

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

In the Patent of: **Yang, Xiu Zheng**, Shulin (TW);
Ren-Jr Chen, Hsinchu (TW);
Chang-Lung Hsiao, Hsinchu (TW);
Pang-An Ting, Fongyuan (TW)

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Title: METHOD FOR CONSTRUCTING FRAME STRUCTURES

INTER PARTES REVIEW OF
U.S. PATENT NO. 8,265,096 B2
Case IPR2021-00734

DECLARATION OF SUMIT ROY, Ph.D.
Ex. 1002

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APPENDIX A (Curriculum Vitae)

I. INTRODUCTION

1. My name is Sumit Roy, Ph.D., and I have been retained by counsel for Petitioner ZyXEL Communication Corporation (“ZyXEL” or “Petitioner”) as an expert witness to provide assistance regarding U.S. Patent No. 8,265,096 (“the ‘096 Patent”). I previously submitted a substantially identical declaration to this one on behalf of Qualcomm Incorporated in a prior petition for *inter partes* review (IPR2021-00375). Specifically, I have been asked to consider the validity of claims 1-4 and 6-8 of the ‘096 Patent (the “Challenged Claims”) in view of prior art, anticipation and obviousness considerations, and understanding of a person of ordinary skill in the art (“POSA”) as it relates to the ‘096 Patent. I have personal knowledge of the facts and opinions set forth in this declaration, and believe them to be true. If called upon to do so, I would testify competently thereto.

2. I am being compensated for my time at my standard consulting rate of \$650 per hour. I am also being reimbursed for expenses that I incur during the course of this work. My compensation is not contingent upon the results of my study, the substance of my opinions, or the outcome of any proceeding involving the challenged claims. I have no financial interest in the outcome of this matter or in the pending litigation between Petitioner and UNM Rainforest Innovations (“UNM”), which I understand has asserted the ‘096 Patent against Petitioner in litigation.

3. My opinions are based on my years of education, research and experience, as well as my investigation and study of relevant materials, including those cited herein.

4. I may rely upon these materials, my knowledge and experience, and/or additional materials to rebut arguments raised by UNM. Further, I may also consider additional documents and information in forming any necessary opinions, including testimony of other expert witnesses or documents that may not yet have been provided to me.

5. I have been informed that UNM (formerly STC.UNM) has asserted the patent in the following lawsuits: *UNM Rainforest Innovations v. ZyXEL Commc'ns Corp.*, 6:20-cv-00522 (W.D. Tex.); *UNM Rainforest Innovations v. Dell Techs., Inc.*, 6:20-cv-00468 (W.D. Tex.); *UNM Rainforest Innovations v. ASUSTek Comput., Inc.*, 6:20-cv-00142 (W.D. Tex.); *UNM Rainforest Innovations v. D-Link Corp.*, 6:20-cv-00143 (W.D. Tex.); *UNM Rainforest Innovations v. Apple Inc.*, 1:20-cv-00351 (W.D. Tex.); *UNM Rainforest Innovations v. TP-Link Techs. Co., Ltd.*, 6:19-cv-00262 (W.D. Tex.).

6. In this declaration, I will discuss my qualifications and background, the technology background related to the '096 Patent and then provide my analyses and opinions on claims 1-4 and 6-8 of the '096 Patent. This overview provides bases for my opinions with respect to the '096 Patent.

7. My analysis of the materials produced in this proceeding 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. BACKGROUND AND QUALIFICATIONS

8. I am an expert in the field of wireless networks. I have studied, taught, practiced, and researched this field for over thirty years. I have summarized in this section my educational background, work experience, and other relevant qualifications. Attached hereto as Appendix A, is a true and correct copy of my curriculum vitae describing my background and experience.

9. I earned my Bachelor of Technology degree in Electrical Engineering from Indian Institute of Technology in Kanpur in 1983. In 1985, I earned my Master of Science degree in Electrical Engineering from University of California in Santa Barbara. I earned a Doctor of Philosophy in Electrical Engineering and Master of Arts in Statistics & Applied Probability from University of California in Santa Barbara in 1988, with my dissertation being on “Estimation Strategies for a Network of Distributed Sensors.”

10. While a graduate student, from 1983 through 1988, I worked on various projects related to networked wireless communication and radar systems using a mix of analytical modeling and computer simulation.

11. In July of 1988, I joined the faculty of the University of Pennsylvania as an Assistant Professor in the Department of Electrical Engineering. While in this position, I taught upper level undergraduate course called “Communication Systems” and graduate level courses “Advanced Digital Signal Processing” and “Digital Communications”.

12. In January of 1995, I became a tenured Associate Professor in the Division of Engineering at the University of Texas at San Antonio, in San Antonio, Texas. In April of 1998, I transferred to a tenured Associate Professor in the Department of Electrical Engineering at the University of Washington in Seattle, Washington and was promoted to Professor in September of 2002. As a faculty member at University of Washington, I have taught courses and directed research in networking and telecommunications, including 802.11 WLAN and Cellular technologies. From September 2014 to September of 2019, I received Integrated Systems Term Professorship at the University of Washington in recognition of my leadership and national stature in this area.

13. I took full-time leave from my University of Washington position to serve as a Senior Staff Researcher at Intel Labs, Hillsboro, OR from September 2001

to December 2003. At Intel, I served as Wireless Systems Architect researching IEEE 802.15.3a Ultra-Wideband PHY layer for Wireless Personal Area Networks and nascent pre-802.11n (MIMO WiFi) technology, with responsibility for representing Intel at IEEE Standards meetings and coordination with other industry partners. My research resulted in several patents relating to the above, including design implementation of MIMO WiFi transceivers.

14. I have knowledge and experience throughout my academic career and industry experience in technologies used in wireless networks. Since 1988, I have received over ten million dollars in funding from various national and international organizations to support my work on wireless networking.

15. In addition to advising and mentoring students at UW, I have served as external dissertation reviewer in McGill Univ., Montreal, National University of Singapore, University of Victoria, and SIIT in Bangkok. At UW and U. Penn., I have advised and supervised over 20 Ph.D students and visiting scholars.

16. In addition to my academic work, I have remained active in the communication industry through my consulting work. I consulted for Mathworks, a vendor of WLAN toolbox products for design, on current 802.11 designs including MIMO systems. I am also the named inventor on U.S. Patent Nos. 7,782,970 and 8,289,836 titled "Apparatus and associated methods to introduce diversity in a

multicarrier communication channel,” among others, which are listed in my *curriculum vitae*.

17. I have authored and co-authored over 200 journal publications, conference proceedings, technical papers, book chapters, and technical presentations in a broad array of communications-related technologies, including networking and wireless communication. I have also developed and taught over 10 courses related to communications and computer systems, including several courses on signals and systems, wireless communication, communications systems. These courses included introductory courses on communication systems, as well as more advanced courses on wireless communications. A complete list of my publications and the courses I have developed and/or taught is also contained in my *curriculum vitae*.

18. My professional affiliations include services in various professional organizations and serving as a reviewer for a number of technical publications, journals, and conferences. I have also received a number of awards and recognitions, including IEEE Communications Society’s Distinguished Lecturer award (2014-15, 2017-18), Shanghai JiaoTung University High-end Foreign Expert award (1 month/year, 2014-16), which are listed in my *curriculum vitae*.

19. I have also served as an expert in certain legal proceedings. A list of cases in which I have testified at trial, hearing, or by deposition (including those

during the past five years) is provided in my *curriculum vitae*. Over the years, I have been retained by both patent owners as well as petitioners.

III. MATERIALS RELIED UPON

20. In reaching the conclusions described in this declaration, I have relied on the documents and materials cited herein as well as those identified in this declaration, including the ‘096 Patent (Ex. 1001)¹, the prosecution history of the ‘096 the Exhibits to Patent, the prior art references, and information discussed and any other references specifically identified in this declaration, including the materials identified in the chart below.

21. I have considered information from various other sources in forming my opinions. I have also drawn on almost three decades of research and development in the field of wireless communication systems.

Exhibit	Description
Ex. 1001	U.S. Patent No. 8,265,096 (“the ‘096 Patent”)
Ex. 1003	<i>Sand Revolution II, LLC v. Continental Intermodal Group-Trucking LLC</i> , Paper 24, IPR2019-01393 (PTAB June 16, 2020)
Ex. 1004	Seventh Supplemental Order Regarding Court Operations Under Exigent Circumstances Created by the Covid 19 Pandemic (W.D. Tex. Aug. 6, 2020)
Ex. 1005	Excerpts from JEFFREY G. ANDREWS ET AL., FUNDAMENTALS OF WIMAX (2007) (“Fund. of WiMAX”)
Ex. 1006	Five Criteria Statement for P802.16m PAR Proposal, IEEE 802.16-06/055r3 (Nov. 15, 2006)

¹ The citations in this declaration to an “Exhibit” or “Ex.” refer to the exhibits to the ‘096 Petition.

Exhibit	Description
Ex. 1007	IEEE 802.16m System Requirements, IEEE 802.16m-07/002r4 (Oct. 19, 2007)
Ex. 1008	Listing of Challenged '096 Patent Claims
Ex. 1009	U.S. Provisional App. No. 60/929,
Ex. 1010	Excerpts from '096 Patent File History
Ex. 1011	Claim Construction Order in <i>STC.UNM v. Apple Inc.</i> , No. 1-20- cv-00351 (W.D. Tex. Apr. 9, 2020), ECF No. 69
Ex. 1012	U.S. Pub. No. 2009/0067377 A1 ("Talukdar")
Ex. 1013	U.S. Provisional Application No. 60/956,031 ("Talukdar Provisional")
Ex. 1014	Canadian Patent Application No. 2 581 166 A1 ("Wang")
Ex.1015	WIPO Handbook on Industrial Property Information and Documentation, "Examples and Kinds of Patent Documents" (May 2016)
Ex. 1016	U.S. Pub. No. 2007/0155387 A1 ("Li")
Ex. 1017	U.S. Pub. No. 2007/0104174 A1 ("Nystrom")
Ex. 1018	U.S. Pub. No. 2008/0095195 ("Ahmadi")
Ex. 1019	Excerpts from WILLIAM STALLINGS, WIRELESS COMMUNICATIONS AND NETWORKS (2D ED. 2005)
Ex. 1020	U.S. Patent No. 7,460,466 B2 ("Lee")
Ex. 1021	U.S. Patent No. 8,462,611 B2 ("Ma")
Ex. 1022	Fixed, nomadic, portable and mobile applications for 802.16-2004 and 802.16e WiMAX networks (Nov. 2005)
Ex. 1023	Mohammad Azizul Hasan, <i>Performance Evaluation of WiMAX/IEEE 802.16 OFDM Physical Layer</i> (June 2007)
Ex. 1024	U.S. Patent No. 7,710,910 B2 ("Ode")
Ex. 1025	IEEE 802.16m System Requirements, IEEE 802.16m-07/002r4 (Jan. 12, 2007)
Ex. 1026	U.S. Pub. No. 2004/0037215 A1 ("Hwang")

Exhibit	Description
Ex. 1027	Yasamin Mostofi, <i>ICI Mitigation for Pilot-Aided OFDM Mobile Systems</i> (Mar. 2005)

IV. SUMMARY OF OPINIONS

22. Claims 1-4 and 6-7 of the '096 Patent are unpatentable as obvious in light of Talukdar in combination with Li.

23. Claim 8 of the '096 Patent is unpatentable as obvious in light of Talukdar in combination with Nystrom.

V. LEGAL STANDARDS

24. I am not a lawyer. My understanding of legal principles comes from counsel. I have applied the following legal principles in arriving at the opinions set forth in this declaration.

A. Legal Standards for Prior Art

25. I understand that a patent or other publication must first qualify as prior art before it can be used to invalidate a patent claim.

26. I understand that a U.S. or foreign patent qualifies as prior art to a patent if the date of issuance of the U.S. or foreign patent is prior to the invention of the patent. I further understand that a printed publication, such as an article published in a magazine or trade publication or a patent application, qualifies as prior art to a patent if the date of publication is prior to the invention of the patent. My understanding is that, for such prior art references, a patentee may attempt to show

that the claimed invention was conceived prior to the issuance of the U.S. foreign patent or publication of the printed materials. To do so, it is my understanding that patentee must prove with corroborating evidence that the named inventors conceived of the complete claimed invention before the prior art, and were diligent in reducing the claimed inventions to practice.

27. I understand that, regardless of the date of invention of the patent, a U.S. or foreign patent qualifies as prior art to a patent if the date of issuance of the U.S. or foreign patent is more than one year before the earliest effective filing date of the patent. I further understand that a printed publication, such as an article published in a magazine or trade publication or a patent application, constitutes prior art to a patent if the publication occurs more than one year before the earliest effective filing date of the patent, again regardless of the date of invention of the patent.

28. I understand that a U.S. patent or published U.S. application qualifies as prior art to a patent if the application for that patent was filed in the United States before the invention of the patent. My understanding is that, for such prior art references, a patentee may attempt to show that the claimed invention was conceived prior to the filing in the United States of the purported prior art U.S. patent or application. To do so, it is my understanding that patentee must prove with corroborating evidence that the named inventors conceived of the complete claimed

invention before the prior art, and were diligent in reducing the claimed inventions to practice.

29. I understand that to qualify as prior art, a reference must contain an enabling disclosure that allows one of ordinary skill to practice the claims without undue experimentation.

30. I understand that documents and materials that qualify as prior art can be used to invalidate a patent claim as anticipated or as obvious.

B. Legal Standard for Priority Date

31. I understand that the “priority date” or “earliest effective filing date” of a patent is the date on which it is filed, or the date on which an earlier-filed U.S. or international patent application was filed if the patentee claims the benefit of priority to that earlier-filed U.S. or international patent application. I further understand that although a foreign priority document may be used to try to overcome certain prior art references, the effective filing date is not the filing date of a foreign priority document.

C. Legal Standard for Anticipation

32. I have been informed that if each and every element or step of a claim is disclosed within the “four corners” of a prior art reference, that claim is said to be “anticipated” by that single prior art reference and is invalid under 35 U.S.C. § 102 because the claimed invention is not, in fact, new or novel. I have been informed

that the standard for anticipation in an *Inter Partes* Review proceeding is by a preponderance of the evidence.

33. I have also been informed that a prior art reference can disclose a claim feature if that feature is expressly described by that reference or inherent from its disclosure. I have been informed that something is inherent from a prior art reference, if the missing descriptive matter must necessarily be present, and it would be so recognized by a person of ordinary skill in the art (“POSA”). I have also been informed that inherency cannot be established by probabilities or possibilities, and that the mere fact that something may result from a given set of circumstances is not sufficient to show inherency.

34. I have further been informed that where a reference discloses multiple embodiments, the reference should not be limited to a preferred embodiment. Instead, each disclosed embodiment may anticipate.

35. Moreover, I have been informed that as part of an anticipation analysis, it is proper to take into account not only specific teachings of the reference, but also the inferences that one skilled in the art would reasonably be expected to draw therefrom. A reference can anticipate a claim even if it does not expressly spell out all the limitations arranged or combined as in the claim, if a person of skill in the art, reading the reference, would at once envisage the claimed arrangement or combination.

36. I have been informed that a prior art document can disclose a claimed feature, and anticipate a claimed invention, if that feature is described in another document that has been incorporated by reference. I have also been informed that, to incorporate by reference, the host document must identify with detailed particularity what specific material it incorporates, and clearly indicate where that material is found in the incorporated document.

37. I have also been informed that, in making the determination of the extent to which material is incorporated into a host document, the standard of a POSA should be used to determine whether the host document describes the material to be incorporated by reference with sufficient particularity.

D. Legal Standard of Obviousness

38. I have been informed that a claim may be invalid under 35 U.S.C. § 103(a) if the subject matter described by the claim as a whole would have been obvious to a hypothetical person of ordinary skill in the art in view of a prior art reference or in view of a combination of references at the time the claimed invention was made.

39. I have been informed that obviousness is determined from the perspective of a hypothetical POSA and that the asserted claims of the patent should be read from the point of view of such a person at the time the claimed invention

was made. I have been informed that a hypothetical POSA is assumed to know and to have all relevant prior art in the field of endeavor covered by the patent in suit.

40. I have been informed that there are two criteria for determining whether prior art is analogous and thus can be considered prior art to a challenged patent: (1) whether the art is from the same field of endeavor, regardless of the problem addressed, and (2) if the reference is not within the field of the patentee's endeavor, whether the reference still is reasonably pertinent to the particular problem with which the patentee is involved. I have also been informed that the field of endeavor of a patent is not limited to the specific point of novelty, the narrowest possible conception of the field, or the particular focus within a given field. I have also been informed that a reference is reasonably pertinent if, even though it may be in a different field from that of the patentee's endeavor, it is one which, because of the matter with which it deals, logically would have commended itself to a patentee's attention in considering his problem.

41. I have also been informed that an analysis of whether a claimed invention would have been obvious should be considered in light of the scope and content of the prior art, the differences (if any) between the prior art and the claimed invention, and the level of ordinary skill in the pertinent art involved. I have been informed as well that a prior art reference should be viewed as a whole.

42. I have also been informed that in considering whether an invention for a claimed combination would have been obvious, I may assess whether there are apparent reasons to combine known elements in the prior art in the manner claimed in view of interrelated teachings of multiple prior art references, the effects of demands known to the design community or present in the market place, and/or the background knowledge possessed by a person having ordinary skill in the art. I have been informed that other principles may be relied on in evaluating whether a claimed invention would have been obvious, and that these principles include the following:

- A combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results;
- When a device or technology is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or in a different one, so that if a person of ordinary skill can implement a predictable variation, the variation is likely obvious;
- If a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill;

- An explicit or implicit teaching, suggestion, or motivation to combine two prior art references to form the claimed combination may demonstrate obviousness, but proof of obviousness does not depend on or require showing a teaching, suggestion, or motivation to combine;
- Market demand, rather than scientific literature, can drive design trends and may show obviousness;
- In determining whether the subject matter of a patent claim would have been obvious, neither the particular motivation nor the avowed purpose of the named inventor controls;
- One of the ways in which a patent's subject can be proved obvious is by noting that there existed at the time of invention a known problem for which there was an obvious solution encompassed by the patent's claims;
- Any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed;
- "Common sense" teaches that familiar items may have obvious uses beyond their primary purposes, and in many cases a person of ordinary skill will be able to fit the teachings of multiple patents together like pieces of a puzzle;

- A person of ordinary skill in the art is also a person of ordinary creativity, and is not an automaton;
- A patent claim can be proved obvious by showing that the claimed combination of elements was “obvious to try,” particularly when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions such that a person of ordinary skill in the art would have had good reason to pursue the known options within his or her technical grasp; and
- One should be cautious of using hindsight in evaluating whether a claimed invention would have been obvious.

43. I have further been informed that, in making a determination as to whether or not the claimed invention would have been obvious to a person of ordinary skill, the Board may consider certain objective factors if they are present, such as: commercial success of products practicing the claimed invention; long-felt but unsolved need; teaching away; unexpected results; copying; and praise by others in the field. These factors are generally referred to as “secondary considerations” or “objective indicia” of nonobviousness. I have been informed, however, that for such objective evidence to be relevant to the obviousness of a claim, there must be a causal relationship (called a “nexus”) between the claim and the evidence and that this nexus must be based on what is claimed and novel in the claim rather than

something in the prior art. I have also been informed that even when they are present, secondary considerations may be unable to overcome primary evidence of obviousness (*e.g.*, motivation to combine with predictable results) that is sufficiently strong.

44. In sum, my understanding is that prior art teachings are properly combined where a person of ordinary skill in the art at the time of the alleged invention having the understanding and knowledge reflected in the prior art and motivated by the general problem facing the inventor would have been led to make the combination of elements recited in the claims. Under this analysis, the prior art references themselves, or any need or problem known in the field of endeavor at the time of the invention, can provide a reason for combining the elements of multiple prior art references in the claimed manner.

45. I have been informed and understand that the obviousness analysis requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

VI. CLAIM CONSTRUCTION

46. I have been informed that for purposes of this *Inter Partes* Review, the standard for claim construction is the same as the standard used in federal district court litigation: claim terms should generally be given their ordinary and customary

meaning as understood by one of ordinary skill in the art at the time of the invention and after reading the patent and its prosecution history.

47. I have been informed that the following terms of the '096 Patent were construed in a case between UNM and Apple:

- “frame structure” (claims 1, 8): “a single structure comprising one or more frames, wherein each frame may have one or more subframes”;
- “symbol” (claims 1, 8): Plain-and-ordinary meaning, wherein the plain-and-ordinary meaning means “a transmissible unit of information”;
- “at least one of [...] and [...]” (claims 1, 2, 3, 4, 6, 8): “[...] and/or [...]”;
- “symbol period” (claim 1): “the time it takes to transmit one symbol”;
- “pilot symbols that are denser than” (claim 8): “more pilot symbols per unit time than, wherein a unit time is the symbol period of the first communication system”;
- “communication system” (claims 1, 8): Plain-and-ordinary meaning, where the plain-and-ordinary meaning is “a combination of hardware and software that transmits and receives data according to one or more communications standards”;
- “wherein the first communication system’s symbols and the second communication system’s symbols co-exist in one transmission scheme”

(claims 1, 8): Plain-and-ordinary meaning where the plain-and-ordinary meaning is “wherein symbols of the first communication system and symbols of the second communication system exist together in one transmission scheme”;

- “data” / “non-data” (claims 1, 2, 3, 6, 7, 8): Plain-and-ordinary meaning (both); and
- “support higher mobility than” (claim 1): “support higher relative velocity between a transmitter and a receiver than.” Apple Claim Construction Order (Ex. 1011).

48. I offer no opinion herein on the merits of the claim constructions, but reserve my right to do so in the future. I do not necessarily agree that these constructions are correct, but I also do not view them as inconsistent with my opinions that the challenged claims are unpatentable in view of the prior art discussed below and in the Petition. For the remaining claim terms, I have been asked to assume that the terms have their plain and ordinary meaning.

VII. LEVEL OF ORDINARY SKILL IN THE ART

49. In rendering the opinions set forth in this declaration, I was asked to consider the patent claims and the prior art through the eyes of a POSA at the time of the alleged invention, which I understand is potentially as early as September 17, 2007 (the filing date of the later provisional patent application identified on the face

of the '096 Patent). I understand that the factors considered in determining the ordinary level of skill in a field of art include the level of education and experience of persons working in the field; the types of problems encountered in the field; the teachings of the prior art, and the sophistication of the technology at the time of the alleged invention. I understand that a POSA is not a specific real individual, but rather is a hypothetical individual having the qualities reflected by the factors above. I understand that a POSA would also have knowledge from the teachings of the prior art, including the art cited below.

50. Taking these factors into consideration, in my opinion, on or around September 17, 2007, a POSA relating to the technology of the '096 Patent would have had a Bachelor's degree in electrical engineering, computer engineering, or a related field, and around two years of experience in the design or development of wireless communication systems, or the equivalent. Individuals with additional education or additional industrial experience could still be of ordinary skill in the art if that additional aspect compensates for a deficit in one of the other aspects of the requirements stated above.

51. Well before September 17, 2007, my level of skill in the art was at least that of a POSA. I am qualified to provide opinions concerning what a POSA would have known and understood at that time, and my analysis and conclusions herein are from the perspective of a POSA as of that date.

VIII. BACKGROUND ON THE STATE OF THE ART

A. Overview of Cellular Communication Systems

52. A cellular system typically includes a number of mobile stations (*e.g.*, cellular telephones) and a number of fixed base stations that provide coverage for the mobile stations. WILLIAM STALLINGS, WIRELESS COMMUNICATIONS AND NETWORKS (2D ED. 2005) (Ex. 1019, “Wireless Comm.”) at 269-70. When a user initiates a call using a particular mobile station, the mobile station connects to a nearby base station and sends a data transmission to the base station. *Id.* at 269 (“The BS [(base station)] includes an antenna, a controller, and a number of transceivers, for communicating on the channels assigned to that cell. The controller is used to handle the call process between the mobile unit and the rest of the network.”). The base station is connected to a mobile telephone switching office (MTSO), which is connected to the public wired telephone network and other networks (*e.g.*, the Internet). *Id.* The signal from the mobile station can be relayed across these connections until it reaches its intended destination, which could be another wireless mobile station or a wired telephone. *Id.* The following figure provides an overview of cellular system. *Id.* at 270.

