domain" to determine the X time intervals.

6. Claim 5

[5a]: "The method according to claim 1, further comprising: receiving a second radio signal;"

95. *Yeo* describes that "data for eMBB, URLLC, and mMTC, which are services to be considered in a 5G or NR system are allocated in frequency-time resources," and also specifically "allocating frequency and time resources for information transmission in each system." APPLE-1005, 15:64-16:3; APPLE-1006, [0165]-[0166]. *Yeo* also describes that "base station is the subject performing resource allocation of a terminal," and that "downlink (DL) means a radio transmission path of a signal transmitted from a base station to a terminal." APPLE-1005, 18:48-50; APPLE-1006, [0182]. Because *Yeo* is directed to wireless communications, a POSITA would have readily understood from these disclosures, that any frequency allocation (e.g., the subband allocation depicted in FIG. 1C and 1D) would be communicated over a radio signal that would constitutes or at least render obvious "the second radio signal." Specifically, *Yeo* describes that "the system information is transmitted in two ways over two different transmission channels. Master information block (MIB): transmission using PBCH 3d-03" and "System information block (SIB): transmission using PDSCH 3d-04." APPLE-1005, 45:27-32; APPLE-1006, [0390]-[0392].

96. Patent Owner's infringement contentions in the related litigation proceeding equates the "second radio signal" to both "MIB information element" as well as a "BCH/BCCH channel." *Yeo* specifically describes—with reference to FIG. 3D—"a physical broadcast channel (PBCH)…to which a master information block (MIB)…is transmitted." The MIB includes "[i]nformation on downlink cell bandwidth." APPLE-1005, 45:29-35; APPLE-1006, [0391]. The combination of *Yeo* with *TS36* at least renders this feature obvious.

[5b]: "wherein the second radio signal is used for determining at least one of location of the first subband in frequency domain, or subcarrier spacing of subcarriers included in the first subband;"

97. As discussed for limitations [5a], frequency allocation information (e.g., "location of the first subband" depicted in FIG. 1D) would be communicated as system information over "the second radio signal" communicated over a physical broadcast channel PBCH. Such a radio signal would be used by an UE to decode bandwidth for communicating with a base station. For example, *Yeo* describes that "MIB transmitted through the PBCH…includes…[i]nformation on downlink cell bandwidth," which is then used for communicating DCI information– thereby disclosing the above feature. APPLE-1005, 45:33-35; APPLE-1006, [0393]-[0394]. The combination of *Yeo* with *TS36* at least renders this feature obvious.

[5c]: "the second radio signal carries Master Information Block (MIB) information, or the second radio signal carries System Information Block (SIB) information."

98. As discussed for limitation [5a], frequency allocation information (e.g., "location of the first subband" depicted in FIG. 1D) would be communicated as system information over "the second radio signal" communicated over a physical broadcast channel PBCH. *Yeo* describes that "for the purpose of establishing a radio link with a base station…synchronization with a cell in a network is acquired, and a master information block (MIB) is acquired by physical broadcast channel (PBCH) decoding. The MIB contains the most basic information for connection to the system. Based on the information, a physical downlink control channel (PDCCH) and a physical downlink shared channel (PDSCH) are decoded to obtain a system information block(SIB)." APPLE-1005, 3:17-27; APPLE-1006, [0012]. As such, *Yeo* in combination with *TS36* renders obvious the above limitation.

7. Claim 7

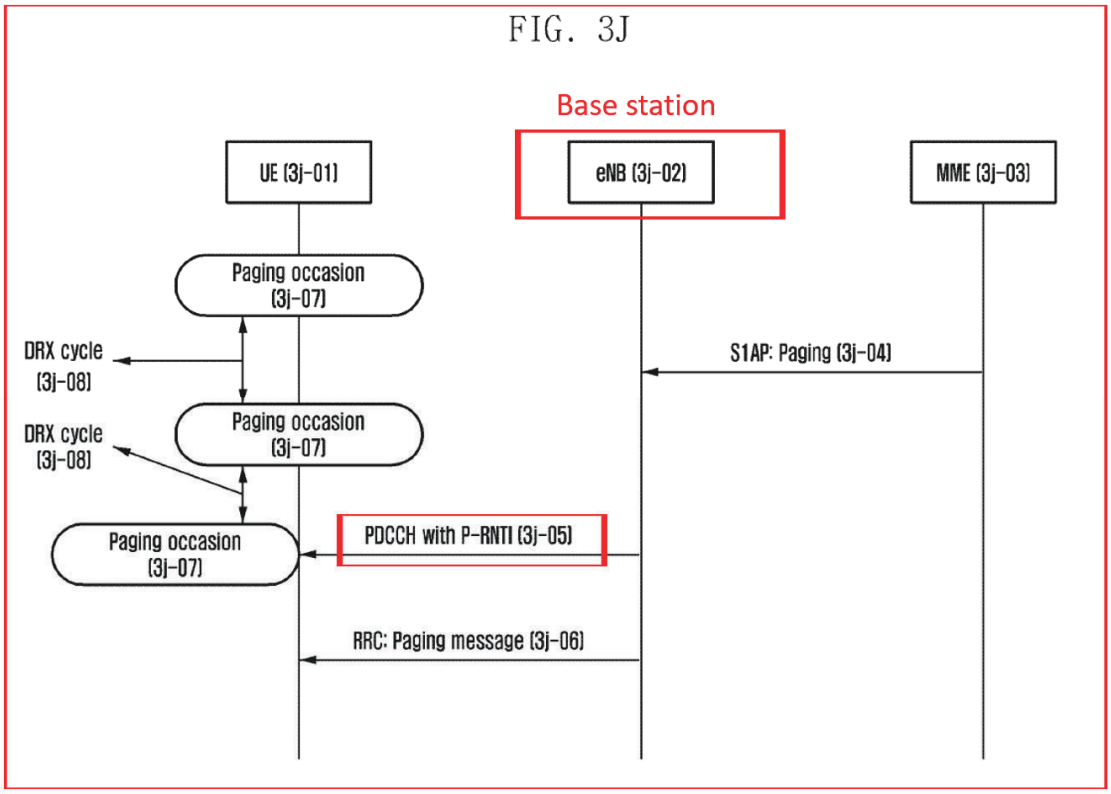
[7pre]: "A method in a base station for paging, comprising:"

99. As discussed for claim [1pre], *Yeo* describes a method in a UE for paging, to monitor a PDCCH in a paging occasion. *Yeo* also describes the paging process from the perspective of a base station. APPLE-1005, FIG. 3L; APPLE-

1006, FIG. 5k. The combination of *Yeo* with *TS36* at least renders this feature obvious.

[7a]: "transmitting a first signaling in a positive integer number of time intervals of X time intervals; and"

100. As discussed for claim [1a], *Yeo* describes monitoring a PDCCH configured as P-RNTI (claimed "first signaling") in paging occasions - the time intervals for which correspond to the claimed X time intervals. *Yeo* also describes transmitting the PDCCH configured as P-RNTI from a base station eNB. APPLE-1005, FIG. 3J (annotated below); APPLE-1006, FIG. 5i. The combination of *Yeo* with *TS36* at least renders this feature obvious.



[6b]: "transmitting a first radio signal;"

101. As discussed for limitation [1b], *Yeo* describes that "[t]he paging message is transmitted through the PDSCH, and scheduling information on the PDSCH can be acquired from the PDCCH configured as P-RNTI." APPLE-1005, 53:48-51; APPLE-1006, [0013]. A POSITA would have understood that the PDSCH is a radio signal. The combination of *Yeo* with *TS36* at least renders this feature obvious.

Remaining limitations of claim 7

102. The remaining limitations of claim 7 are substantially similar to limitations [1c]-[1i] of claim 1, and thus are respectively rendered obvious by *Yeo* and *TS36* for the same reasons discussed above for limitations [1c]-[1i]. See claim comparison tables provided above.

8. Claim 11

103. The *Yeo/TS36* combination renders obvious claim 7. The remaining limitations of claim 11 are substantially similar to claim 5, and thus are rendered obvious by *Yeo* in view of *TS36* for the reasons discussed for claim 5.

9. Claims 13 and 17

104. The *Yeo/TS36* combination renders obvious each of these claims. Independent claim 13 is substantially similar to claim 1, except it is an apparatus claim directed to "[a] UE for paging," and requires (1) "a first receiver" to monitor a first radio signaling in X time intervals, and (2) "a second receiver" to receive a first radio signal. *Yeo* in combination with *TS36* renders obvious these apparatus-related limitations as I show below.

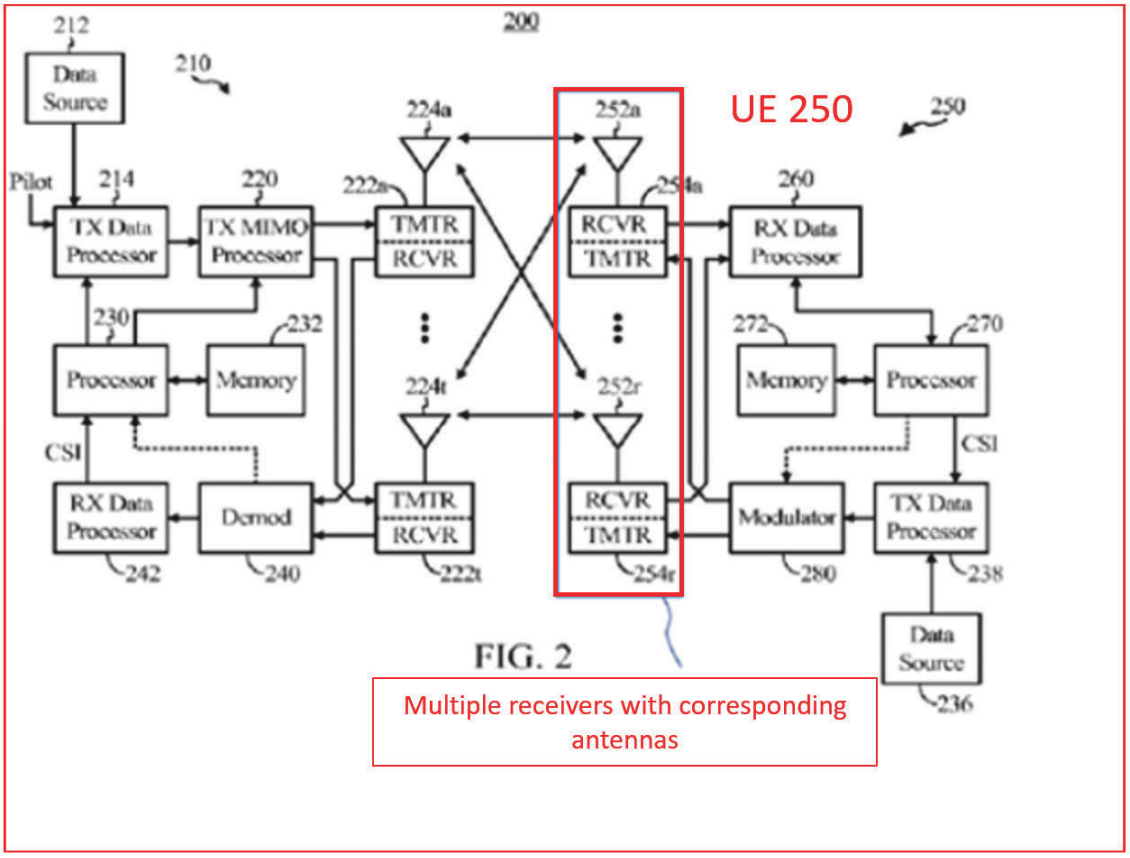
"A UE for paging"

105. *Yeo* describes a UE executing a paging process. APPLE-1005, FIG. 3J; APPLE-1006, FIG. 5i.

"a first receiver" and "a second receiver"

106. *Yeo*'s "block diagram of a structure of a terminal transceiver" renders obvious the above limitations. APPLE-1005, FIG. 3Q; APPLE-1006, FIG. 5m. *Yeo* specifically notes the a "terminal may include user equipment (UE), a mobile station (MS), a cellular phone, a smart phone, a computer, or a multimedia system performing a communication function." APPLE-1005, 18:52-55; APPLE-1006, [0182]. *Yeo* further describes that a "terminal receiver…and the terminal transmitter…may collectively be referred to as a transceiver," and "the transceiver may include…an RF receiver" that "may receive a signal through a radio channel and output the received signal to the terminal processor." I note that the claim

does not require the second receiver to be different from the first receiver. Further, a POSITA would have understood that the PDCCH and PDSCH are transmitted on different time-frequency resources, and hence a PDCCH reception and a PDSCH reception would process corresponding received signals separately. Indeed, *Yeo* specifically describes transmitting and receiving DCI information on PDCCH by "spatial multiplexing using…multiple antenna," APPLE-1005, 13:11-24; APPLE-1006, [0144]. A POSITA would have reasonably envisaged or gleaned as obvious from this that multiple receiver circuits are connected, respectively, to multiple antennas, with each receiver circuit being used to process the signal received from its respective antenna. *Id*. Such parallel processing of the antenna signals was well-known to a POSITA as of the Critical Date, (*see* APPLE-1021, Fig. 2 (annotated below - showing one receiver at each antenna)), and would allow *Yeo*'s terminal receiver to simultaneously decode and demodulate the signals received from multiple receive antennas, thereby improving the system speed. *Id.*, [0037]-[0038].



Luo, Fig. 2., Annotated.

107. Therefore, *Yeo-TS36* renders obvious multiple receivers, each including a receive antenna and an associated receiver circuit that includes a transmitter, a receiver and one or more processors. APPLE-1005, FIG. 3Q; APPLE-1006, FIG. 5m. A POSITA would have reasonably expected to succeed in providing two receivers, each receiving the claimed "first signaling" and "first radio signal" respectively, in *Yeo*'s UE because multiple receivers receiving these signals were conventional and routine in the MIMO antennas

described in *Yeo*, APPLE-1005, 1:32-40; APPLE-1006, [0002]; APPLE-1021, Fig. 2. As such, the combination represents nothing more than known components operating according to their ordinary and expected functions to yield predictable results (receiving signals).

Remaining limitations of claims 13 and 17

108. Given the similarity between claims 1 and 13, the remaining features of claim 13 are respectively rendered obvious for the same reasons discussed above for the corresponding features of claim 1. See claim comparison tables provided above.

109. Similarly, claims 5 and 17 are similar to one another and claim 17 is obvious for the same reasons discussed above with respect to claim 5, respectively. See claim comparison tables provided above.

10. Claims 19 and 23

110. The *Yeo/TS36* combination renders obvious each of these claims. Independent claim 19 is substantially similar to claim 7, except it is an apparatus claim directed to a base station for paging, and requires (1) "a first transmitter" to transmit a first signaling in a positive integer number of time intervals of X time intervals, and (2) "a second transmitter" to transmit a first

radio signal. *Yeo* in combination with *TS36* renders obvious these apparatus-related limitations..

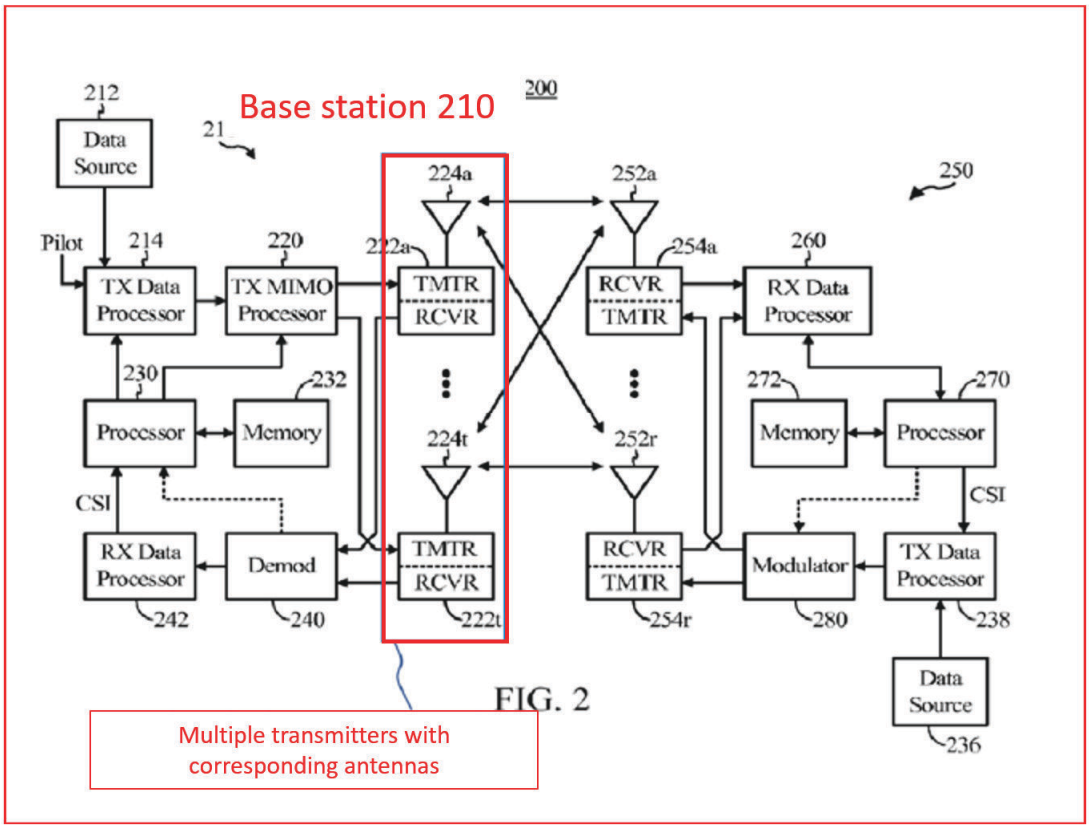
"A base station for paging"

111. *Yeo* describes a base station executing a paging process. APPLE-1005, FIG. 3J (*see* annotated version above); APPLE-1006, FIG. 5i.

"a first transmitter" and "a second transmitter"

112. *Yeo*'s "block diagram of a structure of a base station transceiver" renders obvious the above limitations. APPLE-1005, FIG. 3R; APPLE-1006, FIG. 5n. *Yeo* further describes that a "base station receiver…and the base station transmitter…are collectively referred to as a transceiver," and that "the transceiver may include…an RF transmitter" that may "transmit the signal output from the base station processor." I note that the claim does not require the second transmitter to be different from the first transmitter. Further, a POSITA would have understood that the PDCCH and PDSCH are transmitted on different time-frequency resources, and hence a PDCCH transmission and a PDSCH transmission would process corresponding received signals separately. Indeed, *Yeo* specifically describes transmitting and receiving DCI information by "spatial multiplexing using…multiple antenna," APPLE-1005, 13:11-24; APPLE-1006, [0045]. A POSITA would have reasonably envisaged or gleaned as obvious from this that

multiple transmitter circuits are connected, respectively, to multiple antennas, with each transmitter circuit being used for transmitting signals through the respective transmit antenna. Such parallel processing of the antenna signals was well-known to a POSITA as of the Critical Date (*see* APPLE-1021, Fig. 2 (annotated below - showing one transmitter for each antenna)), and would allow *Yeo*'s base station to simultaneously transmit signals through multiple transmit antennas, thereby implementing a MIMO system. *Id.*, [0035]-[0036].



Luo, Fig. 2., Annotated

113. Therefore, *Yeo* in combination with *TS36* renders obvious multiple transmitters, each including a transmit antenna and an associated transmitter circuit. A POSITA would have reasonably expected to succeed in providing two transmitters, each transmitting the claimed "first signaling" and "first radio signal" respectively, in *Yeo*'s base station because multiple transmitters transmitting these signals were conventional and routine in the MIMO antennas described in *Yeo*, APPLE-1005, 1:32-40; APPLE-1006, [0002]; APPLE-1021, Fig. 2. As such, the combination represents nothing more than known components operating according to their ordinary and expected functions to yield predictable results (receiving signals).

Remaining limitations of claims 19 and 23

114. Given the similarity between claims 7 and 19, the remaining features of claim 19 are respectively rendered obvious for the same reasons discussed above for the corresponding features of claim 7. See claim comparison table provided above.

115. Similarly, claims 11 and 23 are similar to one another and claim 23 is obvious for the same reasons discussed with respect to claim 11. See claim comparison table provided above.

B. [Ground 2] Claims 2, 3, 7, 8, 12, 13, 17, and 18 Are Obvious over *Yeo*, *TS36*, and *Mallick*

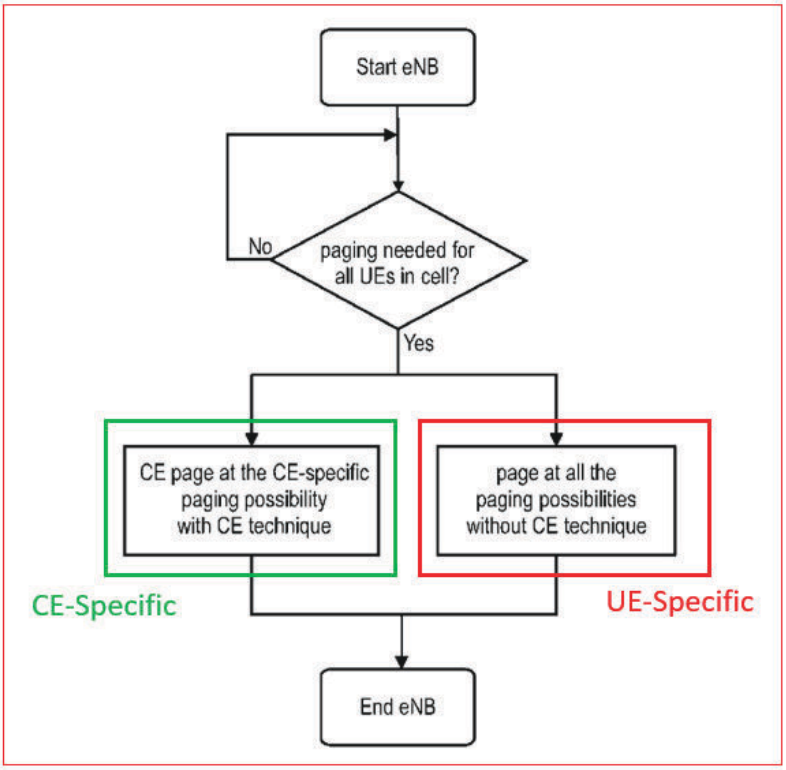
1. Overview of *Mallick*

116. Similar to *Yeo*'s description of mMTC for coverage enhancement (see APPLE-1005, 41:61-67; APPLE-1006, [0309]), *Mallick* discusses using coverage extension (CE) to page MTC devices (APPLE-1008, Abstract, [0140]-[0141], [0145]). *Mallick* also explains that "[c]overage [e]xtension" is another term for coverage enhancement. *Id.*, [0060]. *Mallick* recognizes that CE requires repeated transmission of paging control information and/or increased power, imposing a heavier burden on the base station than normal coverage. *Id.*, [0072], [0078], [0151]. To alleviate this problem, instead of indiscriminately applying CE to all UEs in a cell and at all the possible paging occasions, *Mallick* proposes limiting CE to only a selected group of UEs at a subset of the paging occasions. *Id.*, [0160].

117. Specifically, the UEs in a cell covered by a base station are divided into UEs that experience bad radio conditions and thus require CE ("CE-UEs"), and normal UEs that do not require CE ("non-CE-UE[s]"). *Id.*, [0075], [0135]. As shown in Figure 7, the base station (i.e., eNB) may page all the UEs in its cell (including the CE-UEs and non-CE-UEs) at UE-specific paging

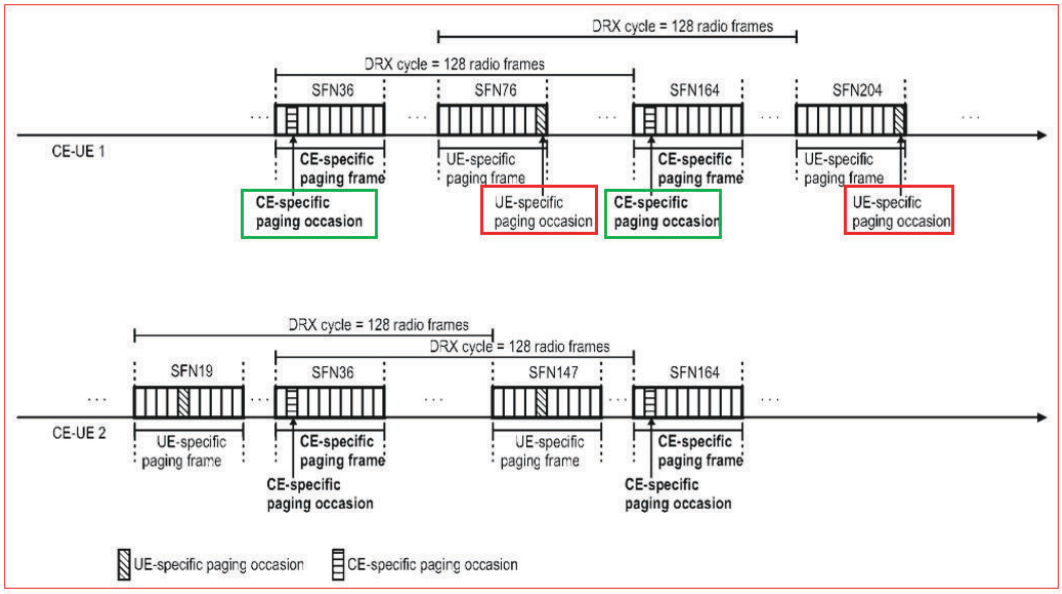
possibilities without using the CE technique. *Id*., [0146], [0159], Fig. 7. Additionally, the eNB also pages the CE-UEs at CE-specific paging possibilities by using the CE technique. *Id*. The term "paging possibility" refers to the combination of a paging frame (i.e., a radio frame) and a paging occasion (i.e., one or more subframes within the paging frame). *Id*., [0024], [0072], [0148], [0161].

118. The UE-specific paging possibilities are determined based on the ordinary UE identifiers (UE-specific IDs), in the same way defined in the 4G/LTE standards, and thus are specific to the UEs. *Id*., [0025]-[0029], [0148]. The CE-specific paging possibilities may be determined based on a CE-specific ID common to a group of CE-UEs, and thus are the same for these CE-UEs. *Id*., [0079], [0093], [0101], [0107], [0148], [0169]-[0170], claim 5.



Mallick., Fig. 7., Annotated

119. Figure 5 shows two CE-specific UEs monitoring the normal paging PDCCHs at different UE-specific paging possibilities, and monitoring the CE paging PDCCHs at the same CE-specific paging possibilities. *Id*., [0157]-[0158]. Meanwhile, non-CE-UEs (not shown) only monitor their respective UE-specific paging possibilities. *Id*., [0148], [0154].



Mallick, Fig. 5., Annotated

120. By limiting the CE to the CE-specific paging possibilities, the downlink resources can be saved and the burden on the base station can be reduced. *Id*., [0078], [0160], [0174]-[0175].

121. *Mallick* is analogous art to the ’581 patent because *Mallick*, like the ’581 patent, describes methods for a UE to monitor paging scheduling information for a number of times. *Compare Id.*, [0001], [0139], [0152], *with* APPLE-1001, Abstract, 2:40-54.