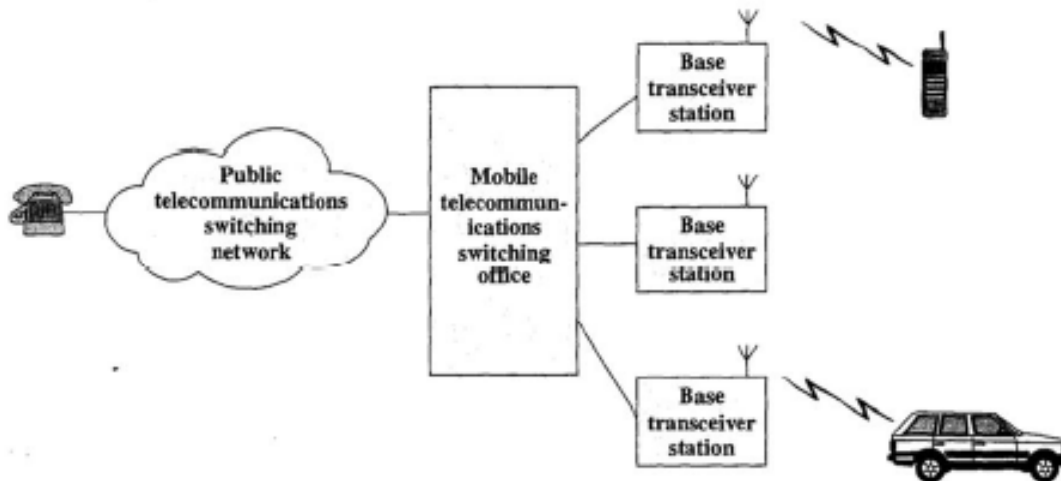


Figure 10.5 Overview of Cellular System

53. Mobile and base stations communicate with each other over wireless communication channels. *Id.* at 269. To send a data transmission, a modulator at the mobile or base station varies a parameter of a carrier wave, such as amplitude, phase, or frequency, to impart information. *Id.* at 131. A receiving antenna receives the signal, and a demodulator extracts the information from the carrier wave. *Id.* The wireless link from a base station to mobile users is called the “downlink” channel, and the link from mobile users to the base station is called the “uplink” channel.

54. Cellular wireless was different from wired broadband communication systems. JEFFREY G. ANDREWS ET AL., FUNDAMENTALS OF WIMAX (2007) (Ex. 1005, “Fund. of WiMAX”) at 3. While wireless was for cellular telephones, broadband generally involved user equipment with more computational power (*e.g.*, personal computers) connected to the Internet or a local network over a wireline medium, such as DSL (Digital Subscriber Line), cable modems, or fiber.

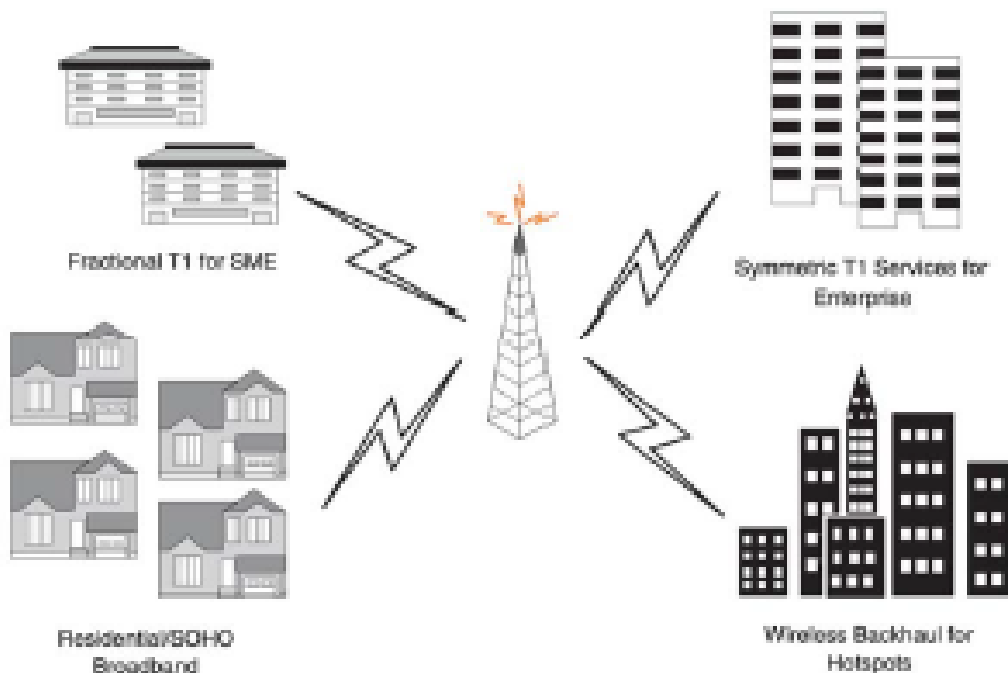
Id. at 3-4. Broadband systems provided users with significantly higher bandwidth than wireless systems and facilitated data-heavy applications such as Internet browsing, file downloading, and media streaming. Wireless systems provided users with the ability to stay connected while moving around and were used primarily for voice calls, cellular wireless systems, or applications that did not require high bitrates. *Id.* But it was “extremely difficult for broadband wireless systems to match the rising throughput performance of traditional broadband,” and rather than attempt to meet these data speeds, WiMAX relied on “portability and mobility” to differentiate itself—features that were not provided by traditional broadband. *Id.* at 22. The 802.16 group therefore began to work on mobility-related revisions to the 802.16 standard. *Id.* at 8 (“In 2003, the 802.16 group began work on enhancements to the specifications to allow vehicular mobility applications.”).

B. Overview of Broadband Wireless Communication Systems

55. “Broadband wireless is about bringing the broadband experience to a wireless context, which offers users certain unique benefits and convenience. There are two fundamentally different types of broadband wireless services. The first type attempts to provide a set of services similar to that of the traditional fixed-line broadband but using wireless as the medium of transmission. This type, called fixed wireless broadband, can be thought of as a competitive alternative to DSL or cable modem. The second type of broadband wireless, called mobile broadband, offers the

additional functionality of portability, nomadicity (the ability to connect to the network from different locations via different base stations), and mobility (the ability to keep ongoing connections active while moving at vehicular speeds).” Fund. of WiMAX at 4.

56. “Applications using a fixed wireless solution can be classified as point-to-point or point-to-multipoint. Point-to-point applications include interbuilding connectivity within a campus and microwave backhaul. Point-to-multipoint applications include (1) broadband for residential, small office/home office (SOHO), and small- to medium-enterprise (SME) markets, (2) T1 or fractional T1-like services to businesses, and (3) wireless backhaul for Wi-Fi hotspots. Figure 1.2 illustrates the various point-to-multipoint applications.” *Id.* at 10-11.



57. The wireless link from a base station to users is called the “downlink” channel, and the link from users to the base station is called the “uplink” channel.

1. First-Generation Broadband Systems

58. “In the late 1990s, one of the more important deployments of wireless broadband happened in the so-called multichannel multipoint distribution services (MMDS) band at 2.5GHz. The MMDS band was historically used to provide wireless cable broadcast video services, especially in rural areas where cable TV services were not available.” Fund. of WiMAX at 6. “The first generation of these fixed broadband wireless solutions were deployed using the same towers that served wireless cable subscribers. These towers were typically several hundred feet tall and enabled LOS [line-of-sight] coverage to distances up to 35 miles, using high-power transmitters.” *Id.* “The outdoor antenna and LOS requirements proved to be significant impediments.” *Id.* at 7. “Besides, since a fairly large area was being served by a single tower, the capacity of these systems was fairly limited.” *Id.*

2. Second-Generation Broadband Systems and OFDM

59. “Second-generation broadband wireless systems were able to overcome the LOS issue and to provide more capacity.” *Id.* at 8. “Many solved the NLOS [non-line-of-sight] problem by using such techniques as orthogonal frequency division multiplexing (OFDM), code division multiple access (CDMA), and multiantenna processing.” *Id.*

60. “OFDM has become the solution of choice for mitigating ISI [inter-symbol interference] in broadband systems.” *Id.* at 25. “In a multipath environment, when the time delay between the various signal paths is a significant fraction of the transmitted signal’s symbol period, a transmitted symbol may arrive at the receiver during the next symbol period and cause [ISI]. At higher data rates, the symbol time is shorter; hence, it takes only a smaller delay to cause ISI. This makes ISI a bigger concern for broadband wireless and mitigating it more challenging.” *Id.* at 24. Although equalization is the conventional method for dealing with ISI but at high data rates requires too much processing power. *Id.* at 24-25. That is why OFDM is better at mitigating ISI. *Id.*

61. Although OFDM became widely used “relatively” as of 2007, the concept dated back some 50 years prior. This brief history of OFDM cites some landmark dates that are given in the table below. *Id.* at 9.

Sidebar 1.1 A Brief History of OFDM
Although OFDM has become widely used only recently, the concept dates back some 40 years. This brief history of OFDM cites some landmark dates. 1966: Chang shows that multicarrier modulation can solve the multipath problem without reducing data rate [4]. This is generally considered the first official publication on multicarrier modulation. Some earlier work was Holsinger's 1964 MIT dissertation [5] and some of Gallager's early work on waterfilling [6]. 1971: Weinstein and Ebert show that multicarrier modulation can be accomplished using a DFT [7]. 1985: Cimini at Bell Labs identifies many of the key issues in OFDM transmission and does a proof-of-concept design [8]. 1993: DSL adopts OFDM, also called discrete multitone, following successful field trials/competitions at Bellcore versus equalizer-based systems. 1999: The IEEE 802.11 committee on wireless LANs releases the 802.11a standard for OFDM operation in 5GHz UNI band. 2002: The IEEE 802.16 committee releases an OFDM-based standard for wireless broadband access for metropolitan area networks under revision 802.16a. 2003: The IEEE 802.11 committee releases the 802.11g standard for operation in the 2.4GHz band. 2003: The multiband OFDM standard for ultrawideband is developed, showing OFDM's usefulness in low-SNR systems.

C. Overview of 802.16/WiMAX

62. WiMAX (worldwide interoperability for microwave access) technology is designed to accommodate both fixed and mobile broadband applications. Fund. of WiMAX at 4. The first generation of fixed broadband wireless solutions were deployed to serve wireless cable subscribers using LOS (line of sight) coverage. *Id.* at 6. Second generation broadband wireless systems were able to overcome the LOS issue and to provide more capacity using orthogonal frequency division multiplexing (OFDM) and multi antenna systems. *Id.* at 8.

1. History of 802.16

63. “In 1998, the Institute of Electrical and Electronics Engineers (IEEE) formed a group called 802.16 to develop a standard for what was officially called a

wireless metropolitan area network, or wireless MAN,” and commercially called WiMAX. Fund. of WiMAX at 8. Wireless MAN was meant to combine broadband-level service with wireless techniques to increase the throughput of data for wireless services. *Id.* “The IEEE 802.16 group produced a standard that was approved in December 2001.” *Id.* at 7-9. “After completing this standard, the group started work on extending and modifying it to work in both licensed and license-exempt frequencies in the 2GHz to 11GHz range, which would enable NLOS [non-line-of-sight] deployments.” *Id.* at 8. “This amendment, IEEE 802.16a, was completed in 2003, with OFDM schemes added as part of the physical layer for supporting deployment in multipath environments.” *Id.* In multipath environments, the received signal contains reflected radio waves that have arrived at the receiver via different paths.

64. “Further revisions to 802.16a were made and completed in 2004.” *Id.* “Besides the OFDM physical layers, 802.16a also specified additional MAC-layer options, including support for orthogonal frequency division multiple access (OFDMA).” *Id.* “This revised standard, IEEE 802.16-2004, replaced 802.16, 802.16a, and 802.16c with a single standard.” *Id.* “In December 2005, the IEEE group completed and approved IEEE 802.16e-2005, an amendment to the IEEE 802.16-2004 standard that added mobility support.” *Id.* at 34. Revision 802.16(e) “specifies scalable OFDM for the physical layer and makes further modifications to

the MAC layer to accommodate high-speed mobility.” *Id.* at 9. This was the first 802.16 revision to overtly support mobility and it aimed to do so for up to vehicular speeds. *E.g.*, Ex. 1016 (“Li”), [0001] (“802.16e aims to enhance the specifications to the 802.16 standard to support both fixed and mobile subscriber stations to accommodate, for example, subscriber stations moving at vehicular speeds.”).

65. “The IEEE developed the specifications but left to the industry the task of converting them into an interoperable standard that [could] be certified. The WiMAX Forum was formed to solve this problem and to promote solutions based on the IEEE 802.16 standards.” *Id.* “The forum ... beg[a]n interoperability testing and announced its first certified product based on IEEE 802.16-2004 for fixed applications in January 2006.” *Id.* at 10. “Products based on IEEE 802.18e-2005 [we]re expected to be certified in early 2007.” *Id.* at 9-10.

66. In 2006, the 802.16 group began developing another mobility-focused revision, 802.16(m), which sought to support higher data rates for mobility scenarios and improve the levels and quality of service of cell coverage required by competing international cellular standards. Five Criteria Statement for P802.16m PAR Proposal, IEEE 802.16-06/055r3 (Nov. 15, 2006) (Ex. 1006, “Criteria for Standards Development”) at 2 (“No existing IEEE 802 standards or projects meet the preliminary cellular layer IMT-Advanced target requirements, such as 100 Mbit/s in high-speed mobility applications.”). During development, the 802.16 group stated

that the new 802.16(m) revision would also support legacy 802.16(e) systems. IEEE 802.16m System Requirements, IEEE 802.16m-07/002r4 (Oct. 19, 2007) (Ex. 1007, “Oct. IEEE 802.16m System Requirements”) at 4 (“This amendment provides continuing support for legacy WirelessMAN-OFDMA equipment.”). The final 802.16(m) revision was released in 2011, although the underlying ideas were established earlier.

67. The following table provides an overview of some important dates in the development of broadband wireless and 802.16. Fund. of WiMAX at 7.

Table 1.1 Important Dates in the Development of Broadband Wireless

Date	Event
February 1997	AT&T announces development of fixed wireless technology code named "Project Angel"
February 1997	FCC auctions 30MHz spectrum in 2.3GHz band for wireless communications services (WCS)
September 1997	American Telecasting (acquired later by Sprint) announces wireless Internet access services in the MMDS band offering 750kbps downstream with telephone dial-up modem upstream
September 1998	FCC relaxes rules for MMDS band to allow two-way communications
April 1999	MCI and Sprint acquire several wireless cable operators to get access to MMDS spectrum
July 1999	First working group meeting of IEEE 802.16 group
March 2000	AT&T launches first commercial high-speed fixed wireless service after years of trial
May 2000	Sprint launches first MMDS deployment in Phoenix, Arizona, using first-generation LOS technology
June 2001	WiMAX Forum established
October 2001	Sprint halts MMDS deployments
December 2001	AT&T discontinues fixed wireless services
December 2001	IEEE 802.16 standards completed for > 11GHz.
February 2002	Korea allocates spectrum in the 2.3GHz band for wireless broadband (WiBro)
January 2003	IEEE 802.16a standard completed
June 2004	IEEE 802.16-2004 standard completed and approved
September 2004	Intel begins shipping the first WiMAX chipset, called Rosedale
December 2005	IEEE 802.16e standard completed and approved
January 2006	First WiMAX Forum-certified product announced for fixed applications
June 2006	WiBro commercial services launched in Korea
August 2006	Sprint Nextel announces plans to deploy mobile WiMAX in the United States

2. Frame Structure of 802.16

68. The following figure shows an OFDMA and OFDM frame, as specified by 802.16(e). Fund. of WiMAX at 44-45, Fig. 2.1:

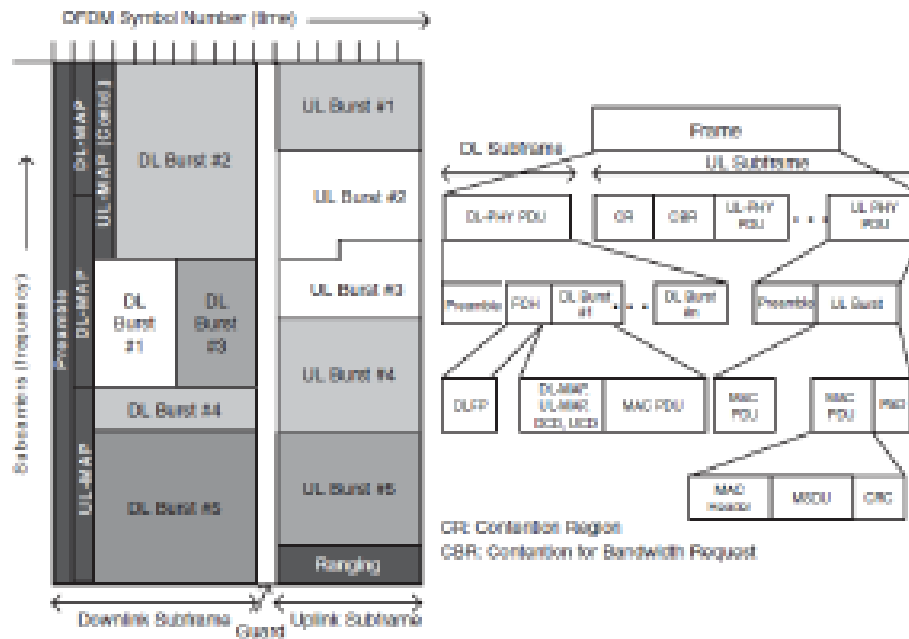


Figure 2.1 A sample TDD frame structure for mobile WiMAX

“The frame is divided into two subframes: a downlink frame [DL] followed by an uplink frame [UL] after a small guard interval” (shown in Fig. 2.1 as white space between the subframes). *Id.* “The downlink-to-uplink-subframe ratio may be varied from 3:1 to 1:1 to support different traffic profiles.” *Id.* at 44. WiMAX also supported “frequency division duplexing [FDD], in which case the frame structure is the same except that both downlink and uplink are transmitted simultaneously over different carriers.” *Id.* “TDD allows for a more flexible sharing of bandwidth between uplink and downlink, does not require paired spectrum, has a reciprocal channel that can be exploited for spatial processing, and has a simpler transceiver design.” *Id.* at 44-45. In addition to the frame being divided into downlink and uplink data, the frame could also be divided according to communication systems.

Canadian Patent Application No. 2 581 166 A1 (Ex. 1014, “Wang”) at 8 (“The main purpose of the present invention [wa]s to provide a method for assigning frequency spectrum bandwidth of an OFDM and OFDMA coexistence system, and constitut[e] a frame structure which could meet the requirements of the said coexistence system.”); U.S. Pub. No. 2008/0095195 (Ex. 1018, “Ahmadi”) at Abstract (“A method and system for partitioning frames into sub-frames, transmitting one or more sub-frames including a legacy preamble for communicating with a legacy terminal ... and transmitting sub-frames including a supplemental preamble for communicating with a non-legacy terminal...”); *id.* at 19-20 (disclosing a frame divided into an OFDM and OFDMA sub-frame).

69. “[T]he downlink subframe begins with a downlink preamble that is used for physical-layer procedures, such as time and frequency synchronization and initial channel estimation. The downlink preamble is followed by a frame control header (FCH), which provides frame configuration information, such as the MAP message length, the modulation and coding scheme, and the usable subcarriers. Multiple users are allocated data regions within the frame, and these allocations are specified in the uplink and downlink MAP messages (DL-MAP and UL-MAP) that are broadcast following the FCH in the downlink subframe. MAP messages include the burst profile for each user, which defines the modulation and coding scheme used in that link.” *Id.* at 44. “Although the MAP messages are an elegant way for the base

station to inform the various users of its allocations and burst profiles on a per-frame basis, it could form a significant overhead, particularly when there are a large number of users with small packets (e.g., VoIP) for which allocations need to be specified. To mitigate the overhead concern, mobile WiMAX systems can optionally use multiple sub-MAP messages where the dedicated control messages to different users are transmitted at higher rates, based on their individual SINR conditions.” *Id.*

70. “There are two ways to transmit training symbols: preamble or pilot tones. Preambles entail sending a certain number of training symbols prior to the user data symbols. In the case of OFDM, one or two preamble OFDM symbols are typical. Pilot tones involve inserting a few known pilot symbols among the subcarriers. Channel estimation in MIMO-OFDM systems can be performed in a variety of ways, but it is typical to use the preamble for synchronization and initial channel estimation and the pilot tones for tracking the time-varying channel in order to maintain accurate channel estimates.” *Id.* at 185. It was well known in the art that pilot symbols were crucial to performance and that “a sufficiently large number of pilot symbols...prevent[ed] a deterioration of reception performance caused by a channel variation.” U.S. Patent No. 7,460,466 (Ex. 1020, “Lee”) at 1:22-25; U.S. Patent No. 7,710,910 (Ex. 1024, “Ode”) at Abstract (“A wireless base station that performs data communication using a plurality of sub carriers...and transmits data for mobile terminals having poor receiving quality in a frame having a large number

of common pilots, and transmits data for mobile terminals having good receiving quality in a frame having a small number of common pilots.”).

3. OFDM in 802.16

71. The WiMAX physical layer (PHY) is based on orthogonal frequency division multiplexing (OFDM), a scheme that offers good resistance to multipath, and allows WiMAX to operate in NLOS conditions. As of 2007, OFDM was recognized as the method of choice for mitigating multipath for broadband wireless. Fund. of WiMAX at 37. OFDM was incorporated into various IEEE standards, including the 802.11 standards for wireless local area network Wi-Fi communications, and it was incorporated into 802.16 in the 2003 amendment. *Id.* at 8, 37.

72. “OFDM belongs to a family of transmission schemes called multicarrier modulation, which is based on the idea of dividing a given high-bit-rate data stream into several parallel lower bit-rate streams and modulating each stream on separate carriers—often called subcarriers.” *Id.* at 39. “Multicarrier modulation schemes eliminate or minimize inter symbol interference (ISI) by making the symbol time large enough so that the channel-induced delays ... are an insignificant (typically, <10 percent) fraction of the symbol duration.” *Id.* “In order to completely eliminate ISI, guard intervals are used between OFDM symbols. By making the

guard interval larger than the expected multipath delay spread, ISI can be completely eliminated.” *Id.* at 40.

73. “OFDM is a spectrally efficient version of multicarrier modulation, where the subcarriers are selected such that they are all orthogonal to one another over the symbol duration, thereby avoiding the need to have nonoverlapping subcarrier channels to eliminate intercarrier interference.” *Id.* at 39-40. However, an increased symbol duration to reduce ISI may reduce subcarrier spacing and make the system more vulnerable to intercarrier interference (ICI). *Id.* at 40 (“A reduced subcarrier spacing, however, also makes the system more vulnerable to intercarrier interference owing to Doppler spread in mobile applications.”). Intercarrier interference is especially felt in mobile applications where the faster speeds of higher-mobility users cause a larger Doppler shift. *Id.* at 40, 25 (“The relative motion between the transmitter and the receiver causes carrier frequency dispersion called *Doppler spread*. Doppler spread is directly related to vehicle speed and carrier frequency.”); U.S. Pub. No. 2007/0155387 A1 (Ex. 1016, “Li”) at [0034] (“[H]igh mobility, [or] high speed ... causes ICI [inter-subcarrier interference] for OFDM and OFDMA systems that may limit their application to mobile channels.”). A larger Doppler shift keeps the carriers from remaining orthogonal and thus losing the benefits of OFDM. Fund. of WiMAX at 25 (“Doppler spread is of particular concern for OFDM systems, since it can corrupt the orthogonality of the OFDM

subcarriers.”); *id.* at 281 (“When the time and/or frequency synchronization between the transmitter and the receiver is not perfect, the orthogonality between the subcarriers is lost, resulting in intercarrier interference (ICI).”). Shorter symbol periods were known to increase subcarrier spacing and thus reduce inter-carrier interference. Li at [0035] (“[A] short OFDM symbol duration and larger subcarrier spacing reduces ICI[.]”); Yasamin Mostofi, *ICI Mitigation for Pilot-Aided OFDM Mobile Systems* (Mar. 2005) 765 (Ex. 1027, “ICI Mitigation”) (“[F]or mobile applications channel time-variations in one OFDM symbol introduce intercarrier-interference (ICI) which degrades the performance. This becomes more severe as mobile speed carrier frequency, carrier frequency or OFDM symbol duration increases.”); U.S. Pub. No. 2004/0037215 (Ex. 1026, “Hwang”) at [0063] (“influence of inter symbol interference (ISI) can be overcome ... by adaptively changing the length of a transmission symbol.”).

74. The following table provides an overview of the OFDM parameters used in WiMAX. Fund. of WiMAX at 42.

Table 2.3 OFDM Parameters Used in WiMAX

Parameter	Fixed WiMAX		Mobile WiMAX Scalable		
	OFDM-PHY		OFDMA-PHY ^a		
FFT size	256	128	512	1,024	2,048
Number of used data subcarriers ^b	192	72	360	720	1,440
Number of pilot subcarriers	8	12	60	120	240
Number of null/guardband subcarriers	56	44	92	184	368
Cyclic prefix or guard time (T _g /T _b)	1/32, 1/16, 1/8, 1/4				
Oversampling rate (F _s /BW)	Depends on bandwidth: 7/6 for 256 OFDM, 8/7 for multiples of 1.75MHz, and 28/25 for multiples of 1.25MHz, 1.5MHz, 2MHz, or 2.75MHz.				
Channel bandwidth (MHz)	3.5	1.25	5	10	20
Subcarrier frequency spacing (kHz)	15.625			10.94	
Useful symbol time (μs)	64			91.4	
Guard time assuming 12.5% (μs)	8			11.4	
OFDM symbol duration (μs)	72			102.9	
Number of OFDM symbols in 5 ms frame	69			48.0	

a. Boldfaced values correspond to those of the initial mobile WiMAX system profiles.

b. The mobile WiMAX subcarrier distribution listed is for downlink PUSC (partial usage of subcarrier).

4. OFDMA in 802.16

75. “Mobile WiMAX [in 802.16(e)] uses OFDM as a multiple-access technique, whereby different users can be allocated different subsets of the OFDM tones.” Fund. of WiMAX at 38. The physical-layer architecture allowed the system to easily scale and use more bandwidth when available. *Id.* at 37. “Orthogonal frequency division multiple access (OFDMA) ... facilitates the exploitation of frequency diversity and multiuser diversity to significantly improve the system capacity.” *Id.* at 38 (“Mobile WiMAX uses OFDM as a multiple-access technique, whereby different users can be allocated different subsets of the OFDM tones.”). Although OFDMA was considered its own communication system, an “OFDMA

[system] ha[d] the similar basic principle to that of [an] OFDM [system].” Wang at 4. “The IEEE802.16 standard adopt[ed] OFDM and OFDMA techniques, but the two kinds of techniques [were] independent of each other relatively in the standard.” *Id.*

76. “Mobile WiMAX based on OFDMA-PHY, however, allows sub-channelization in both the uplink and the downlink, and here, subchannels form the minimum frequency resource-unit allocated by the base station. Therefore, different subchannels may be allocated to different users as a multiple-access mechanism.” *Id.* at 43.

D. 802.16/WiMAX and Mobility

77. Although initial WiMAX deployments were likely to be for fixed applications, it was understood that the full potential of WiMAX would be realized only when it was used for nomadic and mobile broadband applications, like cellular phones and other handheld devices. Fund. of WiMAX at 12. Mobile broadband offered the additional functionality of portability, nomadicity (the ability to connect to the network from different locations via different base stations), and mobility (the ability to keep ongoing connections active while moving at vehicular speeds). *Id.* at 4.

78. As stated earlier, in 2003, the 802.16 group began work on enhancements to the specifications to allow vehicular mobility applications. *Id.* at 8.

That revision was completed in December 2005 and was published formally as IEEE 802.16e-2005 (often abbreviated as 802.16(e)). *Id.* at 9. It specified scalable OFDM for the physical layer and made further modifications to the MAC layer to accommodate high-speed mobility. *Id.* at 8-9; Mohammad Azizul Hasan, *Performance Evaluation of WiMAX/IEEE 802.16 OFDM Physical Layer* (June 2007) (Ex. 1023, “Performance of WiMAX”) at 14 (“The first version of the standard only supported single carrier modulation. Since that time, OFDM and scalable OFDMA have been included to operate in NLOS environment and to provide mobility.”). The mobile WiMAX variant of the system had mechanisms to support secure seamless handovers for delay-tolerant full-mobility applications, such as VoIP. The system also had built-in support for power-saving mechanisms that extended the battery life of handheld subscriber devices. Physical-layer enhancements, such as more frequent channel estimation, uplink sub-channelization, and power control, were also specified in support of mobile applications. Fund. of WiMAX at 39.

79. The IEEE 802.16e-2005 standard defined a framework for supporting mobility management. Performance of WiMAX at 11 (“As IEEE 802.16e supports mobility, so the mobile user in the business areas can access high speed services through their IEEE 802.16/WiMAX enabled handheld devices like PDA, Pocket PC and smartphone.”). In particular, the standard defined signaling mechanisms for

tracking subscriber stations as they moved from the coverage range of one base station to another when active or as they moved from one paging group to another when idle. The standard also had protocols to enable a seamless handover of ongoing connections from one base station to another. The WiMAX Forum used the framework defined in IEEE 802.16e-2005 to further develop mobility management within an end-to-end network architecture framework. The architecture also supported IP-layer mobility using mobile IP. Fund. of WiMAX at 52.

80. The following table provides an overview of types of access provided by 802.16-2004 and 802.16e, the earlier forms of WiMAX.

Table 1. Types of access to a WiMAX network					
Definition	Devices	Locations/ Speed	Handoffs	802.16-2004	802.16e
Fixed access	Outdoor and indoor CPEs	Single/ Stationary	No	Yes	Yes
Nomadic access	Indoor CPEs, PCMCIA cards	Multiple/ Stationary	No	Yes	Yes
Portability	Laptop PCMCIA or mini cards	Multiple/ Walking speed	Hard handoffs	No	Yes
Simple mobility	Laptop PCMCIA or mini cards, PDAs or smartphones	Multiple/ Low vehicular speed	Hard handoffs	No	Yes
Full mobility	Laptop PCMCIA or mini cards, PDAs or smartphones	Multiple/ High vehicular speed	Soft handoffs	No	Yes

Fixed, nomadic, portable and mobile applications for 802.16-2004 and 802.16e WiMAX networks (Nov. 2005) (Ex. 1022, “Applications for WiMAX”) at 3 (“Table 1 shows how WiMAX supports different types of access and their requirements.”).

81. However, providing mobility support did have its challenges, particularly for OFDM systems. Fast-moving user devices experienced frequently changing channel conditions, Doppler spreads, and higher levels of interference between OFDM subcarrier frequencies. Fund. of WiMAX at 24-25 (explaining the challenges for a wireless channel for broadband). Fast-moving devices also required enhanced support for handover scenarios, in which the device switched from one base station to another within the network. *Id.* at 52. Wireless systems typically used “pilot” symbols—non-data symbols with an expected format, transmitted at a known interval—to perform channel estimation, which was helpful in compensating for changing channel conditions, Doppler effects, and interference, and to determine what base station they should communicate with. *Id.* at 185. WiMAX provided a mobility management architecture designed that took into account many of these challenges, including ones associated with high-speed handover, route optimization, and security. *Id.* at 352-53.

82. In early 2007, the WiMAX Forum released a preliminary statement of requirements for 802.16m. These requirements specified that 802.16m would “meet the cellular layer requirements of IMT-Advanced next generation mobile networks.”

IEEE 802.16m System Requirements (Jan. 12, 2007) (Ex. 1025, “IEEE 802.16m Syst. Req.”) at 1. “It [wa]s predicted that potential new radio interfaces w[ould] need to support data rates of up to approximately 100Mbps for high mobility such as mobile access.” *Id.* at 2. “Key Technologies” identified for IMT-Advanced that would be required in 802.16m were “Mobile platform technology,” “authentication and mobile electronic commerce,” and “handover between different radio interfaces (vertical and horizontal),” to name a few. *Id.* at 3. IEEE 802.16m was also intended to “provide seamless interworking with legacy radio access systems including legacy 802.16 systems.” *Id.* at 3; Oct. IEEE 802.16m System Requirements at 4 (“This amendment provides continuing support for legacy WirelessMAN-OFDMA equipment.”).

IX. THE CHALLENGED ‘096 PATENT

A. Background and ‘096 Patent Specification

83. The ‘096 Patent is titled “Method For Constructing Frame Structures” and relates to frame structures for transmitting data using a “first section comprising data configured in a first format compatible with a first communication system,” a “second section comprising data configured in a second format compatible with a second communication system, wherein the second format is different from the first format,” and “at least one non-data section containing information describing an aspect of data in at least one of the first section and the second section.” ‘096 Patent

at Abstract. The second system is either “configured to support higher mobility than the first communication system” and uses “a shorter symbol period than that in the first communication system” (Claim 1) or “has pilot symbols that are denser than those in the first communication system” (Claim 8).

84. The patent refers to orthogonal frequency-division multiple access (“OFDMA”) systems that allow “simultaneous transmission of data from different users without interference from one another.” *Id.* at 1:24-27. The patent specifically identifies IEEE standards 802.16e and 802.16m as examples of two communication systems, and labels them the “legacy” and “new” systems, respectively. *Id.* at 1:27-31. One purpose of this combined system is to support backwards compatibility in 802.16m systems. *Id.* at 1:31-35.

85. The patent also discloses the “prior art” frame structure that was defined by the 802.16(e) standard. *Id.*, Fig. 1 and 1:36-49. This 802.16(e) frame structure included a preamble, FCH, and DL-MAP portions, and subframes for carrying downlink and uplink data.

B. Overview of the ‘096 Patent Prosecution History

86. The application leading to the ‘096 Patent was filed on July 7, 2008 as U.S. Pat. App. No. 12/168,855 and claimed priority to Provisional application Nos. 60/929,798 (“Prov. No. ‘798”, Ex. 1009) and 60/973,157 (filed on July 12, 2007 and September 17, 2007, respectively).

87. Prov. No. '798 is a 9-page slide deck that does not contain any disclosure relating to a frame structure with two sections wherein the second section has a shorter symbol period or denser pilot symbols. The Summary refers generically to "[a]n OFDMA system with multiple zones" and "[a]n OFDMA system with multiple DL (UL) subframes from multiple standards," but it does not refer to any symbol structure for any system. Prov. No. '798 at 9, 10.

88. The summary also refers to 802.16e and "[n]ew standard 802.16m," but provides no details about proposed or actual symbol structures of 802.16e or 802.16m systems. A POSA would not have understood generic references to 802.16e or 802.16m to indicate anything specific about symbol periods or pilot density; indeed, at the time Prov. No. '798 was filed, no draft of the 802.16m standard had yet been issued. A POSA would not have understood anything in Prov. No. '798 to disclose any details relating to shortening a symbol period or increasing pilot density for certain communication systems.

89. During prosecution of the application that issued as the '096 Patent, the applicants amended the challenged independent claims to recite, "wherein the first communication system and the second communication system co-exist in one transmission scheme." The applicants directed the Examiner to "paragraph [0025]" of the specification for the filed application (corresponding to '096 Patent at 4:21-41) as the support for this amendment. '096 Patent File History (Ex. 1010) at 41.

90. The indicated passage states in relevant part, “Examples of the present invention may allow data of an old [OFDMA] system ... and data of a new OFDMA system to co-exist in an OFDMA frame by changing a frame structure of the OFDMA frame.” *Id.* at 5. I understand this statement by the applicants to indicate that one example of communication systems that “co-exist in one transmission scheme” is when data from two communication systems co-exists in a frame.

X. OVERVIEW OF THE PRIOR ART REFERENCES

A. Overview of “Talukdar” (Ex. 1012)

91. The Talukdar publication (U.S. Pub. No. 2009/0067377 A1, (Ex. 1012, “Talukdar”)) was filed August 13, 2008 and was published on March 12, 2009. It claims priority to Provisional Application No. 60/956,031 (Ex. 1013, “Talukdar Provisional”) which was filed on August 15, 2007. I have been informed that Talukdar is entitled to the benefit of its provisional filing date for prior art purposes if the disclosure of the provisional application supported at least one of Talukdar’s claims.

92. Talukdar disclosed generating a radio frame with regions formatted for first and second protocols. Talukdar considered the expected lifespan of the legacy 802.16e technology and designed a system so that “evolutionary wireless communication systems [could] also support [] legacy system equipment.” Talukdar at [0003]. “For example, some IEEE 802.16e and IEEE 802.16m base stations and

mobile stations [were] likely to coexist within the same network while upgrading to the new system.” *Id.* Thus, the respective compatible base stations and mobile stations should be compatible with the others’ base stations and mobile stations. *Id.* at [0003], [0027] (“[I]t is generally desirable for the new technologies to be backward compatible with the legacy technology. For the evolution of IEEE 802.16(e), the backward compatibility constraint implies that the legacy frame structure, for example, the 5 msec duration 802.16(e) frame, must be supported by 802.16(m) base stations.”). Designing 802.16(m) base stations to “service both 802.16(m) and legacy terminals within the common frame structure” was important to “efficiently support delay sensitive applications.” *Id.* at [0027].

93. Talukdar explained that to “deliver low latency in 802.16m systems with backward compatibility, it is necessary to develop a sub-frame structure based on the legacy 802.16(e) frame” which requires a 5msec frame. *Id.* at [0028]. Following this rule, Talukdar disclosed an 802.16(m) 5msec frame “composed of [the] following types of basic regions: **e-DL region used for transmission of downlink traffic to 802.16(e) terminals;**² e-UL: region allocated for transmission of data and control messages by 802.16(e) terminals; m-DL: region allocated for transmission to 802.16(m) terminals; and m-UL: region allocated for transmission by 802.16(m) terminals.” *Id.* at [0029]. Also, consistent with the 802.16 default

² All emphasis is added unless otherwise noted.

frame format, the preamble and mapping regions were placed at the beginning of the 802.16(e) block. *Id.* at [0051].

94. Thus, Talukdar disclosed, for example, methods for constructing a frame structure that included first and second sections containing data formatted for first and second communication systems (802.16(e) and 802.16(m) systems), and a non-data section describing aspects of the transmitted data.

95. The Talukdar Provisional described the subject matter of at least claim 1 of Talukdar. Specifically, the Talukdar Provisional disclosed “A method in a second protocol wireless communication infrastructure entity” at, *e.g.*, Claim 1, [0024], [00026]-[00027], [00044], [0062]; “allocating radio resources, in a radio frame, to a wireless terminal compliant with a first protocol and to a wireless terminal compliant with a second protocol” at, *e.g.*, Claim 1, Figs. 7, 11, 16, 17 and [00029]-[00030], [00044]-[0048], [00051], [0061]-[0062], [0070]-[0071]; “the radio frame including a first protocol resource region and a second protocol resource region” at, *e.g.*, Claim 1, Figs. 7, 11, 16, 17 and [00029]-[00030], [00044]-[0048], [00051], [0061]-[0062], [0070]-[0071]; and “the radio frame including a first protocol allocation control message and a second protocol allocation control message, the first protocol allocation control message allocating resources within the first protocol resource region to wireless terminal compliant with the first protocol, the second protocol allocation control message allocating resources within

the second protocol resource region wireless terminal compliant with the second protocol” at, *e.g.*, Claim 1, Figs. 7, 11, 16, 17 and [00044]-[00048], [00051], [00061]-[00062], [0070]-[0071].

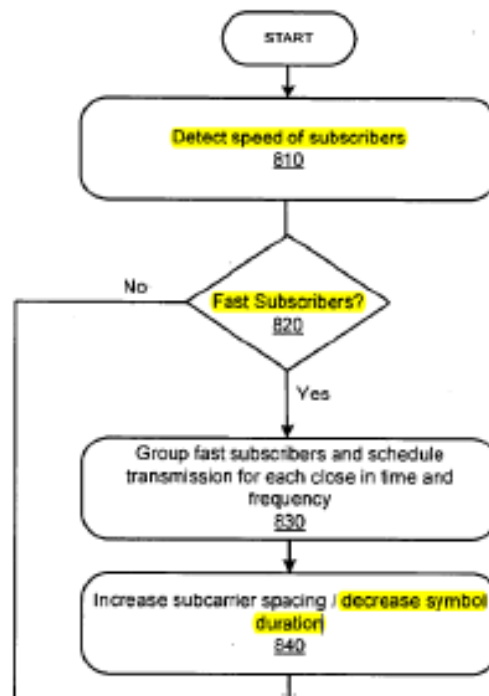
B. Overview of “Li” (Ex. 1016)

96. Li (U.S. Pub. No. 2007/0155387 A1 (Ex. 1016, “Li”)) was filed on December 30, 2005 and published on July 5, 2007. Li disclosed a system that modified the OFDM symbol duration in a frame depending on the speed of a mobile subscriber station. At the time of Li’s filing, 802.16e was understood to “enhance the specifications to the 802.16 standard to support both fixed and mobile subscriber stations to accommodate ... subscriber stations moving at vehicular speeds.” Li at [0001]. Accommodating mobility applications alongside fixed applications within 802.16 was thus a focus of Li’s techniques.

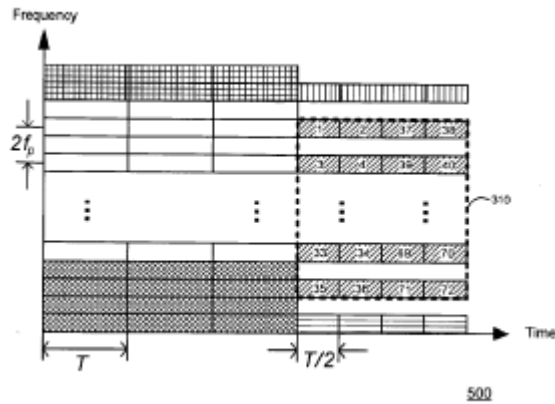
97. Li disclosed the issues with higher mobility applications moving at vehicular speed. Higher mobility caused inter-subcarrier interference in OFDM/OFDMA systems, preventing faster-moving users from being able to transmit over multiple subcarriers. *Id.* at [0034]. Li recognized, however, that “a short OFDM symbol duration” could “reduce[] ICI [inter-subcarrier interference].” *Id.* at [0035].

98. Li took advantage of OFDMA’s ability to allocate subchannels to multiple users and applied different OFDM symbol durations to different subscribers

moving at relatively different speeds. *Id.* at [0010] (“One embodiment may comprise, for example, a scheduling/adaptation scheme for OFDMA for which different Orthogonal Frequency Division Multiplexing (“OFDM”) symbol durations are employed for slow and fast subscribers respectively.”). A communication system (such as a base station) detected the speed of a subscriber station and scheduled “slow subscribers with ... longer OFDM symbol durations” and “fast subscribers with ... shorter OFDM symbol durations.” *Id.* at [0022]; *id.* at Fig. 8 (excerpted and highlighted):



99. More specifically, Li’s system could “transmit to the fast subscriber two OFDM symbols...in two time slots with $T/2$ each,” which was half the duration of the slow subscriber symbol duration.” *Id.* at [0038]; *id.* at Fig. 5.



100. Li thus disclosed, for example, a system supporting higher-mobility users that used symbols with a shorter symbol period for faster subscriber stations.

C. Overview of Nystrom (Ex. 1017)

101. Nystrom (U.S. Pub. No. 2007/0104174 A1 (Ex. 1017, “Nystrom”)) was filed on December 1, 2004 and published on May 10, 2007. Nystrom disclosed a set of pilot symbol structures for use in different environments related to channel conditions. Nystrom taught that “most wireless systems” used “special well known training sequences or pilot signals ... so that the receiver can estimate the channel parameters sufficiently well for detection of any data signal, not previously known by the receiver.” Nystrom at [0002]. But channel estimation was substantially more complex in multi-carrier, multi-user systems in which a base station had to accommodate many users with “different channel characteristics” that “travel[ed] at different speeds” which created “different Doppler shifts.” *Id.* at [0004]. Existing pilot structures were “either not at all suitable for considerably changing radio

conditions” or “designed for worse cases which ... result[ed] in vast pilot overhead.” *Id.* at [0009].

102. Nystrom described a “multi-user multi-carrier wireless communications system” that “provide[d] all users with sufficient pilots without causing unnecessary pilot overhead[.]” *Id.* at [0010]. “The radio conditions for a user [we]re estimated...[and] [e]ach user [wa]s then assigned an area in resource space for its communication, which ha[d] a suitable pilot configuration.” *Id.* at [0011]. Specifically, Nystrom described “a number of pilot configurations ... believed to suit different radio conditions” that could “be handled by both sides of the transmission connection.” *Id.* at [0037]; Fig. 4. “The transmitter”—*e.g.*, a base station—“manage[d] the sending of pilots according to [the] configurations and the receiver [wa]s capable of performing channel estimation based on the ... pilot configurations.” *Id.* at [0037]. Users with “radio conditions demanding a high density of pilots”—such as fast-moving users—could be allocated resource space with increased pilot density in the time dimension, frequency dimension, or both. *Id.* at [0043]; Fig. 5A (showing portions of the radio resource space 110A, 110C, and 110D with higher pilot density).

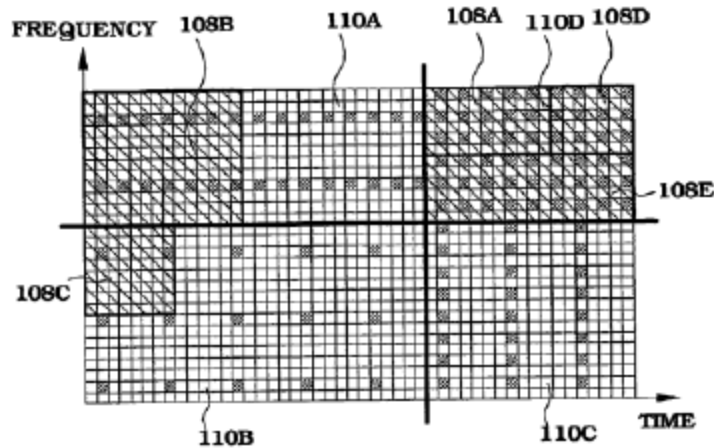


Fig. 5A

103. The denser pilot patterns supported higher mobility subscribers to accommodate for “fast varying channel or Doppler conditions” that arise due to the movement of the subscribers. *Id.* at [0043] (“It is beneficial, e.g. to assign resources for mobiles with certain fast varying channel or Doppler conditions in the dense parts of the pilot pattern and users with more slowly varying conditions in the less dense parts.”).

104. Thus, Nystrom disclosed, for example, a communication system that used denser pilot symbols for faster users.

XI. SPECIFIC GROUNDS OF CHALLENGE

105. As explained below, it is my opinion that the prior art references discussed in this declaration disclose or render obvious every limitation in claims 1-4 and 6-8 of the ‘096 Patent, rendering them unpatentable.

106. Based on my review of the prior art references, claims 1-4 and 6-8 of the '096 Patent merely include subject matter that is the same as or obvious over the teachings of references described briefly above.

- Claims 1-4 and 6-7 are unpatentable as obvious in light of Talukdar combined with Li.
- Claim 8 is unpatentable as obvious in light of Talukdar combined with Nystrom.

A. Ground 1: Claims 1-4 and 6-7 were rendered obvious by Talukdar in View of Li

107. The combination of Talukdar and Li, described below, rendered claims 1-4 and 6-7 obvious.

1. Claim 1

a) 1[pre]: “A method of constructing a frame structure for data transmission, the method comprising”

108. Talukdar disclosed 1[pre] because it disclosed methods of constructing hybrid frames (or, equivalently, h-frames) for data transmission that included data configured for units that communicated using different protocols (802.16(e) versus 802.16(m)). Although Talukdar's terminology varied at times, a POSA would have understood its disclosure relating to hybrid frames, h-frames, and HEM-frames to relate to variations on the same general hybrid frame structure.