2. Combining *Yeo/TS36* with *Mallick*

122. A POSITA would have been motivated to combine *Yeo/TS36* with *Mallick*’s improved CE paging procedure, including its description about how

to determine the UE-specific paging possibilities and CE-specific paging possibilities. *Mallick*, *Yeo*, and *TS36* are all related to paging/DRX procedure in MTC UEs that are compliant with 3GPP 4G/LTE or 5G/NR standards. APPLE-1005, 53:8-20; APPLE-1006, [0455]; APPLE-1009, p.39-40; APPLE-1008, Abstract, [0143], [0145]. *Mallick* describes that limiting the CE to CE-UEs and the CE-specific paging possibilities can save downlink resources and reduce the burden on the base station. APPLE-1008, [0078], [0160], [0174]-[0175]. Moreover, for a higher granularity, *Mallick*'s CE-specific IDs and CE-specific paging possibilities can be further classified according to the CE levels, such that a CE-UE can skip monitoring the CE-specific paging possibilities not associated with its CE level, thereby reducing the CE-UE's power consumption. *Id*., [0169]-[0172]. And *Yeo* describes coverage enhancement of UEs specifically for mMTC in 5G. APPLE-1005, 41:61-67; APPLE-1006, [0309]. Thus, a POSITA would combine *Mallick*'s advantageous CE design to improve the implementations contemplated by the *Yeo*/*TS36* combination. A POSITA would have a reasonable expectation of success in combining *Yeo*/*TS36* with *Mallick* because it only requires combining elements according to known methods. Indeed, *Mallick*'s equations "SFN mod T=(T div N)*(UE_ID mod N)" to determine the paging frame number SFN, and "i_s= floor(UE_ID/N) mod Ns" to determine the paging occasion index i_s are identical to the

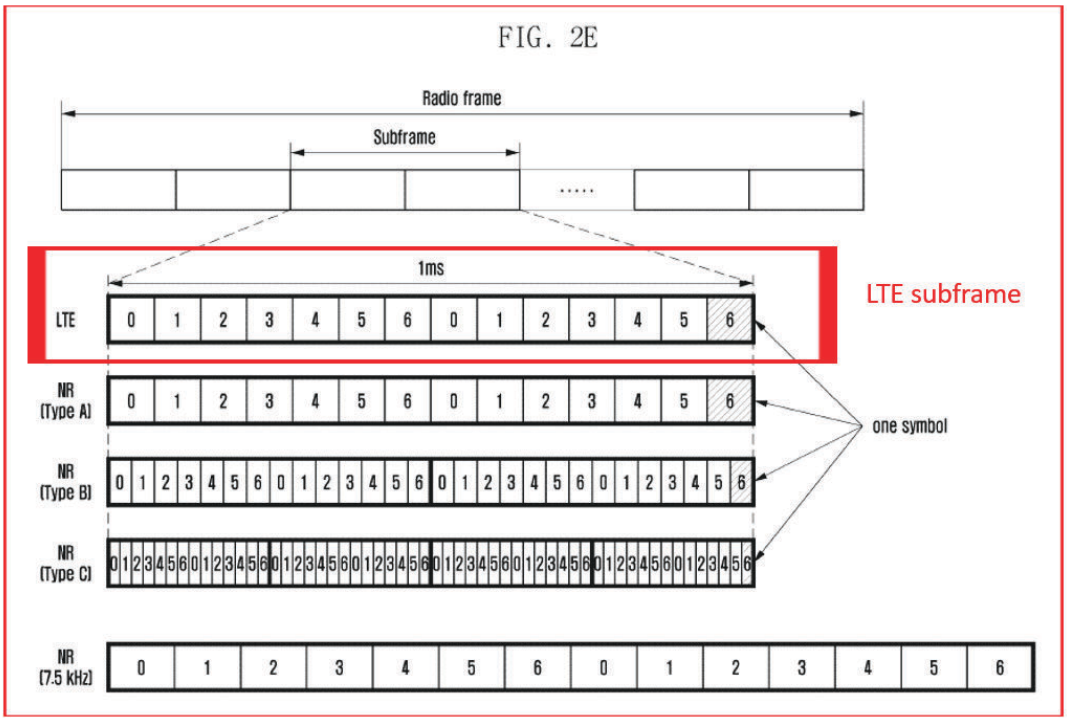
corresponding equations described in *TS36*. A POSITA would have a reasonable expectation of success in combining *Mallick* with the *Yeo/TS36* combination at least because *Mallick* explicitly refers to an earlier version of the *TS36* as the specification relied on for determining paging occasions. APPLE-1008, [0025]-[0028]; APPLE-1009, p.39-40. A POSITA would also have understood that the combination would lead to predictable results by reducing the burden on a base station and/or power consumption in certain UEs—as described by *Mallick*—in the paging/DRX procedure in MTC UEs, as described by the *Yeo*/*TS36* combination.

3. Claim 2

[2a]: "The method according to claim 1, wherein any one of the X time intervals belongs to a first time window in time domain;"

123. As discussed with respect to [1a], *Yeo* defines each paging occasion "as a subframe in which the PDCCH [is] configured as the P-RNTI," and a paging frame as "one radio frame including one or more POs." APPLE-1005, 53:14-17; APPLE-1006, [0455]. *Yeo* also describes that "a radio frame…is a time domain unit which includes 10 subframes." APPLE-1005, 30:11-12; APPLE-1006, [0372]. As such, for LTE (having a subframe duration of 1 ms)—as shown in FIG. 2E of *Yeo* (annotated below)—the radio frame length is 10 ms. The 10 ms time window corresponding to an LTE frame

constitutes or at least renders obvious the claimed "first time window." APPLE-1005, FIG. 2E; APPLE-1006, FIG. 3e. The combination of *Yeo/YS36/Mallick* renders this feature obvious.



[2b]: "the time length of the first time window is predefined;"

124. As noted with reference to limitation [2a], the duration of an LTE frame is 10 ms – which is a predefined time window. Thus, *Yeo*/TS36/Mallick renders obvious that the time length of the first time window is predefined.

[2c]: "the first time window is divided into Y time intervals;"

125. *Yeo* describes that the 10 ms time window is divided into multiple time intervals and the number of time intervals depends on the subframe type.

For example, in a frame structure Type A, the subframe size is 1 ms, and the number of time intervals is Y=10; in a frame structure Type B, the subframe size is 0.5 ms, and the number of time intervals is Y=20; in a frame structure Type C, the subframe size is 0.25 ms, and the number of time intervals is Y=40. APPLE-1005, 30:67-31:15; APPLE-1006, [0224]. The combination of *Yeo/YS36/Mallick* renders this feature obvious.

[2d]: "the X time intervals are X time intervals of the Y time intervals, Y being a positive integer not smaller than X;"

126. As discussed with respect to [1a], *Yeo* defines each paging occasion "as a subframe in which the PDCCH [is] configured as the P-RNTI," and a paging frame as "one radio frame including one or more POs." APPLE-1005, 53:14-17; APPLE-1006, [0455]. *Yeo* further describes that the duration of a subframe is 1 ms, 0.5 ms, or 0.25 ms, depending on whether the NR frame structure is of Type A, Type B, or Type C, respectively – resulting in the following parameters within the **10 ms "first time window"**:

NR frame type	Subframe duration	No. of subframes or Y time intervals per 10 ms time window	No. of frames or paging occasions (X) per 10 ms time window
Type A	1 ms	10	1
Type B	0.5 ms	20	2
Type C	0.25	40	4

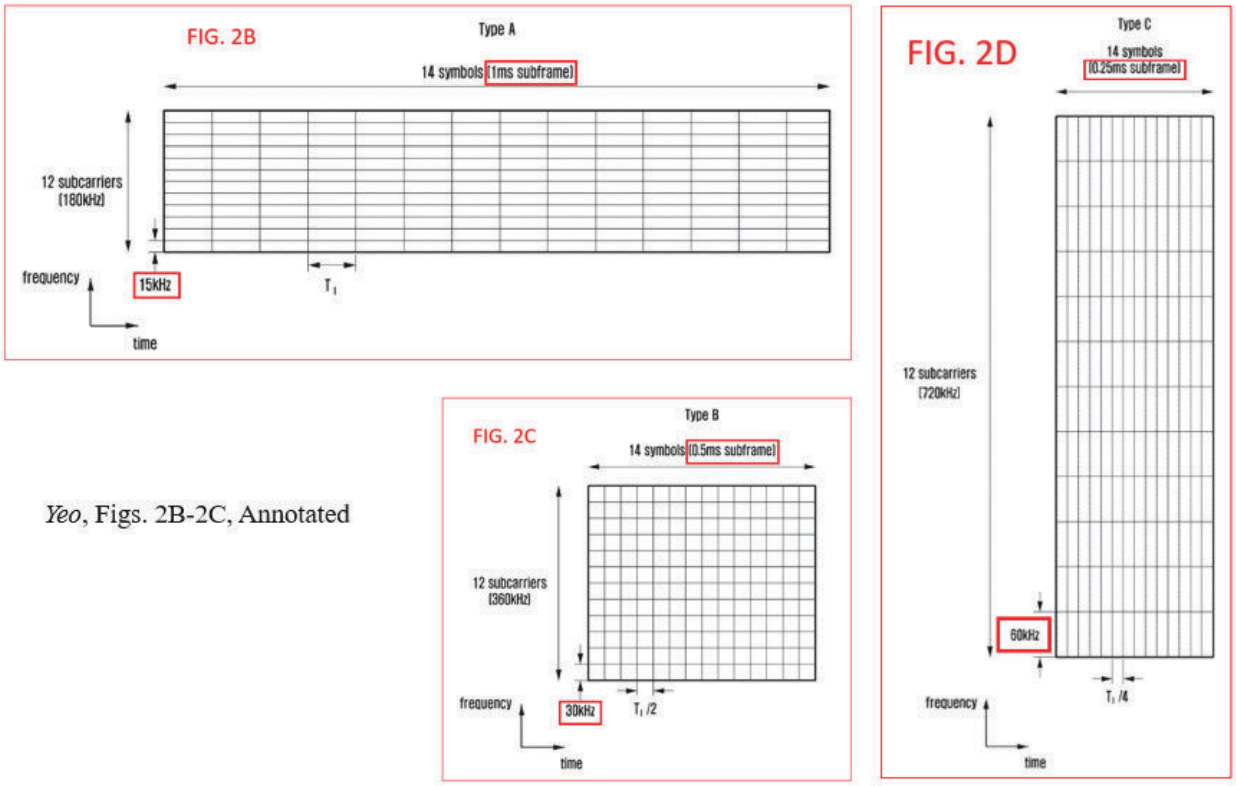
APPLE-1005, 30:67-31:15; APPLE-1006, [0224].

127. Because for each frame type, the number of paging occasions X is one of the subframes corresponding to the Y time intervals, *Yeo* describes the foregoing feature. The combination of *Yeo/YS36/Mallick* renders this feature obvious.

[2e]: "the subcarrier spacing of subcarriers included in the first subband is used for determining Y; and"

128. As shown with respect to limitation [2d], the number of Y time intervals within the 10 ms "first time window" depends on the subframe duration. *Yeo* further describes with respect to FIGs. 2B, 2C, and 2D (reproduced below with annotations) that the duration of the subframe in turn depends on the subcarrier spacing. Specifically, *Yeo* describes that "in a frame structure type A, subcarrier spacing is 15 kHz, a subframe of 1 ms includes 14 symbols"; "in a frame structure type B, the subcarrier spacing is 30 kHz, a

subframe of 0.5 ms includes 14 symbols"; and "in a frame structure type C, subcarrier spacing is 60 kHz, a subframe of 0.25 ms includes 14 symbols." APPLE-1005, 30:67-31:15; APPLE-1006, [0224]. For at least the foregoing reasons, *Yeo* describes that the Y intervals are determined based on the subcarrier spacing of subcarriers included in the first subband. The combination of *Yeo/YS36/Mallick* renders this feature obvious.



Yeo, Figs. 2B-2C, Annotated

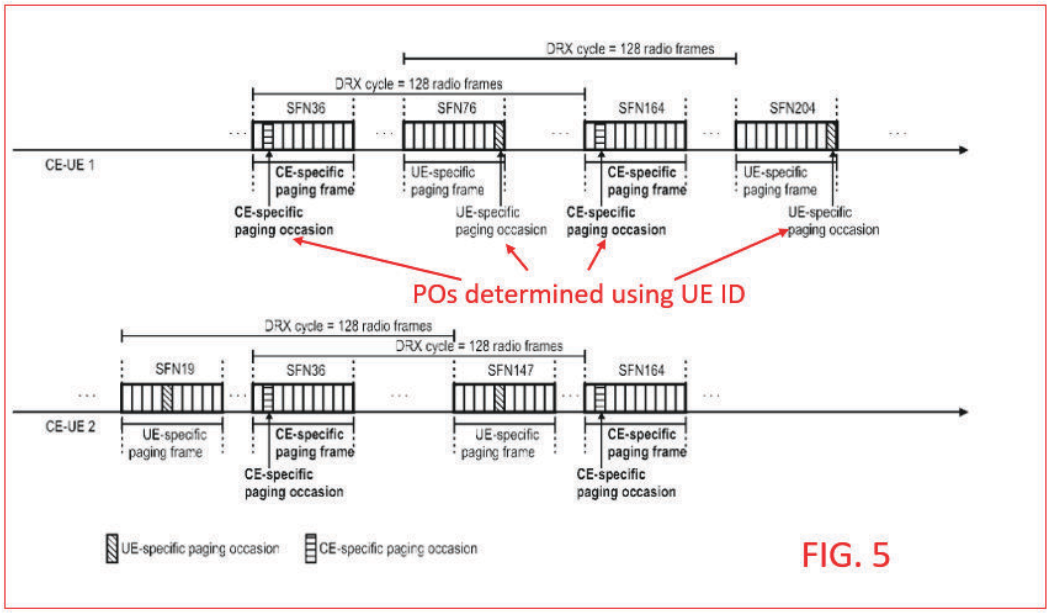
[2f]: "a feature ID of a monitor of the first signaling is used for determining the X time intervals in the Y time intervals,"

129. *Yeo* in view of *TS36* and *Mallick* renders obvious this limitation. As discussed for limitation [1a], *Yeo*'s "PDCCH configured as P-RNTI"

constitutes or at least renders obvious the claimed "first signaling." APPLE-1005, 14:5-8, APPLE-1006, [0055]. *Yeo* further defines the "subframe in which the PDCCH [is] configured as the P-RNTI," as a paging occasion and a paging frame as "one radio frame including one or more POs," APPLE-1005, 53:14-17; APPLE-1006, [0455]. However, while *Yeo* (i) describes the exact same equation for determining a PF as *TS36*, and (ii) notes that a PF includes "one or more POs," *Yeo* does not specifically describe how those "one or more POs" are determined by a UE. Both *TS36* and *Mallick* fill this gap by describing that the index "i_s pointing to PO" is given by the equation "i_s = floor(UE_ID/N) mod Ns." Because the UE monitors the PDCCH, and a POSITA would readily recognize that the UE_ID constitutes or at least renders obvious the "feature ID" of the UE that is used for determining paging occasions, both *TS36* and *Mallick* describe the claimed "feature ID of a monitor of the first signaling," and that it "is used for determining the X time intervals.". APPLE-1009, p.39-40; APPLE-1008, [0027], [0170]. A POSITA would have a reasonable expectation of success in combining *Yeo* and *TS36/Mallick* at least because a POSITA would understand that the combination leads to the predictable result of determining the UE-specific POs within the PF of *Yeo*.

130. In addition, *Mallick* describes multiple paging occasions for an UE within a predefined time window. For example, *Mallick* describes (with

reference to FIG. 5, reproduced below with annotations) that "CE-UE1 monitors a UE-specific paging possibility at radio frame number 76 and number 204…etc., respectively at subframe 9…and that CE-UE2 monitors a UE-specific paging possibility at radio frame number 19 and 147…etc., respectively at subframe 4." APPLE-1008, [0157]. *Mallick* also clarifies that "the term paging possibility [refers] to the combination of the paging frame and paging subframe," and is determined as a function of the UE_ID. APPLE-1008, [0024]-[0027].



131. As shown with respect to limitation [2d], the number of subframes within a given time window constitutes or at least renders obvious the Y time intervals, and the *Yeo*/*TS36*/*Mallick* combination renders obvious determining the paging occasions within the Y time intervals based on the UE_ID.

Specifically, Because *Yeo* describes coverage enhancement of UEs specifically for mMTC in 5G (APPLE-1005, 41:61-67; APPLE-1006, [0309]), a POSITA would have been motivated to combine *Yeo/TS36* with *Mallick*'s improved CE paging procedure, including its description about how to determine the UE-specific paging possibilities and CE-specific paging possibilities. A POSITA would have had a reasonable expectation of success in combining *Mallick* with the *Yeo/TS36* combination at least because *Mallick* explicitly refers to an earlier version of the *TS36* as the specification relied on for determining paging occasions, (APPLE-1008, [0025]-[0028]; APPLE-1009, p.39-40), and the combination would lead to predictable results by reducing the burden on a base station and/or power consumption in certain UEs—as described by *Mallick*—in the paging/DRX procedure in MTC UEs, as described by the *Yeo*/*TS36* combination. As such, the limitation [2f] is rendered obvious by *Yeo*, *TS36*, and *Mallick*.

[2g]: "the feature ID refers to a remainder when an International Mobile Subscriber Identification Number (IMSI) is divided by 1024."

132. Each of *Yeo*, *TS36*, and *Mallick* describes the claimed "feature ID of a monitor of the first signaling" by disclosing a UE ID that is used for determining a paging occasion in a paging frame. APPLE-1005, 53:38-39; APPLE-1006, [0460]; APPLE-1009, p.39-40; APPLE-1008, [0027]. Further,

each of *Yeo*, *TS36*, and *Mallick* also explicitly describes that the UE ID is determined using a modulo (MOD) operator as: "UE_ID: IMSI mod 1024, if P-RNTI is monitored on PDCCH." APPLE-1005, 53:38-39; APPLE-1006, [0460]. *See also*, APPLE-1009, p.40; APPLE-1008, [0025].

4. Claim 3

[3a]: "The method according to claim 2, wherein the first time window belongs to one of Z time windows, Z being an integer greater than 1;"

133. As discussed for limitation [2a], *Yeo*/*TS36* in view of *Mallick* renders obvious that the paging occasions are subframes within a 10 ms time window. *Mallick* further describes that a DRX cycle contains an integer number (e.g., 32, 64, 128 or 256) of radio frames. APPLE-1008, [0038], Fig. 5 (reproduced below with annotations).

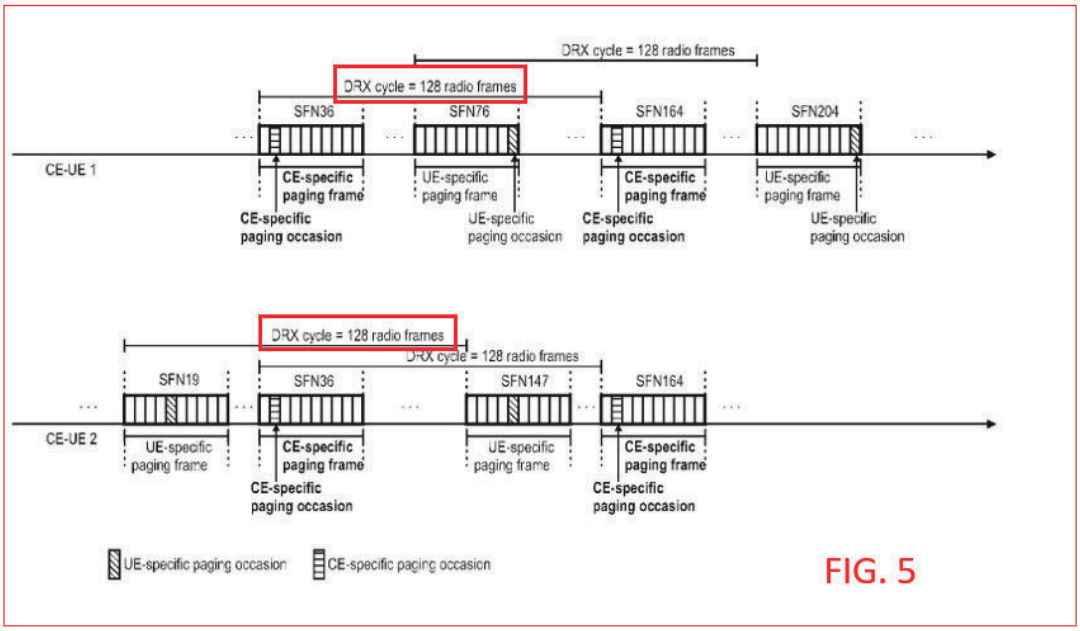


FIG. 5

134. Taking the example of the shortest default paging cycle of 32 radio frames, and the NR Type A frame described in *Yeo* (Figure 2E, above), the duration of the paging cycle is 32 * 10 ms = 320 ms - a time duration that includes 32 time windows each of duration 10 ms. The 32 time windows (each of duration 10 ms) in the paging cycle constitutes or at least render obvious the "Z time windows," and the "first time window" of 10 ms is one of the 32 time windows. In the examples of 64, 128, or 256 frame paging cycles for the NR Type A frame, the number of Z time windows is 64, 128, or 256, respectively, and the "first time window" of 10 ms is one of the corresponding number of time windows. As such, *Yeo*/*TS36* in view of *Mallick* renders obvious feature [3a].

[3b]: "Z is predefined, or Z is configurable;"

135. *Yeo* in view of *TS36* and *Mallick* renders obvious this limitation. *Yeo* describes—with reference to FIG. 2E—multiple frame structures both for LTE as well as for NR. APPLE-1005, FIG. 2E, APPLE-1006, FIG. 3e. *Yeo* also describes that in LTE systems "a length of the subframe is 1.0 ms," which does not change. APPLE-1005, 30:10-11; APPLE-1006, [0372]. *Yeo* also describes that in 5G "the frame structure type is generalized, the subcarrier spacing, the CP length, and the subframe length that are the essential parameter sets have an integer multiple relationship with each other for each type, such that high

scalability may be provided." APPLE-1005, 31:20-24; APPLE-1006, [0227]. As such, *Yeo* describes that the frame structures are either predefined (LTE) or configurable (NR Types A, B, C).

136. Further, as described with reference to limitation [3a], the subframe structure directly affects the number of time windows Z in a paging cycle of a given length. Because *Yeo* describes that the frame structures are either predefined or configurable, *Yeo* therefore describes predefined or configurable number of time windows Z.

[3c]: "any two of the Z time windows have an equal time length; and"

137. As shown with reference to the limitation [3a], taking the example of the shortest default paging cycle of 32 radio frames, and the NR Type A frame described in *Yeo* (Figure 2E, above), the duration of the paging cycle is 32 * 10 ms = 320 ms - a time duration that includes 32 time windows each of duration 10 ms. As such, *Yeo* in combination with *TS36* renders obvious that "any two of the Z time windows have an equal time length." The combination of *Yeo/YS36/Mallick* renders this feature obvious.

[3d]: "any two of the Z time windows are orthogonal in time domain,"

138. The '581 Patent notes that orthogonality of two time intervals mean that "there is no time unit that belongs to any two of the…time intervals

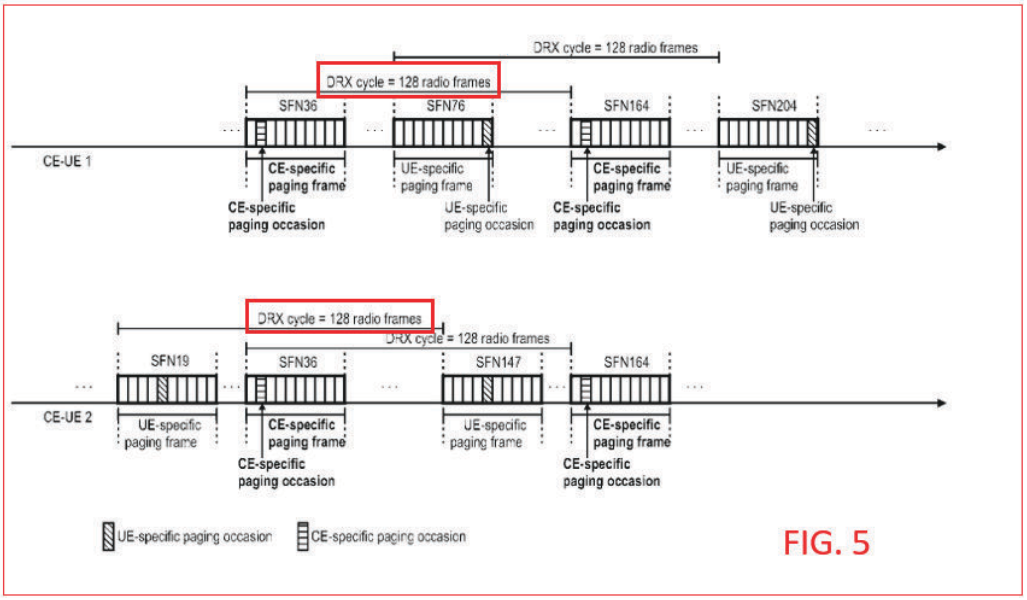
simultaneously." APPLE-1001, 3:5-7. As shown with reference to limitation [3a], for NR Type A frame of *Yeo*, the 32 time windows each of duration 10 ms—which constitutes or at least render obvious the "Z time windows"—are non-overlapping in time, and therefore pairwise "orthogonal in time domain" in the context of the '581 Patent claims. Similarly, in the examples of 64, 128, or 256 frame paging cycles for the NR Type A frame, the number of Z time windows is 64, 128, or 256, respectively, and no two time windows of the Z time windows overlap in time. As such, *Yeo* in view of *TS36* and *Mallick* renders obvious that "any two of the Z time windows are orthogonal in time domain."

[3e]: "any one of the Z time windows is a radio frame,"

139. As established with respect to limitation [3a] and [3d], taking the example of the shortest default paging cycle of 32 radio frames, and the NR Type A frame described in *Yeo* (Figure 2E, above), the corresponding paging cycle includes 32 non-overlapping time windows as the "Z time windows." Similarly, in the examples of 64, 128, or 256 frame paging cycles for the NR Type A frame, the number of non-overlapping Z time windows is 64, 128, or 256, respectively. As such, a POSITA would readily understand that "any one of the Z time windows is a radio frame," and thus *Yeo* in view of *TS36* and *Mallick* renders obvious this limitation.

[3f]: "Z is equal to the number of radio frames included in a Discontinuous Reception (DRX) cycle; and"

140. As discussed for limitation [3a] and [3e], *Yeo*/*TS36* in view of *Mallick* renders obvious that "any one of the Z time windows is a radio frame," and that in the examples of 32, 64, 128, or 256 frame paging cycles for the NR Type A frame, the number of Z time windows is 32, 64, 128, or 256, respectively. *Mallick* further describes that a DRX cycle contains an integer number (e.g., 32, 64, 128 or 256) of radio frames. APPLE-1008, [0038], Fig. 5 (reproduced below with annotations). As such, a POSITA would readily understand that "Z is equal to the number of radio frames included in a Discontinuous Reception (DRX) cycle," and thus *Yeo* in view of *TS36* and *Mallick* renders obvious this limitation.



Mallick, FIG. 5, Annotated

[3g]"the feature ID of the monitor of the first signaling is used for determining the first time window in the Z time windows."

141. As discussed for limitation [2f], both *TS36* and *Mallick* describe the claimed "feature ID of a monitor of the first signaling" by disclosing a UE ID that is used for determining a paging occasion in a paging frame. Both *TS36* and *Mallick* further describe that the same UE ID can be used to determine the paging frame itself. *Compare* APPLE-1008, [0025] and APPLE-1009, p.39-40 *with* '581 patent, 5:23-28 (using substantially the same formula to determine "the paging frame number (SFN)" based on the "UE_ID"). As such, the combination of *Yeo* with *TS36* and *Mallick* renders obvious this limitation.

5. Claim 4

[4]: "The method according to claim 3, further comprising: receiving a third signaling; wherein, the third signaling is used for configuring Z."

142. The '581 Patent does not describe the term "third signaling" except for in the claims and the summary. Neither does the prosecution history inform any specific interpretation beyond the plain meaning of the term – that it is a signaling transmitted to the UE to configure the number of Z time windows in a DRX cycle.

143. As discussed with respect to limitation [3f], *Yeo* in view of *TS36* and *Mallick* renders obvious that "Z is equal to the number of radio frames included in a Discontinuous Reception (DRX) cycle." *Yeo* further describes a parameter T as a

"value corresponding to the DRX period," which "can be set through higher layer signaling." APPLE-1005, 53:34-41; APPLE-1006, [0458]-[0460]. The higher layer signaling constitutes or at least renders obvious the claimed "third signaling" and the parameter T carried by the higher layer signaling informs the number of radio frames in a DRX cycle. From at least this description, a POSITA would understand that the combination of *Yeo* with *TS36* and *Mallick* renders obvious this limitation.