109. In Figure 7, Talukdar disclosed a hybrid radio frame used to transmit data for both 802.16(e) and 802.16(m) base units and remote units in a wireless communication system. Talukdar at [0051] (“FIG. 7 is a hybrid frame 700, also referred to as a HEM-I frame, having equal size sub-blocks designed to serve both 802.16(e) and 802.16(m) data traffic in the same 5msec interval.”), Fig. 1 (showing wireless communication system with base and remote units). Talukdar disclosed constructing the frame by dividing it into multiple regions that corresponded to 802.16(e) and 802.16(m). *Id.* at [0044] (“In one embodiment, a frame is divided into multiple blocks of equal size, wherein the blocks may support one or more protocols, for example, IEEE 802.16(e) and/or 802.16(m).”), [0045] (“Generally, the radio frame includes at least one first protocol block and/or at least one second protocol block, for example, 802.16(e) and/or 802.16(m) blocks.”), [0051] (“FIG. 7 is a hybrid frame 700, also referred to as a HEM-I frame, having equal size sub-blocks designed to serve both 802.16(e) and 802.16(m) data traffic in the same 5 msec interval.”). Talukdar disclosed that the hybrid frame was constructed by combining different types of frame regions that could be used for transmitting traffic to 802.16(e) and 802.16(m) units. *Id.* at [0030] (“Using these different types of regions, various types of 5 msec frame structures can be created to suit the traffic service requirements. These are: ... h-frames containing both e-DL/e-UL and m-DL/m-UL regions for serving 802.16(e) and 802.16(m) terminals.”).

110. By constructing a frame that supported both 802.16(e) and 802.16(m), Talukdar disclosed that wireless communication systems were able to communicate with devices compliant with newer protocols while maintaining backwards compatibility with devices compliant with older protocols, consistent with industry best practices. *Id.* at [0003] (“Evolutionary wireless communication systems should also support for legacy system equipment. For example, some IEEE 802.16e and IEEE 802.16m base stations and mobile stations are likely to coexist within the same network while upgrading to the newer system. Thus IEEE 802.16e mobile stations should be compatible with IEEE 802.16m base stations.”); Applications for WiMAX at 5 (“The new version of the 802.16 standard is backwards-compatible, so new specifications of the OFDM mode are compatible with previous versions.”). Constructing a frame with two systems was also well known in the art. Wang at 8 (“The main purpose of the present invention [wa]s to provide a method for assigning frequency spectrum bandwidth of an OFDM and OFDMA coexistence system, and constitute[ed] a frame structure which could meet the requirements of the said coexistence system.”); Ahmadi at Abstract (“A method and system for partitioning frames into sub-frames, transmitting one or more sub-frames including a legacy preamble for communicating with a legacy terminal ... and transmitting sub-frames including a supplemental preamble for communicating with a non-legacy terminal ...”).

b) 1[a]: “generating a first section comprising data configured in a first format compatible with a first communication system using symbols”

111. Talukdar disclosed 1[a] because it disclosed generating a frame with a first “e-DL” traffic section (which was “generating a first section comprising data”) that was configured in a format compatible with a remote unit compliant with an 802.16(e) remote unit (which was “a first communication system using symbols”).

112. Talukdar disclosed a wireless system 100 that included multiple base units communicating with multiple remote units. “In FIG. 1, the wireless communication system 100 includes one or more fixed base infrastructure units forming a network distributed over a geographical region.... The one or more base units 101 and 102 serve a number of remote units 103 and 110 within a serving area, for example, a cell, or within a cell sector.” Talukdar at [0024] and Fig. 1 (wireless system 100 including “base units,” “remote units”). Base units could be “an access point, access terminal, Node-B, eNode-B, or by other terminology used in the art.” *Id.* at [0024]. The remote units included fixed and mobile terminals. “The remote units may be fixed or [mobile] terminal[s]. The remote units may also be referred to as subscriber units, mobile stations, users, terminals, subscriber stations, user equipment (UE), terminals, or by other terminology used in the art.” *Id.* In other words, Talukdar disclosed a wireless system that included remote units that were fixed and remote units that were moving, at various speeds. *Id.*, Fig. 1 (annotated to

identify an example fixed remote unit and an example mobile remote unit, moving at some speed, within system 100).

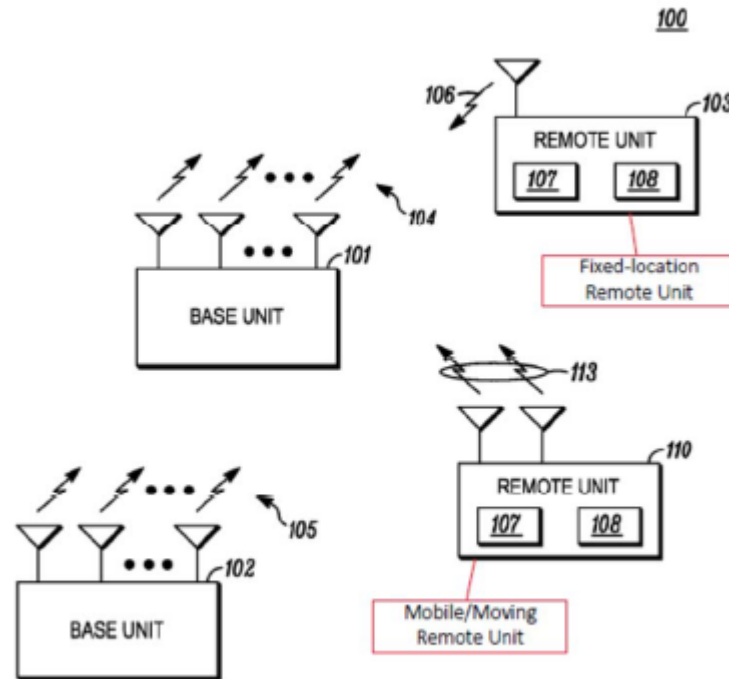


FIG. 1

113. Each of the remote units included “one or more transmitters and one or more receivers” over which they transmitted and received data, for example, from one or more base units. *Id.* at [0025]. Each remote unit implemented a communication standard, including specifically either 802.16(e) or 802.16(m). *Id.* at [0027] (“Generally, the wireless communication system may implement more than one communication technology ... [I]t is generally desirable for the new technologies to be backward compatible with the legacy technology. ... [T]o efficiently support delay sensitive applications, 802.16(m) base stations should be

able to service *both 802.16(m) and legacy [802.16(e)] terminals* within the common frame structure.”). The hardware remote units illustrated in Figure 1 would also have required software for encoding/decoding and processing data according to the 802.16(e) and 802.16(m) communication standards. The remote units were thus each a “communication system” under the construction adopted by the Court in the Apple litigation. *Supra* § VI (construing “communication system” under its plain-and-ordinary meaning, where the plain-and-ordinary meaning is “a combination of hardware and software that transmits and receives data according to one or more communications standards”).

114. The units in system 100 communicated using symbols because each was compliant with either 802.16(e) or 802.16(m), both of which used OFDM symbols. The units within Talukdar’s wireless system could implement “legacy technology,” such as the “IEEE 802.16(e) protocol.” Talukdar at [0027] (“Generally, the wireless communication system may implement more than one communication technology as is typical of systems upgraded with newer technology In FIG. 1, for example, one or more of the base units 101 may be legacy technology base stations, for example, IEEE 802.16(e) protocol base stations[.]”). A POSA would have understood the remote units in system 100 to similarly include 802.16(e) units, because Talukdar disclosed that the base stations “should be able to service both 802.16(m) and legacy terminals [*i.e.*, remote units] within the common frame

structure.” *Id.* This would also have been expected of a system like Talukdar’s, because base stations (base units) would need to be able to communicate with the remote units within a system, which would generally include newer as well as older consumer equipment. A POSA would have understood Talukdar’s disclosure to indicate that wireless system 100 included a collection of fixed and mobile remote units that included both 802.16(e) and 802.16(m) compliant devices. Specifically, the system included a fixed 802.16(e) remote unit as well as a moving 802.16(m) remote unit. *Id.*, Fig. 1 (annotated to identify an example fixed 802.16(e) remote unit and an example mobile 802.16(m) remote unit within system 100).

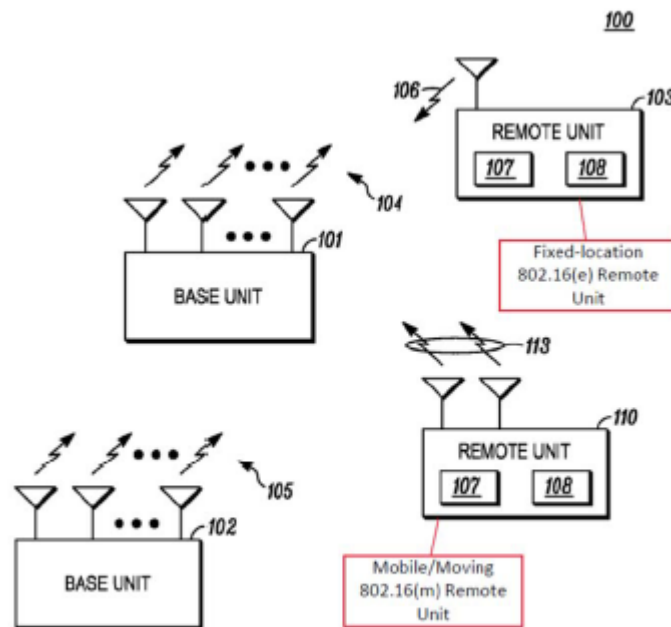


FIG. 1

115. Talukdar recognized that the 802.16(e) protocol was OFDM-based and transmitted information in symbols. *Id.* at [0026] (“In OFDM based systems, the

radio resources include OFDM symbols An exemplary OFDM based protocol is IEEE 802.16(e).”). Figure 7 of Talukdar showed the 802.16(e) DL block as transmitted in the first “12 symbols” of the hybrid frame; *id.* at [0044] (“Generally, the radio frame includes a plurality of blocks, including a first block and last block, wherein each block comprises a plurality of symbols.”). Further, a POSA would have understood that 802.16(e) used symbols. “[I]n an OFDM system, a high-data rate sequence of symbols is split into multiple parallel low-data rate-sequences, each of which is used to modulate an orthogonal tone, or subcarrier.” Fund. of WiMAX at 280; *id.* at 282 (“In the frequency domain, each OFDM symbol is created by mapping the sequence of symbols on the subcarriers.”). Each 802.16(e) remote unit in Talukdar’s wireless system 100 was a “first communication system” using “symbols,” under the construction adopted by Court in the Apple litigation. *Supra* § VI (construing “symbol” under its plain-and-ordinary meaning, where the plain-and-ordinary meaning is “a transmissible unit of information”).

116. Talukdar disclosed a hybrid frame that included an “802.16(e) DL traffic resource region 708” section containing downlink traffic (which was “a first section comprising data,” as recited by 1[a]) that was configured for 802.16(e) units (which was “a first format compatible with a first communication system,” as recited by 1[a]). Talukdar disclosed “a frame [] divided into multiple blocks of equal size, wherein the blocks [could] support one or more protocols, for example, IEEE

802.16(e) and/or 802.16(m).” Talukdar at [0044]. “Generally, the radio frame include[d] at least **one first protocol block** and/or at least one second protocol block, for example, **802.16(e)** and/or 802.16(m) blocks.” *Id.* at [0045]. Talukdar confirmed that the 802.16(e) sub-blocks “conform[ed] to the legacy specification of 802.16(e) frames and [could not] be distinguished from legacy 802.16(e) frames by a legacy mobile.” *Id.* at [0047]. This type of frame was referred to as a “hybrid frame” and exemplified in, *e.g.*, Figure 7. *Id.* A POSA would have understood traffic, such as downlink or uplink traffic, to be an example of “data.”

117. In Figure 7, the “hybrid frame 700” was configured with “equal size sub-blocks designed to serve both 802.16(e) and 802.16(m) data traffic in the same 5msec interval.” *Id.* at [0051]. Talukdar identified “[t]he first block [as] an 802.16(e) DL region starting with a 1-symbol preamble followed by 802.16(e) MAPs [706] and an 802.16(e) DL traffic resource region 708.” *Id.*; Fig. 7 (e-DL [802.16(e)-downlink] section 708 in yellow; labels and color-coding added to figure).

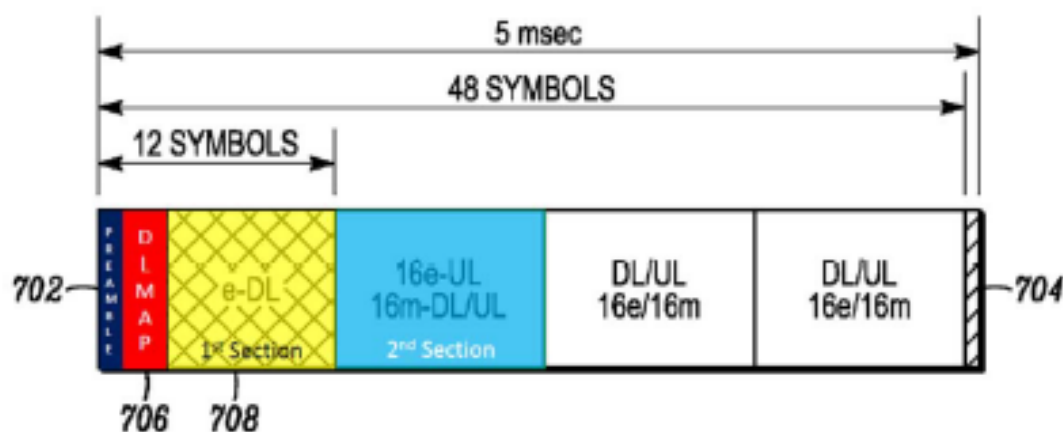


FIG. 7

The “802.16(e) DL traffic resource region 708” included data configured in a first format compatible with a remote unit compliant with 802.16(e) (“a first communication system using symbols”). Indeed, Talukdar disclosed that the “types of basic [frame] regions” used to create “h-frames ... for serving 802.16(e) and 802.16(m) terminals” included an “e-DL region used for transmission of downlink traffic to 802.16(e) terminals. *Id.* at [0029]-[0030].

- c) **1[b]: “generating a second section following the first section, the second section comprising data configured in a second format compatible with a second communication system using symbols, wherein the first communication system’s symbols and the second communication system’s symbols co-exist in one transmission scheme”**

118. Talukdar disclosed 1[b] because it disclosed a “16e-UL / 16m-DL/UL” traffic section (“a second section following the first section”) comprising data configured in a format compatible with an 802.16(m) remote unit (“a second communication system using symbols”) and the 802.16(e) DL traffic resource region 708 and 16e-UL / 16m-DL/UL traffic section were both included in the hybrid frame (“wherein the first communication system’s symbols and the second communication system’s symbols co-exist in one transmission scheme”).

119. Talukdar’s system 100 included units with “newer generation technologies, for example, IEEE 802.16(m) protocol base stations.” Talukdar at [0027]. A POSA would have understood that the remote units within system 100

similarly included 802.16(m)-compliant remote units, because the base stations “service[d] both 802.16(m) and legacy terminals [*i.e.*, remote units] within the common frame structure.” *Id.* Each of these 802.16(m) remote units in system 100 was a “second communication system.” *Supra* § VI (construing “communication system” under its plain-and-ordinary meaning, where the plain-and-ordinary meaning is “a combination of hardware and software that transmits and receives data according to one or more communications standards”). Further, the 802.16(m) protocol used symbols to transmit information. *Id.* at Fig. 7 (showing that hybrid frame 700 comprised 48 symbols, allocated between different sub-blocks). Each of the 802.16(m) remote units in Talukdar’s wireless system 100 was “a second communication system using symbols.” *Supra* § VI (“symbol” construed by the Court in the Apple litigation under its plain-and-ordinary meaning, where the plain-and-ordinary meaning is “a transmissible unit of information”).

120. Talukdar disclosed a hybrid frame 700 with “equal size sub-blocks designed to serve both 802.16(e) and **802.16(m) data traffic** in the same 5msec interval.” *Id.* at [0051]; *id.* (“The first block [of frame 700] is an 802.16(e) DL region The other 3 blocks are a combination of 802.16(e) and 802.16(m) regions (DL [downlink] or UL [uplink]).”). The second block identified by Figure 7 was a “16e-UL / 16m-DL/UL” block (shown below in light blue) that could contain either 802.16(e) uplink data, 802.16(m) downlink data, or 802.16(m) uplink data. The

hybrid frame (or h-frame) was created by combining “various types of 5msec frame structures ... to suit the traffic service requirements.” *Id.* at [0030]. The “m-DL” and “m-UL” labels in Figure 7 denoted regions for carrying downlink data for an 802.16(m) remote unit or uplink data from an 802.16(m) remote unit. “The 802.16(m) 5 msec frame can be perceived to be composed of [the] following types of basic regions: ... m-DL: region allocated for transmission to 802.16(m) terminals; and m-UL: region allocated for transmission by 802.16(m) terminals.” *Id.* at [0029]. The “e-DL” label denoted a region for 802.16(e) downlink data, but this was also configured to transmit 802.16(m) data. “The e-DL and e-UL regions can also be used for transmissions to/from 802.16(m) terminals.” *Id.* The “16e-UL / 16m-DL/UL” section was therefore a “second section comprising data configured in a second format compatible with a second communication system using symbols.”

121. Additionally, Talukdar’s “16e-UL / 16m-DL/UL” block was “a second section *following* the first section.” Figure 7 showed the “16e-UL / 16m-DL/UL” block as positioned after “802.16(e) DL traffic resource region 708” in time. Figure 7 showed the e-DL section as lasting 12 symbols in the time dimension, with the “16e-UL / 16m-DL/UL” section starting at symbol 13 (and at approximately 1.25ms into the frame). Talukdar described the hybrid frame’s components as being ordered to “follow” each other in the time sequence, such that “[t]he first block is an 802.16(e) DL region starting with a 1-symbol preamble ***followed by*** 802.16(e) MAPs

806 and an 802.16(e) DL traffic resource region 708” (Talukdar, [0051]); by extension, and as shown in Fig. 7, the 802.16(e) DL traffic resource region 708 was “followed by” the “16e-UL / 16m-DL/UL” section. Talukdar also disclosed that “[t]o construct a Subframe 1:2, the 2nd block must be m-UL” which would place 802.16m, a second format compatible with a second communication system, after or following, the first block comprised of 802.16e data. “For 802.16(e) terminals, the 802.16(m) sub-frames [were] in a separate zone with dedicated pilots.” Talukdar at [0051]; *id.* at Fig. 7 (16m-DL/UL [802.16(m)-downlink/uplink] section in light blue).

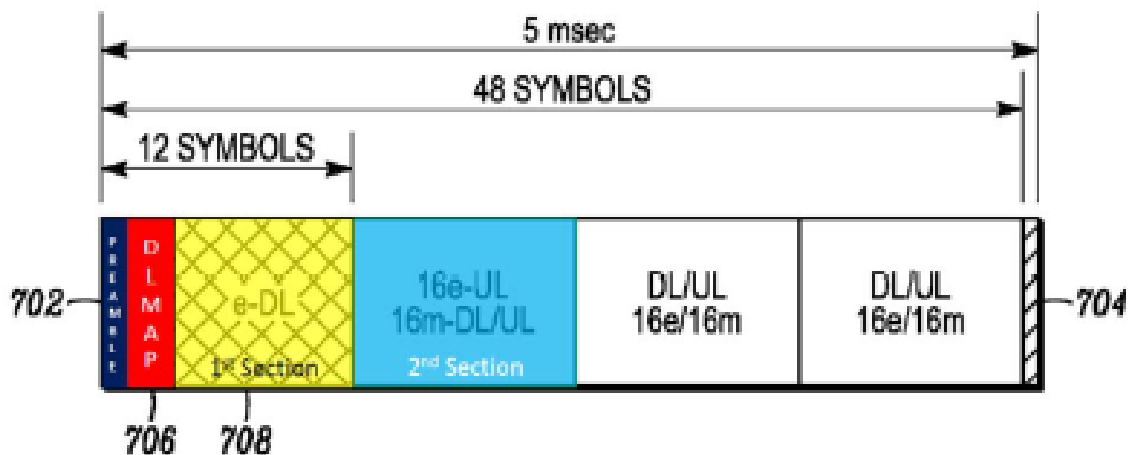


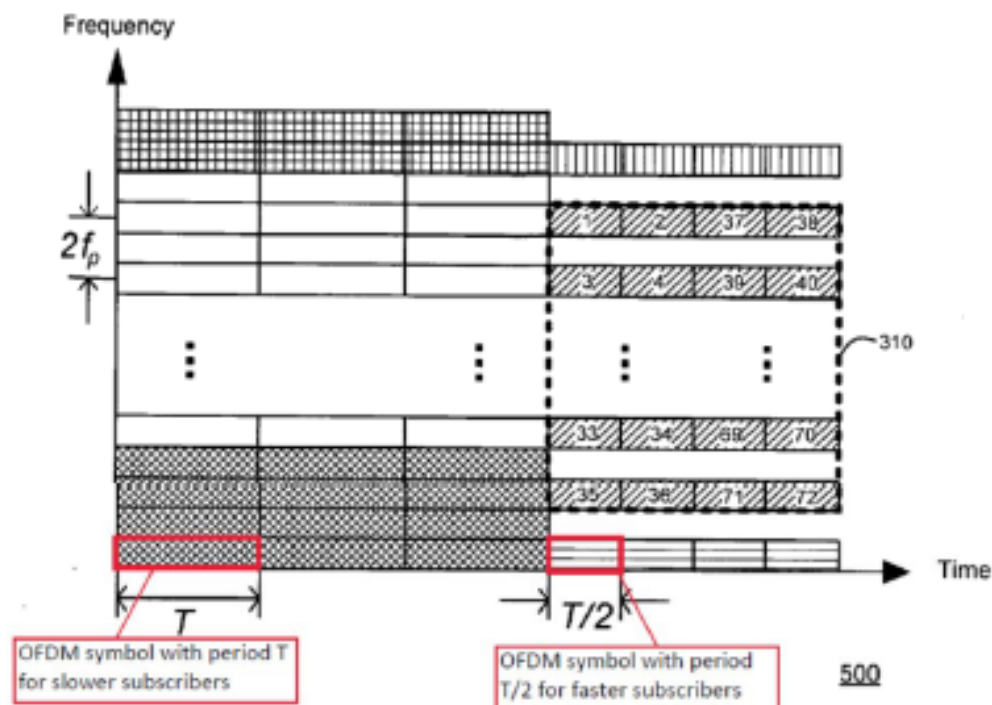
FIG. 7

122. Talukdar disclosed that “the first communication system’s symbols and the second communication system’s symbols co-exist[ed] in one transmission scheme,” because, as depicted in Figure 7, the “802.16(e) DL traffic resource region 708” and “16e-UL / 16m-DL/UL” sections carried data configured for the 802.16(e)

remote unit and 802.16(m) remote unit respectively within a single frame. *Id.* at Fig. 7 and [0045] (“Generally, the radio frame includes at least one first protocol block and/or at least one second protocol block, for example, 802.16(e) and/or 802.16(m) blocks.”). This matched the disclosure of the ‘096 Patent, in which data from the legacy and newer system co-existed in a frame. ‘096 Patent at 4:20-24 (“present invention may allow data of ... a legacy system[] and data of a new OFDMA system to co-exist in an OFDMA frame”). Talukdar also disclosed that “the first communication system’s symbols and the second communication system’s symbols co-exist[ed] in one transmission scheme,” because 802.16(e) and 802.16(m) were within the same family of 802.16 standards. Talukdar recognized that “[t]he IEEE 802.16m protocol is an evolution of the WiMAX-OFDMA specification for the IEEE 802.16e protocol.” Talukdar at [0002]. Further, both 802.16(e) and 802.16(m) used OFDM/OFDMA symbols, and were part of one transmission scheme (same frame). Wang at 4 (“In a broad sense, the OFDM system comprises OFDM and OFDMA systems, and OFDMA has the similar basic principle to that of the OFDM.”); ‘096 Patent at 1:27-31 (“The multiple access scheme of the OFDMA may generally be applied in various communication systems, such as those defined in IEEE standard 802.16e (‘legacy system’ hereafter) and IEEE standard 802.16m (‘new system’ hereafter).”); Fund. of WiMAX at 280-82 (discussing OFDM symbol structure).