6. Claims 8-10

144. The combination of *Yeo/YS36/Mallick* renders obvious each of these claims. Aside from their dependency on claim 7, claims 8-10 are substantially similar to claims 2-4, respectively, and thus are rendered obvious by *Yeo* in view of *TS36* and *Mallick* for the reasons discussed for claims 7, and 2-4. See claim comparison chart provided above.

7. Claims 14-16

145. The combination of *Yeo/YS36/Mallick* renders obvious each of these claims. Aside from their dependency on claim 13, claims 14-16 are substantially similar to claims 2-4, respectively, and thus are rendered obvious by *Yeo* in view of *TS36* and *Mallick* for the reasons discussed for claims 13, and 2-4. See claim comparison chart provided above.

8. Claims 20-22

146. The combination of *Yeo/YS36/Mallick* renders obvious each of these claims. Aside from their dependency on claim 19, claims 20-22 are substantially similar to claims 2-4, respectively, and thus are rendered obvious by *Yeo* in view of *TS36* and *Mallick* for the reasons discussed for claims 19, and 2-4. See claim comparison chart provided above.

IX. CONCLUSION

147. For all the reasons I have noted in the foregoing paragraphs, 1-5, 7-11, 12-17, and 19-23 of the ’581 Patent are obvious in view of the references discussed above.

148. I declare that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true, and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable under Section 1001 of Title 18 of the United States Code.

Date: May 1, 2025

By: Zhi Ding
Digitally signed by Zhi Ding
Date: 2025.05.01 17:17:21 -07'00'

Dr. Zhi Ding

APPENDIX A

Expert/Consultant Curriculum Vitae

Professor Zhi Ding

Ph.D. and Fellow of IEEE

Expertise

- Wireless Communication Systems
- Cellular Wireless (2G, 3G, 4G, 5G)
- Communication Network Protocols
- Multi-Antenna Technologies
- WLAN (WiFi, Bluetooth)
- xDSL Internet Services
- DOCSIS Modems
- Optical Networks

Professional Summary

- Professor of major US universities for 35 years.
- *Consulted for multiple major technology companies*
- Worked as expert on multiple patent infringement cases.
- Conducted research works on Communications and Signal Processing for over 30 years.
- Supervised over 30 PhD students.
- Author of more than 200 journal papers and 2 books on communication technologies.

Dr. Zhi Ding has been a professor of electrical engineering at major US universities for 32 years. Since 1995, he has consulted for both engineering companies such as Nortel, Analog Devices, Intel, and worked as expert for major law firms from US, UK, China, and Canada including Kirkland & Ellis, WilmerHale, Quinn Emanuel, Fish & Richardson, Sheppard Mullin, Sidley Austin, Mayer Brown, Venable, and Finnegan, on multiple technical and patent infringement cases. He has been conducting research works on wireless communications and signal processing since 1984. He has supervised over 30 PhD students. He is an author of 500 peer-reviewed papers and 2 technical books on communication technologies. He has taught classes that cover the fundamentals of signal detection, communications, and systems.

Dr. Ding currently holds the position of Distinguished Professor at the University of California, where he was also the Child Family Professor of Engineering and Entrepreneurship in 2009-2014. He served as the steering committee chair of the IEEE Transactions on Wireless Communications. He was elevated to Fellow of IEEE in 2002 by the IEEE Signal Processing Society. He also served as the Technical Program Chair of the IEEE Globecom 2006 (the flagship conference of the IEEE Communications Society), Dr. Ding is an eminent scholar and expert of wireless technologies AND signal processing. He received the IEEE Communications Society's 2012 TC Recognition Award and the 2020 Education Award.

Intellectual Property Dispute Consulting:

Past Client	Past Engagement
Kirkland & Ellis LLP	2007 (Intel v. WiLAN)
	2008 (Cisco, Motorola, etc., v. R.),
	2008 (Apple v. N.)
	2009 (Cisco v. WiAV)
	2009 (Apple v. P.)
	2009 (Cisco v. M.)
	2010 (Netgear v. R.)
	2011 (Intel v. E.)
	2011 (Cisco v. M.)
	2011 (Cisco, Motorola v. I.)
	2011 (Netgear v. E.)
	2013 (Alcatel Lucent matter)
	2015 (Intel "project Impala")
	2020 (Xiaomi Global)
	2021 (Samsung v. E.)
	2023 (TP v. N.)
Wilmer Cutler Pickering Hale, & Dorr, LLP	2009 (Apple v. N.)
	2011 (Apple v. S.)
	2013 (Apple v. A.)
	2015 (Apple v. E.)
	2018 (Unified matter)
	2019 (Apple v. O.)
	2023 (Z. v. N.)
	2023 (Apple v. Lionra)
Fish and Richardson, LLP	2014 (Marvell v. I.)
	2018 (NEC v. X.)
	2020 (DISH v. T.)
	2020 (Huawei SEP)
	2020 (Samsung v. E.)
	2021 (LG Electronics, Dell v. N.)
	2021 (Quectel v. P.)
	2021 (Apple v. E.)
	2022 (Apple v. S.)
	2022 (LG Electronics v. C.)
	2023 (Dish v. E.)
	2023 (G Project)
	2024 (A. vs. V.H.)
	2024 (A. vs. A. B.)
	2025 (S. vs. W.)
Kaye Scholer LLP	2012 (Timer Warner+Ceres+Atlanta Broadband Finance v. K.)

Bridges and Mavrakakis, LLP	2011(Apple matter)
	2014 (Apple v. C.)
	2015 (Marvell "IP evaluation matter")
Sterne, Kessler, Goldstein & Fox, LLC	2014 (Marvell, MediaTek v. B.)
	2019 (Volkswagen v. C.)
	2020 (Apple v. S.)
Bramson, Plutzik, Mahler & Birkhaeuser	2013 (Karim v. H.)
Gibson, Dunn & Crutcher, LLP	2014 (AT&T v. I)
Desmarias	2024 (C. v. OptiMorphix)
Quinn Emanuel	2014 (Canon v. I.)
	2023 (Z. v. E.)
	2024 (ASSA v. Charter)
Norton Rose Fulbright US LLP	2015 (Qualcomm v. B.)
	2018 (Qualcomm v. A.)
	2021 (NXP v. Me.)
	2023 (NXP v MI.)
Sheppard, Mullin, Richter, and Hampton, LLP	2015 (TLC v. E.)
	2017 (ZTE v. H.)
	2018 (HTC v. I.)
	2019 (Motorola v. U.)
	2019 (U-Blox AG v. I.)
	2019 (Continental v. A.)
	2019 (Toyota matter)
	2020 (Oppo v. S.)
	2021 (HTC v. S.)
Duane Morris	2015 (Comcast, Cox, Time Warner, Verizon v. T.)
Rothwell, Figg, Ernest, & Manbeck, P.C.	2016 (LG Electronics v. O.)
Mayer Brown LLP	2016 (LG Electronics v. N.)
Sidley Austin, LLP	2016 (Huawei v. S.)
	2018 (Huawei v. O.)
Irell & Manella, LLP	2016 (Juniper v. M.)
	2021 (NXP v. M.)
Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P	2017 (LGE v. BLU)
	2017 (Sol IP)
Arnold, Porter, Kaye, and Scholer	2017 (Charter v. S.)
	2021 (Samsung v. X.)
Venable, LLP	2017 (Verizon v. S.)
Pillsbury LLP	2017 (ZTE v. H.)
Alston, Bird, LLP	2018 (ASUSTeK v. H.)
Gibson, Dunn & Crutcher, LLP	2019 (AT&T v. S.)
Allen & Overy, LLP, UK	2019 (Huawei v. Conversant.)
Erise IP	2019 (Apple v. I.) 2022 (Apple v. L.)
Xiaomi (China)	2020 (Siemens)

Munger Tolles & Olson, LLP (Tesla)	2021 (Tesla v. O.)
	2023 (G. v. U.)
Orrick, Herrington, & Sutcliffe, LLP	2021 (Canon v. W.)
Saikrishna & Associates (India)	2019 (Xiaomi v. Ericsson)
	2020 (OPPO v. NOKIA)
	2022 (OPPO v. Phillips) (OPPO v. IDC)
	2023 (OPPO v. Voiceage)
	2022 (vivo v. Nokia)
	2024 (vivo v. Phillips)
Anand & Anand (India)	2025 (SEC in India)
Dannemann Siemsen (Brazil)	2023 (OPPO v. NOKIA)
Continental	2022 (Continental v. N.)
Kelley Dryer	2022 (Keep Truckin v. F.)
Haynes Boone	2022 (Apple v. T.)
	2024 (T. v. IV)
Quinsumbing Torres (Philippines)	2022 (vivo v. N.)
Biro Oktroi Roosseno (Indonesia)	2022 (vivo v. N.)
Paul Hastings	2022 (Samsung v. G.)
Cabello Hall Zinda, PLLC	2023 (K. v. E.)
DLA Piper	2023 (D. & M. v. Ozmo)
King and Spalding	2024 (DGS v. D)
Kilpatrick Townsend & Stockton LLP	2024 (IV et al. v. Lenovo) (Iv et al. v. Zebra)
Warren Kash Warren LLP	2024 (Viasat)
Bookoff	2024 (L.v. I.V.)

Expert Testifying and Depositions (13 Trials and 18 Depositions)

Clients	Deposition/Testifying Experience
Bramson, Plutzik, Mahler & Birkhaeuser LLP	2013: ***Deposition*** on Case No. CV 12-05240 PJH Nad Karim v. Hewlett Packard, Co. UNITED STATES NORTHERN DISTRICT COURT OF CALIFORNIA. Settlement ordered Jan. 18, 2017.
Fish and Richardson	2015 (Feb): ***Deposition*** for Marvell. US PTAB *Inter Partes* Review IPR2014-00548 Marvell Semiconductor, Inc. v. Intellectual Ventures I LLC
	2015 (August): ***Deposition*** for Marvell. US PTAB *Inter Partes* Review IPR2014-00548 Marvell Semiconductor, Inc. v. Intellectual Ventures I LLC
Norton, Rose, Fulbright, US, LLP	2016 (April): ***Deposition*** for Qualcomm. US PTAB *Inter Partes* Review cases IPR2015-10577, IPR2015-10580, IPR2015-10581 Qualcomm Inc. v Bandspeed Inc.

Sheppard, Mullin, Richter, and Hampton, LLP	2016 (May): ***Deposition*** for in *TCL Communication Technology Holdings, LTD., et al. v. Ericsson, et al.,* Case No. 8:14-cv-341 (C. D. CA).
	2017 (Feb): **Testified at C.D. California** bench trial.
Sidley Austin, LLP	2016 (December): **Testified at** trial involving Huawei Technologies, Co. Ltd v. Samsung regarding FRAND licensing disputes in Shenzhen Court, P.R. China.
	2018 (June): ***Deposition*** for N.D. CA on IP matter concerning Huawei Technologies, Co. Ltd v. Samsung.
	2018 (December): **Testified at** trial involving Huawei Technologies, Co. Ltd v. Samsung regarding FRAND licensing disputes in Beijing Court of Intellectual Properties, P.R. China.
Mayer Brown LLP	2017 (January): **Testified during tribunal proceeding** for LG Electronics, Inc. in standard essential patent (SEP) licensing dispute of Nokia Technologies, Ltd. *v*. LG Electronics, Inc. During arbitration hearing in Paris, France.
Venable LLP	2017 (October): ***Deposition*** as expert witness for Verizon Services Corp. in Case No. 2:16-CV-588-WCB (E. D. TX) on US Patent disputes.
Pillsbury LLP	2018 (Feb): ***Deposition*** (E. D. Texas Case No. 5:16-cv-00179-RWS)
	2018 (June): **Testified at E. D. Texas** (Texarkana) jury trial (Case No. 5:16-cv-00179-RWS).
Allen & Overy LLP UK	2019 (April) **Testified at** trial involving Huawei Technologies, Co. Ltd v. Conversant regarding FRAND licensing disputes in Nanjing Intermediate Court, P.R. China.
Sidley Austin LLP, US	2019 (Sept.) **Testified at** trial involving Huawei Technologies, Co. Ltd v. PanOptics, regarding FRAND licensing disputes in Shenzhen Intermediate Court, P.R. China.
Sheppard, Mullin, Richter, and Hampton, LLP	2019 (Dec. 3rd): ***Deposition*** for HTC and Apple in *HTC Corporation, HTC America, Inc., and Apple Inc. v. INVT SPE LLC,* Case Nos. IPR2018-01555 and IPR2018-01581.
Sterne, Kessler, Goldstein & Fox, LLC	2020 (Feb.): ***Deposition*** for Volkswagen Group of America, In. v. Carucel Investments, L.P. Case Nos. IPR2019-01573 and IPR2019-01101.
Jincheng Tongda & Neal, LLP	2021 (June) **Testified at** trial involving TCL. v. Ericsoon, regarding FRAND licensing disputes in Shenzhen Intermediate Court, P.R. China.
Orrick, Herrington, & Sutcliffe, LLP	2021 (October): ***Deposition*** for Canon, Inc, in Canon, v. WSOU Investments, LLC d/b/a/ Brazos Licensing, W.D. Texas, Case No. 6:20-cv-980.
Fish & Richardson, P.C.	2021 (November) 1st ***Deposition*** for Petitioner IPR 2021-00560 in Quectel v. Koninklijke Philips N.V.
	2021 (December) 1st ***Deposition*** for Petitioner on IPR 2021-00563 Proceeding in Quectel v. Koninklijke Philips N.V.
	2022 (March 31) 2nd ***Deposition*** for Petitioner IPR 2021-00560

	in Quectel v. Koninklijke Philips N.V. (028) (-)
	2022 (April 1) 2nd ***Deposition*** for Petitioner on IPR 2021-00563 Proceeding in Quectel v. Koninklijke Philips N.V. (+)
	2022 (Oct. 28) ***Deposition*** for Petitioner on IPR 2022-00339 in Apple v. Ericsson.
	2023 (Nov. 18) ***Deposition*** for Petitioner on IPR 2023-00496 Proceeding (Apple).
Jauar Jahja and Partners (Indonesia)	2022 (April 25) **Testified** at trial involving OPPO v. Nokia regarding one patent disputes at Court in Jakarta, Indonesia. ***Successful denial of temporary injunction.*** 2022 (April 26) **Testified** at trial involving OPPO v. Nokia regarding another patent dispute at Court in Jakarta, Indonesia. ***Successful denial of temporary injunction.***
Quinsambing & Torres (Philippines)	2022 (September) **Testified** on site at trial involving vivo v. Nokia regarding patent disputes in Regional Trial Court in Manila, the Philippines. ***Successful denial of temporary injunction.***
Orrick, Herrington, & Sutcliffe, LLP	2021 (Oct. 12) ***Deposition*** Western D. of Texas cas: 6:20-cv-00980-ADA (Canon**)**
Arnold, Porter, Kaye, and Scholer	2022 (Dec. 30) ***Deposition*** for Petitioner on IPR 2022-00613 Proceeding (Samsung)
Biro Oktroi Roosseno (Indonesia)	2023 (Jan. 4) **Testified** online at trial involving vivo v. Nokia regarding patent disputes at Court in Jakarta, Indonesia. ***Successful denial of temporary injunction.*** 2023 (Feb. 1) **Testified** on site at trial involving vivo v. Nokia regarding patent disputes at Court in Jakarta, Indonesia. ***Successful denial of temporary injunction.***
Paul Hastings	2023 (June 22) ***Deposition*** for Petitioner on IPR 2022-01598 Proceeding (Samsung)
	2023 (Sept. 23) ***Deposition*** for Petitioner on IPR 2023-00171 Proceeding (Samsung)
Kirkland & Ellis LLP	2024 (May 31) ***Deposition*** for Petitioner on IPR 2023-01469 Proceeding (TP Link)

IPR Opinions 70+	**Expert Opinions (Excluding links before 2019 for brevity):**
Older IPR Cases	IPR2014-00547 IPR2014-00548 IPR2014-01562 IPR2015-00237 IPR2015-00314 IPR2015-00315 IPR2015-00316 IPR2015-00531 IPR2015-01577 IPR2015-01580 IPR2015-01581

	IPR2015-01582 IPR2016-00620 IPR2016-00623 IPR2018-00237 IPR2018-01160 IPR2018-01190 IPR2018-01555 IPR2018-01581 IPR2019-00070
Recent IPR Declarations	IPR2019-01573 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2020-01-22); Final Decision: Unpatentable (2020-11-20) IPR2019-01105 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2019-12-02); Final Decision: Unpatentable (2020-11-20) IPR2019-01101 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2019-12-02); Final Decision: Unpatentable (2020-11-20) IPR2020-00038 Expert Declaration to the Patent Trial and Appeal Board (Filed 2019-10-11); Institution Decision: (2020-04-13). IPR2021-00560 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2021-09-13); Final Decision: (2022-09-09) IPR2021-00563 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2021-09-15); Final Decision: Unpatentable (2022-9-13) IPR2021-00587 Expert Declaration to the Patent Trial and Appeal Board. Filed (2021-02-26); Withdrawn. IPR2021-00644 Expert Declaration to the Patent Trial and Appeal Board. Filed (2021-03-12); Settled. IPR2021-00683 Expert Declaration to the Patent Trial and Appeal Board. Filed (2021-03-19); Withdrawn. IPR2021-01468 Expert Declaration to the Patent Trial and Appeal Board. Filed (2021-09-01). IPR2021-01486 Expert Declaration to the Patent Trial and Appeal Board. Filed (2021-09-16).

	IPR2022-00339 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2022-08-22); Settlement (2022-12-20). IPR2022-00348 Expert Declaration to the Patent Trial and Appeal Board, Filed (2022-02-15). IPR2022-00349 Expert Declaration to the Patent Trial and Appeal Board, Filed (2022-02-15), Settled. IPR2022-00616 Expert Declaration to the Patent Trial and Appeal Board, Filed (2022-02-18), Withdrawn. IPR2022-00619 Expert Declaration to the Patent Trial and Appeal Board, Filed (2022-02-25). IPR2022-00613 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2022-10-20); Settled. IPR2022-01512 Expert Declaration to the Patent Trial and Appeal Board. Filed (2022-09-09); Instituted (2023-05-15). IPR2022-01598 Expert Declaration to the Patent Trial and Appeal Board. Filed (2022-10-04); Instituted (2023-04-04). IPR2023-00136 Expert Declaration to the Patent Trial and Appeal Board. Filed (2022-11-30); Instituted (2023-05-22). IPR2023-00151 Expert Declaration to the Patent Trial and Appeal Board; Filed (2022-11-30); Instituted (2023-06-09). IPR2023-00174 Expert Declaration to the Patent Trial and Appeal Board, Filed (2022-11-30); Instituted (2023-05-19). IPR2023-00171 Expert Declaration to the Patent Trial and Appeal Board. Filed (2022-11-08); Instituted (2023-05-31). IPR2023-00441 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-01-05); Instituted (2023-08-03). IPR2023-00496 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-01-20); Institute (2023-08-21). IPR2023-00525 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-07-10); Institute (2023-10-02).

	IPR2023-00644 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-03-07); Institute (2023-10-11). IPR2023-00645 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-03-22); Institute (2023-10-11). IPR2023-00665 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-03-22) IPR2023-00720 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-03-16). IPR2023-00721 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-03-16); Institute (2023-10-11). IPR2023-00796 IPR2023-01393 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2023-11-13). IPR2023-01060 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-09-07); Instituted (2024-01-16). IPR2023-01393 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-09-07). IPR2023-01400 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-09-07); Instituted (2024-03-08). IPR2023-01403 Expert Declaration to the Patent Trial and Appeal Board; Instituted (2024-03-06). IPR2023-01429 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-09-18). IPR2023-01469 Expert Declaration to the Patent Trial and Appeal Board, Instituted (2024-04-02). Settled. IPR2024-00125 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-10-30). Settled. IPR2024-00148 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-11-10). IPR2024-00883 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-05-01). IPR2024-01224 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-08-02).

	IPR2024-01358 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-08-28). IPR2024-01362 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-08-30). Instituted (2025-03-11). IPR2024-01363 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-08-30). Instituted (2025-03-11). IPR2024-01364 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-08-30). Instituted (2025-03-11). IPR2025-00049 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-10-14). IPR2025-00194 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-11-19). IPR2025-00218 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-11-21). IPR2025-00220 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-11-25). IPR2025-00343 Expert declaration to the Patent Trial and Appeal Board, Filed (2024-12-31).

Employment History

From:	2000	**University of California at Davis**
To:	Present	Davis, CA
	Position:	*Professor* (2000-2020) and *Distinguished Professor* (2020-), *Department of Electrical and Computer Engineering*

From:	01/1999	**University of Iowa**
To:	09/2000	Iowa City, IA
	Position:	*Assoc. Professor, Department of Electrical and Computer Engineering*

From:	01/1997	**Hong Kong University of Science and Technology**
To:	12/1997	Hong Kong

Position: *Visiting Associate Professor, Department of Electrical and Electronic Engineering*

From: 09/1995 **Auburn University**
To: 12/1998 Auburn, AL
Position: *09/1995-12/1998: Associate Professor, Department of Electrical and Computer Engineering*
09/1990-08/1995: Assistant Professor, Department of Electrical and Computer Engineering

From: 08/1993 **Australian National University**
To: 09/1993 Canberra, Australia
Position: *Visiting Research Fellow, Faculty of Information Technology and Engineering*

From: 06/1993 **US Air Force Wright Laboratory**
To: 08/1993 Eglin AFB, Florida
Position: *Faculty Research Associate, Armament Directorate*

From: 06/1992 **NASA Lewis Research Center**
To: 08/1992 Cleveland, OH
Position: *Visiting Faculty Research Fellow*

From: 08/1987 **Cornell University**
To: 08/1990 Ithaca, NY
Position: *Research Assistant*

From: 09/1984 **University of Toroto**
To: 08/1987 Toronto, Ontario, Canada
Position: *Research Assistant*

Technical Consulting

Consulted for multiple major technology companies, aside from IP litigation related matters.

Patents (Granted and/or Licensed)

Patent Number	Date Issued	Title

US 6,396,885	Mar.28, 2002	Co-channel interference reduction in wireless communications systems
US 6,463,099	Oct.8, 2002	Blind channel equalizers and methods of blind channel equalization (Licensed)
US 7,379,513	Mar. 20, 2008	Channel estimation in CDMA communications systems using both lower power pilot channel and higher power date channel
US 9,554,388	Jan. 24, 2017	Method and apparatus of resource sharing for device-to-device and cellular communications
US 10,623,230	Apr. 14, 2020	Trans-layer robust header-compression technique
US 11,019,530	May 25, 2021	Trans-layer bidirectional robust header compression system
US 11,368,940	June 21, 2022	Systems and Methods for Data transmission over Wi-Fi and LTE-U coexistence framework

Education

1990	Cornell University, Ithaca, NY	Ph.D., Electrical Engineering
1987	University of Toronto, Toronto, Canada	MS, Electrical Engineering
1982	Nanjing Institute of Technology, Nanjing, China	BS, Wireless Engineering

Publications

Books & Book Chapters

[1] B. P. Lathi and Z. Ding, *Modern Digital and Analog Communication Systems,* 5th edition, Oxford University Press, 2018.

[2] Zhi Ding and Ye Li, *Blind Equalization and Identification*, Marcel Dekker, New York, 2001.

[3] Z. Ding, "Chapter 7: Linear Predictive Algorithms for Blind Multichannel Identification," in *Signal Processing Advances in Wireless and Mobile Communications*, Vol. I: Trends in Channel Estimation and Equalization, G. B. Giannakis, Y. Hua, P. Stoica, and L. Tong (Editors), Prentice Hall, 2000.

[4] Z. Ding, "Blind Channel Identification and Equalization using Spectral Correlation Measurements: Frequency Domain Analysis," in *Cyclostationarity in Communications and Signal Processing*, William A. Gardner, Ed., pp.417-436, IEEE Press, 1993.

[5] Z. Ding, C. R. Johnson, Jr., and R. A. Kennedy, "Chapter 3: Global Convergence Issues with Linear Blind Adaptive Equalizers," in *Blind Deconvolution*, Simon Haykin, Ed., pp.60-120, Prentice-Hall, 1994.

[6] Z. Ding, "Adaptive Filters for Blind Equalization," in *IEEE DSP Handbook*, Douglas B. Williams, Ed., pp.24.1-24.17, IEEE Press, 1998.

Journal Papers

[1] K. Wang, Z. Ding, D. K. C. So and Z. Ding, ``Exploring Age-of-Information Weighting in Federated Learning under Data Heterogeneity'', in IEEE Transactions on Wireless Communications, doi: 10.1109/TWC.2025.3545456, 2025.

[2] Zhang, Songyang, Brian Choi, Feng Ouyang, and Zhi Ding, ``Physics-inspired machine learning for radiomap estimation: Integration of radio propagation models and artificial intelligence. IEEE Communications Magazine, 62, no. 8, pp. 155-161, 2024. doi: 10.1109/MCOM.001.2300782.

[3] Wang, Kaidi, Yi Ma, Mahdi Boloursaz Mashhadi, Chuan Heng Foh, Rahim Tafazolli, and Zhi Ding, ``Convergence Acceleration in Wireless Federated Learning: A Stackelberg Game Approach." IEEE Transactions on Vehicular Technology, 2024. doi: 10.1109/TVT.2024.3452933

[4] Q. Deng, Y. Zhang, M. Li, S. Zhang and Z. Ding, ``Efficient Eigen-Decomposition for Low-Rank Symmetric Matrices in Graph Signal Processing: An Incremental Approach," IEEE Transactions on Signal Processing, 2024 doi: 10.1109/TSP.2024.3438676.

[5] Q. Deng, S. Zhang and Z. Ding, ``Body Motion Segmentation via Multilayer Graph Processing for Wearable Sensor Signals," IEEE Open Journal of Signal Processing, Volume 5, pp. 934-947, 2024 doi: 10.1109/OJSP.2024.3407662.

[6] S. Jing, S. Zhang and Z. Ding, ``Reinforcement Learning for Robust Header Compression (ROHC) Under Model Uncertainty," IEEE Transactions on Machine Learning in Communications and Networking, vol. 2, pp. 1033-1044, 2024, doi: 10.1109/TMLCN.2024.3409200.

[7] A. Wijesinghe, S. Zhang and Z. Ding, ``PS-FedGAN: An Efficient Federated Learning Framework With Strong Data Privacy," IEEE Internet of Things Journal, vol. 11, no. 16, pp. 27584-27596, 15 Aug.15, 2024, doi: 10.1109/JIOT.2024.3399226.

[8] Z. Liu, L. Wang, L. Xu and Z. Ding, ``Deep Learning for Efficient CSI Feedback in Massive MIMO: Adapting to New Environments and Small Datasets," IEEE Transactions on Wireless Communications, 2024. doi: 10.1109/TWC.2024.3390583.

[9] C. -H. Hsu and Z. Ding, ``Unsupervised Learning for Resource Allocation and User Scheduling in Wideband MU-MIMO Systems," IEEE Open Journal of the Communications Society, vol. 5, pp. 2240-2256, 2024, doi: 10.1109/OJCOMS.2024.3384110.

[10] S. Zhang, T. Yu, B. Choi, F. Ouyang and Z. Ding, ``Radiomap Inpainting for Restricted Areas based on Propagation Priority and Depth Map," *IEEE Transactions on Wireless Communications,* 23(8): 9330-9344, August 2024. doi: 10.1109/TWC.2024.3360872.

[11] K. Wang, Z. Ding, D. K. C. So and Z. Ding, ``Age-of-Information Minimization in Federated Learning based Networks with Non-IID Dataset," *IEEE Transactions on Wireless Communications,* 23(8): 8939-8953, August 2024. doi: 10.1109/TWC.2024.3357208.

[12] C. Feres, B. C. Levy and Z. Ding, ``Over-the-Air Multisensor Collaboration for Resource Efficient Joint Detection," *IEEE Transactions on Signal Processing,* vol. 72, pp. 384-399, 2024, doi: 10.1109/TSP.2023.3310895.