123. Separately and additionally, Li disclosed that “the first communication system’s symbols and the second communication system’s symbols co-exist[ed] in one transmission scheme.” Li disclosed a transmission frame that included symbols for subscriber stations that were moving faster and that were moving slower. *E.g.*, Li, Fig. 5; *id.*, [0022] (“In an embodiment, the communications system 100 is arranged to schedule slow subscribers with smaller subcarrier spacing and longer OFDM symbol durations. The communications system 100 is further arranged to schedule fast subscribers with larger subcarrier spacing and shorter OFDM symbol durations.”) and [0038] (“For example ... for a given time slot T and N adjacent subcarriers with total bandwidth Nf_p , the communications system 100 and/or node 110 of an embodiment can transmit an OFDM symbol of N subcarriers with subcarrier spacing f_p to slow subscriber. Using the **same frequency and time resource**, the communications system 100 and/or node 110 of an embodiment can transmit to the fast subscriber two OFDM symbols with $N/2$ subcarriers each in two time slots with $T/2$ each, where the subcarrier spacing is $2f_p$.”); *id.*, Fig. 5. Referring to Figure 5 of Li, Li disclosed one embodiment in which a frame included symbols for a slower subscriber station with a symbol period of T , and symbols for a faster subscriber station with a symbol period half as long, $T/2$: “In an embodiment, the communications system 100 and/or node 110 **assigns the even OFDM subcarriers**

(e.g., $N/2$ nonadjacent subcarriers) to a fast subscriber and shortens the symbol duration from T to $T/2$.”). *Id.* at [0038]; *id.*, Fig. 5 (annotations added).



124. A POSA would have understood Figure 5 of Li to depict an OFDM frame, comprising a number of subcarriers (shown as elements on the frequency axis) and extending across some number of symbols (shown as elements on the time axis). Li confirmed that its disclosed techniques were applicable to communications formatted as frames. Li, [0015] (“It can be appreciated that the described embodiments are applicable to any type of communication content or format, such as ... frames[.]”). For the Figure 5 embodiment in particular, Li disclosed that “the even OFDM subcarriers (e.g., $N/2$ nonadjacent subcarriers) [were assigned to] to a fast subscriber” in the frame and that the symbol period for the fast subscriber was

“shorten[ed] ... from T to T/2.” *Id.*, [0038] and Fig. 5. A POSA would have found it obvious to incorporate this teaching, of a frame that included symbols for slower-moving stations (each a “first communication system”) and faster-moving stations (each a “second communication system”) into Talukdar in connection with 1[c], as discussed below.

- d) **1[c]: “and wherein: the second format is compatible with the second communication system configured to support higher mobility than the first communication system, wherein each symbol in the second communication system has a shorter symbol period than that in the first communication system”**

125. Talukdar disclosed a “second communication system configured to support higher mobility than the first communication system” in that it disclosed that its wireless system 100 included an 802.16(m) remote unit that was mobile (“configured to support higher mobility”). Talukdar disclosed that the second zone of the hybrid frame was configured to support 802.16(m) traffic while the first zone supported 802.16(e) traffic. Talukdar at [0051] (“FIG. 7 is a hybrid frame 700, ... designed to serve both 802.16(e) and 802.16(m) data traffic in the same 5msec interval.”). It was generally known that 802.16(m) was configured to provide higher mobility support than 802.16(e). *Supra*, VIII(C)(1); Ahmadi at [0027] (“Embodiments of the invention may enable the next generation of mobile WiMAX systems (e.g., based on IEEE 802.16m standard) to efficiently support **substantially high mobility** and low latency applications”).

126. Talukdar also disclosed that the remote units within wireless system 100 (including both 802.16(e) and 802.16(m) remote units) included both fixed and mobile remote units. Talukdar at [0024] (“The remote units may be fixed ... The remote units may also be ... mobile stations[.]”); *supra* § XI(A)(1)(b). For example, Talukdar disclosed that its system could implement evolving UMTS technology, such as “the evolution of GSM to UMTS and future UMTS releases thereof.” *Id.* at [0027]. UMTS was a cellular technology, and a POSA would understand this disclosure to indicate that Talukdar’s remote units included cellular devices, like cellular phones. *E.g., id.* at [0024] (“The one or more base units 101 and 102 serve a number of remote units 103 and 110 within a serving area, for example, a cell, or within a cell sector.”). A POSA would have understood Talukdar’s description of system 100 to indicate that the 802.16(e) and 802.16(m) remote units within wireless system 100 included both fixed remote units and remote units moving at different speeds—that is, all combinations of 802.16(e)/802.16(m) and fixed/mobile—such that the wireless system 100 included a faster-moving 802.16(m) remote unit, which was a “second communication system configured to support higher mobility,” and a separate slower-moving or fixed-location 802.16(e) remote unit, which was “a first communication system.” At a minimum, a POSA would have found it obvious for Talukdar’s wireless system 100 to have included each of a fixed or slower-moving 802.16(e) remote unit and a faster-moving 802.16(m) remote unit, because wireless

system 100 is described as including both fixed and mobile remote units and both 802.16(e)-compliant and 802.16(m)-compliant remote units—that is, a general representation of the various types of 802.16(e) and 802.16(m) “user equipment” in existence. *Id.* at [0024]-[0027]. Talukdar’s description of the process for constructing a hybrid frame was applicable to the units within system 100 generally. Nothing about the disclosed process would have worked differently depending on the speed of any particular remote unit. To the contrary, Talukdar specifically taught that its hybrid frame was a “common frame structure” that was applicable to any 802.16(e) or 802.16(m) remote unit in system 100. *Id.* at [0027] (“In FIG. 1, for example ... 802.16(m) base stations should be able to service both 802.16(m) and legacy terminals [i.e., remote units] within the common frame structure.”).

127. Because Talukdar’s system 100 included both a faster-moving remote unit (a “second communication system configured to support higher mobility than [a] first communication system”) and a fixed or slower-moving unit (a “first communication system”), and because Talukdar disclosed its frame structure as being a “common” structure generally applicable to the units within system 100, a POSA would have understood Talukdar to provide a teaching, suggestion, or motivation to generate a hybrid frame (*e.g.*, Talukdar’s hybrid frame 700) with a first section including data configured in a format compatible with an 802.16(e) remote unit that was fixed or slower-moving (the “first communication system”) and

a second section with data configured in a format compatible with an 802.16(m) remote unit that was faster-moving (a “second communication system configured to support higher mobility than the first communication system”). This would also have been beneficial in that a hybrid frame configured in this manner would have been able to service more remote units within Talukdar’s wireless communication system (e.g., the fixed units as well as the mobile units) by, for example, accommodating all combinations of data for the differently-configured remote units (fixed/mobile and 802.16(e)/802.16(m)). This would also have been an expected configuration for Talukdar’s “common frame structure”: Talukdar’s hybrid frame 700 (which was designed to carry “both 802.16(e) and 802.16(m) data traffic in the same 5 msec interval,” see [0051]) was applicable to configurations of fixed or mobile 802.16(e) and 802.16(m) remote units, meaning that the frame could carry data for (1) a fixed 802.16(e) and a fixed 802.16(m) unit; (2) a fixed 802.16(e) and a mobile 802.16(m) unit; (3) a mobile 802.16(e) and a fixed 802.16(m) unit; or (4) a mobile 802.16(e) and a mobile 802.16(m) unit. Given this limited set of permutations, and given that Talukdar’s process for generating the hybrid frame did not differ based on the speed of a remote unit, a POSA would have found it obvious to try generating a hybrid frame configured in any one of these limited ways, including specifically a configuration that included data configured for both a faster-moving 802.16(m) device and a slower-moving or fixed 802.16(e) device, and would have had a

reasonable expectation of success in generating a frame with this configuration. Talukdar's teachings thus rendered obvious the part of 1[c] that recites "and wherein: the second format is compatible with the second communication system configured to support higher mobility than the first communication system."

128. Li also disclosed a "second communication system configured to support higher mobility." Li disclosed that a node (such as a base station, *see* Li at [0026]) assigned faster-moving subscriber stations (each a "second communication system configured to support higher mobility than the first communication system," *supra* § VI) OFDM symbols with a shorter symbol period than the symbols the base station assigned to slower stations. Li stated that 802.16(e) devices could be either fixed-location or mobile devices. "802.16e aim[ed] ... to support both fixed and mobile subscriber stations to accommodate ... subscriber stations moving at vehicular speeds." Li at [0001]; *id.* at [0034] (mobile stations could have "mobile speeds ... [that] may be substantially different from other subscribers," with speeds "rang[ing] from 0 to 250 km/h"). Li disclosed that a base station first designated "subscribers ... as either fast or slow" and then "employ[ed] two OFDM symbol durations ... one set assigned to the slow and fast subscribers respectively." *Id.* at [0037]. Each of Li's faster-moving subscriber stations was a "second communication system configured to support higher mobility than" Li's fixed or

slower-moving subscriber stations, which were each “[a] first communication system.”

129. A POSA would have found it obvious to modify Talukdar’s process for generating a hybrid frame such that the frame would have included a first section with data configured for a fixed-location or slower-moving 802.16(e) remote unit (a “first communication system”) and a second section with data configured for a mobile 802.16(m) remote unit (a “second communication system configured to support higher mobility than the first communication system”) in view of Li’s disclosure of subscriber stations compliant with 802.16 moving at “substantially different speeds” with respect to a base station, as discussed below for the latter portion of limitation 1[c]. Further, in a manner similar to that discussed for Talukdar alone, a hybrid frame having this configuration would have accommodated a greater range of remote units in Talukdar’s wireless communication system, for example by accommodating all combinations of data for the differently-configured remote units in the broader system. Also as discussed above for Talukdar, a POSA would have had a reasonable expectation of success in combining Li’s teachings with Talukdar to generate a hybrid frame having this configuration, because Talukdar described its system as including 802.16(e) and 802.16(m) remote units that were fixed and mobile and described its techniques as generally applicable to these units within system 100, and because these techniques did not depend on or vary according to

the speed of the remote units. As with Talukdar alone, Talukdar in combination with Li thus rendered obvious the part of 1[c] that recites “wherein: the second format is compatible with the second communication system configured to support higher mobility than the first communication system.”

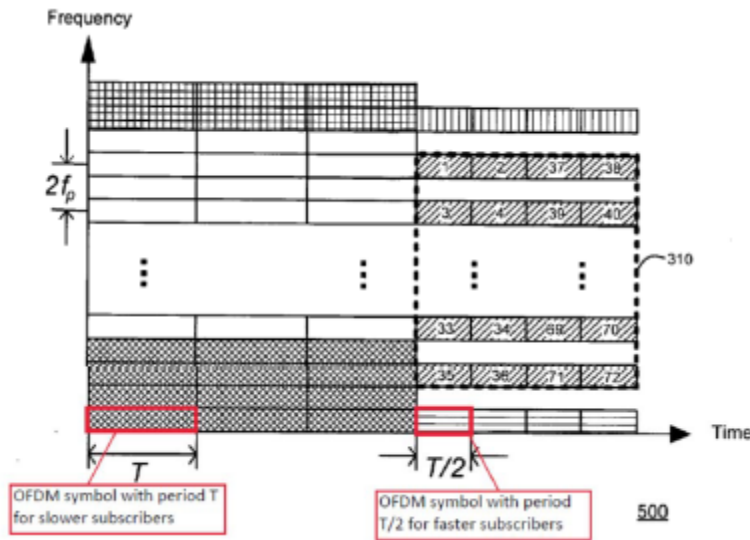
130. The second part of 1[c] recites “wherein each symbol in the second communication system has a shorter symbol period than that in the first communication system.” Li disclosed that higher-mobility subscriber stations experienced greater levels of interference between subcarriers. Li at [0034] (“[H]igh mobility, [or] high speed ... causes ICI [inter-subcarrier interference] for OFDM and OFDMA systems that may limit their application to mobile channels.”). Inter-subcarrier interference (ICI) is a concern in OFDM systems. *E.g., supra* § VIII(C)(3). Its effects come into play even more in higher mobility applications. Li at [0034] (“The mobility or speed of an individual subscriber...may be an important feature of that subscriber. For example, high mobility, high speed, or fast fading causes ICI for OFDM and OFDMA systems”); Fund. of WiMAX at 40 (“A reduced subcarrier spacing, however, also makes the system more vulnerable to intercarrier interference owing to Doppler spread in mobile applications.”). This is because faster speeds of higher-mobility users cause a larger Doppler shift, which causes subcarriers to no longer be orthogonal to one another and results in an increased ICI. Faster speeds also cause intercarrier interference from carrier

frequency offset, which is mismatched channel frequencies at the transmitter and receiver. A POSA would have understood that mobile remote units within Talukdar's system 100 (Talukdar at [0024]) would have experienced inter-subcarrier interference for these same reasons.

131. Li taught that using a shorter symbol duration for faster-moving stations (each a “second communication system configured to support higher mobility,” as recited by 1[c]) helped reduce inter-subcarrier interference. “[A] short OFDM symbol duration and larger subcarrier spacing reduces ICI[.]” Li at [0035]; *id.* at [0010] (“The grouping of subscribers according to their speed ... may reduce inter-subcarrier interference (‘ICI’) in OFDM and the corresponding OFDMA systems that support the subscribers.”). Thus, Li described embodiments where “the communications system 100 may be arranged to employ different OFDM symbol durations and subcarrier spacing for slow and fast subscribers, respectively.” *Id.* at [0022]. “In an embodiment, the communications system 100 [wa]s arranged to schedule slow subscribers with smaller subcarrier spacing and longer OFDM symbol durations. The communication system 100 [wa]s further arranged to schedule **fast subscribers with** larger subcarrier spacing and **shorter OFDM symbol durations.**” *Id.* at [0022], [0037] (“In an embodiment, the communications system 100 and/or node 110 of an embodiment assign[ed] shorter symbol duration and larger subcarrier spacing (e.g., OFDM signal 410) to the fast subscribers and longer symbol duration

and smaller subcarrier spacing (e.g., OFDM signal 400) to the slow subscribers less prone to ICI.”). Nodes could be, for example, a “base station or node B, router, switch, hub, gateway, media gateway, and so forth.” *Id.* at [0026].

132. Li provided an example of its symbol shortening teaching in Figure 5, which demonstrated an instance of a base station “shorten[ing] the symbol duration from T to $T/2$ ” for a fast subscriber. *Id.* at [0038] (“Using the same frequency and time resource, the communications system 100 and/or node 110 of an embodiment [could] transmit to the fast subscriber two OFDM symbols with $N/2$ subcarriers each in two time slots with $T/2$ each, where the subcarrier spacing is $2f_p$.”). This “duration” of a symbol was the “symbol period,” under the construction of the Court in the Apple litigation “the time it takes to transmit one symbol.” *Supra* § VI. The first zone shown in Figure 5 was comprised of three OFDM symbols with a symbol duration of T , appropriate for a slower subscriber. The second zone was comprised of four OFDM symbols with a symbol duration of $T/2$, for a faster subscriber. *Li* at [38]; Fig. 5 (with annotations).



133. Li further taught that in a communication system with both fast and slow subscribers, assigning “a symbol duration that [was] half the duration of the slow subscriber symbol duration,” could still maintain quality throughput by transmitting “two OFDM symbols with $N/2$ subcarriers each in two time slots with $T/2$ each, where the subcarrier spacing [wa]s $2f_p$.” *Id.* at [0038]. “For an embodiment..., the communications system 100 and/or node 110 of an embodiment [could] communicate[] the same amount of data with either subcarrier spacing/symbol duration.” *Id.* Li therefore disclosed a “second communication system configured to support higher mobility than the first communication system”—a mobile subscriber station that was faster-moving than a fixed or slower-moving mobile station—and Li further disclosed that the symbols used by the faster stations had a shorter symbol period than those used by the slower stations.

134. A POSA would also have recognized higher-mobility applications (*i.e.*, wireless systems that included faster-moving user equipment) as being the direction in which the industry was headed. The progression of 802.16(e) to 802.16(m) reflected an increased focus on mobility support. Fund. of WiMAX at 8 (“In 2003, the 802.16 group began work on enhancements to the specifications to allow vehicular mobility applications. That revision, 802.16e, was completed in December 2005 and was published formally as IEEE 802.16e-2005. It specifies scalable OFDM for the physical layer and makes further modifications to the MAC layer to accommodate high-speed mobility.”); Applications for WiMAX at 2 (“The WiMAX Forum is committed to providing optimized solutions for fixed, nomadic, portable and mobile broadband wireless access.”), 11 (“The WiMAX Forum expects that initial products will support only simple mobility, which uses hard handoffs and does not support real-time applications. As demand for more advanced forms of mobility is fueled by the introduction of PDAs and smartphones, certified products will include support for soft handoffs, mobile VoIP, and real-time applications.”). The industry expected versions of 802.16 released after 802.16(e) to provide evolving “services in a nomadic or mobile context” and for “WiMAX to meet this demand.” Fund. of WiMAX at 12; Ahmadi at [0027] (“Embodiments of the invention may enable the next generation of mobile WiMAX systems (e.g., based on IEEE 802.16m standard) to efficiently support **substantially high mobility** and low latency

applications[.]”). This industry focus on enhancing support for higher- mobility applications would have further led a POSA to incorporate data for an 802.16(m) remote unit moving at a higher speed into Talukdar’s hybrid frame.

135. A POSA would have understood Li’s teaching of assigning symbols with shorter periods to faster-moving mobile stations to reduce inter-subcarrier interference as providing a teaching, suggestion, or motivation to incorporate this technique into Talukdar, by using shorter symbol periods for a faster-moving 802.16(m) remote unit. A POSA would have been motivated to do this in order to reduce the inter-subcarrier interference experienced by faster-moving mobile remote units in Talukdar’s system 100. Li specifically taught that moving (mobile) stations suffered from inter-subcarrier interference when traveling at higher speeds and that shortening the symbol period helped reduce this interference. Li at [0034]-[0035], [0010]. A POSA would have recognized that the mobile remote units in Talukdar’s wireless system would have been affected by inter-subcarrier interference in the way described by Li. A POSA would also have recognized that shortening the symbol period used for these faster-moving remote units would have yielded the predictable benefit of reducing the inter-subcarrier interference experienced. Indeed, Li specifically taught this benefit, as discussed above. *Supra* ¶¶ 130-33. Thus, a POSA would have understood Li’s disclosure as providing an express teaching, suggestion,

or motivation to modify Talukdar by using shorter symbol periods for faster-moving 802.16(m) remote units.

136. A POSA would have had a reasonable expectation of success in combining Li's teaching of shortening symbol periods for faster-moving stations with Talukdar. Li specifically identified one example implementation that a POSA could have used to make the combination: by using symbols in the section for a mobile 802.16(m) remote unit that had a symbol period half as long as the symbol period used a fixed 802.16(e) unit. For example, Talukdar's hybrid frame could have used symbols with a period of T in the 802.16(e) DL traffic resource region 708, and symbols with a period of $T/2$ in the block carrying "16e-UL / 16m-DL/UL" traffic. This would have been straightforward to implement by adjusting the control information in the frame. For example, mobile stations were typically pre-programmed to recognize one of multiple different symbol configurations. The base station could include a flag in the frame control header of a frame that identified one of these different symbol configurations (*i.e.*, a configuration with a shorter symbol period) to the mobile station. A POSA would also have known how to program the mobile station directly to accommodate a specific symbol length, especially if that revised length was an integer multiple of the mobile station's hardware clock cycle. Halving the symbol period, as disclosed by Li, would have been straightforward, because a POSA could have simply adjusted the clock frequency to put two symbols

where there had originally been one symbol. A POSA would have had a reasonable expectation of success in doing so, because it was known that, as taught by Li, different symbol periods were appropriate for different channel characteristics. *E.g.*, Hwang at [0063] (“influence of inter symbol interference (ISI) can be overcome ... by adaptively changing the length of a transmission symbol.”); Talukdar at [0064] (“It is possible to define a new pilot/subchannel/control structure in the 802.16(m) zones, which is more efficient than the 802.16(e) structures.... parameters such as subcarrier spacing ... or symbol duration, may be the same as or different from those defined in 802.16(e).”). Li’s teaching of shortening symbol duration was thus consistent with the recommended adjustments suggested in Talukdar itself and known in the art.

137. A POSA would also have been motivated to combine Li’s teaching of faster subscriber stations and shortening the symbol period for these faster stations with Talukdar, and would have had a reasonable expectation of success in doing so, because the systems of Talukdar and Li were structurally and operationally similar. Both were 802.16 systems. Talukdar at [0003] (“Thus IEEE 802.16e mobile stations should be compatible with IEEE 802.16m base stations, and IEEE 802.16e base stations should support IEEE 802.16m mobile stations.”); Li at [0001] (“802.16e aims to enhance the specifications to the 802.16 standard to support both fixed and mobile subscriber stations to accommodate ... subscriber stations moving at

vehicular speeds”). And both used OFDM/OFDMA symbols. Talukdar at [0026] (“In one embodiment, the communication system utilizes OFDMA In OFDM based systems, the radio resources include OFDM symbols[.]”); Li at [0010] (“One embodiment may comprise ... a scheduling/adaptation scheme for OFDMA for which different Orthogonal Frequency Division Multiplexing (‘OFDM’) symbol durations are employed for slow and fast subscribers respectively.”). Talukdar and Li also both disclosed combining data for different communication systems in a single frame. Talukdar, Fig. 7 (hybrid frame 700) and [0051] (“FIG. 7 is a hybrid frame 700, also referred to as a HEM-I frame, having equal size sub-blocks designed to serve both 802.16(e) and 802.16(m) data traffic in the same 5 msec interval”); Li, Fig. 5 (frame with symbols for slower- and faster-moving subscribers) and [0015] (“the described embodiments are applicable to any type of communication content or format, such as packets, cells, frames, fragments, units, and so forth”), [0022] (“[T]he communications system 100 is arranged to schedule slow subscribers with smaller subcarrier spacing and longer OFDM symbol durations. The communications system 100 is further arranged to schedule fast subscribers with larger subcarrier spacing and shorter OFDM symbol durations.”), [0038] (“Using the same frequency and time resource, the communications system 100 and/or node 110 of an embodiment can transmit to the fast subscriber two OFDM symbols with

N/2 subcarriers each in two time slots with T/2 each, where the subcarrier spacing is $2f_p$ ”).

138. Modifying Talukdar to incorporate the identified teachings of Li would have involved combining known techniques—incorporating faster-moving mobile stations and using shorter symbol periods, taught by Li, and the frame construction process taught by Talukdar—and a POSA could have effected the combination by simply using a symbol period T/2 for the faster-moving stations (again as taught by Li). This implementation would have been within a POSA’s level of ordinary skill, as discussed. This would have reduced inter-subcarrier interference for the faster-moving units, which was predictable in view of Li’s teachings and knowledge in the art more generally. The proposed combination would also have used a known technique (Li’s technique of communicating with faster stations using OFDM symbols with shorter periods) to improve Talukdar’s similar method (communicating with mobile remote units within wireless system 100 using OFDM symbols) in the same way (by reducing inter-subcarrier interference experienced by the mobile remote units within wireless system 100).

- e) **1[d]: “generating at least one non-data section containing information describing an aspect of data in at least one of the first section and the second section”**

139. I understand that the phrase “at least one of [...] and [...]” in this limitation has been construed as “[...] and/or [...]”. *Supra* § VI. The “at least one

of” language in limitation 1[d] applies to only two items, the first section and the second section, and operates as shorthand for “and/or.” This construction is consistent with the specification, which describes embodiment with non-data sections—for example, “DL-MAP 11 and the sub-MAP 42-2 of DATA 40-3... [or] the UL-MAP (not shown) in the DL burst#1 13”—that provide information for the “new system (extended system) under high mobility” (i.e., “data in... the second section”) only. ‘096 Patent at 5:18-26. Talukdar disclosed 1[d] because it described generating a section of the hybrid frame that included DL-MAP messages that described aspects of the 802.16(e) traffic (a “non-data section containing information describing an aspect of data in ... the first section.”). Talukdar at [0051] (“The first block [wa]s an 802.16(e) DL region starting with a 1-symbol preamble followed by **802.16(e) MAPs 806**³ and an 802.16(e) DL traffic resource region 708.”), [0047] (“A legacy DL Lead Sub-block [wa]s identical to legacy frames containing a 802.16(e) pre-amble, 802.16(e) FCH, **802.16(e) DL-MAP.**”), Fig. 7 (“DL-MAP,” shown in red).

³ This is a typo; the cite should be to MAPs 706, as shown in Figure 7.

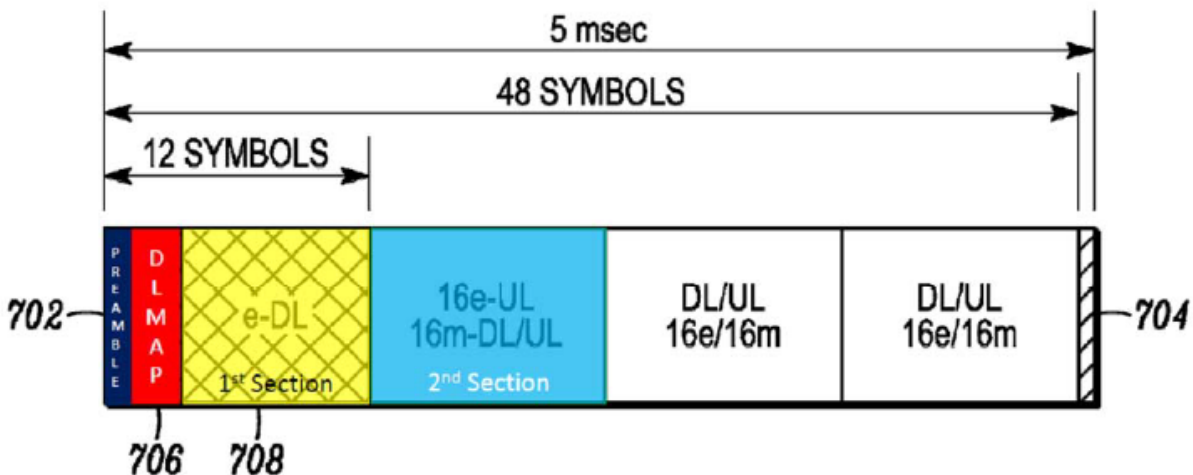


FIG. 7

140. The DL-MAP message did not contain traffic (*i.e.*, data) but instead provided control information regarding the 802.16(e) traffic. A POSA would have considered non-traffic information, such as control information and information in the preamble, DL-MAP, and FCH fields, to be “non-data.” The DL-MAP message was “a full size 16e MAP overhead to support 802.16(e) traffic.” *Id.* at [0051]. Talukdar disclosed that the 802.16(e) MAP message included information for allocating resources within the 802.16(e) e-DL traffic resource region 708. Talukdar, [0073] (“the first protocol allocation control message (e.g., 802.16(e) MAP) can allocate resources within the first protocol resource region (e.g., 802.16(e) region or zone”), [0059] (“The 802.16(e) terminals determine the 802.16(e) and 802.16(m) allocations from the 802.16(e) MAP in which the 802.16(m) region is allocated as a separate zone. ... This scheme is similar as HEM-I [*i.e.*, shown in Fig. 7].”), [0045] (“the first allocation control message is located in the first block. The first block may

be a first ... protocol block, for example, an 802.16(e) ... block.”), Abstract (“radio frame including a first protocol allocation control message that allocates resources within the first protocol resource region”). As shown in Talukdar’s Table 305, which listed elements of a compressed version of the 802.16(e) DL-MAP message, DL-MAP included information indicating the total “[n]umber of OFDMA symbols in the DL sub-frame”; a “Map message length” field (which indicated the length of the traffic portion of the DL sub-frame); and DL IE [Information Element] count and DL-MAP_IE fields, which identified the start time of the traffic and channel details. *Id.* at [0052] and Table 305.

TABLE 305		
<u>Compressed DL-MAP message format</u>		
Syntax	Size	Notes
Compressed_DL-MAP() {		
Compressed map indicator	23 bits	Set to binary 110 to indicate a compressed map format
UL-MAP appended	1 bit	
Reserved	1 bit	Shall be set to zero
Map message length	11 bits	
PHY Synchronization Field	32 bits	
DCD Count	8 bits	
Operator ID	8 bits	
Sector ID	8 bits	
No. OFDMA symbols	8 bits	Number of OFDMA symbols in the DL

TABLE 305-continued		
<u>Compressed DL-MAP message format</u>		
Syntax	Size	Notes
DL IE count	8 bits	subframe including all AA5/permeation zone and including the preamble
for (j = 1 <J = DL IE count; j++) {		
DL-MAP_IE()	variable	
}		
if (byte boundary) {		
Padding Nibble	4 bits	Padding to reach byte boundary
}		
}		

141. A POSA would have understood Talukdar's description of the "basic 802.16(e) MAP" whose elements are depicted in Table 305 as referring to the MAP of the 802.16(e) standard, and as consistent with the 802.16(e) DL-MAP of Figure 7. A POSA would also have understood Talukdar's DL-MAP message to be consistent with the frame structure defined in 802.16. *E.g., id.* at [0047] (the 802.16(e) sub-blocks "conform[ed] to the legacy specification of 802.16(e) frames"). The 802.16 standard required the DL-MAP to include control information about "the burst profile for each user, which define[d] the modulation and coding scheme" and the locations of the data allocated to each user. Fund. of WiMAX at 44 ("Multiple users are allocated data regions within the frame, and these allocations are specified in the uplink and downlink MAP messages (DL-MAP and UL-MAP) that are broadcast ... in the downlink subframe. MAP messages include the burst profile for each user, which defines the modulation and coding scheme used in that link."). Talukdar's description of the DL-MAP section matched the '096 Patent's disclosure, which recognizes that DL-MAP messages are distinct from the "data" sections of the frame. '096 Patent at 1:46-49 ("The DL sub-frame 16 may include ... a downlink map (DL-MAP) ... and a data region (DATA)[.]"); *id.*, Fig. 1 (differentiating the "Prior Art" [*i.e.*, 802.16] DL-MAP from separate from DATA section).

- f) 1[e]: “combining the first section, the second section and the at least one non-data section to form the frame structure”

142. Talukdar disclosed combining the 802.16(e) “e-DL” section (“first section”) and the 802.16(m) “16e-UL / 16m-DL/UL” section (“second section”) along with the 802.16(e) DL MAP regions (“the at least one non-data section”) as disclosed in Figure 7.

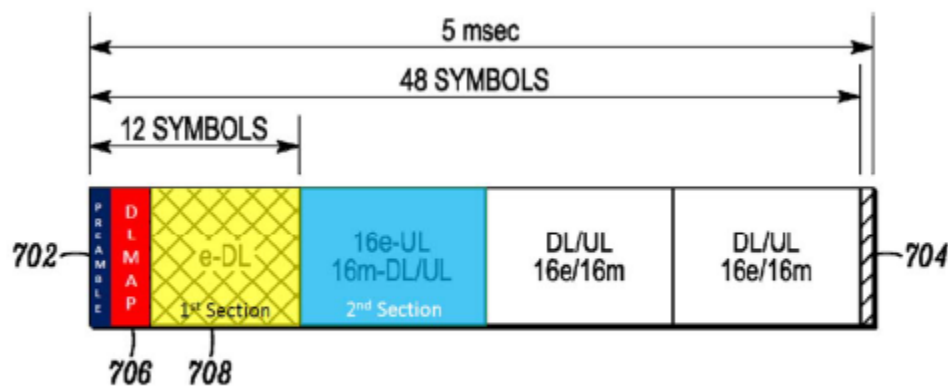


FIG. 7

143. The hybrid frame was “designed to serve both 802.16(e) and 802.16(m) data traffic in the same 5msec interval.” Talukdar at [0051]. “The frame contain[ed] a preamble 702 The first block [wa]s an 802.16(e) DL region starting with a 1-symbol preamble followed by 802.16(e) MAPs [706] and an 802.16(e) DL traffic resource region 708. The other 3 blocks [were] a combination of 802.16(e) and 802.16(m) regions (DL or UL).” *Id.*

2. Claim 2

144. Claim 2 recites: “The method of claim 1, wherein the non-data section comprises mapping information for at least one of the first section and the second

section.” As discussed for claim 1, I understand that the phrase “at least one of [...] and [...]” in this limitation has been construed as “[...] and/or [...]”. The “at least one of” language in claim 2 applies to only two items, the first section and the second section, and operates as shorthand for “and/or.” This construction is consistent with the specification, which describes non-data sections (*e.g.*, sub-MAP 42-2 and UL-MAP in DL burst #1) that contain mapping information for only one of the first and second sections (only for data for the higher-mobility section). ‘096 Patent at 5:18-26 (“Moreover, the DATA 40-3 ... for the new system (extended system) under high mobility may be divided based on the mapping information defined in at least one of ... the sub-MAP 42-2 of DATA 40-3... [or] in the UL-MAP (not shown) in the DL burst#1 13”). This claim 2 therefore requires a non-data section that comprises mapping information for the first section *or* the second section (or a non-data section that comprises mapping information for the first section *and* the second section).

145. As also discussed in claim 1, Talukdar and Li disclosed or rendered obvious each limitation of claim 1. As further discussed for 1[d], Talukdar disclosed “the non-data section comprise[d] mapping information for at least one of the first section and the second section” by disclosing 802.16(e) DL-MAP message 706. *Supra* § XI(A)(1)(e); Talukdar at [0051] (“The first block [wa]s an 802.16(e) DL region starting with a 1-symbol preamble followed by **802.16(e) MAPs [7]06** and an 802.16(e) DL traffic resource region 708.”), [0047] (“A legacy DL Lead Sub-block

[wa]s identical to legacy frames containing a 802.16(e) pre-amble, 802.16(e) FCH, **802.16(e) DL-MAP.**”), [0073] (“the first protocol allocation control message (e.g., 802.16(e) MAP) [could] allocate resources within the first protocol resource region (e.g., 802.16(e) region or zone).”), [0059] (“The 802.16(e) terminals determine[d] the 802.16(e) and 802.16(m) allocations from the 802.16(e) MAP in which the 802.16(m) region [wa]s allocated as a separate zone. ... This scheme is similar as HEM-I [in Figure 7.]”), [0045] (“The radio frame includes an allocation control message for allocating resources within a protocol block. ... In one embodiment, the first allocation control message is located in the first block.”).

146. This DL-MAP message was “mapping information for at least one of the first section and the second section,” specifically, for the e-DL data traffic resource region 708 (“the first section”). Talukdar disclosed that the 802.16(e) DL-MAP message contained information (“mapping information”) for allocating resources within the 802.16(e) traffic region. *Id.* at [0073] (“the first protocol allocation control message (e.g., 802.16(e) MAP) can allocate resources within the first protocol resource region (e.g., 802.16(e) region or zone)”), [0059] (“The 802.16(e) terminals determine the 802.16(e) and 802.16(m) allocations from the 802.16(e) MAP in which the 802.16(m) region is allocated as a separate zone.”). Allocated resources included the subcarriers that could be used by a given remote

unit on the downlink and on the uplink, and the location of the data for a specific remote unit when multiple units were receiving information in a frame.

3. Claim 3

147. Claim 3 recites: “The method of claim 1, wherein the non-data section comprises at least one of a preamble, a frame control header (FCH), a burst, and a map of at least one of the first section and the second section.” I understand that the phrase “at least one of [...] and [...]” in this limitation has been construed as “[...] and/or [...]”. Claim 3 includes two occurrences of this language. In the last clause of claim 3—“a map of at least one of the first section and the second section”—the “at least one of” language applies to only two items, the first section and the second section, and operates as shorthand for “and/or.” This construction is consistent with the specification, which describes non-data sections (*e.g.*, sub-MAP 42-2 and UL-MAP in DL burst #1) that contain a map for only one of the first and second sections (only for data for the higher-mobility section). ‘096 Patent at 5:18-26 (“Moreover, the DATA 40-3 ... for the new system (extended system) under high mobility may be divided based on the mapping information defined in ... the sub-MAP 42-2 of DATA 40-3... [or] in the UL-MAP (not shown) in the DL burst#1 13.”). The language is also found in the first clause of claim 3: “the non-data section comprises at least one of a preamble, a frame control header (FCH), a burst, and a map.” The specification indicates that the “at least one of” language in this clause should also

be construed as “and/or,” because the ‘096 Patent discloses embodiments in which the non-data section includes fewer than all of these recited preamble, frame control header, burst, and map components. For example, Figure 4 and 5:18-33 disclose a non-data section made up of only a preamble and sub-MAP (elements 43 and 42-2). Further, the ‘096 Patent uses expressly permissive language, indicating that the frame “may” (and thus may not) include these distinct components. ‘096 Patent at 5:43-45. The disjunctive construction (“and/or”) is correct for each occurrence of the “at least one of” clauses in claim 3, meaning that claim 3 requires that the non-data section comprises a preamble, a frame control header (FCH), a burst, *or* a map (or a preamble, a frame control header (FCH), a burst, *and* a map) of the first section and/or the second section.

148. Talukdar disclosed that the hybrid frame included multiple non-data sections, including a preamble, a frame control header (FCH), and the DL-MAP message (“a map of at least one of the first section and the second section”). *Id.* at [0051] (“The first block [wa]s an 802.16(e) DL region starting with a **1-symbol preamble followed by 802.16(e) MAPs 806** and an 802.16(e) DL traffic resource region 708.”); *id.* at [0047] (“A legacy DL Lead Sub-block [wa]s identical to legacy frames containing a **802.16(e) pre-amble, 802.16(e) FCH [frame control header], 802.16(e) DL-MAP.**”); *id.* at [0047] (“802.16(e) sub-blocks ... includ[ed] ... a **802.16(e) pre-amble, 802.16(e) FCH, 802.16(e) DL-MAP**”). Each of these was a

non-data section that provided information regarding the 802.16(e) traffic in traffic resource region 708.

4. Claim 4

149. Claim 4 recites: “The method of claim 3, wherein the second section follows the first section in at least one of time sequence and frequency spectrum.” I understand that the phrase “at least one of [...] and [...]” in this limitation has been construed as “[...] and/or [...]”. The “at least one of” language in claim 4 applies to only two items, the time sequence and the frequency spectrum, and operates as shorthand for “and/or.” This construction is consistent with the specification, because the ‘096 Patent discloses embodiments in which the second section follows the first section in the time sequence only. ‘096 Patent at Figs. 3 and 4 (Zones 2 and 3 carrying data for a new, higher-mobility system (“second section”) follow Zone 1, which carries data for an old system (“first section”), in the time sequence). This claim requires that the second section follows the first section in the time sequence *or* frequency spectrum (or that the second section follows the first section in the time sequence *and* frequency spectrum).

150. In Figure 7, Talukdar showed that the “16e-UL / 16m-DL/UL” traffic section (“the second section”) followed the “e-DL” traffic resource region 708 (“the first section”) in the time sequence. Talukdar, Fig. 7 (showing “second section”

16m-DL/UL [802.16m-downlink/uplink] in light blue, following “first section” e-DL [802.16(e)-downlink] in yellow).

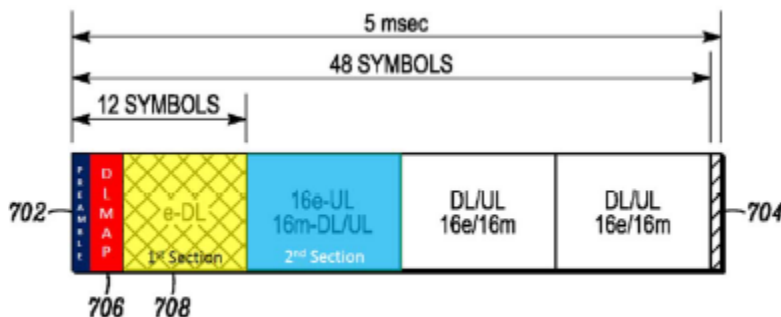


FIG. 7

151. Figure 7 showed the frame in the time domain, with a duration of 48 symbols (spanning 5 msec). *Id.* at Fig. 7; [0034] (teaching that “a position within the frame in time” may “be denoted by the symbol number within the frame or absolute time or time offset from the start of the frame”); *id.* at [0048]. Thus, the “16e-UL / 16m-DL/UL” traffic section followed the “e-DL” traffic resource region 708 in time within the hybrid frame.

5. Claim 6

152. Claim 6 recites: “The method of claim 1, wherein each of the first section and the second section carries at least one of uplink and downlink data.” I understand that the phrase “at least one of [...] and [...]” in this limitation has been construed as “[...] and/or [...]”. The “at least one of” language in claim 6 applies to only two items, uplink and downlink data, and operates as shorthand for “and/or.” This construction is consistent with the specification, which describes embodiments

where each of the first and second sections carries only uplink or down-link data (*e.g.*, the first section carries only downlink data, and the second section also carries only downlink data). For example, the specification discloses an OFDMA frame structure in which sections 40-1 and 40-3 (a “first section” and “second section,” respectively) carry downlink data only for the old and new systems; and sections 44-1 and 44-3 (also a “first section” and “second section,” respectively) carry uplink data only for the old and new systems. ‘096 Patent at Fig. 4 and 4:39-5:40. This claim requires that each of the first section and the second section carries uplink *or* downlink data (or that each of the first section and the second section carries uplink *and* downlink data).

153. Talukdar disclosed the first block was an 802.16(e) DL block and the following blocks could be a combination of 802.16(e) or 802.16 (m) blocks of DL or UL. Talukdar, Fig. 7 (showing e-DL [802.16(e)-downlink] region 708, followed by 16m-DL/UL [802.16(m) uplink/downlink] region); *id.* at [0051] (“FIG. 7 [wa]s a hybrid frame 700 The first block [wa]s an 802.16(e) DL region ... [with] an 802.16(e) DL traffic resource region 708. The other 3 blocks [we]re a combination of 802.16(e) and 802.16(m) regions (DL or UL).”); *id.* at [0029] (the “e-DL region [was] used for transmission of downlink traffic to 802.16(e) terminals”; “m-DL [was a] region allocated for transmission to 802.16(m) terminals” and “m-UL [was a]

region allocated for transmission by 802.16(m) terminals”). A POSA would have understood downlink and uplink traffic to be an example of “data.”

6. Claim 7

154. Claim 7 recites: “The method of claim 1, wherein the second section carries mapping information for data in the second section.”

155. Talukdar disclosed that the “16e-UL / 16m-DL/UL” traffic section (the “second section”) could include an 802.16(m) MAP message (“mapping information for data in the second section”). *Id.* at [0064] (“[T]he first symbol of the frame contain[ed] the 802.16(e) preamble and the 802.16(m) MAP or control channel/control signaling ...[wa]s in a different position or positions in the frame. For example: within the portion of the frame labeled as 16m DL[.]”); *id.* at [0046] (“An 802.16(m) DL Sub-Block ... contain[ed] 802.16(m) Downlink data and 802.16(m) control. This [could have] occup[ied] the 2nd, 3rd or 4th sub-frames.”). For example, Figure 13 showed a hybrid frame with an 802.16m DL data section that included a 16m MAPs message.

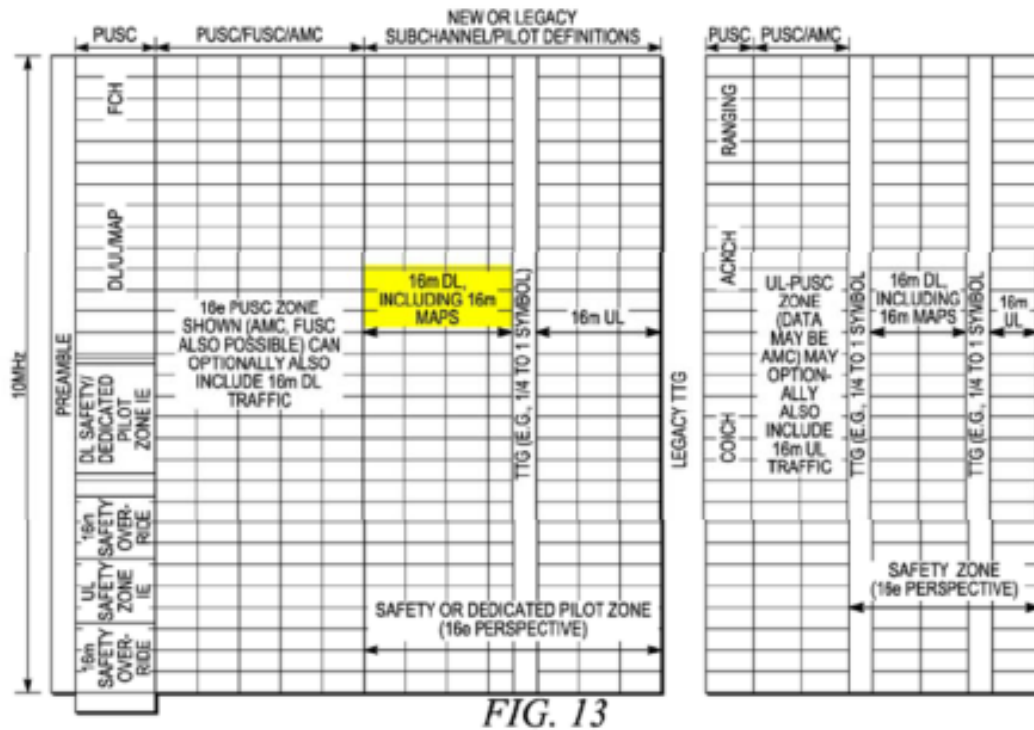


Figure 14 similarly showed a hybrid frame with an 802.16(m) data region that included a MAPs message. *Id.* at Fig. 14 (“16m DL INCLUDING 16m MAPS”). A POSA would have understood Talukdar’s illustrations of hybrid frames to be illustrative views relating to a hybrid frame with first and second traffic regions corresponding to first and second protocols. Specifically, a POSA would have understood the placement and content of the 802.16(m) MAP message within the hybrid frames illustrated in the Figure 13 and 14 examples to be consistent with and applicable to the hybrid frame illustrated in the Figure 7 example.

B. Ground 2: Talukdar and Nystrom Rendered Claim 8 Obvious

156. I have reviewed independent claim 8 and it has the same limitation as claim 1, except for limitation 8[c]. Because of these similarities, my opinion is that

8[pre]-8[b] and 8[d]-8[e] are unpatentable for the same reasons given regarding the unpatentability of limitations 1[pre]-1[b] and 1[d]-1[e]. *Supra* § XI(A)(1).

1. 8[c]: “and wherein the second communication system has pilot symbols that are denser than those in the first communication system”

157. Nystrom disclosed a “second communication system [with] pilot symbols that are denser than those in the first communication system” by describing mobile stations that used denser pilot patterns in the time and/or frequency dimension. Nystrom disclosed that wireless systems that serviced faster-moving user equipment (which could be “mobile stations,” *see* Nystrom at [0029]) needed to receive “frequent pilots” because of the mobile stations’ quickly changing channel conditions. *Id.* Nystrom disclosed example user equipment 30A and 30B that required different pilot densities based on their speed and/or distance from an access point 20. *Id.* “User equipment 30A [which] [wa]s located at a relatively large distance from the access point 20” had a speed 32A (illustrated as an arrow) that was small. *Id.* “User equipment 30[B] [wa]s located closer to the access point 20, but ha[d] a high speed 32B (also illustrated as an arrow).” *Id.* at Fig. 1.