[13] Y. -C. Lin, T. -S. Lee and Z. Ding, ``A Scalable Deep Learning Framework for Dynamic CSI Feedback With Variable Antenna Port Numbers," *IEEE Transactions on Wireless Communications,* vol. 23, no. 4, pp. 3102-3116, April 2024, doi: 10.1109/TWC.2023.3305546.

[14]

[15] Y. -C. Lin, T. -S. Lee and Z. Ding, ``Exploiting Partial FDD Reciprocity for Beam Based Pilot Precoding and CSI Feedback in Deep Learning," IEEE Transactions on Wireless Communications, doi: 10.1109/TWC.2023.3289929.

[16] S. Zhang, Q. Deng and Z. Ding, ``Signal Processing Over Multilayer Graphs: Theoretical Foundations and Practical Applications," IEEE Internet of Things Journal, vol. 11, no. 2, pp. 2453-2471, 15 Jan.15, 2024, doi: 10.1109/JIOT.2023.3294470.

[17] W. Cao, X. Ling, J. Wang, Z. Ding and X. Gao, ``A Framework for QoS-Guaranteed Fast Access Services in Blockchain Radio Access Network," IEEE Transactions on Wireless Communications, vol. 23, no. 4, pp. 2711-2725, April 2024, doi: 10.1109/TWC.2023.3302415

[18] Q. Deng, Y. Ge and Z. Ding, ``Jamming Suppression via Resource Hopping in High-Mobility OTFS-SCMA Systems," IEEE Wireless Communications Letters, vol. 12, no. 12, pp. 2138-2142, Dec. 2023, doi: 10.1109/LWC.2023.3309787.

[19] X. Liang, W. Fang, J. Wang, Z. Ding, X. Gao and C. Zhao, ``Robust Transceiver Design for RIS-Aided Spatially Correlated MIMO Channels With Uncertainty," IEEE Wireless Communications Letters, vol. 12, no. 12, pp. 2013-2017, Dec. 2023, doi: 10.1109/LWC.2023.3304335.

[20] Qi S, He M, Hoang R, Zhou Y, Namadi P, Tom B, Sandhu P, Bai Z, Chung F, Ding Z, Anderson J. ``Salinity Modeling Using Deep Learning with Data Augmentation and Transfer Learning" .*Water,* 15(13):2482, 6 July, 2023.

[21] S. Zhang, A. Wijesinghe and Z. Ding, ``RME-GAN: A Learning Framework for Radio Map Estimation based on Conditional Generative Adversarial Network" *IEEE Internet of Things Journal* 2023. doi:10.1109/JIOT.2023.3278235.

[22] Y. Ge, Q. Deng, D. Gonzalez G., Y. L. Guan and Z. Ding, ``OTFS Signaling for SCMA With Coordinated Multi-Point Vehicle Communications," *IEEE Transactions on Vehicular Technology*, doi: 10.1109/TVT.2023.3248119.

[23] H. Ma, X. Yuan, Z. Ding, D. Fan and J. Fang, "Over-the-Air Federated Multi-Task Learning via Model Sparsification, Random Compression, and Turbo Compressed Sensing," *IEEE Transactions on Wireless Communications,* doi: 10.1109/TWC.2022.3231088.

[24] Siyu Qi, Minxue He, Zhaojun Bai, Zhi Ding, Prabhjot Sandhu, Francis Chung, Peyman Namadi, Yu Zhou, Raymond Hoang, Bradley Tom, Jamie Anderson, and Dong Min Roh, "Novel Salinity Modeling Using Deep Learning for the Sacramento-San Joaquin Delta of California" in *Water* , 2022, 14(22), 3628; https://doi.org/10.3390/w14223628

[25] M. Del Rosario and Z. Ding, ``Learning-Based MIMO Channel Estimation under Practical Pilot Sparsity and Feedback Compression," in IEEE Transactions on Wireless Communications, 2022, doi: 10.1109/TWC.2022.3202750.

[26] C. Sun, X. Gao and Z. Ding, ``Optimization of Workload Balancing and Power Allocation for Wireless Distributed Computing," in IEEE Transactions on Wireless Communications, vol. 21, no. 9, pp. 7682-7695, Sept. 2022, doi: 10.1109/TWC.2022.3160493.

[27] C. -H. Hsu, C. Feres and Z. Ding, ``Wirtinger Flow for Nonconvex Blind Demixing with Optimal Step Size," in IEEE Wireless Communications Letters, 2022, doi: 10.1109/LWC.2022.3203313.

[28] Zhang, S., Deng, Q. & Ding, Z., ``Multilayer graph spectral analysis for hyperspectral images," EURASIP Journal of Adv. Signal Process, 2022, 92 (2022). doi: https://doi.org/10.1186/s13634-022-00926-8;

[29] C. Feres and Z. Ding, ``An Unsupervised Learning Paradigm for User Scheduling in Large Scale Multi-Antenna Systems," in IEEE Transactions on Wireless Communications, 2022, doi: 10.1109/TWC.2022.3215471.

[30] L. D. Chamain, S. Qi, and Z. Ding, ``End-to-End Image Classification and COmpression with variational autoencoder" IEEE Internet of Things Journal, vol. 70, 2022, doi: 10.1109/JIOT.2022.3182313.

[31] C. Feres and Z. Ding, ``A Riemannian Geometric Approach to Blind Signal Recovery for Grant-Free Radio Network Access," IEEE Transactions on Signal Processing, vol. 70, pp. 1734-1748, 2022, doi: 10.1109/TSP.2022.3159988.

[32] Q. Deng, S. Zhang and Z. Ding, ``An Efficient Hypergraph Approach to Robust Point Cloud Resampling," IEEE Transactions on Image Processing, vol. 31, pp. 1924-1937, 2022, doi: 10.1109/TIP.2022.3149225.

[33] X. Ling, B. Zhang, H. Xie, J. Wang, Z. Ding, Hash Access in Blockchain Radio Access Networks: Characterization and Optimization IEEE Internet of Things Journal, 9(11): 8053-8066, 1 June 2022 doi: 10.1109/JIOT.2021.3111915.

[34] Qi, S.; He, M.; Bai, Z.; Ding, Z.; Sandhu, P.; Zhou, Y.; Namadi, P.; Tom, B.; Hoang, R.; Anderson, J. ``Multi-Location Emulation of a Process-Based Salinity MOdel Using Machine Learning',' Water , 14(13):2030, 2022, doi: 10.3390/w14132030.

[35] C. Wang, A. -A. Lu, X. Gao and Z. Ding, ``Robust Precoding for 3D Massive MIMO Configuration With Matrix Manifold Optimization," IEEE Transactions on Wireless Communications, vol. 21, no. 5, pp. 3423-3437, May 2022, doi: 10.1109/TWC.2021.3121734.

[36] Z. Liu, M. Del Rosario, and Z. Ding, ``A Markovian Model-Driven Deep Learning Framework for Massive MIMO CSI Feedback," in IEEE Transactions on Wireless Communications,, vol. 21, no. 2, pp. 1214-1228, Feb. 2022, doi: 10.1109/TWC.2021.3103120.

[37] L. Teng, G. Zhai, Y. Wu, X. Min, W. Zhang, Z. Ding, and C Xiao, ``QoE Driven VR 360Â° Video Massive MIMO Transmission," IEEE Transactions on Wireless Communications, vol. 21, no. 1, pp. 18-33, Jan. 2022, doi: 10.1109/TWC.2021.3093305.

[38] Q. Deng, S. Zhang and Z. Ding, ``Point Cloud Resampling via Hypergraph Signal Processing," IEEE Signal Processing Letters, vol. 28, pp. 2117-2121, 2021, doi: 10.1109/LSP.2021.3119257.

[39] X. Ling, P. Chen, J. Wang and Z. Ding, ``Data Broker: Dynamic Multi-Hop Routing Protocol in Blockchain Radio Access Network," in IEEE Communications Letters, vol. 25, no. 12, pp. 4000-4004, Dec. 2021, doi: 10.1109/LCOMM.2021.3114218.

[40] Qi, Siyu, Zhaojun Bai, Zhi Ding, Nimal Jayasundara, Minxue He, Prabhjot Sandhu, Sanjaya Seneviratne, and Tariq Kadir, ``Enhanced Artificial Neural Networks for Salinity Estimation and Forecasting in the Sacramento-San Joaquin Delta of California." Journal of Water Resources Planning and Management 147, no. 10 (2021): 04021069.

[41] Y. -C. Lin, Z. Liu, T. -S. Lee and Z. Ding, ``Deep Learning Phase Compression for MIMO CSI Feedback by Exploiting FDD Channel Reciprocity," in IEEE Wireless Communications Letters, vol. 10, no. 10, pp. 2200-2204, Oct. 2021, doi: 10.1109/LWC.2021.3096808.

[42] C. J. Feres and Z. Ding, ``Wirtinger Flow Meets Constant Modulus Algorithm: Revisiting Signal Recovery for Grant-Free Access," in IEEE Transactions on Signal Processing, vol 69, pp. 6515-6529, Aug. 2021. doi: 10.1109/TSP.2021.3103038.

[43] Q. Hu, Y. Liu, Y. Cai, G. Yu and Z. Ding, ``Joint Deep Reinforcement Learning and Unfolding: Beam Selection and Precoding for mmWave Multiuser MIMO With Lens Arrays," in IEEE Journal on Selected Areas in Communications, vol. 39, no. 8, pp. 2289-2304, Aug. 2021, doi: 10.1109/JSAC.2021.3087233.

[44] C. Sun, J. Wang, X. Gao, Z. Ding and X. Zheng, ``Fiber-Enabled Optical Wireless Communications With Full Beam Coverage," in IEEE Transactions on Communications, vol. 69, no. 5, pp. 3207-3221, May 2021, doi: 10.1109/TCOMM.2021.3059458.

[45] Y. Ge, Q. Deng, P.C. Ching, Z. Ding ``OTFS Signaling for Uplink NOMA of Heterogeneous Mobility Users," in IEEE Transactions on Communications, 2021, doi: 10.1109/TCOMM.2021.3059456.

[46] Y. Ge, Q. Deng, P.C. Ching, Z. Ding ``Receiver design for OTFS with fractionally spaced sampling approach", in IEEE Transactions on Wireless Communications, 2021, doi: 10.1109/TWC.2021.3055585.

[47] S. Zhang, S. Cui and Z. Ding, ``Hypergraph Spectral Analysis and Processing in 3D Point Cloud," in IEEE Transactions on Image Processing, vol. 30, pp. 1193-1206, 2021, doi: 10.1109/TIP.2020.3042088.

[48] S. Zhang, S. Cui and Z. Ding, ``Hypergraph Spectral Clustering for Point Cloud Segmentation," in IEEE Signal Processing Letters, vol. 27, pp. 1655-1659, 2020, doi: 10.1109/LSP.2020.3023587.

[49] X. Ling, Y. Le, J. Wang and Z. Ding, ``Hash Access: Trustworthy Grant-Free IoT Access Enabled by Blockchain Radio Access Networks," in IEEE Network, vol. 34, no. 1, pp. 54-61, January/February 2020, doi: 10.1109/MNET.001.1900159.

[50] Ling, X.; Gao, Z.; Le, Y.; You, L.; Wang, J.; Ding, Z.; Gao, X. ``Satellite-Aided Consensus Protocol for Scalable Blockchains", Sensors Vol. 20, Issue 19, 2020.

[51] Z. Jiang, X. Shen, H. Wang and Z. Ding, ``Joint PSK Data Detection and Channel Estimation Under Frequency Selective Sparse Multipath Channels," in IEEE Transactions on Communications, vol. 68, no. 5, pp. 2726-2739, May 2020, doi: 10.1109/TCOMM.2020.2975172.

[52] Z. Liu, L. Zhang and Z. Ding, ``An Efficient Deep Learning Framework for Low Rate Massive MIMO CSI Reporting," in IEEE Transactions on Communications, vol. 68, no. 8, pp. 4761-4772, Aug. 2020, doi: 10.1109/TCOMM.2020.2993626.

[53] Q. Chen and Z. Ding, ``Accommodating LAA Within IEEE 802.11ax WiFi Networks for Enhanced Coexistence," in IEEE Transactions on Wireless Communications, vol. 19, no. 11, pp. 7621-7636, Nov. 2020, doi: 10.1109/TWC.2020.3014425.

[54] C. Sun, J. Wang, X. Gao and Z. Ding, ``Networked Optical Massive MIMO Communications," in IEEE Transactions on Wireless Communications, vol. 19, no. 8, pp. 5575-5588, Aug. 2020, doi: 10.1109/TWC.2020.2994545.

[55] Q. Liu, J. Xu, Z. Ding and H. C. So, ``Target Localization With Jammer Removal Using Frequency Diverse Array," in IEEE Transactions on Vehicular Technology, vol. 69, no. 10, pp. 11685-11696, Oct. 2020, doi: 10.1109/TVT.2020.3016948.

[56] T. Bouchoucha and Z. Ding, ``Anchor selection for topology inference and routing in wireless sensor networks," in Journal of Communications and Information Networks, vol. 5, no. 3, pp. 318-323, Sept. 2020, doi: 10.23919/JCIN.2020.9200895.

[57] X. Ling, Y. Le, J. Wang, Z. Ding and X. Gao, ``Practical Modeling and Analysis of Blockchain Radio Access Network," in IEEE Transactions on Communications, 2020 doi: 10.1109/TCOMM.2020.3029779.

[58] Z. Liu, L. Zhang and Z. Ding, ``Overcoming the Channel Estimation Barrier in Massive MIMO Communication via Deep Learning," in IEEE Wireless Communications, vol. 27, no. 5, pp. 104-111, October 2020, doi: 10.1109/MWC.001.1900413

[59] Q. Hu, Y. Cai, Q. Shi, K. Xu, G. Yu and Z. Ding, ``Iterative Algorithm Induced Deep-Unfolding Neural Networks: Precoding Design for Multiuser MIMO Systems," in IEEE Transactions on Wireless Communications, 2020. doi: 10.1109/TWC.2020.3033334.

[60] X. Ling, J. Wang, Y. Le, Z. Ding and X. Gao, ``Blockchain Radio Access Network Beyond 5G," in IEEE Transactions on Wireless Communications, in IEEE Wireless Communications, 2020. doi: 10.1109/MWC.001.2000172.

[61] A. Jalali and Z. Ding, ``Joint Detection and Decoding of Polar Coded 5G Control Channels", *IEEE Transactions on Wireless Communications,* 19(3), pp. 2066-2078, Mar. 2020.

[62] Yang, Kai, Yuanming Shi, Wei Yu, and Zhi Ding, ``Energy-efficient processing and robust wireless cooperative transmission for edge inference," *IEEE Internet of Things Journal*, accepted, 2020. DOI: 10.1109/JIOT.2020.2979523

[63] J. Dong, Y. Shi, and Z. Ding, ``Blind Over-the-Air Computation and Data Fusion via Provable Wirtinger Flow", *IEEE Transactions on Signal Processing* vol. 68, pp. 1136-1151, 2020. DOI: 10.1109/TSP.2020.2970338.

[64] Y. Ma, Z. Quan, D. Li, S. Zhang, X. Li, Z. Feng, and Z. Ding, Optimal Linear Cooperation for Signal Classification via M-ary Hypothesis Testing in Cognitive Communication Networks, *IEEE Transactions on Wireless Communications,* 19(5), pp. 3144-3155, May 2020.

[65] S. Zhang, Z. Ding and S. Cui, ``Introducing Hypergraph Signal Processing: Theoretical Foundation and Practical Applications," *IEEE Internet of Things Journal,* , vol.7, no.1, pp. 639-660, Jan. 2020. doi: 10.1109/JIOT.2019.2950213

[66] Z. Jiang, X. Shen, H. Wang and Z. Ding, ``Joint PSK Data Detection and Channel Estimation under Frequency Selective Sparse Multipath Channels," in *IEEE Transactions on Communications*, doi: 10.1109/TCOMM.2020.2975172.

[67] R. Liu, Q. Chen, G. Yu, G. Y. Li and Z. Ding, ``Resource Management in LTE-U Systems: Past, Present, and Future," *IEEE Open Journal of Vehicular Technology,* vol. 1, pp. 1-17, 2020 DOI: 10.1109/OJVT.2019.2949020

[68] Li, Pei-Rong, Zhi Ding, and Kai-Ten Feng, ``Enhanced Receiver Based on FEC Code Constraints for Uplink NOMA With Imperfect CSI." *IEEE Transactions on Wireless Communications* vol. 18, no. 10, pp. 4790-4802, 2019.

[69] Z. Liu, L. Zhang, and Z. Ding, ``Exploiting Bi-Directional Channel Reciprocity in Deep Learning for Low Rate Massive MIMO CSI Feedback", *IEEE Wireless Communications Letters*, Feb. 2019. doi:10.1109/LWC.2019.2898662

[70] K. Yang, Y. Shi and Z. Ding, ``Generalized Low-Rank Optimization for Topological Cooperation in Ultra-Dense Networks," *IEEE Transactions on Wireless Communications,* vol. 18, no. 5, pp. 2539-2552, May 2019. doi: 10.1109/TWC.2019.2904570

[71] K. Yang, Y. Shi and Z. Ding, ``Data Shuffling in Wireless Distributed Computing via Low-Rank Optimization," *IEEE Transactions on Signal Processing,* vol. 67, no. 12, pp. 3087-3099, 15 June, 2019. doi: 10.1109/TSP.2019.2912139

[72] S. Bi, J. Lyu, Z. Ding, and R. Zhang, R., ``Engineering Radio Maps for Wireless Resource Management," *IEEE Wireless Communications,* 26(2), pp.133-141, Feb. 2019. doi:10.1109/MWC.2019.1800146

[73] Z. Zhang, Z. Zhu, B. Bazor, S. Lee, Z. Ding and T. Pan, ``FeetBeat: A Flexible Iontronic Sensing Wearable Detects Pedal Pulses and Muscular Activities," *IEEE Transactions on Biomedical Engineering,* 2019. doi: 10.1109/TBME.2019.2900224

[74] L. Jing, H. Wang, C. He and Z. Ding, ``A Novel Spatial CCK Modulation Design for Underwater Acoustic Communications," *IEEE Transactions on Vehicular Technology,* vol. 68, no. 6, pp. 6192-6196, June 2019. doi: 10.1109/TVT.2019.2912583

[75] T. Bouchoucha, C. N. Chuah, and Z. Ding, ``Topology Inference of Unknown Networks Based on Robust Virtual Coordinate Systems", *IEEE/ACM Transactions on Netorking*, vol. 27, no. 1, pp. 405-418, Jan. 2019. doi:10.1109/TNET.2018.2888600

[76] W. Wu and Z. Ding, ``A Markovian Design of Bi-Directional Robust Header Compression for Efficient Packet Delivery in Wireless Networks" *IEEE Transactions on Wireless Communications*, vol.18, no.1, pp. 20-33, Jan. 2019. doi:10.1109/TWC.2018.2875448

[77] X. Ling, J. Wang. T. Bouchoucha, B. C. Levy, and Z. Ding, ``Blockchain Radio Access Network (B-RAN): Towards Decentralized Secure Radio Access Paradigm," IEEE Access, vol. 7, pp. 9714-9723, Jan. 2019. doi: 10.1109/ACCESS.2018.2890557

[78] H. Wang, L. Jing, C. He, and Z. Ding, `` High Rate CCK Modulation Design for Bandwidth Efficient Link Adaptation," IEEE Wireless Communications Letters, , pp. 4960499, 8(2), April 2019.

[79] Q. Chen, G. Yu, and Z. Ding, ``Enhanced LAA for Unlicensed LTE Deployment Based on TXOP Contention," IEEE Transactions on Communications, vol. 67, no. 1, pp. 417-429, Jan. 2019. doi: 10.1109/TCOMM.2018.2868694

[80] Hema K. Achanta, Soura Dasgupta, Raghuraman Mudumbai, Weiyu Xu, and Zhi Ding, ``Optimum sensor placement for localization of a hazardous source under log normal shadowing," Numerical Algebra, Control & Optimization, no. 3, pp. 361-382, 2019. doi: 10.3934/naco.2019024

[81] C. Sun, X. Gao, J. Wang, Z. Ding and X. Xia, "Beam Domain Massive MIMO for Optical Wireless Communications With Transmit Lens," IEEE Transactions on Communications, vol. 67, no. 3, pp. 2188-2202, March 2019. doi: 10.1109/TCOMM.2018.2883622

[82] P. Ge, X. Liang, J. Wang, C. Zhao, X. Gao and Z. Ding, "Optical Filter Designs for Multi-Color Visible Light Communication", IEEE Transactions on Communications, vol. 67, no. 3, pp. 2173-2187, March 2019. doi: 10.1109/TCOMM.2018.2883422

[83] Y. Wu, C. Xiao, Z. Ding, X. Gao, and S. Jin A Survey on MIMO Transmission With Finite Input Signals: Technical Challenges, Advances, and Future Trends," Proceedings of the IEEE, vol. 106, No. 10, 1779-1833, October, 2018.

[84] Q. Wu, C. Feres, D. Kuzmenko, Z. Ding, Z. Yu, X. Liu, and Xiaoguang Liu, ``Deep learning based RF fingerprinting for device identification and wireless security," Electronics Letters, vol. 54, no. 24, pp. 1405-1407, 2018. doi: 10.1049/el.2018.6404

[85] L. Liang, S. Xie, G. Y. Li, Z. Ding and X. Yu, ``Graph-Based Resource Sharing in Vehicular Communication," IEEE Transactions on Wireless Communications, vol. 17, no. 7, pp. 4579-4592, July 2018. doi: 10.1109/TWC.2018.2827958

[86] Q. Ji, Z. Ding, N. Wang, M. Pan and G. Song, ``A Novel Waveform Optimization Scheme for Piezoelectric Sensors Wire-Free Charging in the Tightly Insulated Environment,"> IEEE Internet of Things Journal, vol. 5, no. 3, pp. 1936-1946, June 2018. doi: 10.1109/JIOT.2018.2817601

[87] X. Ling, J. Wang, Z. Ding, C. Zhao and X. Gao, ``Efficient OFDMA for LiFi Downlink," *Journal of Lightwave Technology,* vol. 36, no. 10, pp. 1928-1943, 15 May 2018. doi: 10.1109/JLT.2018.2796120

[88] C. Jiang, W. Wu, and Z. Ding, ``LTE Multimedia Broadcast Multicast Service Provisioning Based on Robust Header Compression," *IEEE Transactions on Wireless Communications,* vol. 17, no. 2, pp. 1161-1172, Feb. 2018. doi: 10.1109/TWC.2017.2776906

[89] X. Ling, J. Wang, X. Liang, Z. Ding, C. Zhao, and X. Gao ``Biased Multi-LED Beamforming for Multicarrier Visible Light Communications," IEEE Journal on Selected Areas in Communications, vol. 36, no. 1, pp.106-120, Jan. 2018. doi: 10.1109/JSAC.2017.2774539

[90] X. Liang, Z. Ding and C. Xiao, ``On Linear Precoding of Non-Regenerative MIMO Relay Networks For Finite-Alphabet Source," *IEEE Transactions on Vehicular Technology,* vol. 66, no. 11, pp. 9761-9775, Nov. 2017. doi: 10.1109/TVT.2017.2717925

[91] X. Liang; M. Yuan; J. Wang; Z. Ding; M. Jiang; C. Zhao, ``Constellation Design Enhancement for Color-Shift Keying Modulation of Quadrichromatic LEDs in Visible Light Communications," *Journal of Lightwave Technology,* vol.15, no.17, pp.3650-3663, September 2017. doi: 10.1109/JLT.2017.2720579

[92] L. Jing, C. He, J. Huang and Z. Ding, ``Energy Management and Power Allocation for Underwater Acoustic Sensor Network,"*IEEE Sensors Journal,* vol. 11, no. 11, pp. 1789-1796, August 2017. doi: 10.1109/JSEN.2017.2737229

[93] W. Wu and Z. Ding, ``On Efficient Packet-Switched Wireless Networking: A Markovian Approach to Trans-layer Design and Optimization of ROHC," in IEEE Transactions on Wireless Communications , vol.16, no.7, pp.4232-4245, July 2017. doi: 10.1109/TWC.2017.2694840

[94] W. Wu, H. Mittelmann, and Z. Ding, ``Modulation Design for MIMO-CoMP HARQ," IEEE Communications Letters, vol.21, no.2, pp.290-293, Feb. 2017. doi: 10.1109/LCOMM.2016.2618796

[95] Lianyou Jing, C. He, Jian-guo Huang, and Z. Ding, ``Joint Channel Estimation and Detection Using MCMC Method over Sparse Underwater Acoustic Channels". *IET Communications,* May 2017. doi: 10.1049/iet-com.2016.1339

[96] L. Jing, H. Wang, C. He and Z. Ding, ``Spatial CCK Modulation and Iterative Detection over Frequency-Selective Fading Channels," *IEEE Wireless Communications Letters,* vol.6, no.4, pp.506-509, June 2017. doi: 10.1109/LWC.2017.2709315

[97] Hesham Elmaghraby and Zhi Ding, ``Scheduling and Power Allocation for Hybrid Access Cognitive Femtocells," *IEEE Transactions on Wireless Communications* vol.16, No.4, pp. 2520-2533, April 2017.

[98] Chen Sun, Xiqi Gao, and Zhi Ding. ``BDMA in Multi-Cell Massive MIMO Communications: Power Allocation Algorithms", *IEEE Transactions on Signal Processing,* vol. 65, No. 11, pp. 2962-74, June 2017.

[99] Dongrun Qin and Zhi Ding, ``Transport capacity analysis of wireless in-band full duplex ad hoc networks." *IEEE Transactions on Communications,* vol. 65, no. 3, pp.1303-18, March 2017. doi: 10.1109/TCOMM.2016.2640278

[100] Qimei Chen, Guanding Yu, Hesham M. Elmaghraby, Jyri Hamalainen, Zhi Ding, ``Embedding LTE-U within Wi-Fi Bands for Spectrum Efficiency Improvement", *IEEE Network*, Vol.31, No. 2, pp. 72-79, March 2017.

[101] K. Wang; Z. Ding, ``FEC Code Anchored Robust Design of Massive MIMO Receivers," in *IEEE Transactions on Wireless Communications,* vol.15, no.12, pp.8223-8235, 2016, doi: 10.1109/TWC.2016.2613516

[102] Q. Chen, G. Yu and Z. Ding, ``Optimizing Unlicensed Spectrum Sharing for LTE-U and WiFi Network Coexistence," in *IEEE Journal on Selected Areas in Communications,* vol. 34, no. 10, pp. 2562-2574, Oct. 2016. doi: 10.1109/JSAC.2016.2604998

[103] Z. Zheng; J. Hamalainen; Z. Ding, ``On the sum rate of fair resource allocation with selective feedback," in *IEEE Transactions on Wireless Communications*, vol.15, no.8, pp.5193 - 5205, doi: 10.1109/TWC.2016.2554579

[104] D. Qin and Z. Ding, ``Exploiting Multi-Antenna Non-Reciprocal Channels for Shared Secret Key Generation,"in *IEEE Transactions on Information Forensics and Security,* vol. 11, no. 12, pp. 2693-2705, Dec. 2016. doi: 10.1109/TIFS.2016.2594143

[105] Han, Huy-Dung, Zhi Ding, and Muhammad Zia. ``A Convex Relaxation Approach to Higher-Order Statistical Approaches to Signal Recovery." *IEEE Transactions on Vehicular Technology*, vol.PP, no.99, pp.1-1 doi: 10.1109/TVT.2016.2542108

[106] H. Wang; C. Zhu; Z. Ding, ``Femtocell Power Control for Interference Management Based on Macro-Layer Feedback," IEEE Transactions on Vehicular Technology, vol.64, no.6, pp.5222-5236 July 2016. doi: 10.1109/TVT.2015.2463718

[107] W. Wu, H. Mittelmann, and Z. Ding, ``Modulation Design for Two-Way Amplify-and-Forward Relay HARQ," IEEE Wireless Communications Letters, vol.5, no.3, pp.244-247, June 2016. doi: 10.1109/LWC.2016.2530659

[108] K. Wang; Z. Ding, ``Diversity Integration in Hybrid-ARQ with Chase Combining under Partial CSI," in IEEE Transactions on Communications, vol.64, no.6, pp.2647-2659, June 2016. doi: 10.1109/TCOMM.2016.2553664

[109] Xintong Ling, J. Wang, X. Liang, Z. Ding, C. Zhao, Offset and power optimization for DCO-OFDM in visible light communication systems," *IEEE Transactions on Signal Processing,* 64(2), 349-363, 2016.