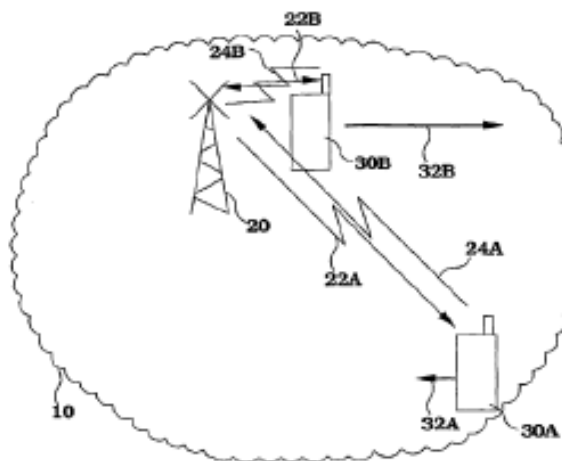
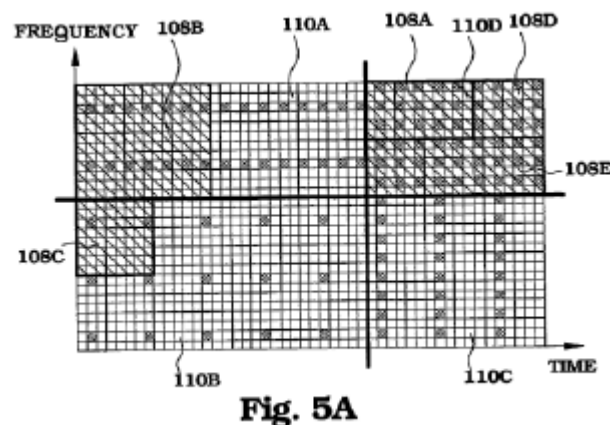


Fig. 1

158. Nystrom taught that user equipment 30B needed to receive pilots more frequently in the time dimension due to its rapidly changing channel conditions, which resulted from its speed. Nystrom at [0029] (“User equipment 30b ... has a high speed 32B (also illustrated as an arrow)... [T]he radio conditions are probably changing rapidly in time, whereby frequent pilots in time dimension are required.”). User equipment 30A might also need to receive pilots more frequently in the frequency dimension depending on the conditions of the subcarriers over which it was communicating. *Id.* (“The user equipment 30A may have a relatively high need for repetitive pilots in the frequency dimension, since the propagation conditions for the different carriers may differ considerably over the bandwidth in case of multi-path propagation with large delay spread.”).

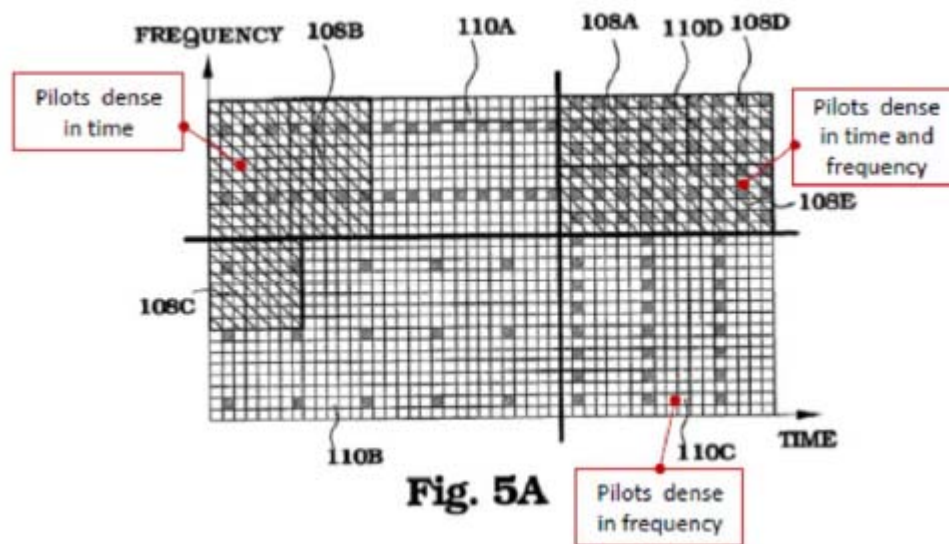
159. Nystrom explained a “basic setup” for increasing the pilot symbol density in a manner appropriate for differently situated mobile stations, including

higher-mobility mobile stations. In Figure 5A, the radio resource space allocated to multiple different users was depicted (separated by the thick lines), and the different parts of the resource space used different pilot density patterns. *Id.* at [0039] (The radio resource was shown during a certain time period with certain frequencies. “The resolution in frequency dimension is one OFDM carrier and in time it is one OFDM symbol. Pilot symbols are as above depicted with hatched boxes.”).



160. The radio resource space was divided into four parts, labeled 110A-D in Figure 5A. Resource space part 110A had a dense pilot pattern in time, with pilots spaced at every second OFDM symbol for certain subcarriers. The pilot density of resource space part 110B was diluted as compared to the other resource space parts, with pilots spread farther apart in both time and frequency. Resource space part 110C also had a dense pilot pattern in the frequency dimension, with pilots used in every other subcarrier, but spaced farther apart in the time dimension. Lastly, resource space part 110D had a denser pilot structure in both time and frequency dimensions.

Id. at [0041]. These various patterns were used to accommodate the user equipment's specific conditions. "[W]henver a certain user ha[d] certain demands, the user [wa]s assigned resources in the resource space where pilots with the appropriate density [could] be utilized for channel estimation." *Id.* at [0042]. The following annotated version of Figure 5A shows these different parts of the resource space, with higher-density parts labeled.



161. Nystrom described various example scenarios in which user equipment was allocated resource space within these parts according to its conditions. User equipment with radio conditions demanding a high density of pilots in both dimensions was allocated resource subspace 108A within part 110D in Fig. 5A. "A second user, only having need for dense pilot in the time dimension [wa]s allocated resources in a resource sub-space 108B in part 110A. Finally, two more users, having high demands on pilot density [we]re given resources in two sub-spaces 108D and

108E, respectively in part 110D.” *Id.* at [0043]. The resource space used depended on the individual needs of the user equipment, which could be dependent on “certain fast varying channel or Doppler conditions.” *Id.*

162. A POSA would have been motivated to incorporate Nystrom’s teaching of using denser pilot symbols into Talukdar because Nystrom disclosed that this better compensated for the effects of Doppler shift and fading experienced by faster-moving remote units (such as those in Talukdar’s wireless system) and thus provided a teaching, suggestion, or motivation to apply this technique in the context of Talukdar’s system. Nystrom taught that mobile stations traveling at higher speeds experienced higher Doppler shift and fading in time and/or frequency. Nystrom at [0004]. Nystrom further taught that increasing the density of pilot symbols for these mobile stations allowed the mobile stations to better estimate their channel conditions and reduce the effects of Doppler shift and fading. Nystrom at [0037], [0042]-[0043]. Indeed, it was well-known that increasing pilot density improved performance in wireless communications by enhancing the ability of mobile stations to perform channel estimation. *E.g.*, Nystrom at [0003] (“A shorter time interval between successive pilot data gives a more accurate channel estimation”); Lee at 1:22-27 (“In the design of pilot assignment, it is necessary to use a sufficiently large number of pilot symbols for the sake of preventing a deterioration of reception performance caused by a channel variation”), 1:37-40 (“The distance between

pilot symbols must be quite small in designing pilot symbols in the worst environment, or when using non-optimal channel estimation filters having a lower complexity.”); Ode at 12:63-13:2 (“[T]he number of pilot symbols is increased in frames FH used by mobile stations moving at high speed, and the interval between pilot symbols becomes narrow, so the precision for measuring the pilot receiving power and the precision for channel estimation is improved even when the mobile station is moving at high speed.”); U.S. Patent No. 8,462,611 (Ex. 1021, “Ma”) at 6:59-65 (“In some embodiments,...the channel is updated more frequently both in the frequency direction and in the time direction in order to obtain the correct channel responses To deal with high frequency and time dispersions, a denser pilot grid is preferably employed.”).

163. Talukdar’s system included (and it would have been obvious for Talukdar’s system to have included) a mobile 802.16(m) remote unit that was faster-moving than a fixed or slower-moving 802.16(e) remote unit. Talukdar at [0024], [0027]; *supra* ¶ 126. This faster-moving remote unit would have experienced Doppler shift and fading when moving at higher speeds. A POSA would have recognized that increasing the density of pilot symbols for these mobile remote units (each a “communication system”) would have yielded the benefits of enhancing the mobile remote units’ ability to perform channel estimation (and thus reducing the effects of Doppler shift and fading). A POSA would have had a reasonable

expectation of success in making this combination because Nystrom identified an example implementation that a POSA would have been able to execute in the context of Talukdar—by using a less dense, “diluted” pilot pattern for a fixed or slower-moving remote unit (*e.g.*, a “first communication system”), but a “a pilot pattern[] having a dense occurrence in [the] time dimension (every second OFDM symbol at certain carriers)” (“pilot symbols that are denser”) for a faster-moving mobile remote unit (a “second communication system”). A POSA could have used pilot density patterns as shown in Figure 5A of Nystrom, where a pattern similar to that used in resource space parts 110A, 110C, and 110D could be used for faster-moving 802.16(m) remote units. As a specific example, a base unit in Talukdar could have sent a faster-moving 802.16(m) remote unit a pilot at every other symbol within the time dimension. This implementation would have been within a POSA’s level of ordinary skill.

164. A POSA would also have been motivated to combine Nystrom’s pilot density teachings with Talukdar with a reasonable expectation of success because Talukdar specifically taught that a hybrid frame could be more efficiently implemented for 802.16(m) remote units by adjusting pilot density. Talukdar at [0064] (“**It [wa]s possible to define a new pilot/subchannel/control structure in the 802.16(m) zones, which [wa]s more efficient than the 802.16(e) structures....** Also, in the 802.16(m) downlink and uplink zones (second protocol regions on

downlink and uplink) the permutations, pilot patterns and **pilot density**...[could] be the same as or **different from those defined in 802.16(e).**”). “In general, the structures of the 802.16(m) region (sub-channel and pilot structures) [could] be different from those of the 802.16(e) regions,” *id.* at [0029], which further indicates the techniques of Nystrom could be combined with Talukdar.

165. A POSA would have been motivated to combine Nystrom’s teachings with Talukdar because these disclosed similar systems that used OFDM symbols, and that used different symbols in the time dimension of the same resource space for different systems in one OFDM transmission scheme. Talukdar disclosed (at [0026]) that “the communication system utilizes OFDMA In OFDM based systems, the radio resources include OFDM symbols” and (at [0051]) that “FIG. 7 is a hybrid frame 700, ... having equal size sub-blocks de-signed to serve both 802.16(e) and 802.16(m) data traffic in the same 5 msec interval.” Nystrom similarly disclosed (at [0027]) “OFDM ... systems ... for exemplifying the present invention” and (at [0041]) that “[t]he entire radio resource space illustrated is divided into four rectangular parts, 110A-D. ... The resource space part 110B has a very diluted pilot pattern ... [while] resource space part 110D has a very dense pilot structure in both dimensions, comprising a pilot symbol in every fourth resource unit.” *See also id.* at [0043] (“A first user, having radio conditions demanding a high density of pi-lots in both dimensions is allocated to the resource sub-space 108A within the part 110D.

... A third user with very favourable radio conditions is allocated to a resource sub-space 108C in part 110B.”).

166. Additionally, modifying Talukdar to incorporate Nystrom’s pilot density teachings would have combined prior art elements (the use of a denser pilot symbol pattern, as taught by Nystrom, for faster-moving mobile stations/remote units, as taught by Nystrom and Talukdar) according to known methods (by inserting pilots more frequently in the time dimension in the regions configured for the faster-moving mobile station/remote unit, as taught by Nystrom), and would have yielded the predictable results of enhancing the ability of a faster-moving 802.16(m) remote unit (a “second communication system”) to perform channel estimation. This result was predictable in view of Nystrom’s teachings (at, *e.g.*, [0037], [0042]-[0043]) and the general knowledge regarding pilot density in the art. Further, the proposed modification would have been the use of a known technique (Nystrom’s disclosed method of using symbols with different pilot density patterns for different communication systems) to improve a similar method (using symbols with different formats for different communication systems, as taught by Talukdar) in the same way (by enhancing the faster-moving system’s channel estimation capabilities, as taught by Nystrom).

XII. SECONDARY CONSIDERATIONS

167. At this time, after review of the documents and materials cited herein, such as the prosecution history of the '096 Patent, I have found no evidence of secondary considerations or objective factors of non-obviousness, and it is my opinion that claims 1-4 and 6-8 of the '096 Patent are obvious over the prior art. And to the extent UNM alleges secondary considerations in this proceeding, it is my opinion that they would not outweigh the strong evidence of obviousness of the '096 Patent Challenged Claims, as set forth herein. I have been informed that if UNM presents in this proceeding evidence of objective factors that it argues support a finding of non-obviousness, I may be asked to review such evidence and to formulate an opinion and reserve the right to address any such evidence and/or arguments that UNM may raise in this regard.

XIII. CONCLUSION

168. In summary, I have concluded that each limitation of the Challenged Claims is invalid as disclosed and/or obvious under 35 U.S.C. § 103 in light of the prior art references as discussed above and the knowledge of one of ordinary skill in the art, as described in this declaration.

169. Furthermore, I have used my background and experience in forming my opinions that claims 1-4 and 6-8 are unpatentable as obvious over the prior art.

170. To the extent it is argued that any further disclosure is required for a limitation in claims 1-4 and 6-8 than I have identified above, a POSA would have found that limitation obvious to include based on the same disclosure and analysis I have identified above.

171. I reserve the right to supplement my opinions in the future to respond to any arguments that UNM or its expert(s) may raise, and to take into account new information as it becomes available to me.

I declare under penalty of perjury that the foregoing is true and correct. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed this 21st day of March, 2021.



Dr. Sumit Roy, Ph.D

APPENDIX A

Sumit Roy, Fellow IEEE

Curriculum Vitae

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Dept. of Electrical Engineering	FAX: (206) 543-3842
Univ. of Washington, Box 352500	email: roy@ee.washington.edu
Seattle, WA 98195	http://www.ee.washington.edu/faculty

EDUCATION

<i>Degree</i>	<i>Institution</i>	<i>Year</i>
Ph.D. Electrical Engineering	University of California, Santa Barbara	1988
M. A. Statistics & Appl. Probability	University of California, Santa Barbara	1988
M. S. Electrical Engineering	University of California, Santa Barbara	1985
B. Tech. Electrical Engineering	Indian Institute of Technology, Kanpur	1983

PERSONAL

Date & Place of Birth: Nov. 17, 1960; Calcutta, India.

Married, 1 child; U. S. Citizen.

EMPLOYMENT

9/14 -9/19	Integrated Systems Term Professorship , ECE & CoE
9/02 -	Prof. (with tenure), Dept. of Electrical Engineering Univ. of Washington, Seattle
	<i>Assoc. Chair for Research</i> , Sep. 2005-07, Sep. 08 - 11
9/98 - 9/02	Assoc. Prof. (with tenure), Dept. of Electrical Engineering Univ. of Washington, Seattle
1/95 - 8/98	Assoc. Professor (with tenure), Division of Engineering University of Texas at San Antonio
7/88 - 12/94	Asst. Professor, Dept. of Electrical Engineering University of Pennsylvania
10/83 - 5/ 88	Research Assistant, Dept. of Electrical & Computer Engineering University of California at Santa Barbara
	M. S. Thesis: "Target Signature Evaluation Based on Radar Turntable Data"
	Ph. D. Diss.: "Estimation Strategies for a Network of Distributed Sensors"

OTHER SIGNIFICANT PROFESSIONAL EXPERIENCE

Dec. 2014-Feb. 2015	Visiting Research Scientist, Microsoft Research, Bangalore, India
Aug-Dec. 2014	Visiting Faculty and External Consultant; IIIT-Delhi, India
Sep. 2001 - Dec. 2003	Sr. Staff Researcher, Wireless Technology, Intel Labs, Hillsboro, OR
Summer 1996	Visiting Member of Technical Staff, Center for Wireless Communications National Univ. of Singapore
Summer 1989	Visiting Researcher, GE Corporate R & D Center, Schenectady, NY

RESEARCH INTERESTS

• Analysis, Evaluation & Prototyping of Wireless Communication Systems/Networks • Emerging Networks:
5G beyond (mobile cellular and WiFi), Internet of Things, Vehicular Networks

PROFESSIONAL HONORS & RECOGNITIONS

Fellow, IEEE	Communications Society (2007)
Science Foundation of Ireland	E.T.S. Walton Visiting Faculty Award (Feb.-July 2008)
Royal Acad. Engineering (UK)	Distinguished Visiting Fellow (summer 2011)
Best Student Paper Award	L. Bai, S. Roy and M. Rangaswamy, "Compressive Radar Clutter Subspace Estimation using Dictionary Learning," <i>IEEE Radarcon</i> , Ottawa, CA, May 2013.
Best Paper Award	R. Patidar, S. Roy, T. R. Henderson and A. Chandramohan "Link-to-System Mapping for ns-3 Wi-Fi OFDM Error Models," <i>ns-3 Workshop</i> , Jun 2017
Integrated Systems Professor	U Washington, 2013 -
Distinguished Lecturer	IEEE Communications Society, 2014-15, 2017-18
Visiting Erskine Fellow	Univ. of Canterbury, Christchurch, New Zealand (2015)
High-end Foreign Expert	Shanghai JiaoTung University (1 month/year, 2014 - 16)
Member, Executive Comm. (elected)	National Spectrum Consortium, 2018-19

PROFESSIONAL ACTIVITIES

IEEE ComSoc Activities	Member of Technical Comm. on Cognitive Radios and Commn. Theory Numerous Technical Program Comm. Memberships (Globecom, ICC)
Proposal Reviewer	NSF, U.S. Dept. of Defense, Hong Kong Research Council IEEE Trans. Communications, Wireless Commn. J. Select. Areas in Commn., Vehicular Tech.; Trans. Networking
Editorial Duties	IEEE Trans. Communications 1996 - 99, 2009-2012 IEEE JSAC Wireless/Trans. Wireless Commn. 1999 - 2003 Wireless Communications & Mobile Computing J. (Wiley), 2003-08 IEEE Trans. Mobile Comput., 2006-07 IEEE Trans. Intelligent Transp. Syst., 2006 - 2011 IEEE Trans. Smart Grid, 2010-2012 IEEE Trans. Circuits & Syst. II, 2014-2015 Guest Editor, J. Sel. Areas Commn. Spl. Series on Smart Grid, July 2014

OTHER RECOGNITIONS

- University of California Regents Fellowship (1983-84)
- University of California Dissertation Fellowship (1987-88)
- External Dissertation Reviewer (McGill Univ., Montreal; National Univ. of Singapore; U. Victoria; SIIT, Bangkok)
- Referee for Promotion Cases (CMU, U. Minnesota, North Carolina State U., U. Arizona, U. Utah, Iowa State, U. Texas Dallas)

TEACHING

U. Pennsylvania	Commun. Systems (Theory and Lab)	3/4th Yr. Undergrad
	Advanced Digital Signal Processing	2nd Yr. Grad.
	Digital Communications	2nd Yr. Grad.
	Radar Systems	2nd Yr. Grad.
U. Texas San Antonio	Found. of Commun. Theory	1st Yr. Grad.
	Random Signal Analysis	1st Yr. Grad.
	Linear Systems	3rd Yr. Undergrad
	Mobile Communications	2nd Yr. Grad.
U. Washington	Wireless Networks	2nd Yr. Grad.
	Random Processes	1st Yr. Grad.
	Stochastic Process	2nd Yr. Grad
	Digital Communications	2nd Yr. Grad.
	Capstone Design in Communications Systems	4th Yr. Undergrad
	Computer Networks	4th Yr. Undergrad
	Signals & Systems	3rd Yr. Undergrad

PATENTS

1. "A System to Cancel Ghosts in NTSC Television Transmission", (with J. Yang and C. B. Patel) U.S. Patent No. 5361102, Nov. 1994.
2. "Improved Deghosting for Multipath Transmission of TV Signals," (with J. Yang and C. B. Patel), U.S. Patent No. 5341177, Aug. 1994.
3. "Time Frequency Coding in a Multi-Band UWB System," (with J. R. Foerster and V.S. Somayazulu, Intel Corpn.), U.S. Patent No. 7613223, Nov. 2009.
4. "Apparatus and Associated Methods to Introduce Diversity in a MultiCarrier Channel," (with L. Shao and S. Sandhu), U.S. Patent No. 7782970, Aug. 2010; U.S. Patent 8289836, Oct. 2012.
5. "Achieving Quality of Service in a Wireless Local Area Network," (with R. Gupta), U.S. Patent No. 8144613, Mar. 2012.
6. "Adaptive Uplink Protocol" (with Y-C. Ko), U.S. Patent No. 8223664, July 2012.
7. "Method, Apparatus and Computer Program Product for Quiet Period Management in Wireless Networks for Co-existence," (with Chittabrata Ghosh and Klaus Doppler), U.S. Patent No. 0070605, Mar. 2013.
8. "Efficient Broadcasting via Random Linear Combining," (with H. Liu and M. Hamed Firooz) U.S. Patent No. 8953612, Feb. 2015.
9. "Sensing and/or Transmission Coverage Adaptation Using Interference Information," (with H. Ali Safavi-Naeni, Chittabrata Ghosh, Klaus Doppler and Sayantan Chowdhury), U.S. Patent No. 9510369, Nov. 2016.
10. "Enhanced Communication Infrastructure for Hierarchical Intelligent Power Distribution Grid," (with E. Boardman and S. S. Venkata), US Patent 9641026, May 2017.

RESEARCH SUPERVISION

• Ph.D. Dissertations Completed

J. Yang	“Signal Processing for Multi-user Communications” (UPenn, May 1993)
J. S. Stadler	“Contributions to the Theory and Practice of Importance Sampling” (UPenn, July 1993)
P. S. Kumar	“Interference Cancellation with Applications to Mobile Radio and Magnetic Recording Systems” (UPenn, Sep. 1993)
B. Jelicic	“Channel Coding for Non Additive White Gaussian Noise Environments” (UPenn, July 1995)
M. P. Wylie	“Contributions to Spatio-temporal Processing” (UPenn, Aug. 1995)
L. A. Baccala	“Data Unaided Identification of Linear Communication Channels by Time-domain Methods” (UPenn, Dec. 1995)
A. Abouzeid	“Stochastic Models of Congestion Control in Heterogeneous Next Generation Packet Networks” (UW, July 2001)
C. Li	“Parameter Estimation in OFDM Systems for High Rate Wireless Communication” (UW, Sep. 2002)
H. Yan	“Parameter Estimation and Receiver Design for Overlay Communication Systems” (UW, Nov. 2002)
J. Zhu	“Layer 2 Performance Analysis and Improvement for Wireless Heterogeneous Networks” (UW, Sep. 2004)
L. Shao	“Code Design for MIMO-OFDM/OFDMA Systems” (UW, Oct. 2004)
R. Iyappan	“Joint PHY-MAC Optimization for Energy Constrained Wireless Networks” (UW, Nov. 2006)
H. Ma	“Adaptive Network Management for 802.11 Wireless LANs” (UW, Sep. 08)
R. Gupta	“PHY/MAC Cooperation Strategies for High Density Wireless Networks” (UW, Dec. 2009)
L. Luo	“Modeling and Optimization of Dynamic Spectrum Access” (UW, Dec. 2010)
F. Ye	“System Optimization and Protocol Design for Vehicular Networks” (UW, Mar. 2011)
Mohammad Hamed Firooz	“Application of Network Coding and Compressed Sensing in Networking,” (UW, May 2013)
Linda Bai	“Compressive Detection & Estimation with Applications to Cognitive Radio/Relay” (UW, June 2013)
C. S. Boyer	“RFID: A Communication System Perspective,” (UW, Mar. 2014).
A. Al-mutairi	“Distributed Multiple Access for OFDMA Femto-cells,” (UW, Jun. 2014)
Farzad Hesar	“Spectrum Sharing in White Spaces” (UW, Apr. 2015)
Yue Yang	“Contributions to Smart Metering: Protocol Design & Data Analytics,” (UW, Jun. 2015)
S. Ashrafi	“Random Access Communications over Multi-packet Reception Channels” (UW, Jun 2016)
H.-Ali Safavi-Naeini	“Heterogeneous Coexistence of Wireless Systems” (UW, July 2016)
Xuhang Ying (co supervisor)	“Crowdsensing & Resource Allocation in Shared Spectrum” (UW, Ph.D. Jun. 2018)

• **M. S. Theses Completed**

L. I. Ou	“Fault Detection Algorithms” (UPenn, Dec. 1990)
K. Gang	“Real-time Adaptive Nulling in Presence of Array Imperfections” (UPenn, May 1991)
H.-Y. Wang	“Performance Analysis of Aloha Multiple Access with Multi-user Detection” (U. Texas, Sep. 1998)
M. Albuquerque	“Effects of Asymmetry, Link Losses and Packet Sizing on Performance of a TCP Reno Connection” (UW, Mar. 2001)
P. Lu	“Performance Analysis of Bluetooth MAC with Priority Scheduling,” (UW, Mar. 2002)
M. Duke	“Directional Antenna Media Access Protocols in a Multipath Environment,” (UW, Dec. 2003)
D. Daoura	“Traffic Modelling and Prediction for Spatial Time Division Multiple Access Bandwidth-on-Demand Protocol,” (UW, Dec. 2003)
R. Iyappan	“Acquisition of DS Ultrawideband Signals,” (UW, Dec. 2003)
A. Margolis	“Modelling Throughput and Starvation in 802.11 Wireless Networks with Multiple Flows,” (UW, Aug. 2006)
T. Shing	“CCA and Time Fair Algorithms for Joint Adaptation in HD WLANs,” (UW, Aug. 2007)
I. Purushothaman	“Fast Hand-off in 802.11 Networks for Voice Over WLAN” (UW, Aug. 2008)
T. Bosaw	“An Improved 802.11b Interference Model for Network Simulation” (UW, June 2010)
B. Cizdziel	“Coexistence of Radar Systems & WiFi Networks” (UW, May 2015)
Jarrett Gaddy	“Layer 2.5 Wireless Network Coding to Improve .11 Network Efficiency” (UW, May 2016)
A. Ashok	“Contributions to Radar-WiFi Spectrum Sharing” (UW, May 2017)
E. Ding	“Optimized Beam Training for mmWave Communications” (UW, June 2018)
A. Jadon	“UAV Networking: Design Considerations” (UW, July 2018).