[110] H. Tang and Z. Ding, ``Mixed Mode Transmission and Resource Allocation for D2D Communication," IEEE Transactions on Wireless Communications, vol. 15, no. 1, pp. 162-175, Jan. 2016. doi: 10.1109/TWC.2015.2468725

[111] X. Ling, J. Wang, X. Liang, Z. Ding and C. Zhao, ``Offset and Power Optimization for DCO-OFDM in Visible Light Communication Systems," IEEE Transactions on Signal Processing, vol. 64, no. 2, pp. 349-363, Jan.15, 2016. doi: 10.1109/TSP.2015.2477799

[112] H. Wang, J. Wang and Z. Ding, ``Distributed Power Control in a Two-Tier Heterogeneous Network," IEEE Transactions on Wireless Communications, vol. 14, no. 12, pp. 6509-6523, Dec. 2015. doi: 10.1109/TWC.2015.2456055

[113] Bi, Suzhi, Rui Zhang, Zhi Ding, and Shuguang Cui. ``Wireless communications in the era of big data." IEEE Communications Magazine, vol. 53, no. 10, pp. 190-199, October 2015. doi: 10.1109/MCOM.2015.7295483

[114] Michal Cierny, Zhi Ding, and Risto Wichman. ``Higher Rank Interference Effect on Weak Beamforming or OSTBC Terminals." IEEE Transactions on Wireless Communications, vol. 14, no. 9, pp. 4948-4957, Sept. 2015. doi: 10.1109/TWC.2015.2429648

[115] Haile, B.B.; Dowhuszko, A.A.; Hamalainen, J.; Wichman, R.; Ding, Z., ``On Performance Loss of Some CoMP Techniques Under Channel Power Imbalance and Limited Feedback,", IEEE Transactions on Wireless Communications, vol.14, no.8, pp.4469-4481, Aug. 2015. doi: 10.1109/TWC.2015.2421898

[116] Kun Wang, Hong Shen, Wenhao Wu, and Zhi Ding, Joint Detection and Decoding in LDPC-Based Space-Time Coded MIMO-OFDM Systems via Linear Programming" IEEE Transactions on Signal Processing, 63. 3411-3424. 2015. doi: 10.1109/TSP.2015.2422681

[117] Elsherif, A.R.; Wei-Peng Chen; Ito, A.; Zhi Ding, ``Resource Allocation and Inter-Cell Interference Management for Dual-Access Small Cells," *IEEE Journal on Selected Areas in Communications,* vol.33, no.6, pp.1082-1096, June 2015. doi: 10.1109/JSAC.2015.2416990

[118] Elsherif, A.R.; Chen, Wei-Peng; Ito, A.; Z. Ding, ``Adaptive resource allocation for interference management in small cell networks," IEEE Transactions on Communications, vol.63, no.6, pp.2107-2125, June 2015. doi: 10.1109/TCOMM.2015.2420676

[119] Sun, C.; Gao, X.; Jin, S.; Matthaiou, M.; Ding, Z.; Xiao, C., ``Beam Division Multiple Access Transmission for Massive MIMO Communications," IEEE Transactions on Communications," vol.63, no.6, pp.2170-2184, 2015. doi: 10.1109/TCOMM.2015.2425882

[120] Sam Siu, Qing Ji, Wenhao Wu, Gangbing Song, and Zhi Ding, ``Stress wave communication in concrete: I. Characterization of a smart aggregate based concrete channel," *Smart Materials and Structures,* 23(12): 125030, Dec. 2014.

[121] Sam Siu, Qing Ji, Wenhao Wu, Gangbing Song, and Zhi Ding. ``Stress wave communication in concrete: II. Evaluation of low voltage concrete stress wave communications utilizing spectrally efficient modulation schemes with PZT transducers," *Smart Materials and Structures,* 23(12): 125031, Dec. 2014.

[122] Wang, Haining, and Zhi Ding, ``Power Control and Resource Allocation for Outage Balancing in Femtocell Networks," *IEEE Transactions on Wireless Communications,* 14, no. 4 (2015): 2043-2057. doi: 10.1109/TWC.2014.2379282

[123] Wu, Wenhao, Kun Wang, Weiliang Zeng, Zhi Ding, and Chengshan Xiao, ``"Cooperative Multi-Cell MIMO Downlink Precoding With Finite-Alphabet Inputs," *IEEE Transactions on Communications,* vol. 63, no. 3 (2015): 766-779. doi: 10.1109/TCOMM.2015.2388584

[124] Huan Tang, Zhi Ding, and B. C. Levy, ``Enabling D2D Communications Through Neighbor Discovery in LTE Cellular Networks," IEEE Transactions on Signal Processing, vol.62, no.19, pp.5157-5170, Oct.1, 2014. doi: 10.1109/TSP.2014.2348950

[125] Haining Wang; Zhi Ding, ``Macrocell-Queue-Stabilization-Based Power Control of Femtocell Networks," *IEEE Transactions on Wireless Communications*, vol.13, no.9, pp.5223-5236, Sept. 2014

[126] Zia, M.; Ding, Z., ``Bandwidth Efficient Variable Rate HARQ Under Orthogonal Space-Time Block Codes," IEEE Transactions on Signal Processing, vol.62, no.13, pp.3360-3370, July 2014 doi: 10.1109/TSP.2014.2327580

[127] Binbin Guan; Djordjevic, S.S.; Fontaine, N.K.; Linjie Zhou; Ibrahim, S.; Scott, R.P.; Geisler, D.J.; Zhi Ding; Ben Yoo, S.J., "CMOS Compatible Reconfigurable Silicon Photonic Lattice Filters Using Cascaded Unit Cells for RF-Photonic Processing," IEEE Journal of Selected Topics in Quantum Electronics, vol.20, no.4, pp.1,10, July-Aug. 2014 doi: 10.1109/JSTQE.2013.2296233

[128] Hong Shen; Zhi Ding; Dasgupta, S.; Chunming Zhao, "Multiple Source Localization in Wireless Sensor Networks Based on Time of Arrival Measurement,"IEEE Transactions on Signal Processing, vol.62, no.8, pp.1938-1949, April 15, 2014 doi: 10.1109/TSP.2014.2304433

[129] Dongrun Qin; Zhi Ding; Dasgupta, S., "On Forward Channel Estimation for MIMO Precoding in Cooperative Relay Wireless Transmission Systems," IEEE Transactions on Signal Processing, vol.62, no.5, pp.1265-1278, March 2014 doi: 10.1109/TSP.2013.2296880

[130] Elsherif, A.R.; Zhi Ding; Xin Liu, "Dynamic MIMO Precoding for Femtocell Interference Mitigation," IEEE Transactions on Communications, vol.62, no.2, pp.648-666, February 2014 doi: 10.1109/TCOMM.2013.122913.130062

[131] Tseng, Po-Hsuan, Zhi Ding, and Kai-Ten Feng. "Cooperative Self-Navigation in a Mixed LOS and NLOS Environment", IEEE Transactions on Mobile Computing, 13, no. 2 (2014): 350-363. doi: 10.1109/TMC.2013.6

[132] Ahmed R. Elsherif, Zhi Ding, Xin Liu, and Jyri Hamalainen, ``Resource Allocation in Two-Tier Heterogeneous Networks through Enhanced Shadow Chasing," IEEE Transactions on Wireless Communications, vol. 12, no.12, pp. 6439-6453, Dec. 2013. doi:10.1109/TWC.2013.101813.130732

[133] Enyang Xu, Z.Ding, and S. Dasgupta, ``Target tracking and mobile sensor navigation in wireless sensor networks". IEEE Transactions on Mobile Computing, 12(1):177-186. 2013. doi: 10.1109/TMC.2011.262

[134] Jacklin, Neil, and Zhi Ding. "A linear programming based tone injection algorithm for papr reduction of OFDM and linearly precoded systems", IEEE Transactions on Circuits and Systems I: Regular Papers, vol. 60, no. 7 (2013): 1937-1945. doi: 10.1109/TCSI.2012.2230505

[135] M. Cierny, Haining Wang, R. Wichman, Zhi Ding, and C. Wijting, ``On Number of Almost Blank Subframes in Heterogeneous Cellular Networks," IEEE Transactions on Wireless Communications, vol.12, no.10, pp.5061-5073, October 2013.

[136] Zhe Jiang; Haiyan Wang; Zhi Ding, ``A Bayesian Algorithm for Joint Symbol Timing Synchronization and Channel Estimation in Two-Way Relay Networks,"IEEE Transactions on Communications, vol.61, no.10, pp.4271-4283, October 2013. doi:10.1109/TCOMM.2013.082813.110691

[137] Yongpeng Wu; Chengshan Xiao; Xiqi Gao; Matyjas, J.D.; Zhi Ding, "Linear Precoder Design for MIMO Interference Channels with Finite-Alphabet Signaling," IEEE Transactions on Communications, vol.61, no.9, pp.3766-3780, September 2013. doi: 10.1109/TCOMM.2013.072213.130132

[138] Xiao Liang; Chun-Ming Zhao; Zhi Ding, ""Piggyback Retransmissions over Wireless MIMO Channels: Shared Hybrid-ARQ (SHARQ) for Bandwidth Efficiency," IEEE Transactions on Wireless Communications, vol.12, no.8, pp.3770,3782, August 2013. doi: 10.1109/TWC.2013.051313.121098

[139] Kun-Yu Wang, Neil Jacklin, Zhi Ding, and Chong-Yung Chi, ``Robust MISO Transmit Optimization under Outage-Based QoS Constraints in Two-Tier Heterogeneous Networks," IEEE Transactions on Wireless Communications, 12 (4):1883-1897, April 2013. doi: 10.1109/TWC.2013.022013.121111

[140] Enyang Xu, Zhi Ding, and S. Dasgupta, ``Target Tracking and Mobile Sensor Navigation in Wireless Sensor Networks", IEEE Transactions on Mobile Computing, 12(1):177 - 186, Jan. 2013.

[141] F. E. Lapiccirella, X. Liu, and Z. Ding, ``Distributed Control of Multiple Cognitive Radio Overlay for Primary Queue Stability", IEEE Transactions on Wireless Communications, 12(1):112-122, January 2013. doi:10.1109/TWC.2012.121112.111783

[142] Shafi, A. Bashar, Zhi Ding, and Chengshan Xiao, ``On Secrecy Rate Analysis of MIMO Wiretap Channels Driven by Finite-Alphabet Input," IEEE TRANSACTIONS ON COMMUNICATIONS, 60 (12):3816-3825, Dec. 2012.

[143] Huy-Dung Han and Z. Ding, ``Steepest descent algorithm implementation for multichannel blind signal recovery", IET Communications, 6(18):3196-3203, December 2012.

[144] Y. Wu, C. Xiao and Z. Ding, X. Gao, and S. Jin, ``LINEAR PRECODING FOR FINITE-ALPHABET SIGNALING OVER MIMOME WIRETAP CHANNELS," IEEE Transactions on Vehicular Technology, 61(6): 2599-2612, 2012

[145] Y. Wu, M. Wang, C. Xiao, Z. Ding, X.-Q. Gao ``Linear Precoding for MIMO Broadcast Channels With Finite-Alphabet Constraints", IEEE Transactions on Wireless Communications, 11(8): 2906 - 2920, August 2012

[146] Neil Jacklin, Zhi Ding, Wei Chen, Chunqi Chang, ``Noniterative Convex Optimization Methods for Network Component Analysis" IEEE/ACM Transactions on Computational Biology and Bioinformatics, 9(5):1472-1481, Sept.-Oct. 2012

[147] F.~E. Lapiccirella, Z. Ding, and X. Liu, ``Cognitive Spectrum Access Control Based on Intrinsic Primary ARQ Information", IET Communications, 6(8):900-908, August 2012.

[148] X. Liang, Z. Ding and C. Xiao, ``OPTIMIZED POWER ALLOCATION FOR PACKET RETRANSMISSIONS OF NON-GAUSSIAN INPUTS THROUGH SEQUENTIAL AWGN CHANNELS", IEEE Transactions on Communications, 60(7): 1889-1902, 2012.

[149] T. Miyajima and Zhi Ding, ``Subcarrier Nulling Algorithms for Channel Shortening in Uplink OFDMA Systems," IEEE Transactions on Signal Processing, vol.60, no.5, pp.2374-2385, May 2012.

[150] C. Xiao, Y. R. Zheng, and Z. Ding, ``Globally optimal linear precoders for finite alphabet signals over complex vector Gaussian channels," IEEE Trans. Signal Process., vol.59, pp.3301-3314, July 2011.

[151] Li Zhang, Shu Lin, K. Abdel-Ghaffar, Zhi Ding, and Bo Zhou, ``Quasi-Cyclic LDPC Codes on Cyclic Subgroups of Finite Fields" , IEEE Transactions on Communications, 59(9):2330-2336, Sept. 2011

[152] Z. Muhammad, and Z. Ding, ``Blind Multiuser Detection for Synchronous High Rate Space-Time Block Coded Transmission", IEEE Transactions on Wireless Communications, Issue: 99, July 2011, Page(s): 2171 - 2185.

[153] S. Bashar, Z. Ding, C. Xiao, ``On the Secrecy Rate of Multi-Antenna Wiretap Channel under Finite-Alphabet Input", IEEE Communications Letters, Vol. 15, No. 5, 2011, Page(s): 527-529.

[154] Xiao Liang, Chunming Zhao, and Zhi Ding, ``Sequential Linear MIMO Precoder Optimization for Hybrid ARQ Retransmission of QAM Signals", IEEE Communications Letters, 15(9): 913 - 915, September 2011.

[155] Enyang Xu; Zhi Ding; Dasgupta, S.; ``Source Localization in Wireless Sensor Networks From Signal Time-of-Arrival Measurements", IEEE Transactions on Signal Processing, Volume: 59 , Issue: 6, June 2011, Page(s): 2887 - 2897

[156] S. Bashar, Z. Ding, and (G.) Y. Li, `` On Secrecy of Codebook-Based Transmission Beamforming under Receiver Limited Feedback," IEEE Transactions on Wireless Communications, Volume: 10 , Issue: 4, April 2011 , Page(s): 1212 - 1223

[157] Senhua Huang, Xin Liu, and Zhi Ding; ``Decentralized Cognitive Radio Control Based on Inference from Primary Link Control Information", IEEE Journal on Selected Areas in Communications, Volume: 29 Issue:2, February 2011; page(s): 394 - 406.

[158] Enyang Xu, Zhi Ding, Soura Dasgupta, ``Reduced Complexity Semidefinite Relaxation Algorithms for Source Localization based on Time Difference of Arrival," IEEE Transactions on Mobile Computing, vol. 99, no. 9, 2011.

[159] Djordjevic, S.S.; Luo, L.W.; Ibrahim, S.; Fontaine, N.K.; Poitras, C.B.; Guan, B.; Zhou, L.; Okamoto, K.; Ding, Z.; Lipson, M.; Yoo, S.J.B.; ``Fully Reconfigurable Silicon Photonic Lattice Filters With Four Cascaded Unit Cells," IEEE Photonics Technology Letters, vol.23, no.1, pp.42-44, Jan.1, 2011

[160] Z. Shi, W. Xu, S. Jin, C. Zhao, and Z. Ding, ``On Wireless Downlink Scheduling of MIMO Systems With Homogeneous Users" IEEE Transactions on Information Theory, Volume 56, July 2010. page(s): 3367 - 3378.

[161] S. Song, S. Lin, K. Abdel-Ghaffar, Z. Ding, W.H. Fong, M.P.C. Fossorier, ``Burst Decoding of Cyclic Codes Based on Circulant Parity-Check Matrices," IEEE Transactions on Information Theory, Volume 56, March 2010. page(s): 1038 - 1047.

[162] M. Muhammad and Z. Ding, ``A Linear Programming Receiver for Blind Detection of Full Rate Space-Time Block Codes" IEEE Transactions on Signal Processing, Volume: Issue: 99, Nov. 2010.

[163] S. Huang, X. Liu, and Z. Ding, ``Optimal Transmission Strategies for Dynamic Spectrum Access in Cognitive Radio Networks," IEEE Transactions on Mobile Computing, Volume 8, No. 12, December 2009. Page(s):1636 - 1648

[164] C. He, J. Huang, and Z. Ding, ``A Variable-Rate Spread-Spectrum System for Underwater Acoustic Communications" IEEE Journal of Oceanic Engineering, 34(4): 624-633, Oct. 2009.

[165] W. Xu, C. Zhao, and Z. Ding, ``Optimisation of limited feedback design for heterogeneous users in multi-antenna downlinks" , Institution of Engineering and Technology Communications, Volume 3, Issue 11, Page(s):1724 - 1735, November 2009

[166] S. Bashar and Zhi Ding, ``Admission control and resource allocation in a heterogeneous OFDMA wireless network" IEEE Transactions on Wireless Communications, Volume 8, Issue 8, Page(s):4200 - 4210, August 2009

[167] Wei Xu, Chunming Zhao, and Zhi Ding, ``Limited Feedback Multiuser Scheduling of Spatially Correlated Broadcast Channels" , IEEE Transactions on Vehicular Technology, Volume 58, Issue 8, Page(s):4406 - 4418, Oct. 2009.

[168] C. Meng, J. Tuqan, and Z. Ding, `` A Quadratic Programming Approach to Blind Equalization and Signal Separation" IEEE Transactions on Signal Processing, 57(6): 2232-2244, June 2009.

[169] Wei Xu, Chunming Zhao, and Zhi Ding, ``Limited feedback design for MIMO broadcast channels with ARQ mechanism" IEEE Transactions on Wireless Communications, Volume 8, Issue 4, Page(s):2132 - 2141, April 2009.

[170] Xiaofei Dong and Z. Ding, ``Wireless Channel Estimation for Linear MIMO Transmission Precoding" IEEE Transactions on Communications, Volume 57, Issue 4, April 2009 Page(s):1151 - 1161

[171] Bo Zhou, Jingyu Kang, Ying Tai, Shu Lin, and Zhi Ding, ``High Performance Non-Binary Quasi-Cyclic LDPC Codes on Euclidean Geometries LDPC Codes on Euclidean Geometries," IEEE Transactions on Communications, Volume 57, Issue 5, May 2009, Page(s):1298 - 1311.

[172] S. D. Chitte, S. Dasgupta, and Zhi Ding, ``Distance Estimation From Received Signal Strength Under Log-Normal Shadowing: Bias and Variance", IEEE Signal Processing Letters, 16(3): 216 - 218, March 2009.

[173] X. Dong, Z. Ding, and S. Dasgupta, ``Performance Analysis of a Forward Link Channel Estimation Method for Wireless Multicarrier Systems," IEEE Transactions on Wireless Communications,, 7(8): 3026-3035, August 2008.

[174] Chunqi Chang, Zhi Ding, Yeung Sam Hung, and Peter Chin Wan Fung, ``Fast Network Component Analysis (FastNCA) for Gene Regulatory Network Reconstruction from Microarray Data", Bioinformatics 2008 24(11):1349-1358.

[175] H. Sun, Z. Shi, C. Zhao, J. H. Manton, and Z. Ding, ``Progressive Linear Precoder Optimization for MIMO Packet Retransmissions Exploiting Channel Covariance Information", IEEE Transactions on Communications, Volume: 55, Issue: 5, page(s): 818-827, May 2008.

[176] H. Kameyama, T. Miyajima, and Z. Ding, ``Perfect Blind Channel Shortening for Multicarrier Systems", IEEE Transactions on Circuits and Systems, Volume: 55, Issue: 3, page(s): 851-860, April 2008.

[177] C. Meng, Z. Ding, and S. Dasgupta, ``A Semidefinite Programming Approach to Source Localization in Wireless Sensor Networks", IEEE Signal Processing Letters, Volume 15, 2008, Page(s):253 - 256

[178] Zhihua Shi, Haitong Sun, Chunming Zhao, and Z. Ding, ``Linear precoder optimization for ARQ packet retransmissions in centralized multiuser MIMO uplinks", IEEE Transactions on Wireless Communications, vol. 7, no. 2, February 2008, page(s): 736-745.

[179] Peter M. Hahn, Bum-Jin Kim, Thomas Stutzle, Sebastian Kanthak, William L. Hightower, Harvind Samra, Zhi Ding, and Monique Guignard, The Quadratic Three-dimensional Assignment Problem: Exact and Approximate Solution Methods, European Journal of Operational Research Volume 184, Issue 2, Pages 416-428, 16 January 2008.

[180] Y. Du, F.Xue, S. J. B. Yoo, and Z. Ding, "Security Enhancement of SPECTS O-CDMA Through Concealment Against Upstream DPSK Eavesdropping", Journal of Lightwave Technology, Volume 25, Issue 9, Sept. 2007 Page(s):2799 - 2806

[181] H. Sun and Z. Ding, Iterative Transceiver Design for MIMO ARQ Retransmissions With Decision Feedback Detection" IEEE Transactions on Signal Processing, vol. 55, pp. 3405-3416, July 2007.

[182] C. Yang, N. K. Fontaine, R. P. Scott, V. J. Hernandez, W. Cong, D. L. Harris, K. Okamoto, B. H. Kolner, Z. Ding, J. P. Heritage, and S. J. B. Yoo, ``Two-User 150-km Field Fiber Security Enhanced SPECTS O-CDMA Transmission", IEEE Photonics Technology Letters, Volume 19, Issue 11, June 1, 2007, Page(s):852 - 854.

[183] S. J. Yoo, J. P. Heritage, V. J. Hernandez, R. P. Scott, W. Cong, N. K. Fontaine, R. G. Broeke, J. Cao, S.-W. Seo, J.-H. Baek, F. M. Soares, Y. Du, C. Yang, W. Jiang, K. Aihara, Z. Ding, B. H. Kolner, Anh-Vu Pham, Shu Lin, F. Olsson, S. Lourdudoss, K. Y. Liou, S. N. Chu, R. A. Hamm, B. Patel, W. S. Hobson, J. R. Lothian, S. Vatanapradit, L. A. Gruezke, W. T. Tsang, M. Shearn, and A. Scherer, ``Spectral phase encoded time spread optical code division multiple access technology for next generation communication networks [Invited]", Journal of Optical Networking,, Volume 6, Issue 10, Pages 1210-1227, September 2007.

[184] Tongtong Li, Qi Ling, and Zhi Ding ``Transmit Delay Structure Design for Blind Channel Estimation over Multipath Channels," EURASIP Journal onWireless Communications and Networking, February 2007, Page(s)

[185] V.J. Hernandez, Wei Cong; Junqiang Hu; Chunxin Yang; Fontaine, N.K.; Scott, R.P.; Zhi Ding; Kolner, B.H.; Heritage, J.P.; Yoo, S.J.B.; ``A 320-Gb/s Capacity (32-User X 10 Gb/s) SPECTS O-CDMA Network Testbed With Enhanced Spectral Efficiency Through Forward Error Correction" IEEE Journal of Lightwave Technology, Volume 25, Issue 1, Jan. 2007 Page(s):79 - 86

[186] J. Roberson, X. Dong, and Z. Ding, ``Channel Estimation and Equalization Techniques in Downsampled ARQ Systems" , IEEE Transactions on Signal Processing, Volume 55, Issue 5, Page(s):2251 - 2262, May 2007.

[187] N. Ammar and Z. Ding, ``Blind Channel Identifiability for Generic Linear Space-Time Block Codes", , IEEE Transactions on Signal Processing, Volume 55, Issue 1, Jan. 2007, Page(s):202 - 217.

[188] Y. Du, S. J. B. Yoo, and Z. Ding, ``Nonuniform Spectral Phase Encoding in Optical CDMA Networks" IEEE Photonics Technology Letters, Volume 18, Issue 23, Dec.1, 2006, Page(s):2505 - 2507.

[189] H. Sun, J. Manton, and Z. Ding, ``Progressive Linear Precoder Optimization for MIMO Packet Retransmissions Exploiting Channel Covariance Information", IEEE Journal on Selected Areas in Communications, Vol. 24, no.3, pp. 448-456, March 2006.

[190] H. Samra and Z. Ding, ``Retransmission Diversity Schemes for Multicarrier Modulations", IEEE Transactions on Wireless Communications. Vol. 5, no. 5, pp. 1142-1147, May 2006.

[191] N. Ammar and Z. Ding, ``Channel Identifiability under Space-Time Coded Modulations without Training" , IEEE Transactions on Wireless Communications. Vol. 5, no. 5, pp. 1003-1013, May 2006.

[192] T. A. Drumright and Z. Ding, ``QAM Constellation Classification based on Statistical Sampling for Distortive Channels", IEEE Trans. on Signal Processing. Vol.54, No.5, pp. 1575-1586, May 2006.

[193] H. Samra and Z. Ding, ``New MIMO ARQ Protocols and Joint Detection via Sphere Decoding," IEEE Transactions on Signal Processing, vol. 54, no.2, pp. 473-482, Feb. 2006.

[194] B. Parr, B. L. Cho, K. Wallace, and Z. Ding, ``Performance Analysis of a spectrally compliant ultra-wideband pulse design," IEEE Transactions on Wireless Communications, vol.4, No.5, pp. 2172-2181, September 2005.

[195] X. Tang and Z. Ding, ``Low-Complexity Iterative Equalization for EDGE with Bidirectional Processing," IEEE Transactions on Wireless Communications, vol. 4, No.5, pp.1963-1968, September, 2005.

[196] H. Samra and Z. Ding, ``A Hybrid ARQ Protocol using Integrated Channel Equalization," IEEE Transactions on Communications, vol. 53, No. 12, pp. 1996-2001, Dec. 2005.

[197] X. Dong, Z. Ding, and S. Dasgupta, ``Forward link channel estimation and precoding based on decimated feedback," IEEE Signal Processing Letters. Vol. 12, Issue 6, pp.445-448, Dec. 2005.

[198] H. Samra, Z. Ding, and P.M. Hahn, ``Symbol Mapping Diversity Design for Multiple Packet Transmissions," IEEE Transactions on Communications, Vol. 53, No.5, pp. 810-817, May 2005.

[199] S. Cui, M. Kisialiou, Z.-Q. Luo, and Z. Ding, ``Robust Blind Multiuser Detection Against Signature Waveform Mismatch base on second order cone programming," IEEE Transactions on Wireless Communications, Vol. 4, No. 4, pp. 1285-1291, July 2005.

[200] T. Li, W. Liang, Z. Ding, and J. K. Tugnait, ``Blind Multiuser Detection for Long-code CDMA Systems with Transmission-induced Cyclostationarity," EURASIP Journal on Wireless Communications and Networking, vol.2, pp.206-215, 2005

[201] T. Miyajima and Zhi Ding, ``Second-order statistical approaches to channel shortening in multicarrier systems", IEEE Transactions on Signal Processing, pp.3253 - 3264, vol.52, Nov. 2004.

[202] V. J. Hernandez, Y. Du, W. Cong, R. P. Scott, K. Li, J. P. Heritage, Z. Ding, B. H. Kolner, and S. J. B. Yoo, ``Spectral phase-encoded time-spreading (SPECTS) optical code-division multiple access for terbit optical access networks," IEEE Journal of Lightwave Technology, Vol.22, No. 11, pp. 2671-2678, 2004.

[203] H. Xu, S. Dasgupta, and Z. Ding, ``A Novel Channel-identification Method for Wireless Communication Systems", IEEE Transactions on Communications, vol.52, pp.1767-1776, Oct. 2004.

[204] Wing-Kin Ma, Pak-Chung Ching, and Zhi Ding, ``Semidefinite relaxation based multiuser detection for M-ary PSK multiuser systems", IEEE Transactions on Signal Processing, vol.52 pp.2862-2872, Oct. 2004.

[205] J. Liang and Z. Ding, ``FIR Channel Estimation through Generalized Cumulant Slice Weighting," IEEE Trans. Signal Processing, pp.657-667, Mar. 2004.

[206] J. Liang and Z. Ding, ``Nonminimum Phase FIR Channel Estimation Using Cumulant Matrix Pencils", IEEE Trans. Signal Processing, pp.2310-2320, Sept. 2003.

[207] J. Liang and Z. Ding, ``Blind MIMO System Identification Based on Cumulant Subspace Decomposition", IEEE Trans. Signal Processing, vol.51, pp.1457-1468, June 2003.

[208] Z. Ding and L. Qiu, ``Blind MIMO Channel Identification from Second Order Statistics using Rank Deficient Channel Convolution Matrix," IEEE Trans. on Signal Processing, pp.535-544, Feb. 2003.

[209] Q. Li, E.-W. Bai, and Z. Ding, ``Blind Source Separation of Signals with Known Alphabets using E-Approximation Algorithms", IEEE Trans. on Signal Processing, pp.1-10, Jan. 2003.

[210] B. Parr, B. Cho, K. Wallace, and Z. Ding, ``A Novel Ultra-Wideband Pulse Design Algorithm", IEEE Communications Letters, vol.7, pp. 219-222, Dec. 2002.

[211] J. Liang and Z. Ding, ``Multiuser Channel Estimation from Higher Order Statistical Matrix Pencil", EURASIP Journal on Applied Signal Processing, , vol. 49, no. 2, pp. 1417-1426, Dec. 2002.

[212] X. Tang and Zhi Ding, ``Error Propagation in Blind Sequence Estimation", IEEE Communications Letters, vol.6, pp. 265-267, June 2002.

[213] J. E. Mooney, Z. Ding, and L. S. Riggs, ``Performance Analysis of a GLRT Automated Target Discrimination Scheme," IEEE Transactions on Antenna and Propagation, 49(12):1827-1835, Dec. 2001.

[214] R. Lopez-Valcarce, Zhi Ding, and Soura Dasgupta ``Equalization and Interference Cancellation in Linear Multi-User Systems Based on Second Order Statistics" , IEEE Transactions on Signal Processing , vol. 49, no.9, pp. 2042-2049, 2001.

[215] Erwei Bai and Zhi Ding, ``Blind Decision Feedback Equalization of Time-Varying Channels with DPSK Inputs", IEEE Transactions on Signal Processing, vol.49, no.7, pp. 1533-1542, July, 2001.

[216] Junqiang Shen and Zhi Ding, ``Zero-Forcing Blind Equalization Based on Channel Subspace Estimates for Multiuser Systems", IEEE Transactions on Communications, pp.262-271, Feb. 2001.

[217] Zhi Ding and Jing Liang, ``A Cumulant Matrix Subspace Algorithm for Blind Single FIR Channel Identification", IEEE Transactions on Signal Processing, vol. 49, no. 2, pp. 325-333, Feb. 2001

[218] Ge Li and Zhi Ding, ``Semi-blind Channel Identification for Individual Data Bursts in GSM Wireless Systems", Signal Processing, 80(10):2017-2031, Oct. 2000.

[219] Zhi Ding and Zhi-Quan Luo, ``A Fast Linear Programming Algorithm for Blind Equalization", IEEE Transactions on Communications, COM-48(9):1432-1436, September 2000.

[220] Chor Tin Ma, Zhi Ding, and Sze Fong Yau, ``A Two Stage Algorithm for MIMO Blind Deconvolution of Colored Input Signals", IEEE Transactions on Signal Processing, SP-48(4):1187-1192, April 2000.

[221] Chunqi Chang, Zhi Ding, Sze Fong Yau, and Francis H Y Chan, ``A Matrix-Pencil Approach to Blind Separation of Colored Nonstationary Signals", IEEE Transactions on Signal Processing, SP-48(3):900-907, March 2000.

[222] J.E. Mooney, Z. Ding, and L.S. Riggs, "Performance Analysis of an Automated E-pulse Target Discrimination Scheme," IEEE Trans. Antenna Propagation, vol. 48, pp. 619-628, Apr. 2000.

[223] Zhi Ding and Tuan Nguyen, ``Convergence Study of A Kurtosis Maximization Algorithm for Blind Signal Separation and Antenna Beamforming", IEEE Transactions on Signal Processing, 48(6):1587 -1596, June 2000.

[224] Junqiang Shen and Zhi Ding, ``Direct Blind MMSE Channel Equalization Based on Second Order Statistics", IEEE Transactions on Signal Processing, SP-48(4): 1015-1022, April 2000.

[225] Erwei Bai and Zhi Ding, ``Zero-Forcing Equalizability of FIR and IIR Multi-Channel Systems with and without Perfect Measurements", IEEE Transactions on Communications, vol.48, pp.~17-22, Jan. 2000.

[226] Erwei Bai and Zhi Ding, ``Invertibility of Sampled Data Systems", IEEE Transactions on Circuits and Systems, pp.~279-289, March 2000.

[227] Erwei Bai and Zhi Ding, ``Zero of Sampled Data Systems Represented by FIR Models", Automatica, vol.36, No.1, pp.121-123, , Jan. 2000.

[228] K. K. Borah, R. A. Kennedy, Z. Ding, and I. Fijalkow, ``Sampling and Profiltering Effects on Blind Equalizer Design", IEEE Transactions on Signal Processing, SP-49(1):209-218, Jan. 2000.

[229] J. K. Tugnait, L. Tong and Z. Ding, ``Single-User Channel Estimation and Equalization," IEEE Signal Processing Magazine, vol. 17, no. 3, pp. 17-28, 2000.

[230] J.K. Tugnait and Z. Ding, ``Channel Estimation, Equalization and Synchronization," pp. 14-16 in Highlights of Signal Processing for Communications, G.B. Giannakis (Ed.), IEEE Signal Processing Magazine, vol. 16, no. 3, pp. 14-50, 1999.

[231] J.E. Mooney, Z. Ding, and L.S. Riggs, `` Performance Analysis of a GLRT in Late-Time Radar Target Detection," Journal of Electromagnetic Waves and Applications vol. 13, pp. 1339-1341, 1999; also in Progress in Electromagnetic Research, vol. 24, pp. 77-96, 1999.

[232] Tongtong Li and Zhi Ding, ``Joint Transmitter-Receiver Optimization for Non-maximally Decimated Filterbank Precoding Systems", IEEE Transactions on Signal Processing, vol. 47, pp.2407-2414, Sept. 1999.

[233] Jie Zhu, X.-R. Cao and Z. Ding, ``An Algebraic Principle for Blind Separation of White Non-gaussian Sources", Signal Processing, vol.76, pp.105-115, 1999.

[234] Z. Mao and Zhi Ding, ``A Non-parametric Phase Estimation Method for SIMO Systems based on Second Order and Higher Order Statistics," IEEE Trans. on Signal Processing, pp. 843-847, March 1999.

[235] Jie Zhu, Zhi Ding and Xi-Ren Cao, ``Column-anchored Zeroforcing Blind Equalization for Multiuser Wireless FIR Channels", IEEE Journal on Selected Areas in Communications, pp.411-423, March 1999.

[236] Jon E. Mooney, Z. Ding, and L.S. Riggs, ``Robust Target Identification in White Gaussian Noise for Ultra-Wideband Radar Systems," IEEE Trans. Antenna and Propagation, vol.46, pp.1817-1823, Dec. 1998.

[237] Junqiang Shen and Zhi Ding, ``Edge Decision Assisted Decorrelators for Asynchronous CDMA Channels", IEEE Transactions on Communications, pp. 438-445, March 1998.

[238] Zhi Ding and Ge Li, ``Single Channel Blind Equalization for GSM Cellular Systems", IEEE Journal on Selected Areas of Communications, vol.16, pp.1493-1505, October 1998.

[239] Raul A. Casas, C. Richard Johnson Jr., Rodney A. Kennedy, Zhi Ding, and Roberto Malamut, ``Blind Adaptive Decision Feedback Equalization: A Class of Channels Resulting in Ill-convergence from A Zero Initialization", Int. Journal of Adaptive Control and Signal Processing, vol.12, pp.~173-193, March 1998.

[240] Tuan Nguyen and Zhi Ding, ``Blind CMA Beamforming For Narrowband Signals with Multipath Arrivals", Int. Journal of Adaptive Control and Signal Processing, vol.12, pp.~157-172, March 1998.

[241] Darren B. Ward, Zhi Ding, and Rodney A. Kennedy, ``DOA Estimation for Broadband Signals Using Frequency Invariant Beamforming", IEEE Transactions on Signal Processing, 46(3), pp.~1463-1469, May 1998.

[242] Zhi Ding, ``Matrix Outer-product Decomposition Method for Blind Multiple Channel Identification," IEEE Trans. on Signal Processing, 45(12), pp.~3053-3061, 1997.

[243] Z. Ding, ``On Convergence Analysis of Fractionally Spaced Adaptive Blind Equalizers," IEEE Transactions on Signal Processing, pp.~650-657, March 1997.

[244] Z. Ding, ``Multipath Channel Identification Based on Partial System Information", IEEE Transactions on Signal Processing, pp.~235-240, Jan. 1997.

[245] Z. Ding, ``Characteristics of Band-limited Channels Un-identifiable from Second Order Cyclostationary Statistics" IEEE Signal Processing Letters, 3(5):150-152, May 1996.

[246] Y. Li, K. J. R. Liu, and Z. Ding, ``Length-and Cost-dependent Local Minima of Unconstrained Blind Channel Equalizers," IEEE Transactions on Signal Processing, 44(11):2726-2735, 1996.

[247] Y. Li and Z. Ding, ``Global Convergence of Fractionally Spaced Godard Adaptive Equalizers," IEEE Transactions on Signal Processing, SP-44:818-826, April 1996.

[248] Y. Li and Z. Ding, ``Convergence Analysis of Finite Length Blind Adaptive Equalizers," IEEE Transactions on Signal Processing, pp. 2120-2129, September 1995.

[249] Y. Li and Z. Ding, ``A Simplified Approach to Optimum Diversity Combining and Equalization in Digital Data Transmission," IEEE Transactions on Communications, pp. 2285-2288, August 1995.

[250] Y. Li and Z. Ding, ``ARMA System Identification Based on Second Order Cyclostationarity", IEEE Transactions on Signal Processing, pp. 34983-3493, December 1994.

[251] Y. Li and Z. Ding, ``A New Nonparametric Method for Linear System Phase Recovery from Bispectrum", vol. 41, pp. 415-419, IEEE Transactions on Circuits and Systems II, May 1994.

[252] Z. Ding and Y. Li, ``On Channel Identification Based on Second Order Cyclic Spectra", IEEE Transactions on Signal Processing, vol.42, pp. 1260-1264, May 1994.

[253] Z. Ding, ``Blind Equalization Based on Joint Minimum Mean Square Error Criterion," IEEE Transactions on Communications, vol.42, pp. 648-654, Feb/March/April 1994.

[254] J. Y. Hung and Z. Ding, ``Design of Currents to Reduce Torque Ripple in Brushless DC Motors," IEE Proceedings-B, vol.140, pp. 260-266, July 1993.

[255] Z. Ding and C. R. Johnson, Jr., ``On the non-vanishing stability of undesirable equilibria for FIR Godard blind equalizers," IEEE Transactions on Signal Processing, vol.41, pp. 1940-1944, May 1993.

[256] Z. Ding, R. A. Kennedy, B. D. O. Anderson, and C. R. Johnson, Jr., ``Local Convergence of the Sato Blind Equalizer and Generalizations Under Practical Constraints", IEEE Transactions on Information Theory, vol.39, pp. 129-144, Jan. 1993.

[257] R. A. Kennedy and Z. Ding, ``Blind Adaptive Equalizers for QAM Communication Systems Based on Convex Cost Functions," Optical Engineering, vol.31, pp. 1189-1199, June 1992.

[258] Z. Ding, C. R. Johnson, Jr., and R. A. Kennedy, ``On the (Non)Existence of Local Equilibria of Godard Blind Equalizers," IEEE Transactions on Signal Processing, vol.40, pp. 2425-2432, 1992.

[259] Z. Ding and R. A. Kennedy, ``On the Whereabouts of Local Minima For Blind Adaptive Equalizers," IEEE Transactions on Circuit and Systems II, vol.39, pp. 119-223, Feb. 1992.

[260] Z. Ding, R. A. Kennedy, B. D. O. Anderson, and C. R. Johnson, Jr., ``Ill-Convergence of Godard Blind Equalizers in Data Communications," IEEE Transactions on Communications, vol. COM-39, pp. 1313-1327, 1991.

[261] Z. Ding, C. R. Johnson, Jr., and W. A. Sethares, ``Frequency-dependent Bursting in Adaptive Echo Cancellation and its Prevention using Double-talk Detectors," Int. Journal of Adaptive Control and Signal Processing, pp. 219-236, May 1990.

Conference Publications

[1] S A. Wijesinghe, S. Zhang, S. Qi and Z. Ding, ``UFed-GAN: Secure Federated Learning over Wireless Sensor Networks with Unlabeled Data," *2024 IEEE International Conference on Communications Workshops (ICC Workshops)*, Denver, CO, USA, 2024, pp. 1048-1053, doi: 10.1109/ICCWorkshops59551.2024.10615691.

[2] A. Wijesinghe, S. Zhang, S. Wanninayaka, W. Wang and Z. Ding, ``Diff-GO: Diffusion Goal-Oriented Communications with Ultra-High Spectrum Efficiency," *2024 IEEE International Conference on Communications Workshops (ICC Workshops)*, Denver, CO, USA, 2024, pp. 1079-1084, doi: 10.1109/ICCWorkshops59551.2024.10615283. keyw

[3] K. Wang, Z. Ding, D. K. C. So and Z. Ding, ``Energy Efficient Federated Learning with Age-Weighted FedSGD," *2024 IEEE International Conference on Communications Workshops (ICC Workshops)*, Denver, CO, USA, 2024, pp. 457-462, doi: 10.1109/ICCWorkshops59551.2024.10615715.

[4] Y. -C. Lin, T. -S. Lee and Z. Ding, ``Training-Free Cost-Efficient Compression for Massive MIMO Channel State Feedback," *2023 IEEE Global Communications Conference*, Kuala Lumpur, Malaysia, 2023, pp. 3391-3396, doi: 10.1109/GLOBECOM54140.2023.10436746.

[5] C. Feres, B. C. Levy and Z. Ding, ``Bayesian Decision Making Via Over-the-Air Soft Information Aggregation," *IEEE International Conference on Communications*, Rome, Italy, 2023, pp. 3193-3198, doi: 10.1109/ICC45041.2023.10278705.

[6] C. -H. Hsu, C. Feres and Z. Ding, ``Spectral Clustering Aided User Grouping and Scheduling in Wideband MU-MIMO Systems," *IEEE International Conference on Communications*, Rome, Italy, 2023, pp. 4292-4297, doi: 10.1109/ICC45041.2023.10279388

[7] Y. Ge, L. Liu, S. Huang, D. G. G., Y. L. Guan and Z. Ding, ``Low-Complexity Memory AMP Detector for High-Mobility MIMO-OTFS SCMA Systems," *2023 IEEE International Conference on Communications Workshops (ICC Workshops)*, Rome, Italy, 2023, pp. 807-812, doi: 10.1109/ICCWorkshops57953.2023.10283752.

[8] S. Zhang, T. Yu, J. Tivald, B. Choi, F. Ouyang and Z. Ding, ``Exemplar-Based Radio Map Reconstruction of Missing Areas Using Propagation Priority," *2022 IEEE Global Communications Conference*, Rio de Janeiro, Brazil, 2022, pp. 1217-1222, doi: 10.1109/GLOBECOM48099.2022.10001269.

[9] C. Feres, B.C. Levy, and Z. Ding, ``Over-the-Air Collaborative Learning in Joint Decision Making," *IEEE Global Communications Conference* pp. 3581-3586, Dec. 2022. doi: 10.1109/GLOBECOM48099.2022.10001286.

[10] S. Qi, L. D. Chamain and Z. Ding, ``Hierarchical Training for Distributed Deep Learning Based on Multimedia Data over Band-Limited Networks," IEEE International Conference on Image Processing (ICIP), 2022, pp. 2871-2875, doi: 10.1109/ICIP46576.2022.9897383.

[11] A. Jalali, Y. Shi and Z. Ding, ``Robust Wirtinger Flow Algorithm for Channel Coded Blind Demixing," ICC 2022 - IEEE International Conference on Communications, 2022, pp. 4498-4503, doi: 10.1109/ICC45855.2022.9838429.

[12] Z. Wang, W. Cao, X. Ling, Y. Le, J. Wang, and Z. Ding, ``Analysis of Pooling Principle in Blockchain Radio Access Network" 2022 IEEE Int. Conf. on Communications Workshop, pp. 13-18, doi: 10.1109/ICCWorkshops53468.2022.9814583.

[13] L. D. Chamain, M. C. Ilter, J. Hämäläinen and Z. Ding, Interplay between vertical sectorization and user distribution for urban NB-IoT networks," IEEE Wireless Communications and Networking Conference (WCNC), 2022, pp. 1401-1406, doi: 10.1109/WCNC51071.2022.9771892.

[14] C. Wang, A. -A. Lu, X. Gao and Z. Ding, ``Robust Precoding for 3D Massive MIMO with Riemannian Manifold Optimization," IEEE Wireless Communications and Networking Conference (WCNC), 2022, pp. 1341-1346, doi: 10.1109/WCNC51071.2022.9771720.

[15] L. D. Chamain, S. Qi and Z. Ding, ``An End-to-End Learning Architecture for Efficient Image Encoding and Deep Learning," 29th European Signal Processing Conference (EUSIPCO), 2021, pp. 691-695, doi: 10.23919/EUSIPCO54536.2021.9616312.

[16] Y. -C. Lin, T. -S. Lee and Z. Ding, ``Deep Learning for Partial MIMO CSI Feedback by Exploiting Channel Temporal Correlation," 55th Asilomar Conference on Signals, Systems, and Computers, 2021, pp. 345-350, doi: 10.1109/IEEECONF53345.2021.9723211.

[17] Yihan Zou, Kwang Taik Kim, Xiaojun Lin, Mung Chiang, Zhi Ding, Risto Wichman and Jyri Hamalainen, ``Low-Overhead Joint Beam-Selection and Random-Access Schemes for Massive Internet-of-Things with Non-Uniform Channel and Load" IEEE International Conference on Computer Communications (INFOCOM), Toronto, Canada, 6-9 July 2020.

[18] Zou, Yihan, Kwang Taik Kim, Zhi Ding, Risto Wichman, Jyri Hamalainen, Xiaojun Lin, and Mung Chiang, ``Low-overhead multi-antenna-enabled random access for machine-type communications with low mobility," In 2019 IEEE Global Communications Conference (GLOBECOM), pp. 1-6, Kona, Hawaii, USA, December 2019.

[19] L. D. Chamain and Z. Ding, ``Improving Deep Learning Classification of JPEG2000 Images Over Bandlimited Networks", Proc. 2020 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Barcelona, Spain, 2020, pp. 4062-4066, doi: 10.1109/ICASSP40776.2020.9053778.

[20] Z. Liu, M. del Rosario, X. Liang, L. Zhang and Z. Ding, ``Spherical Normalization for Learned Compressive Feedback in Massive MIMO CSI Acquisition," 2020 IEEE International Conference on Communications Workshops (ICC Workshops), Dublin, Ireland, 2020, pp. 1-6, doi: 10.1109/ICCWorkshops49005.2020.9145171.

[21] L. D. Chamain, S.C.S. Cheung, and Z. Ding, ``Quannet: Joint Image Compression and Classification Over Channels with Limited Bandwidth," Proc. IEEE International Conference on Multimedia and Expo (ICME) pp. 338-343, Shanghai, July 2019.

[22] Z. Zhang, Z. Zhu, B. Bazor, S. Lee, Z. Ding and T. Pan, ``PIS: Wearable Pedal Iontronic Sensing for Arterial Pulses and Muscular Activities," Proc. 20th International Conference on Solid-State Sensors, Actuators and Microsystems & Eurosensors XXXIII (TRANSDUCERS &

EUROSENSORS XXXIII), pp. 2492-2495, Berlin, Germany, 2019, doi: 10.1109/TRANSDUCERS.2019.8808440.

[23] Le, Y., Ling X., Wang J., Ding Z., ``Prototype design and test of blockchain radio access network," Proc. IEEE International Conference on Communications Workshops (ICC Workshops), May 20 (pp. 1-6), 2019. DOI: 10.1109/ICCW.2019.8757042

[24] C. Feres and Z. Ding, ``Low Complexity Header Compression with Lower-Layer Awareness for Wireless Networks," 2019 IEEE International Conference on Communications (ICC), Shanghai, China, 2019, pp. 1-7. doi: 10.1109/ICC.2019.8761888

[25] T. Bouchoucha and Z. Ding, ``Robust Online Social Network Inference," 2019 IEEE International Conference on Communications (ICC), Shanghai, China, 2019, pp. 1-6. doi: 10.1109/ICC.2019.8761335

[26] Q. Chen and Z. Ding, ``On Non-Intrusive Coexistence of eLAA and Legacy WiFi Networks," 2019 IEEE International Conference on Communications (ICC), Shanghai, China, 2019, pp. 1-6. doi: 10.1109/ICC.2019.8761765

[27] K. Yang, T. Jiang, Y. Shi and Z. Ding, ``Federated Learning Based on Over-the-Air Computation," 2019 IEEE International Conference on Communications (ICC), Shanghai, China, 2019, pp. 1-6. doi: 10.1109/ICC.2019.8761429

[28] J. Dong, Y. Shi and Z. Ding, ``Sparse Blind Demixing for Low-latency Signal Recovery in Massive Iot Connectivity," 2019 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Brighton, United Kingdom, 2019, pp. 4764-4768. doi: 10.1109/ICASSP.2019.8683324

[29] C. Jiang, W. Wu, and Zhi Ding ``The Design of Transport Block-Based ROHC U-Mode for LTE Multicast"> IEEE Global Communications Conference (GLOBECOM) Abu Dhabi, United Arab Emirates, 9-13 Dec. 2018. doi: 10.1109/GLOCOM.2018.8648067

[30] K. Wang and Zhi Ding ``Joint Tourbo Receiver for LDPC-coded MIMO Systems based on Semi-Definite Relaxation" *IEEE 88th Vehicular Technology Conference* Chicago, IL, August 27-30, 2018. doi:10.1109/VTCFall.2018.8690886.

[31] A. Jalali and Zhi Ding ``A Joint Detection and Decoding Receiver Design for Polar Coded MIMO Wireless Transmissions" IEEE International Symposium on Information Theory Val, CO, USA, 17-22 June 2018. doi: 10.1109/ISIT.2018.8437879

[32] K. Yang, Y. Shi, and Z. Ding. ``Low-Rank Optimization for Data Shuffling in Wireless Distributed Computing", In 2018 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), pp. 6343-6347. IEEE, 2018.

[33] C. Feres, W. Wu and Z. Ding, ``A Markovian ROHC Control Mechanism Based on Transport Block Link Model in LTE Networks," IEEE International Conference on Communications (ICC), Kansas City, MO, USA, 2018, pp. 1-7. doi: 10.1109/ICC.2018.8422165

[34] H. M. Elmaghraby, K. Liu and Z. Ding, ``Femtocell Scheduling as a Restless Multiarmed Bandit Problem Using Partial Channel State Observation," IEEE International Conference on Communications (ICC), Kansas City, MO, USA, 2018, pp. 1-6. doi: 10.1109/ICC.2018.8422619

[35] L. Liang, S. Xie, G. Y. Li, Z. Ding and X. Yu, ``Graph-Based Radio Resource Management for Vehicular Networks", IEEE International Conference on Communications (ICC), Kansas City, MO, USA, 2018, pp. 1-6. doi: 10.1109/ICC.2018.8422585

[36] H. Lu, G.Liu, R. Proietti, V. Squitieri, K. Zhang, A. Castro, Q. J. Gu, Z. Ding, and S. B. Yoo, ``mmWave beamforming using photonic signal processing for future 5G mobile systems," Proc. Optical Fiber Communication Conference , pp. M4J-3, Optical Society of America, March 2018.

[37] G. Liu, K. Zhang, R. Proietti, H. Lu, Z. Ding, and S. B. Yoo, ``First Demonstration of FPGA-based Hitless Flexible Receiver with Blind Modulation Format Identification", Proc. Optical Society of America Optical Fiber Communication Conference, pp. W2A-45, Mar. 2018.

[38] Q. Wei, L. Wang, Z. Feng and Z. Ding, ``Cooperative coexistence and resource allocation for V2X communications in LTE-unlicensed," Proc. 15th IEEE Annual Consumer Communications & Networking Conference (CCNC), Las Vegas, NV, 2018. doi: 10.1109/CCNC.2018.8319219

[39] H. Wang, P. Shetty and Z. Ding, ``Low Complexity Node Clustering in Cloud-RAN for Service Provisioning and Resource Allocation," *GLOBECOM - 2017 IEEE Global Communications Conference,* Singapore, 2017, pp. 1-6. doi: 10.1109/GLOCOM.2017.8254979

[40] T. Bouchoucha, C. N. Chuah and Z. Ding, ``Finding Link Topology of Large Scale Networks from Anchored Hop Count Reports," *GLOBECOM - 2017 IEEE Global Communications Conference,* Singapore, 2017, pp. 1-6. doi: 10.1109/GLOCOM.2017.8253952

[41] X. Ling, J. Wang, X. Liang, Z. Ding, C. Zhao and X. Gao, ``Biased Beamforming for Multi-LED OFDM in Visible Light Communications," *GLOBECOM - 2017 IEEE Global Communications Conference,* Singapore, 2017, pp. 1-6. doi: 10.1109/GLOCOM.2017.8254777

[42] K. Yang, Y. Shi and Z. Ding, ``Generalized matrix completion for low complexity transceiver processing in cache-aided Fog-RAN via the Burer-Monteiro approach," 2017 IEEE Global Conference on Signal and Information Processing (GlobalSIP), Montreal, QC, 2017, pp. 863-867. doi: 10.1109/GlobalSIP.2017.8309083

[43] L. Jing, H. Wang, C. He, and Z. Ding, ``Joint Channel Estimation and Detection of High Rate CCK Signaling in Underwater Communications", Proc. IEEE Wireless Communications and Networking Conference (WCNC), San Francisco, USA, Mar. 2017.

[44] Chen Jiang, Wenhao Wu, and Z. Ding, ``LTE Multimedia Broadcast Multicast Service Provisioning Based on Robust Header Compression." IEEE Wireless Communications and Networking Conference (WCNC), San Francisco, CA, USA, May 2017.

[45] Chen Jiang, Wenhao Wu, and Z. Ding, ``IP packet header compression and user grouping for LTE Multimedia Broadcast Multicast Services, " Proc. 2017 International Conference on Computing, Networking and Communications (ICNC), pp. 52-57, January 2017.

[46] K. Yang, Y. Shi, J. Zhang, Z. Ding and K. B. Letaief, ``A low-rank approach for interference management in dense wireless networks," 2016 IEEE Global Conference on Signal and Information Processing (GlobalSIP), Washington, DC, 2016, pp. 708-712. doi: 10.1109/GlobalSIP.2016.7905934

[47] Yang, Kai, Yuanming Shi, and Zhi Ding, ``Low-rank matrix completion for mobile edge caching in fog-RAN via riemannian optimization." IEEE Global Communications Conference (GLOBECOM), pp. 1-6, Dec. 2016.

[48] Huan Tang, Zhi Ding, and Bernard C. Levy, ``D2D Neighbor Discovery and Resource Scheduling through Demodulation Reference Signal." IEEE 84th Vehicular Technology Conference (VTC-Fall), September 2016.