OTHER RESEARCH PERSONNEL

D.-S. Chen	Visiting Research Scholar (U. Pennsylvania, 1993-94)
Dr. Y. Song	Post-doctoral Fellow (U. Texas, 1997-98)
Dr. S. Zhang	Visiting Scholar (UW, 2001-02)
Dr. C.H. Cho	Visiting Scholar (UW, 2001-02)
Dr. S.S. Lee	Visiting Scholar (UW, 2002-03)
Dr. R. Vijaykumar	Post-doctoral Fellow (UW, 2004-06)
H. Eui-Seok	Visiting Scientist (UW 2004-05)
J. Choi	Visiting Scientist (UW 2004-05)
Dr. Y-C Ko	Visiting Scholar (UW 2006-08)
Dr. S-Y. Shin	Visiting Scholar (UW 2006-07)
Dr. C. Ghosh	Post-doctoral Fellow (2009-11)
Dr. S. Kim	Visiting Scholar (2011-12)
J. Feng	Visiting Ph.D student (2014-2015)
Y. Yin	Visiting Ph.D student (2014 - 2015)
A. Tang	Visiting Ph.D Student (2015-16)
Dr. Morteza Mehrnoush	Post-Doctoral Scholar (2016-2018)
F. Hao	Visiting Ph.D. student (2016-17)
Dr. Y. Gao	Visiting Asst. Prof. (2017-18)
Dr. L. Lanante	Visiting Asst. Prof. (2018-19)
W. Jiang	Visiting Ph.D. Student (2018-20)
Y. Sun	Visiting Ph.D. Student (2018-19)
P. Jimenez-Mateo	Visiting Ph.D. Student (2019)
S. Gopal	Visiting Ph.D. Student (2019-20)
D. Magrin	Visiting Ph.D. Student (2020)

PRESENT RESEARCH SUPERVISION

Collin Brady	“Contributions to LTE Public Safety Communications Design” (Ph.D. 2021, anticipated)
S. Jin	“Networked Radar” (Ph.D. 2021, anticipated)
X. Gao	“Radar-Camera Sensor Fusion for Automated Driving” (Ph.D. 2022, anticipated)
L. Zhang	“Optimization of 5G Edge Networks” (Ph.D. 2022, anticipated)
S. Nayak	“Low Latency 5G Communications” (Ph.D. 2023, anticipated)
H. Yin	“Resource Allocation in 5G” (Ph.D. 2023, anticipated)

FUNDED RESEARCH

ARO DAAL03-87-K-10119

Dates: 12/88-12/90

AT&T

Dates: 9/1/90-8/30/91

NSF NCR 89-14431

Dates: 9/15/90-2/28/94

SAMSUNG ELEC., PRINCETON, N. J.

Dates: 9/1/91- 12/31/92

NSF CDA 90-22530

Dates: 1/1/91-12/31/94

NSF REU

Dates: 7/1/91-6/30/92

NSF REU

Dates: 7/1/92-6/30/93

NSF REU

Dates: 7/1/93-6/30/94

ESEERCO, New York

Dates: 5/1/93-3/1/94

SHARP ELECT., MAHWAH, N. J.

Dates: 01/01/94 - 12/01/94

ARO DAAH04-96-1-0088

Dates: 06/01/96 - 05/30/99

NSF CDA 9613727

Dates: 09/01/97 - 12/31/99

“Applications of Subsurface Radar for Mine Detection”

Amount: \$251,000 [Co-P.I.]

“Signal Processing Approaches for High-speed Communication over Digital Subscriber Lines”

Amount: \$50,000 [Co-P.I.]

“Blind Algorithms and Other Advanced Techniques For Channel Equalization”

Amount: \$211,000 [P.I.]

“Advanced TV: Analysis, Simulation & Design”

Amount: \$ 87,800 [P.I.]

“CISE Research Instrumentation”

Amount: \$118,000 [Co-P.I.]

“Simulation of Advanced Equalization Techniques for High-speed Data Transmission”

Amount: \$5,000 [P.I.]

“Simulation of Trellis Coded Modulation Systems for Advanced TV Transmission”

Amount: \$5,000 [P.I.]

“Simulation of Multi-user Receivers for Mobile Radio”

Amount: \$5,000 [P.I.]

“Improved Dielectric Fluid Leak Detection”

Amount: \$68,000 [co-P.I.]

“Advanced TV Channel Codec System Design”

Amount: \$ 63,000 [P.I.]

“Design Issues for Advanced Digital Wireless Networks”

Amount: \$ 170,667 [P.I.]

“Broadband Wireless Networks: Joint U.S.-Mexico Research”

Amount: \$ 15,000 [P.I.]

FUNDED RESEARCH (contd.)

ARO AASERT DAAG 55-97-1-0339

Dates: 07/01/97 - 06/30/99

“Simulation, Computation & Software for Advanced Digital Wireless Networks”

Amount: \$38,100 [P.I.]

TEXAS HIGHER EDN. BOARD

Dates: 01/01/98 - 12/30/99

“Design and Evaluation of Wireless Networking Protocols”

Amount: \$160,677 [co-P.I.]

DoD URISP/AFOSR F49620-96-1-0472

Dates: 09/15/96 - 09/14/2001

“Telecommunication Networks for Mobile & Distributed Communications and Computing”

Amount: \$ 2,000,000 [P.I.]

(awarded at UTexas, UW subcontract approx. \$237, 673)

NSF/ITR CCR 00-86032

Dates: 9/01/00 -8/31/05

“Heterogeneous System Integration in System-on-Chip Designs”

Amount: \$4,000,000 [co-P.I, share \$283,440]

NSF SERG CCR 00-90012

Dates: 09/15/00-09/15/02

“Application of Communication-Theoretic Principles to Nano Interconnect Research”

Amount: \$100,00 [co-P.I.]

ARMY/CECOM

Dates: 06/01/01-06/31/04

“Wideband On-the-Move Satellite Communications”

Amount: \$312,273 [P.I.]

Boeing Co.

Dates: 03/30/03 - 12/31/03

“Directional Antenna Multiple Access Protocols”

Amount: \$50,000 [P.I.]

NSF ITR ANI 0325014

Dates: 09/15/03-08/31/07

“RESCUENET: Embedded In-Building Sensor Network to Assist Disaster Rescue”

Amount: \$ 404,687 [co-P.I., U.W. subcontract]

INTEL Corpn.

Dates: 01/15/04-12/31/07

“Next Generation Wireless MESH Networks: PHY/MAC Based Optimization”

Amount: \$ 303,000 [P.I.]

BOEING Co.

Dates: 05/15/2004-09/30/2004

“PHY/MAC Optimization for Connectionless Networking,”

Amount: \$ 20,000 [P.I.]

FORD Co.

Dates: 1/1/2005 - 12/31/2005

“New Wireless Interface Standards for Vehicle Infotronics,”

Amount: \$34,000 [P.I.]

LOCKHEED MARTIN Corpn.

Dates: 5/1/05-5/30/2007

“Network Centric Automatic Target Recognition,”

Amount: \$80,000

T-MOBILE Co.

Dates: 1/1/06- 7/30/07

“Mesh-Sim: Developing a Simulation Tool for Multi-radio Broadband MESH Networks,” [P.I.]

Amount: \$ 79,547

NSF CCLI

Dates: 9/1/05-8/31/07

“A Computing Lab for Integrated Teaching Systems Education,”

Amount \$10K [Co-P.I. portion; total= \$160K]

NSF CRI

Dates: 6/15/06-6/13/10

“Developing Next-Generation Open Source Network Simulator,”

Amount \$97, 431 [Co-P.I. portion; total UW=\$503 K]

FUNDED RESEARCH (contd.)

Boeing Phantom Works

Dates: 1/1/07-12/31/07

NASA

Dates: 9/1/06-8/31/09

“Adaptive MIMO Transceivers: PHY/MAC Design Considerations for Cognitive, Tactical Radio Networks”

Amount \$110,000 [P.I.]

“A Smart Sensor Web for Ocean Observation: System Design, Modeling and Optimization,”

Amount \$329,640 [Co-P.I. portion; total = \$1,481,200]

Ford Corpn.

Dates: 3/1/07-2/28/10

OASD-NI

Dates: 01/01/08-12/31/08

“Broadband Wireless Network Assisted Collaborative Vehicle Infotainment”

Amount \$120,000 [P.I.]

“Hybrid C2 Structures: Between Hierarchies and Edge Organizations

Amount \$114,800 [co-P.I.]

NSF ECS 0801997

Dates: 6/15/08-6/15/11

“Design and Prototyping for Network Convergence”

Amount \$150,200 [co-P.I., total=\$395K]

MIT Lincoln Labs

Dates: 04/01/08 - 06/01/10

“Wireless Networking Research”

Amount \$81, 980 [P.I.]

NSF ECS 0824265

Dates: 9/15/08-9/15/12

“Realizing the Internet of Things via RFID Sensor Nets”

Amount \$ 500,000 [P.I.]

DHS Center of Excellence

Dates: 10/1/08- 07/30/12

“Collaborative E-M Imaging and Network Integration for Detection in Complex Environments ”

Amount \$ 238,046 [P.I.]

AFOSR

Dates: 04/15/2009 - 03/31/2012

“Cross Layer Networking for Airborne Platforms: Integrating Sensing Communications and Access Protocols ”

Amount \$ 290,532 [P.I.]

DoE ISD 3481P1034

Dates: 9/15/2011 - 03/15/2013

“Distributed Energy Resource Management System”

Amount \$ 240,000 [P.I.]

NSF CRI CNS 1205725

Dates: 05/01/2012- 04/30/2015

“Ocean-TUNE: A Community Ocean Testbed for Underwater Wireless Networks,”

Amount \$690,000 [P.I.]

UW Commercialization Gap Fund

Dates: 9/30/2012-9/30-2013

“Broadband Access in TV White Space: System Prototyping for Proof-of-Concept
\$ 22,000

Nokia Research Center

Dates: Multiple Gifts (2012 -18)

“Research in Wireless Networking”

Amount \$ 180,000 [P.I.]

DARPA DSO

Dates: 04/1/2012 - 04/30/2014

“Knowledge Enhanced Compressive Measurement”

Amount \$ 150,000 [P.I.]

NSF EAGER CNS 1244643

Dates: 08/15/2012-08/14/2015

“Achieving Realism in ns-3 Wireless Network Simulation”

Amount \$ 200,000 [P.I.]

FUNDED RESEARCH (contd.)

NSF AST (EARS) 1443923
Dates: 09/01/2014- 08/31/2018

“Measurement-augmented Spectrum Databases for White Spaces”
Amount \$ 345,000 [P.I.]

AFRL CERFER FA8650-14-D-1722
Dates:10/15/2014-05/14/2019

“Networked Cognitive Radar: Architectures & Optimizn.”
Amount \$ 282,000 [P.I.]

NSF SAVI 1546950
Dates:09/01/2015-08/31/2018

“iCON: Institute for Cognitive Networking”
Amount \$ 133,480 [P.I.]

NSF EAGR 1634194
Dates: 05/01/2016-04/30/2018

“A Wide Area, Persistent Spectrum Monitoring System”
Amount \$ 149,495 [P.I.]

Microsoft Azure for Research Awards
Dates: 05/23/2017- 05/23/2018

“CityScape: State-of-Art Metro Area Radio Spectrum Observato
Amount \$20,000

WA JCATI
Dates: 07/01/2016-07/31/2017

“Advancing State-of-the-Art UAS Networking and Communicatio
Amount \$ 97, 324 [P.I.]

NSF CNS NeTS 1617153
Dates: 10/1/2016-09/30/2020

“Can LTE & WiFi Live HappilyEver After?”
Amount \$147,000 [co-P.I. portion]

NSF EARS 1643011
Dates: 09/15/2016-09/14/2021

“Mitigating Ultra Faint RFI to Enable Radio Cosmology”
Amount \$ 376,534 [co-P.I. portion]

Nat. Spectrum Consort.
Dates: 09/01/2016-08/31/2018

“Development & Validation of Accurate Clutter Models for AWS
Amount \$ 589,309 [co-P.I.]

Nat. Inst. Standards Tech. PSIAP
Dates:06/01/2017-09/15/2020
MIT Lincoln Labs
Dates: 04/01/2018 - 09/30/2021

“Modeling, Simulation and Performance Evaluation for Future P
Amount \$ 1,000,000 [P. I.]
“Wireless Networking Research”
Amount \$110,694 [P.I.]

NSF ICE-T 1836725
Dates: 09/16/2018 - 09/15/2021

“Performance Evaluation of Advanced Wireless Networks Edge In
Amount \$346,364 [P.I.]

Cisco Gift
Dates: 03/01/2018 -

“ Performance Evaluation of 802.11ax”
Amount \$50,000

Airbus
Dates 02/01/2019-09/15/2019

“Comm Link Availability Modeling for UAS Risk Assessment”
Amount \$ 64,770

Intel Univ. Research Gift
Dates: 04/15/2019 - 04/15/2022

“mmWave Networking: Design Considerations for 5G ”
Amount \$90,000 [P.I.]

NSF CCRI ENS
Dates 10/01/2020-09/30/2023

“ns-3 Network Simulation for Next-G Wireless”
Amount \$ 962,657

Mathworks Gift
Dates: 09/01/2020 -

“WLAN System Simulation”
Amount \$35,000

Facebook Conn. Gift
Dates: 09/01/2020 -

“LTE modeling in ns-3 ”
Amount \$55,000

FUNDED RESEARCH (contd.)

Nat. Inst. Standards Tech. “Cross-Layer Modeling & Performance Evaluation
of 5G Public Safety based on NR C-V2X Sidelink”
Dates: 10/01/2020 -09/31/2022 Amount \$500,000

ARCHIVAL JOURNAL PUBLICATIONS

1. H. R. Hashemipour, S. Roy and A. J. Laub, “Decentralized Structures for Parallel Kalman Filtering,” *IEEE Trans. Aut. Contr.*, vol. AC-32, Jan. 1988, pp. 88-94.
2. J. J. Shynk and S. Roy, “Convergence Properties and Stationary Points of a Perceptron Learning Algorithm,” *Proc. IEEE* (Spl. Issue on Neural Networks II), Oct. 1990, pp. 1599-1604. [reprinted in *Neural Networks: Theoretical Foundations and Analysis*, IEEE Press, ed. C. L. Lau, 1991].
3. S. Roy and J. J. Shynk, “Analysis of the Momentum LMS Algorithm,” *IEEE Trans. Acoust. Speech Sig. Proc.*, vol. ASSP-32, Dec. 1990, pp. 2088-2098.
4. S. Roy, R. H. Hashemi and A. J. Laub, “Square-root Parallel Kalman Filtering using Reduced Order Local Filters,” *IEEE Trans. Aerosp. Elect. Syst.*, vol. 27, Mar. 1991, pp. 276-290.
5. S. Roy and R. A. Iltis, “Decentralized Linear Estimation in Correlated Measurement Noise,” *IEEE Trans. Aerosp. Elect. Syst.*, vol. 27, Nov. 1991, pp. 939-941.
6. T. Ozdemir, S. Roy and R. S. Berkowitz, “Imaging of Shallow Subsurface Objects: An Experimental Investigation,” *IEEE Trans. Geosci. Rem. Sen.*, May 1992, pp. 472-481.
7. S. A. Raghavan and S. Roy, “Simple Sequence Detector for Coded (1-D) Partial Response Channel,” *Elect. Lett.*, vol. 28, no. 10, May 1992, pp. 962-963.
8. K. C. Abraham and S. Roy, “A Novel High Speed PLC Communication Modem,” *IEEE Trans. Power Delivery*, vol. 7, no. 4, Oct. 1992, pp. 1760-1768.
9. S. Roy, J. Yang and C. B. Patel, “Ghost Cancellation for Advanced Compatible TV System using Complementary Sequences,” *IEEE Trans. Cons. Elect.*, vol. 38, Nov. 1992, pp. 767-777.
10. Y. Sun, S. Roy, S. A. Kassam and F. Haber, “A Pattern Diversity Method for Multiple Coherent Source Location,” *J. Acoust. Soc. Am.*, vol. 92, Dec. 1992, pp. 3213-3220.
11. S. Roy, “Design of Linear Phase FIR Filters using the LMS Algorithm,” *IEEE Trans. Sig. Proc.*, vol. 41, Apr. 1993, pp. 1685-1689.
12. J. S. Stadler and S. Roy, “Adaptive Importance Sampling,” *IEEE J. Sel. Areas Comm.* (Spl. Issue on Comp. Aided Modelling, Analysis and Design of Communication Links), vol. 11, no. 3, Apr. 1993, pp. 309-316.
13. S. Roy and S. A. Raghavan, “Timing Sensitivity of (MMSE) Linear and DF Equalization for Digital Magnetic Recording Channels,” *Proc. IEE*, Pt. I, vol. 140, no. 3, June 1993, pp. 169-175.

14. T. Liu, C. B. Patel, D. Downey, S. Jaffe, J. Yang and S. Roy, "Simulation and Implementation of US QAM-based HDTV Channel Decoder," *IEEE Trans. Cons. Elect.*, vol. 39, Aug. 1993, pp. 676-683.
15. P. S. Kumar and S. Roy, "Two-Dimensional Equalization for High Density Magnetic Recording," *IEEE Trans. Comm.*, vol. 42, no. 2-4, Feb-Apr. 1994, pp. 386-395.
16. J. Yang, S. Roy and N. H. Lewis, "Data Driven Echo Canceller for a Multi-tone Modulating System," *IEEE Trans. Comm.* vol. 42, no. 5, May 1994, pp. 2134-2144.
17. D. S. Chen and S. Roy, "An Adaptive Multi-user Receiver for CDMA Systems," *IEEE J. Sel. Areas Comm.* (Spl. Issue on CDMA Networks II), vol. 12, no. 5, June 1994, pp. 808-816.
18. L. A. Baccala and S. Roy, "A New Time-domain Blind Identification Method Based on Cyclostationarity," *IEEE Sig. Proc. Letters*, vol. 1, no. 6, June 1994, pp. 89-91.
19. J. Yang and S. Roy, "Joint Transmitter/Receiver Optimization for Multi-input, Multi-output (MIMO) Systems with Decision Feedback," *IEEE Trans. Inf. Theory*, vol. 40, no. 5, Sep. 1994, pp. 1334-1347.
20. J. Yang and S. Roy, "On Joint Transmitter and Receiver Optimization for Multiple Input, Multiple Output (MIMO) Transmission Systems," *IEEE Trans. Comm.*, vol. 42, no. 12, Dec. 1994, pp. 3221-3231.
21. M. P. Wylie, S. Roy and H. Messer, "Self-Calibration of Linear Equi-spaced Arrays," *IEEE Trans. Sig. Proc.*, vol. 42, Dec. 1994, pp. 3449-3459.
22. B. Jelićić and S. Roy, "Design of Trellis Coded QAM for Flat Fading and AWGN Channels," *IEEE Trans. Veh. Tech.*, vol. 44, no. 1, Feb. 1995, pp. 192-201.
23. J. S. Stadler and S. Roy, "Importance Sampling for the Detection of Random Signals," *IEEE Trans. Comm.*, vol. 43, Dec. 1995, pp. 2862-2865.
24. P. S. Kumar and S. Roy, "Optimization for Cross-talk Suppression with Non-coordinating Users," *IEEE Trans. Comm.*, vol. 44, July 1996, pp. 894-905.
25. C. B. Schlegel, S. Roy, P. Alexander and Z.-J. Xiang, "Multi-user Projection Receivers," *J. Sel. Areas Commun. Spl. Issue on CDMA Networks III*, vol. 14, Oct. 1996, pp. 1610-1618.
26. B. Jelićić and S. Roy, "Design of AM-TCM Schemes for the Impulse Noise Environment," *IEEE Trans. Comm.*, vol. 44, Oct. 1996, pp.1217-1221.
27. B. Jelićić and S. Roy, "Cutoff Rates for Coordinate Interleaved QAM over Rayleigh Fading Channels," *IEEE Trans. on Comm.*, vol. 44, Oct. 1996, pp. 1231-1233.
28. T.-J. Lim and S. Roy, "Adaptive Detectors for Multiuser CDMA", *Wireless Networks*, vol. 4. no. 4, pp. 307-318, 1998.
29. C. Schlegel, P. Alexander and S. Roy "Coded Asynchronous CDMA and Its Efficient Detection," *IEEE Trans. Info. Theory*, vol. 44, no. 6 Nov. 1998, pp. 2837-2847.

30. Y. Song and S. Roy, "Blind Adaptive Reduced-Rank Detection for DS-CDMA Signals in Multipath Channels," *J. Sel. Areas. Comm. Wireless Series*, vol. 17, no. 11, Nov. 1999, pp. 1960-1970.
31. S. Roy, "Subspace Blind Adaptive Detection for Multi-User CDMA", *IEEE Trans. Comm.*, vol. 48, no. 1, Jan. 2000, pp. 169-175.
32. C-Y. Li and S. Roy, "Performance of Frequency-Time MMSE Equalizer for MC-CDMA over Multipath Fading Channel," *Wireless Personal Communications*, vol. 18, no. 2, 2001, pp. 179-192.
33. S. Roy and H. Yan, "Blind Channel Estimation in Multi-Rate CDMA Systems", *IEEE Trans. Commun.*, vol. 50, June 2002, pp. 995-1004.
34. S. Aramvith, C-W. Lin, S. Roy and M-T. Sun, "Wireless Video Transport Using Conditional Retransmission and Low-Delay Interleaving," *IEEE Trans. Circuits Syst. Video Tech.*, vol. 12, Jun. 2002, pp. 558-565.
35. C.-Y. Li and S. Roy, "Subspace Based Blind Channel Estimation Method for OFDM Systems without Cyclic Prefix," *IEEE Trans. Wireless Commun.*, vol. 1, no. 4, Oct. 2002, pp. 572-579.
36. A.Abouzeid and S. Roy, "Modelling Random Early Detection in a Heterogeneous Differentiated Services Network," *Computer Networks*, vol. 40, Nov. 2002, pp. 537-556.
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