[49] H. Tang and Z. Ding, "Monotone optimization for power control of D2D underlay with partial CSI," 2016 IEEE International Conference on Communications (ICC), Kuala Lumpur, 2016, pp. 1-6. doi: 10.1109/ICC.2016.7511619

[50] H. Wang and Z. Ding, "Joint power and rate optimization for co-channel small cells using Frank-Wolfe algorithm," 2016 IEEE International Conference on Communications (ICC), Kuala Lumpur, 2016, pp. 1-6. doi: 10.1109/ICC.2016.7511345

[51] Kun Wang and Zhi Ding, ``Robust receiver design based on FEC code diversity in pilot-contaminated multi-user massive MIMO systems", Proc. 2016 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Shanghai, China, 2016. Pages: 3426 - 3430.

[52] Zhi Quan; Muyang Ye; Zhi Ding; Shuguang Cui ``Optimal linear cooperation for signal classification", Proc. 2016 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), Shanghai, China, 2016. Pages: 3631 - 3635.

[53] H. M. Elmaghraby and Z. Ding, ``Cognitive Femtocell Scheduling and Power Allocation Based on Channel Quality Report," 2015 IEEE Global Communications Conference (GLOBECOM), San Diego, CA, 2015, pp. 1-6. doi: 10.1109/GLOCOM.2015.7417849

[54] Xintong Ling; Jiaheng Wang; Xiao Liang; Zhi Ding; Chunming Zhao ``Joint Offset and Power Optimization for Visible Light DCO-OFDM Systems," IEEE Global Communications Conference (GLOBECOM) San Diego, CA, 2015.

[55] Dongrun Qin; Zhi Ding ``On Transport Capacity of Full Duplex Ad Hoc Networks," IEEE Global Communications Conference (GLOBECOM) San Diego, CA, 2015.

[56] Chen Sun; Xiqi Gao; Shi Jin; Matthaiou, M.; Zhi Ding; Chengshan Xiao, ``Beam division multiple access for massive MIMO downlink transmission", 2015 IEEE International Conference on Communications (ICC), pp. 1970 - 1975, London, UK, 2015. DOI: 10.1109/ICC.2015.7248614

[57] Huan Tang and Zhi Ding ``Resource allocation in mixed mode Device-to-Device communications", 2015 IEEE International Conference on Communications (ICC), pp. 2554-2559, London, UK, 2015. DOI: 10.1109/ICC.2015.7248709

[58] Wang, Kun, Wenhao Wu, and Zhi Ding. ``Diversity combining in wireless relay networks with partial channel state information." 2015 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), pp. 3138-3142, Brisbane, Australia, May 2015.

[59] Elmaghraby, Hesham M., Dongrun Qin, and Zhi Ding, ``Downlink Scheduling and Power Allocation in Cognitive Femtocell Networks," In Cognitive Radio Oriented Wireless Networks [Proc. 10th Intl. Conf. Cognitive Radio Oriented Wireless Networks (CROWNCOM)], pp. 92-105. Springer International Publishing, Oct. 2015.

[60] Haining Wang and Zhi Ding, ``Power control and rate allocation for outage balancing in femtocell networks," IEEE Global Communications Conference (GLOBECOM), Austin, TX, December 2014.

[61] Alexis Dowhuszko, Jyri Hamalainen, and Zhi Ding, ``Opportunistic interference avoidance scheduling for underlay cognitive radio networks", 9th International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM), July 2014.

[62] Ahmed R. Elsherif, Zhi Ding, Xin Liu, ``A Resource Allocation Scheme for Heterogeneous Networks Using Dynamic Programming Approach ," in IEEE 79th Vehicular Technology Conference, VTC-Spring 2014, May 2014, pp. 1-6.

[63] W. Wu, K. Wang, Z. Ding, and C. Xiao, ``Cooperative multi-cell MIMO downlink precoding for finite-alphabet inputs", in Proc. IEEE Int. Conf. Acoust., Speech, Signal Process. (ICASSP), pp. 464-468, Florence, Italy, May 2014, doi:10.1109/ICASSP.2014.6853639

[64] K. Wang, W. Wu, and Z. Ding, ``Joint detection and decoding of LDPC coded distributed space-time signaling in wireless relay networks via linear programming," in Proc. IEEE Int. Conf. Acoust., Speech, Signal Process. (ICASSP), pp. 1906-1910, Florence, Italy, May 2014, DOI: 10.1109/ICASSP.2014.6853930

[65] Ahmedin, A.; Elsherif, A.R.; Xin Liu; Hamalainen, J.; Wichman, R., ``Macrocell resource adaptation for improved femtocell deployment and interference management," 2014 World Congress on Computer Applications and Information Systems (WCCAIS), pp.1-6, 17-19 Jan. 2014, Tunisia.

[66] Huan Tang, Zhi Ding, S. J. B. Yoo, and Jyri Hamalainen. "Outage constrained joint precoding for D2D underlay cellular networks." In Global Communications Conference (GLOBECOM), 2013 IEEE, pp. 3540-3545. IEEE, 2013.

[67] Elsherif, Ahmed R.; Chen, Wei-Peng; Ito, Akira; Ding, Zhi, ``Design of dual-access-technology femtocells in enterprise environments," IEEE 24th International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC), pp.2774-2779, 8-11 Sept. 2013. doi: 10.1109/PIMRC.2013.6666619

[68] Kun-Yu Wang, Haining Wang, Zhi Ding and Chong-Yung Chi, ``A Low-Complexity Algorithm for Worst-Case Utility Maximization in Multiuser MISO Downlink," in 2013 IEEE 78th Vehicular Technology Conference (VTC Fall), pp.1-5, 2-5 Sept. 2013.

[69] A. R. Elsherif, Wei-Peng Chen, A. Ito, Zhi Ding, "Adaptive small cell access of licensed and unlicensed bands," IEEE International Conference on Communications (ICC), pp.6327,6332, 9-13 June 2013. doi: 10.1109/ICC.2013.6655621

[70] H. Wang, Z. Ding, M. Cierny, and R. Wichman, IEEE International Conference on Communications (ICC), pp.5183-5187, Budapest 9-13 June 2013. doi: 10.1109/ICC.2013.6655407

[71] Qing Ji, Michael Ho, Rong Zheng, Zhi Ding and Gangbing Song, ``An exploratory study of stress wave communication in concrete structures" SMART STRUCTURES AND SYSTEMS (Proc. 6th Int. Conf. on Structural Health Monitoring of Intelligent Infrastructure, vol. 15, no. 1, pp. 135-150, 2015, Hong Kong.

[72] Huan Tang; Chenxi Zhu; Zhi Ding, "Cooperative MIMO precoding for D2D underlay in cellular networks," IEEE International Conference on Communications (ICC), pp.5517-5521, 9-13 June 2013.

[73] Dowhuszko, A.A.; Hamalainen, J.; Elsherif, A.R.; Zhi Ding ``Performance of transmit beamforming for interference mitigation with random codebooks," 8th International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM), pp. 190-195, 2013.

[74] A. Elsherif, Z. Ding, X. Liu, J. Hamalainen, and R. Wichman, ``Inference Driven Dynamic Access Scheme for Interference Management in Heterogeneous Networks", 8th International Conference on Cognitive Radio Oriented Wireless Networks (CROWNCOM), pp. 178-183, 2013.

[75] A. R. Elsherif, Zhi Ding, Xin Liu, J. Hamalainen, ``Shadow chasing enhancement in resource allocation for heterogeneous networks", IEEE Global Communications Conference (GLOBECOM), Page(s): 5531 - 5536, Anaheim, CA, 2012.

[76] Yong Li ; Lin Wang ; Zhi Ding ``Linear programming based joint detection of LDPC coded MIMO systems," IEEE Global Communications Conference (GLOBECOM), Page(s): 4043-48, Anaheim, CA, 2012.

[77] A.R. Elsherif, A. Ahmedin, Zhi Ding, and Xin Liu `` Adaptive precoding for femtocell interference mitigation", Proc.IEEE International Conference on Communications (ICC), Page(s): 4315 - 4320, 10-15 June 2012.

[78] Xiao Liang, Zhi Ding, and Chengshan Xiao, ``On linear precoding of non-regenerative MIMO relays for QAM inputs"Proc. IEEE International Conference on Communications (ICC), Page(s): 2439 - 2444, 10-15 June 2012

[79] Yongpeng Wu, Chengshan Xiao, Zhi Ding, Xiqi Gao, and Shi Jin ``Linear MIMO precoding in multi-antenna wiretap channels for finite-alphabet data", Proc. IEEE International Conference on Communications (ICC), Page(s): 2156 - 2160, 10-15 June 2012

[80] Yongpeng Wu, Mingxi Wang, Chengshan Xiao, Zhi Ding, and Xiqi Gao ``Linear precoding of finite alphabet signals in multi-antenna broadcast channels", Proc. IEEE International Conference on Communications (ICC), Page(s): 4257 - 4261, 10-15 June 2012.

[81] Huy-Dung Han, Chenxi Zhu, Yueqiao Xu, Yi Wang, and Zhi Ding Joint transmission using global codeword and codebook design for coordinated multipoint processing (CoMP) , Proc. 2012 IEEE Globecom Workshops (GC Wkshps), Page(s): 1118 - 1122, Anaheim, CA, USA, Dec. 2012.

[82] Enyang Xu, Zhi Ding, Soura Dasgupta, ``Urban source localization based on time of arrival measurement and street information" Proc. IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) Page(s): 2621 - 2624, Kyoto, Japan, 25-30 March 2012.

[83] Hema Kumari Achanta, Soura Dasgupta, Zhi Ding, ``Optimum sensor placement for localization in three dimensional under log normal shadowing", 5th International Congress on Image and Signal Processing (CISP) , pp.~1898-1901, 16-18 Oct. 2012

[84] Zhe Jiang, Hai-yan Wang, Wang, Zhi Ding, ``Joint Symbol Timing and Channel Estimation in Two-Way Multiple Antenna Relay Networks", Proc. IEEE Vehicular Technology Conference (VTC Fall), 3-6 Sept. 2012

[85] Yang Zhang, Jiandong Li, Lihua Pang, and Zhi Ding ``Maximizing lifetime in multi-source multi-relay non-regenerative OFDM networks", Prof. IEEE 23rd International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC), Page(s): 2259 - 2262, 9-12 Sept. 2012.

[86] Jacklin, N.; Zhi Ding `` A Convex Optimization Approach to Reducing Peak-to-Average-Power Ratio in OFDM", 2011 IEEE International Symposium on Circuits and Systems (ISCAS), 2011, Page(s): 973 - 976.

[87] Chengshan Xiao; Zheng, Y.R.; Zhi Ding, ``Design optimization of linear precoders for complex vector gaussian channelswith finite alphabet inputs", 2011 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP), 2011, Page(s): 3272 - 3275.

[88] Binbin Guan; Fontaine, N.K.; Scott, R.P.; Geisler, D.J.; Djordjevic, S.S.; Ibrahim, S.; Cheung, S.; Tiehui Su; Pomerene, A.T.; Seaford, L.L.; Danziger, S.; Zhi Ding; Yoo, S.J.B., ``Dynamic sub-20 ns reconfiguration of a silicon CMOS photonic filter and filter shape measurement", 2011 Conference on Lasers and Electro-Optics (CLEO), 2011, Page(s): 1 - 2

[89] Lapiccirella, F.E.; Keqin Liu; Zhi Ding, ``Multi-Channel Opportunistic Access Based on Primary ARQ Messages Overhearing" Communications (ICC), 2011 IEEE International Conference on Publication Year: 2011 , Page(s): 1 - 5

[90] Yang Zhang; Jiandong Li; Lihua Pang; Zhi Ding, ``On Precoder Design for Amplify-and-Forward MIMO Relay Systems", 2011 IEEE Vehicular Technology Conference (VTC Fall), 2011, Page(s): 1 - 6

[91] Meng Shen; Chunming Zhao; Xiao Liang; Zhi Ding, ``Best-Effort Interference Alignment in OFDM Systems with Finite SNR", 2011 IEEE International Conference on Communications (ICC), 2011, Page(s): 1 - 6.

[92] Yang Zhang, Jiandong Li, Lihua Pang, Zhi Ding, ``Iterative InterCarrier Interference mitigation for mobile MIMO-OFDM systems", 2011 IEEE 22nd International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC), 2011, Page(s): 959 - 963.

[93] Huy-Dung Han; Zhi Ding; Junqiang Hu; Dayou Qian, ``On Steepest Descent Adaptation: A Novel Batch Implementation of Blind Equalization Algorithms," 2010 IEEE Global Telecommunications Conference , Miami, FL, 2010, Page(s): 1 - 6.

[94] Senhua Huang, Xin Liu, and Zhi Ding, ``Distributed Power Control for Cognitive User Access based on Primary Link Control Feedback", Proc. Conference on Computer Communications (INFOCOM 2010), 14-19 March 2010, Page(s): 1-9, San Diego, USA.

[95] Enyang Xu, Zhi Ding, and Soura Dasgupta, ``Robust and Low Complexity Source Localization in Wireless Sensor Networks Using Time Difference of Arrival Measurement",, Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC), April 2010, Sydney, Australia, Page(s): 18-21.

[96] Dasgupta, S.; Ibeawuchi, S.C.; Zhi Ding; ``Optimum sensor placement for localization under log-normal shadowing", 2010 International Symposium on Communications and Information Technologies (ISCIT), 2010; Page(s): 204 - 208.

[97] Huy-Dung Han and Zhi Ding, ``A blind channel shortening criterion based on high-order cumulants" IEEE International Conf. on Acoustics, Speech and Signal Processing, 14-19 March 2010, Page(s):3210 - 3213.

[98] Enyang Xu, Zhi Ding, Soura Dasgupta, ``Wireless source localization based on time of arrival measurement" IEEE International Conf. on Acoustics, Speech and Signal Processing, 14-19 March 2010, Page(s):2842 - 2845.

[99] Ibrahim, S.; Luo, L.W.; Djordjevic, S.S.; Poitras, C.B.; Zhou, L.; Fontaine, N.K.; Guan, B.; Cheung, S.; Ding, Z.; Okamoto, K.; Lipson, M.; Yoo, S.J.B.; ``Fully reconfigurable silicon photonic lattice filters with four cascaded unit cells," Optical Fiber Communication (OFC), 21-25 Mar. 2010, Page(s):1 - 3.

[100] S. Bashar and Z Ding, ``Optimum Power Allocation against Information Leakage in Wireless Network" IEEE Global Telecommunications Conference, Nov. 30 2009-Dec. 4, 2009, Page(s):1-6.

[101] Huy-Dung Han and Zhi Ding, ``A Convex Optimization Approach to Blind Channel Shortening in Multicarrier Modulations," IEEE Global Telecommunications Conference, Nov. 30 2009-Dec. 4, 2009.

[102] Huy-Dung Han, Junqiang Hu, and Zhi Ding, ``A bandwidth efficient design of IM/DD optical OFDM," Conference on Lasers and Electro-Optics and Conference on Quantum electronics and Laser Science Conf. (CLEO/QELS 2009), 2-4 June 2009 Page(s): 1 - 2

[103] Senhua Huang, Xin Liu, and Zhi Ding, ``Optimal Sensing-Transmission Structure for Dynamic Spectrum Access", Proc. 28th IEEE Conference on Computer Communications (INFOCOM 2009), 19-25 April 2009, Page(s):2295 - 2303, Rio de Janeiro, Brazil.

[104] Linjie Zhou; Djordjevic, S.S.; Fontaine, N.K.; Zhi Ding; Okamoto, K.; Yoo, S.J.B., ``Silicon microring resonator-based reconfigurable optical lattice filter for on-chip optical signal processing" IEEE LEOS Annual Meeting Conference Proceedings (LEOS), 2009, Page(s): 501 - 502.

[105] Lapiccirella, Fabio E.; Huang, Senhua; Liu, Xin; Ding, Zhi; ``Feedback-based access and power control for distributed multiuser cognitive networks" Information Theory and Applications Workshop, 2009 8-13 Feb. 2009 Page(s):85 - 89

[106] Muhammad, Zia; Chen Meng, Zhi Ding, ``Blind detection of high rate orthogonal space-time block codes IEEE International Conference on Acoustics, Speech and Signal Processing, 19-24 April 2009 Page(s):2745 - 2748

[107] Huang, River; Zhi Ding, ``Precoder design for MIMO broadcast channels with power leakage constraints," IEEE International Conference on Acoustics, Speech and Signal Processing, 19-24 April 2009 Page(s):2385 - 2388

[108] Chang, Chunqi; Zhi Ding; Hung, Yeung Sam; ``Nonnegative Network Component Analysis by Linear Programming for Gene Regulatory Network Reconstruction" Proceedings of the 8th International Conference on Independent Component Analysis and Signal Separation, 2009. Pages: 395 - 402

[109] S. Bashar and Z. Ding, "Optimum routing protection against cumulative eavesdropping in multihop wireless networks", Proceedings of 2009 MILCOM, October 2009.

[110] S. Dasgupta, S.-R.C. Ibeawuchi, and Zhi Ding; ``Source localization using a maximum likelihood/semidefinite programming hybrid " 9th Int. Symp. on Communications and Information Technology, 28 - 30 Sept. 2009, Page(s):376 - 381

[111] S.D. Chitte, S. Dasgupta, and Zhi Ding, ``Source Localization from Received Signal Strength Under Log-Normal Shadowing: Bias and Variance" 2nd International Congress on Image and Signal Processing, 2009.

[112] Chang, Chunqi; Hung, Yeung Sam; Ding, Zhi; ``A new optimization algorithm for network component analysis based on convex programming" IEEE International Conf. on Acoustics, Speech and Signal Processing, 19-24 April 2009 Page(s):509 - 512

[113] Senhua Huang, Xin Liu, and Zhi Ding, ``Opportunistic Spectrum Access in Cognitive Radio Networks", INFOCOM 2008: IEEE 27th Conference on Computer Communications, 13-18 April. 2008, Page(s): 1427-1435.

[114] Jingyu Kang, Bo Zhou, Zhi Ding, and Shu Lin, ``LDPC coding schemes for error control in a multicast network", IEEE International Symposium on Information Theory, page(s): 822-826, 6-11 July 2008.

[115] S Bashar and Z Ding, ``Efficient Algorithms for Resource Allocation in Heterogeneous OFDMA Networks", 2008 IEEE Global Telecommunications Conference, Nov. 30 2008-Dec. 4 2008.

[116] M. Zia and Z Ding, ``Joint ARQ Receiver Design for Bandwidth Efficient MIMO Systems", 2008 IEEE Global Telecommunications Conference, Nov. 30 2008-Dec. 4 2008.

[117] J Kang, L Zhang, Z Ding, and S Lin, ``A Two-Stage Iterative Decoding of LDPC Codes for Lowering Error Floors", 2008 IEEE Global Telecommunications Conference, Nov. 30 2008-Dec. 4 2008.

[118] S.-R.C. Ibeawuchi, S. Dasgupta, Cheng Meng, and Zhi Ding, ``Source localization using a maximum likelihood/semidefinite programming hybrid " Proc. 3rd International Conference on Sensing Technology, Nov. 30 2008-Dec. 3 2008 Page(s):585 - 588.

[119] S Huang, X Liu, Z Ding, ``On Optimal Sensing and Transmission Strategies for Dynamic Spectrum Access," DySPAN 2008: New Frontiers in Dynamic Spectrum Access Networks, 14-17 October 2008.

[120] S Bashar, Z Ding, and Y. Li ``QOS aware resource allocation for heterogeneous multiuser OFDM wireless networks" , IEEE Workshop on Signal Processing Advances in Wireless Communications, page(s): 535-539, 6-9 July 2008.

[121] Z. Shi, C. Zhao, and Z. Ding, ``Low Complexity Eigenmode Selection for MIMO Broadcast Systems with Block Diagonalization" IEEE International Conference on Communications, 19-23 May 2008 Page(s):3976 - 3981.

[122] W. Xu, C. Zhao, and Z. Ding, ``Efficient user Scheduling under Low Rate Feedback for Correlated MIMO Broadcast Channels" IEEE International Conference on Communications, 19-23 May 2008 Page(s):3976 - 3981.

[123] He Huang and Zhi Ding, ``Ergodic capacity maximizing MIMO ARQ precoder design based on channel mean information", Information Theory and Applications Workshop, 2008, Jan. 27 2008-Feb. 1 2008 Page(s):58 - 62

[124] Huang, Senhua; Ding, Zhi; Liu, Xin; ``Non-Intrusive Cognitive Radio Networks Based on Smart Antenna Technology", IEEE Global Telecommunications Conference, 26-30 Nov. 2007, Page(s):4862 - 4867.

[125] T. Kazemi and Z. Ding, ``Scalable MIMO ARQ Retransmission using Differential Space-Time Block Codes," Military Communications Conference, 29-31 October 2007.

[126] Ye, Xiaohui; Liu, Xin; Yoo, S. J. Ben; Ding, Zhi; Priority Collision Resolution - Distributed Coordination Function for Distributed Wireless Networks," IEEE Global Telecommunications Conference, 26-30 Nov. 2007 Page(s):4708 - 4713

[127] C. Chang, Z. Ding, Y.S. Hung, P.C.W. Fung, ``Fast Network Component Analysis for Gene Regulation Networks," 2007 IEEE Workshop Machine Learning for Signal Processing, page(s): 21-26, 27-29 August 2007

[128] Q. Ling, T. Li, and Z. Ding, ``A Novel Concept: Message Driven Frequency Hopping (MDFH)", 2007 IEEE International Conference on Communications, Glasgow, Scotland, 24-28 June 2007 Page(s):5496 – 5501.

[129] Ohara, K.; Hernandez, V.J.; Du, Y.; Ding, Z.; Yoo, S.J.B.; Horiuchi, Y.; ``Resiliency of OCDM-PON against near-far problem", Proc. 2007 Optical Fiber Communication and the National Fiber Optic Engineers Conference (OFC/NFOEC 2007), 25-29 March 2007, Anaheim, CA, pp. 1-3,

[130] Fontaine, N.K. Yang, C. Scott, R.P. Hernandez, V.J. Soares, F. Broeke, R. Perry, K. Nowak, G. Cong, W. Okamoto, K. Kolner, B.H. Ding, Z. Heritage, J.P. Yoo, S.J.B. ``SPECTS O-CDMA field trials using subpicosecond pulses and integrated encoders/decoders across 80.8-km and 150-km links", Proc. Photonics in Switching Conference, pp. 95-96, 19-22 August 2007.

[131] Xin Liu and Zhi Ding, ``ESCAPE: A Channel Evacuation Protocol for Spectrum-Agile Networks," 2nd IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN), Dublin, Ireland, 17-20 April 2007, Page(s):292 - 302.

[132] Du, Y.; Yoo, S.J.B.; Ding, Z. ``Non-uniform spectral encoding of measured mode-locked laser pulses for performance enhancement of optical CDMA networks," 2006 Optical Fiber Communication Conference (OFC), 5-10 March 2006, Anaheim, CA.

[133] Haitong Sun, and Zhi Ding, ``Optimal Linear Transceiver Design for Mimo Flat Fading Channels Exploiting Channel Mean Feedback", IEEE Global Telecommunications Conference, Nov., 2006.

[134] Song, Shumei; Lin, Shu; Abdel-Ghaffar, Khaled; Ding, Zhi; Fossorier, Marc, "Cyclic Codes for Correcting Bursts of Errors or Erasures With Iterative Decoding" IEEE Global Telecommunications Conference, Nov., 2006.

[135] Dong, Xiaofei; Ding, Zhi; ``Downlink MIMO Channel Estimation for Transmission Precoding" IEEE Global Telecommunications Conference, Nov., 2006. .

[136] Evans, Ashley A.; Ben Yoo, S. J.; Ding, Zhi; ``Space-Time Coded Modulation and Detection in Coherent Freespace Optical Communications", IEEE Global Telecommunications Conference, Nov., 2006.

[137] Yang, C. ; Cong, W. ; Xue, F. ; Hernandez, V. J. ; Scott, R. P. ; Heritage, J. P. ; Kolner, B. H. ; Ding, Z. ; Yoo, S. J. B. ; ``Experimental Investigation on Using Phase Mask in Spectral-Phase-

Encoded O-CDMA for Security Enhancement", European Conference on Optical Communications (ECOC), 24-28 Sept. 2006, Cannes, France, Page(s): 1 - 2.

[138] Chang, C.Q.; Hung, Y.S.; Fung, P.C.W.; Ding, Z.; Network Component Analysis for Blind Source Separation 2006 International Conference on Communications, Circuits and Systems Proceedings, Volume 1, 25-28 June 2006, Page(s):323 - 326.

[139] N. Ammar and Zhi Ding, ``Semi-Coherent Detection for Differential Space-Time Codes", Proceedings of 2006 IEEE International Conference on Communications, Istabul, Turkey, 2006.

[140] H. Sun and Z. Ding, ``Robust Precoder Design for MIMO Packet Retransmission over Imperfectly Known Flat Fading Channels", Proceedings of 2006 IEEE International Conference on Communications, Istabul, Turkey, 2006.

[141] Haitong Sun, Zhi Ding, and Chunming Zhao, ``Iterative Design of MIMO ARQ Transceiver for Decision Feedback Detection", IEEE 7th Workshop on Signal Processing Advances in Wireless Communications, 2-5 July 2006.

[142] X. Dong and Z. Ding, ``Channel Estimation and Bit-loading in Wireless Multicarrier Systems based on Decimated Signal Feedback" , Proceedings of 2006 IEEE International Conference on Communications, Istabul, Turkey, 2006.

[143] J. Roberson and Zhi Ding, ``A BICM Approach to Type-II Hybrid ARQ", Proceedings of 2006 IEEE International Conference on Acoustics, Speech and Signal Processing, Volume 4, 2006 Page(s):IV-273 - IV-276, 2006, Toulouse, France.

[144] J. Roberson and Z. Ding, ``Integration of Hybrid ARQ and Space-Time Coding through Embebded Quasi-Orthogonal Space-Time Block Codes," Proc. 40th Annual Conference on Informaiton Sciences and Systems, pp. 547-551. 22-24 March 2206.

[145] F. Xue, Y. Du, S. J. B Yoo, and Z. Ding, `` Security issues on spectral-phase-encoded optical CDMA with phase-masking scheme", Proc. 2006 Optical Fiber Communication Conference, March 5-10, 2006.

[146] X. Dong and Z. Ding, ``MIMO Channel Estimation Based on Ambiguity Resistant Filtering and Decimated Feedback", Proc. IEEE Globecom Conference, Vol. 5, pp.2958-2963, St. Louis, MO, 28 Nov.-2 Dec. 2005.

[147] F. Xue, Z. Ding, and S. J. B. Yoo, ``Design and Analysis of Coordinated Access Schemes for Code-Limited Optical-CDMA Networks", Proc. IEEE Globecom Conference, vol. 4, pp.1930-1935, St. Louis, MO, 2005.

[148] J. Roberson, X. Dong, Z. Ding, ``Joint Data Detection for Punctured ARQ Diversity Systems", Proc. International Conference on Acoustics, Speech, and Signal Processing, pp. III-1145-1148, 2005.

[149] T. Li, Q. Ling, and Z. Ding, ``Space-Time Design for Blind Estimation and Equalization over Frequency Selective Channels", Proc. Int. Conference on Acoustics, Speech, and Signal Processing, pp. III-441-444, 2005.

[150] H. Sun, H. Samra, Z. Ding, and J. Manton, ``Constrained Capacity of Linear Precoded ARQ in MIMO Wireless Systems", Proc. Int. Conference on Acoustics, Speech, and Signal Processing, pp. III-425-428, 2005.

[151] A. A. Farid, Z.-Q. Luo, and Z. Ding, ``Blind Channel Equalization based on Second Order Statistics", Proc. Int. Conference on Acoustics, Speech, and Signal Processing, pp. III-557-560, 2005.

[152] F. Xue, Z. Ding, and S. J. B. Yoo, ``Performance Evaluation of Optical CDMA Networks with Random Media Access Schemes", Proc. 2005 Optical Fiber Communication Conference, vol. 4, 6-11 March 2005.

[153] Fei Xue, Zhi Ding, S.J.B. Yoo, ``Performance analysis for optical CDMA networks with random access schemes", Proc. IEEE Global Telecommunications Conf., Volume 3, pp.1883-1887, Nov-Dec., 2004.

[154] J. Roberson, and Z. Ding, ``Joint channel estimation and detection of partial ARQ in OFDM", Conference Record of the Thirty-Eighth Asilomar Conference on Signals, Systems and Computers, Volume 1, Page(s):662 - 666, 7-10 Nov. 2004

[155] Haitong Sun; Mihaela van der Schaar, and Zhi Ding, `` ``Joint data compression and error protection for collaborative transmission," 2004 International Conference on Image Processing, 2004, Volume 1, 24-27 Oct. 2004 Page(s):533 - 536.

[156] Larcher, Aymeric, Haitong Sun, M. van der Schaar, and Zhi Ding. ``Decentralized transmission strategy for delay-sensitive applications over spectrum agile network", Proc. 13h Intl. Packet Video Workshop, Dec. 2004.

[157] H. Sun, M. van der Schaar, and Zhi Ding, ``Joint data compression and error protection over wireless fading channels using LDPC codes" Proc. 38th Asilomar Conf. on Signals, Systems and Computers, Pacific Grove, CA, 2004, Page(s): 978 - 982 Vol.1

[158] S. Neugebauer and Z. Ding, ``A Turbo-Driven Known-modulus Blind Equalization Method", Proceedings of the 5th Workshop on Signal Processing Advances in Wireless Communications, pp. 36-40, Lisbon, Portugal, July 2004.

[159] N. Ammar and Z. Ding, ``Flat Fading Channel Estimation Under Generic Linear Space-Time Block Coded Transmissions", Proceedings of the IEEE International Communications Conference, pp.2616-2620, 2004.

[160] T. Li, Z. Ding, J. K. Tugnait, and W. Liang, ``Channel Identification and Signal Separation for Long-code CDMA Systems using Mulitple Linear Prediction Method", Proceedings of the IEEE Int. Communications Conference, pp. 2437-2441, 2004.

[161] N. Ammar and Z. Ding, ``Frequency Selective Channel Estimation in Time-Reversed Space-Time Coding",, Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC), pp. 1838-1843, March 2004.

[162] T. A. Drumright and Z. Ding, ``Monte-Carlo Equalization and Estimation of Frequency Selective Channels under System Nonlinearity," Proceedings of the IEEE WCNC Conference, pp. 2432-2437, 2004.

[163] X. Dong, Z. Ding and S. Dasgupta, ``Fractional spaced dual channel estimation based on decimated feedback", Proceedings of the IEEE WCNC Conference, pp. 489-494, 2004.

[164] J. Roberson and Z. Ding, ``Joint Channel Identification in Punctured Hybrid ARQ Retransmissions", Proceedings of the IEEE WCNC Conference, pp. 2099-2104, 2004.

[165] Y. Du, S. J.B. Yoo, and Z. Ding, ``Non-uniform Spectrual Encoding for Enhanced Multi-user Performacne in Optical CDMA Networks", Proc. Conference on Lasers and Electro-Optics. Vol. 1, 2 pp. 2004.

[166] W. Cong, V. J. Hernandez, R. P. Scott, K. Li, J. P. Heritage, B. H. Kolner, Z. Ding, and S. J. B. Yoo, ``PERFORMANCE OF A 10GB/S OPTICAL CODE DIVISION MULTPLE ACCESS CHANNEL IN THE PRESENCE OF AN INTERFERER", Proceedings of the Conference on Lasers and Electro-Optics, Vol. 1, 3 pp., 2004.

[167] S. P. Neugebauer and Z. Ding, ``Blind SIMO Channel Estimation for CPM Using the Laurent Approximation", Proceedings of the IEEE Int. Symposium on Circuits and Systems (ISCAS)}, pp.676-679, 2004.

[168] J. Roberson and Zhi Ding, ``Joint semi-blind channel identification in punctured ARQ retransmissions", Proc. IEEE Int. Conf. on Acoustics, Speech, and Signal Processing, pp.II.421-4, May 2004.

[169] H. Samra, and Z. Ding, ``Sphere decoding for retransmission diversity in MIMO flat-fading channels," Proc. IEEE Int. Conf. on Acoustics, Speech, and Signal Processing, pp.IV.585-588, May 2004.

[170] H. Samra, Zhi Ding, and P. M. Hahn, ``Symbol mapping diversity design for packet retransmissions through fading channels", Proc. IEEE Global Telecommunications Conf., vol.4, pp.1989-1993, 1-5 Dec. 2003.

[171] T. A. Drumright, A. A. Tabarrok, and Zhi Ding, ``Array beamforming for long code CDMA under carrier drift", Proc. IEEE Globecom, vol.4, pp.2156-2160, 1-5 Dec. 2003.

[172] Wing-Kin Ma; Ching, P.C.; Ding, Z.; ``Efficient relaxed maximum-likelihood MPSK multiuser detection using semidefinite programming", 4th IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC), 15-18 June 2003 Page(s):522 - 526

[173] T. Miyajima and Z. Ding, ``Multicarrier channel shortening based on second order output statistics", 4th IEEE Workshop on Signal Processing Advances in Wireless Communications (SPAWC), 15-18 June 2003 Page(s):145 - 149.

[174] Honghui Xu, Dasgupta, S. Zhi Ding ``A novel channel identification method for fast wireless communication systems with transmitter and receiver diversity," Proceedings of the 2003 International Symposium on Circuits and Systems, pp. II:9-12, 25-28 May 2003.

[175] H. Samra and Zhi Ding, ``Symbol mapping diversity in iterative decoding/demodulation of ARQ systems," IEEE International Conf. on Communications, vol.5, pp.3585-3589, May 2003.

[176] T. Li, J. K. Tugnait, and Zhi Ding, ``Channel estimation of long-code CDMA systems utilizing transmission induced cyclostationarity", Proc. IEEE Int. Conf. on Acoustics, Speech, and Signal Processing, pp.IV.105-8, April 2003.

[177] H. Samra, Zhi Ding, P.M. Hahn, ``Optimal symbol mapping diversity for multiple packet transmissions", Proc. IEEE Int. Conf. on Acoustics, Speech, and Signal Processing, pp.IV.181-4, April 2003.

[178] H. Xu, S. Dasgupta, and Zhi Ding, ``An improved feedback scheme for dual channel identification in wireless communication systems," Proc. IEEE Int. Conf. on Acoustics, Speech, and Signal Processing, pp.IV.77-80, April 2003.

[179] A. B. Parr, B. L. Cho, and Z. Ding, ``A new UWB pulse generator for FCC spectral masks", Proc. 57th IEEE Vehicular Technology Conference, Spring, Volume: 3, Page(s): 1664-1666 April 22-25, 2003

[180] N. Ammar and Z. Ding, ``On Blind Channel Identifiability Under Space-Time Coded Transmission", Proc. 36th Asilomar Conf., Nov., 2002.

[181] Xiangguo Tang and Zhi Ding, ``A simple iterative bi-directional equalization for EDGE wireless systems", IEEE Globecom, pp. 287-290, Taipei, Nov. 2002.

[182] Xiangguo Tang and Zhi Ding, ``Contradictory block arbitration for bi-directional decision feedback equalizers", IEEE Globecom, pp. 283-286, Taipei, Nov. 2002.

[183] H. Samra and Z. Ding, ``Precoded Integrated Equalization for ARQ Systems", Proc. of the 36th Asilomar Conf. on Signals, Systems, and Computers, Monterey, CA, Nov., 2002.

[184] N. Ammar and Z. Ding, ``Channel Estimation Under Space-Time Block-Coded Transmission", IEEE Sensor Array and Multichannel Signal Processing Workshop, Rosslyn, VA. Aug, 2002, pp. 422-426.

[185] J Liang, Z Ding, ``Higher order statistical approach for channel estimation usingmatrix pencils," IEEE International Conference on Communications (ICC), Volume: 1, page(s): 11-15, 28 April - 2 May 2002, New York.

[186] J. Liang and Z. Ding, ``A Higher Order Matrix Pencil Approach to Blind Channel Estimation," Proc. IEEE Int. Symposium on Circuits and Systems, Scottsdale, AZ, 2002.

[187] T. A. Drumright and Z. Ding, â€œModulation Classification of QAM Signals using Joint Characteristic Function," Proc. IEEE Int. Symposium on Circuits and Systems, Scottsdale, AZ, 2002.

[188] T. A. Drumright and Z. Ding, ``Gibbs Sampling Classification of QAM Signals in Frequency Selective Channels", 36th Asilomar Conf. on Signals, Systems and Computers, Asilomar CA, 2002, Page(s): 833-837.

[189] H. Samra and Z. Ding, ``Iterative Integrated Equalization for ARQ Systems", Int. Symp. on Info. Theory, Lausanne, Switzerland, Jun, 2002.

[190] H. Samra and Z. Ding, ``Integrated iterative equalization for ARQ Systems," IEEE Int. Conf. on Acoustics, Speech, and Signal Processing, Orlando, FL, 2002.

[191] J. Liang, Z. Ding, and S. Lin, ``Joint Equalization with LDPC Decoding under hybrid ARQ Scheme," 35th Asilomar Conference on Signals, Systems and Computers, Pacific Grove, CA, 2001.

[192] X.-G. Tang and Z. Ding, ``Turbo Equalization for EDGE System with DDF-SOVA," 35th Asilomar Conference on Signals, Systems and Computers, Pacific Grove, CA, Nov. 2001.

[193] S. Cui, Z. Luo, and Z. Ding, ``Robust CDMA Signal Detection in the Presence of User and Interference Signature Mismatch," Proc. 3rd IEEE Workshop on Signal Processing Advances in Wireless Communications, pp. 221-224, March 20-23, 2001.

[194] S. Cui, Z. Luo, and Z. Ding, ``Robust Blind Multiuser Detection against CDMA Signature Mismatch," Proc. Int. Conf. on Acoustics, Speech, and Signal Processing, pp. 2297-2300, Salt Lake City, May 2001.

[195] H. Xu, S. Dasgupta, and Z. Ding, ``A Novel Channel Identification Method for Fast Wireless Communication Systems," Pro. 2001 IEEE International Conference on Communications, pp. 2443-2448, 2001.

[196] J. Liang and Z. Ding, ``FIR Multichannel Identification using Weighted Cumulant Matrix," Proc. 34th Asilomar Conference on Signals, Systems and Computers, pp. 1573-1577, 2000.

[197] J. Liang and Z. Ding, ``A cumulant subspace approach to FIR multiuser channel estimation" Proc. 34th Asilomar Conference on Signals, Systems and Computers, pp. 616-620, 2000.

[198] Z. Ding and Li Qiu, ``Properties of matrix polynomials and MIMO channel identifiability from second order statistics", Proceedings of the 39th IEEE Conference on Decision and Control, vol. 5, Page(s): 4302 -4307 vol.5, 2000.

[199] X. Tang and Z. Ding, ``A Differential Correlation Approach to Blind Symbol Estimation," Proc. IEEE Wireless Communications and Networking Conference, Chicago, IL, September 2000.

[200] J. Liang and Z. Ding, ``A cumulant subspace approach to FIR multiuser channel estimation," Proc. 10th IEEE Workshop on Statistical Signal and Array Processing, pp. 616-620, Pocono Manor, PA, August 2000.

[201] E. Bai and Z. Ding, ``Blind decision feedback equalization of time-varying channels with DPSK inputs," Proceedings 2000 IEEE International Symposium on Circuits and Systems, Volume 4, 28-31 May 2000, 96 - 99

[202] E. Bai and Z. Ding, ``Zero-forcing equalizability of FIR and IIR multi-channel systems with and without perfect measurements," Proceedings 2000 IEEE International Symposium on Circuits and Systems, Volume 4, 28-31 May 2000, 699 - 701

[203] Zhu, J.; Cao, X.-R.; Ding, Z., ``An algebraic principle in blind separation of single source signal", Proceedings 2000 IEEE International Symposium on Circuits and Systems, Volume 4, 28-31 May 2000, Page(s):693 - 696.

[204] Xiangyang Zhuang, Zhi Ding, and A. Lee Swindlehurst, ``A Statistical Subspace Method for Blind Channel Identification in OFDM Communication", IEEE Int. Conf. on Acoustics, Speech, and Signal Processing, pp. 2493-2496, Istanbul, Turkey, May 2000.

[205] Jie Zhu, Wee Ser, and Zhi Ding, ``Blind ISI cancellation by anchoring an arbitrary impulse response coefficient of channels", IEEE Int. Conf. on Acoustics, Speech, and Signal Processing, pp. 2465-2468, Istanbul, Turkey, May 2000.

[206] Zhi Ding, S. Dasgupta, and R. Lopez-Valcarce, ``Interference cancellation and blind equalization for linear multi-user systems", IEEE Int. Conf. on Acoustics, Speech, and Signal Processing, pp. 145-148, Istanbul, Turkey, May 2000.

[207] Kennedy, R.A.; Hasnie, S.; Zhi Ding; McGinty, N.C.; ``Decision feedback equalization using fractionally spaced feedback filtering and vector quantization" Proc. 38th IEEE Conference on Decision and Control, . Volume 1, 7-10 Dec. 1999, Page(s):162 - 167.

[208] T. Li and Z. Ding, ``A Reduced-State Viterbi Algorithm for Blind Sequence Estimation of DPSK Sources," Proc. Global Telecommunications Conference (Globecom), pp. 2167-2171, Rio de Janeiro, Brazil, Dec. 1999.

[209] G. Li and Z. Ding, ``Blind Linear Equalization for GSM Signals in a Mobile Environment", Proc. IEEE Wireless Communications and Networking Conference, pp.801-804, New Orleans, LA, September, 1999.

[210] J. Shen and Z. Ding, ``Direct blind MMSE channel equalization based on second order statistics," 1999 IEEE International Conference on Communications, vol.3, pp.1537 -1541, Seattle, WA, June 1999.

[211] G. Li and Z. Ding, ``New Blind/semi-blind Equalization for GSM Systems", 1999 IEEE Workshop on Signal Processing Advances in Wireless Communications, pp.66-69, Annapolis, MD, May 1999.

[212] J. Shen and Z. Ding, ``Blind MMSE CDMA Detection in Multipath Channels", 1999 IEEE Workshop on Signal Processing Advances in Wireless Communications, pp.5-8, Annapolis, MD, May 1999.

[213] Z. Ding, ``Cumulant Matrix Subspace Algorithms for Blind Single FIR Channel Identification", 1999 IEEE Workshop on Higher Order Statistics, pp.85-88, June, Caesarea, Israel, 1999.

[214] Z. Ding, ``A Cumulant Matrix Subspace Algorithm for Blind Single FIR Channel Identification", SPIE Conference on Digital Wireless Communications, SPIE vol.3708, pp.193-201, April, Orlando, FL, 1999.

[215] J.E. Mooney, Z. Ding, and L.S. Riggs, "Performance Analysis of an Automated E-pulse Scheme in White Gaussian Noise," IEEE International Antennas and Propagation Symposium and URSI/USNC Radio Science Meeting, April, Orlando, FL, 1999.

[216] Junqiang Shen and Zhi Ding, ``Zero-Forcing Blind Equalization Based on Channel Subspace Estimates for Multiuser Systems", Proc. Int. Conf. on Acoustics, Speech, and Signal Processing}, Phoenix, AZ, March 1999.

[217] Z. Ding and G. Li, ``Feasibility of linear GSM blind channel equalization," Proc. Int. Telecommunications Symp., vol.1, pp.~359-364, Sao Paulo, Brazil, 1998.

[218] C. T. Ma, Z. Ding, and S. F. Yau, ``A Two-stage Algorithm for MIMO Blind Deconvolution of Colored Input Signals", Proceedings 9th IEEE SP Workshop on Statistical Signal and Array Processing, pp.~384-387, 1998.

[219] Chunqi Chang, Zhi Ding, Mark S.-F. Yau, and Francis H. Y. Chan, ``A Matrix-Pencil Approach to Blind Separation of Non-White Signals in White Noise", Proc. 1998 IEEE International Conf. on Acoustics, Speech, and Signal Processing, pp.2485-2488, Seattle, May 12, 1998.

[220] Zhi Ding, Iain Collings, Ruey-wen Liu, ``A New Blind Zeroforcing Equalizer for Multichannel Systems", Proc. 1998 IEEE International Conf. on Acoustics, Speech, and Signal Processing, pp.3177-3180, Seattle, May 12, 1998.

[221] Ge Li and Zhi Ding, ``Semi-Blind Channel Identification Used in GSM System," Proc. 1998 IEEE International Conf. on Acoustics, Speech, and Signal Processing, pp.3389-3392, Seattle, May 12, 1998.

[222] Zhi Ding and Ge Li, ``Single Channel Linear Blind Equalization for GSM Cellular Systems", Proc. 1998 IEEE International Conf. on Communications, Atlanta, June, 1998. pp. 355-359

[223] C. Chang, Z. Ding, S. F. Yau, and F. H. Y. Chan ``A Matrix-Pencil Approach to Blind Separation of Non-White Sources," Proc. International Symposium on Multimedia Information Processing, pp. 280-285, Taipei, Taiwan, December 1997.

[224] Jie Zhu, Xiren Cao, Zhi Ding, and Junqiang Shen, ``A Blind Intersymbol Interference Cancellation Method for Multi-user Systems with Channel Diversity", Proc. 1997 Asilomar Conference on Signals, Systems, and Computers, pp.565-569, Pacific Grove, 1997.

[225] Zhi Ding and Ge Li, ``New Methods of Blind Channel Equalization for GSM Systems", Proc. 1997 Asilomar Conference on Signals, Systems, and Computers, Pacific Grove, 1997.

[226] Zhi Ding, ``Blind Wiener Filter Estimation for Multi-Channel Systems Base on Partial Information," Proc. 1997 IEEE International Conf. on Acoustics, Speech, and Signal Processing, pp.3609-3612, April 1997.

[227] Tuan Nguyen and Zhi Ding, ``CMA Beamforming for Multipath Correlated Sources'', Proc. 1997 IEEE International Conf. on Acoustics, Speech and Signal Processing, pp.2521-2524, April 1997.
[228] Rodney A. Kennedy, Deva K. Borah, and Zhi Ding, ``Discretization Issues for the Design of Optimal Blind Algorithms'', Proc. 1997 IEEE International Conf. on Acoustics, Speech, and Signal Processing, pp.51-54, April 1997.
[229] Junqiang Shen and Zhi Ding, ``Blind Adaptive Multiuser CDMA Detection Based on a Linear Projection Constraint'', Proc 1st IEEE Workshop on Signal Processing Advances in Wireless Communications, pp.~261-264, Paris, France, April 1997.
[230] Kennedy, R.A.; Zhi Ding, ``Design and optimization of nonlinear mapping in decision feedback equalization,'' Proceedings of the 35th IEEE Decision and Control, Volume 2, Page(s):1888 - 1889, 11-13 Dec. 1996
[231] Z. Ding, ``An Outer-Product Decomposition Algorithm For Multichannel Blind Identification'', Proc. 8th IEEE Workshop on Stat. Signal and Array Processing, pp.~132-135, Corfu, Greece, June 1996.
[232] Zhi Ding, ``On Convergence Analysis of Fractionally Spaced Adaptive Blind Equalizers'', Int. Conf. on Acoustics, Speech, and Signal Processing, May 1996.
[233] J.E. Mooney, Z. Ding, and L.S. Riggs, "Robust Target Identification Using a Generalized Likelihood Ratio Test," Proc. 3rd International Conference on Ultra-Wideband, Short-Pulse Electromagnetics, pp.343-350, Albuquerque, NM, 1996.
[234] D. B. Ward, Z. Ding, and R. A. Kennedy ``Broadband DOA Estimation using Frequency-invariant Beam-space Processing'', Int. Conf. on Acoustics, Speech, and Signal Processing}, pp.2892-2895, May 1996.
[235] R.A. Kennedy and Z. Ding, ``Quantizer Design and Optimization in Decision Feedback Equalization'', Proc. 1996 Int. Symp. on Signal Proc. Applications, pp.614-617, August, Gold Coast Australia.
[236] Zhi Ding, ``A Blind Channel Identification Algorithm Based on Matrix Outer-Product'', 1996 International Communications Conference, Dallas, TX. pp. 852-856.
[237] Casas, R.A.; Zhi Ding; Kennedy, R.A.; Johnson, C.R., Jr.; Malamut, R.; ``Blind adaptation of decision feedback equalizers based on the constant modulus algorithm'', Proc. 29th Asilomar Conference on Signals, Systems and Computers, Volume 1, 30 Oct.-2 Nov. 1995 Page(s):698 - 702
[238] Zhi Ding, ``Myopic Channel Identification: Identifying unknown Channels based on known pulse shapes'', 1995 IEEE Global Telecommunications Conference, vol.1, pp.670-674, Nov. 1995.
[239] Paul Burns* and Zhi Ding, ``Robustification of Cyclostationary Array Processing Techniques'', Proc. Int. Conf. on Acoustics, Speech, and Signal Processing, pp. 1589-1592, Detroit, May 1995.
[240] Zhi Ding and Zhen Mao, ``Knowledge Based Identification of Fractionally Sampled Channels'' Proc. Int. Conf. on Acoustics, Speech, and Signal Processing, pp. 1996-1999, Detroit, May 1995.
[241] Zhi Ding and Rodney A. Kennedy, ``An Algebraic Self-Training Algorithm for Multi-Channel Systems Identification'', Equalizers'', Proc. 33rd IEEE Conf. on Decision and Control Lake Buena Vista, FL, Dec. 1994.
[242] Y. Li and Zhi Ding, ``Global Convergence of Fractionally Spaced Godard Adaptive Equalizers'', Proc. 28th Asilomar Conf. on Signals, Systems and Computers, pp.617-621, Nov. 1994.
[243] Zhi Ding and Rodney A. Kennedy, ``Algebraic Self-Training Algorithms for Multi-Channel System Identification and Equalization'', Proc. 28th Asilomar Conf. on Signals, Systems and Computers, pp. 1453-1457, Pacific Grove, CA, Nov. 1994.
[244] Y. Li and Zhi Ding, ``Global Convergence of Adaptive Blind Equalizers'', Proc. 4th Annual IEEE Dual-Use Technologies and Applications Conference, vol.II, pp. 402-411, Utica, NY, May 1994.
[245] Y. Li and Z. Ding, ``New Results on the Blind Identification of FIR Channels Based on Second Order Statistics'', Proc. 1993 MILCOM, pp. 644-647, Boston, Oct. 1993.
[246] Y. Li and Z. Ding, ``A New Non-Parametric Cepstral Method for Blind Channel Identification from Cyclostationary Statistics'', Proc. 1993 MILCOM, pp. 648-652, Boston, Oct. 1993.

[247] Y. Li and Z. Ding ``Blind Channel Identification Based on Second order Cyclostationary Statistics", Proc. 1993 IEEE ICASSP, pp. IV:81-84, Minneapolis, April 1993.

[248] J. Y. Hung and Z. Ding, ``Minimization of Torque Ripple in Permanent Magnet Motors," 1992 IEEE Industrial Electronics Conference, San Diego, CA.

[249] Z. Ding and Y. Li, ``Channel Identification Using Second Order Cyclic Statistics," Proc. 26th Asilomar Conf. on Signals, Systems, and Computers, Pacific Grove, CA, November 1992.

[250] Z. Ding, ``On Channel Identifiability Based on Second Order Cyclic Spectra," Proc. IEEE 1992 Milcom, San Diego, October 1992.

[251] K. Yamazaki, R. A. Kennedy, and Z. Ding, ``Candidate Admissible Blind Equalization Algorithms for QAM Communication Systems," Proc. 1992 IEEE Int. Conf. on Communications, pp. 1518-1522, June 1992.

[252] K. Yamazaki, R. A. Kennedy, and Z. Ding, ``Globally Convergent Blind Deconvolution Algorithms for Complex Data System," Proc. 1992 IEEE ICASSP, San Fransisco, CA, April 1992.

[253] Z. Ding and R. A. Kennedy, ``A New Adaptive Algorithm for Joint Blind Equalization and Carrier Recovery," Proc. 25th Asilomar Conf. on Signals, Systems, and Computers, pp. 699-703, Pacific Grove, CA, November 1991 (Invited).

[254] Z. Ding and C. R. Johnson, Jr., ``Existing Gap Between Theory and Application of Blind Equalization," Adaptive Signal Processing, Simon Haykin, Editor, Proc. SPIE 1565, pp. 154-165, 1991 (Invited).

[255] Z. Ding, ``A New Method for Automatic Beamforming," Proc. 25th Asilomar Conf. on Signals, Systems, and Computers, pp. 689-693, Pacific Grove, CA, November 1991.

[256] Z. Ding, C. R. Johnson, Jr., and R. A. Kennedy, ``Local Convergence of `Globally Convergent' Blind Adaptive Equalization Algorithms," Proc. 1991 IEEE ICASSP, pp. 1529-1532, Toronto, Canada, May 1991.

[257] Z. Ding,``Joint Blind Equalization and Carrier Recovery of QAM Systems," Proc. 25th Conf. on Info. Sciences and Systems, Baltimore, MD, March 1991.

[258] R. A. Kennedy, B.D.O. Anderson, Z. Ding, and C. R. Johnson, Jr., ``Local stable minima of the Sato recursive identification scheme", Proceedings of the 29th IEEE Conference on Decision and Control, vol.6, Page(s):3194 - 3199, 5-7 Dec. 1990.

[259] Z. Ding, C. R. Johnson, Jr., and R. A. Kennedy, `` Nonglobal convergence of blind recursive identifiers based on gradient descent of continuous cost functions", Proceedings of the 29th IEEE Conference on Decision and Control, vol.1, Page(s):225 - 230, 5-7 Dec. 1990.

[260] Z. Ding, C. R. Johnson, Jr., and R. A. Kennedy, ``On the admissibility of blind adaptive equalizers", Proc. Int. Conf. on Acoustics, Speech, and Signal Processing, vol.3, Page(s):1707 - 1710, 3-6 April 1990.

[261] Z. Ding, C. R. Johnson, R. A. Kennedy and B. D. O. Anderson, ``On the Ill-Convergence of Godard Blind Equalizers in Data Communication Systems", In Proceedings of Conf. Information Science and Systems, vol. 89, pp. 538-543, Baltimore, MD, 1989.

Professional Services and Achievements

- Chief Information Officer, IEEE Communications Society, 2018-2022
- Chief Marketing Officer, IEEE Communications Society, 2020-2022, 2024-Present
- Parliamentarian, IEEE Communications Society, 2022-2024
- Steering Committee Chairman, *IEEE Transactions on Wireless Communications,* 1.2008-1-2010
- Canadian National Science and Engineering Research Council Panelist, 2009-2012
- Fellow of IEEE
- Steering Committee Member, *IEEE Transactions on Wireless Communications,* 1.2006-1-2008
- General Chair, IEEE 2016 International Conference on Acoustics, Speech, and Signal Processing, Shanghai, China.
- Technical Program Chair, *IEEE 2006 Globecom*, San Francisco, CA.
- Editorial Board Member, *IEEE Signal Processing Magazine*, 1/2003-1/2007.
- Associate Editor, *IEEE Signal Processing Letters*, 1.2002-1.2005.
- Associate Editor, IEEE Transactions on Signal Processing, 1.2001-1.2004.
- Editor, Special Issue on Multiuser Detection and Blind Estimation, *EURASIP Journal on Applied Signal Processing*, Dec. 2002.
- Member, IEEE Statistical Signal and Array Processing Technical Committee, 1993-1998.
- Member, IEEE Signal Processing for Communications Technical Committee, 1998-2004.
- Associate Editor, IEEE Transactions on Signal Processing, 1994-1997.
- Technical Program Committee Member, 3rd IEEE Workshop on Signal Processing Advances in Wireless Communications, Taiwan, March 2001.
- Organization Committee Member, 1st IEEE Workshop on Signal Processing Advances in Wireless Communications, Paris, France, April 1997.
- Review Panelist, National Science Foundation, 1997, 2003, 2004, 2005, 2007, 2008, 2010, 2014, 2015, 2016.