

Declaration of Dr. Mark P. Mahon

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ERICSSON INC.
NOKIA OF AMERICA CORPORATION
Petitioners,

v.

ACTIVE WIRELESS TECHNOLOGIES LLC
Patent Owner.

U.S. PATENT NO. 10,531,443
Title: PHYSICAL UPLINK CONTROL CHANNEL (PUCCH) FORMAT
ADAPTION FOR 5TH GENERATION (5G) NEW RADIO (NR)

Inter Partes Review No.: IPR2024-00951

**DECLARATION OF DR. MARK P. MAHON UNDER 37 C.F.R.
§ 1.68 IN SUPPORT OF PETITION FOR INTER PARTES REVIEW**

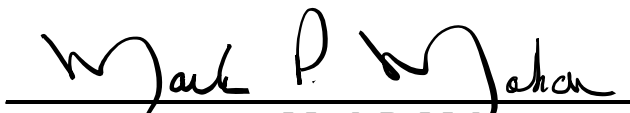
By: 
Mark P. Mahon

TABLE OF CONTENTS

I.	INTRODUCTION	8
II.	BACKGROUND AND QUALIFICATIONS.....	8
III.	MATERIALS REVIEWED	15
IV.	LEGAL STANDARDS	15
V.	LEVEL OF ORDINARY SKILL.....	20
VI.	TECHNICAL BACKGROUND AND STATE OF THE ART	23
A.	Cellular And Wireless Technology.....	23
B.	Digital Communications and Packet Switched Networks	24
C.	Local Area Networks (LANs).....	26
D.	An Overview of 802.11 Local Area Networks	29
E.	Cellular Networking Technology.....	32
1.	The Radio Access Network	33
2.	The Core Network.....	34
3.	First Generation Cellular Telephony	34
4.	2nd Generation Cellular Telephony.....	35
5.	GPRS and Data Calls	39
6.	3rd Generation Cellular Systems	41
F.	Mobile Devices / Smartphones	45
G.	MIMO.....	48
H.	General Related Knowledge.....	72
1.	Radio Channels in a Mobile Wireless Communication System.....	72

Declaration of Dr. Mark P. Mahon

2.	Hybrid-ARQ Acknowledgements (“HARQ-ACK”)	73
3.	DCI Decoding	74
4.	Search Space Configurations	75
5.	U.S. Patent No. 10,735,170.....	78
6.	Summary	80
VII.	OVERVIEW OF THE CHALLENGED PATENT.....	81
A.	Priority Date	81
B.	Overview Of The Content Of The Challenged Patent	81
C.	Prosecution History	87
VIII.	OVERVIEW OF THE PRIOR ART	90
A.	Wang.....	90
B.	Yang	94
IX.	CLAIM CONSTRUCTION	98
X.	THE CHALLENGED CLAIMS OF THE ’443 PATENT ARE OBVIOUS OVER WANG	98
A.	Challenged Claims.	98
1.	Detailed Application of Wang	98
a.	Claim 3.....	98
	[3.0] A base station (gNB), comprising:.....	98
	[3.1] sending circuitry configured to send a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and.....	101
	[3.2] receiving circuitry configured to receive CBG based HARQ- ACK, wherein.....	106

[3.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), the receiving circuitry is configured to receive one HARQ-ACK bit for the transport block, ...110

[3.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), the receiving circuitry is configured to receive HARQ-ACK bits of all CBGs. 113

b. Claim 5..... 116

[5.0] A communication method of a base station comprising:.....116

[5.1] sending a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and 116

[5.2] receiving CBG based HARQ-ACK, wherein 116

[5.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), one HARQ-ACK bit for the transport block is received,.....116

c. Claim 1..... 117

[1.0] A user equipment (UE), comprising: 117

[1.1] receiving circuitry configured to receive a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and.....117

[1.2] transmitting circuitry configured to transmit CBG based HARQ-ACK, wherein.....117

[1.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), the transmitting circuitry is configured to report one HARQ-ACK bit for the transport block, ...117

[1.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), the transmitting circuitry is configured to report HARQ-ACK bits of all CBGs. 118

d. Claim 2..... 118

[2.0] The UE of claim 1, wherein determining circuitry configured to determine a physical uplink control channel (PUCCH) resource for transmission of the CBG based HARQ-ACK which PUCCH resource is one of a plurality PUCCH resources defined for different payload sizes.	118
e. Claim 4.....	120
[4.0] A communication method of a user equipment (UE) comprising:.....	120
[4.1] receiving a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and	120
[4.2] transmitting CBG based HARQ-ACK, wherein.....	120
[4.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), one HARQ-ACK bit for the transport block is transmitted, ...	121
[4.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), HARQ-ACK bits of all CBGs are transmitted.....	121
XI. THE CHALLENGED CLAIMS OF THE ‘443 PATENT ARE OBVIOUS OVER YANG	121
A. Challenged Claims.	121
2. Detailed Application of Yang	121
a. Claim 3.....	121
[3.0] A base station (gNB), comprising:.....	121
[3.1] sending circuitry configured to send a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and.....	124
[3.2] receiving circuitry configured to receive CBG based HARQ-ACK, wherein.....	129

[3.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), the receiving circuitry is configured to receive one HARQ-ACK bit for the transport block, ...135

[3.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), the receiving circuitry is configured to receive HARQ-ACK bits of all CBGs. 139

b. Claim 5 143

[5.0] A communication method of a base station comprising:.....144

[5.1] sending a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and 144

[5.2] receiving CBG based HARQ-ACK, wherein 144

[5.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), one HARQ-ACK bit for the transport block is received,.....144

[5.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), HARQ-ACK bits of all CBGs are received. 144

c. Claim 1 144

[1.0] A user equipment (UE), comprising: 145

[1.1] receiving circuitry configured to receive a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and.....145

[1.2] transmitting circuitry configured to transmit CBG based HARQ-ACK, wherein.....145

[1.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), the transmitting circuitry is configured to report one HARQ-ACK bit for the transport block, ...145

[1.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), the transmitting circuitry is configured to report HARQ-ACK bits of all CBGs.	145
d. Claim 2.....	146
[2.0] The UE of claim 1, wherein determining circuitry configured to determine a physical uplink control channel (PUCCH) resource for transmission of the CBG based HARQ-ACK which PUCCH resource is one of a plurality PUCCH resources defined for different payload sizes.	146
e. Claim 4.....	148
[4.0] A communication method of a user equipment (UE) comprising:.....	148
[4.1] receiving a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and	148
[4.2] transmitting CBG based HARQ-ACK, wherein.....	149
[4.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), one HARQ-ACK bit for the transport block is transmitted, ...	149
[4.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), HARQ-ACK bits of all CBGs are transmitted.....	149
XII. SECONDARY CONSIDERATIONS DO NOT REBUT THE PRIMA FACIE CASE OF OBVIOUSNESS.....	149
XIII. CONCLUSION AND DECLARATION	151
APPENDIX A – MATERIALS RELIED UPON.....	153
APPENDIX B – RÉSUMÉ.....	154

Declaration of Dr. Mark P. Mahon

I, Dr. Mark P. Mahon declare as follows:

I. INTRODUCTION

1. I have been retained by Duane Morris on behalf of Petitioners as an independent, technical expert consultant in this proceeding before the United States Patent and Trademark Office (USPTO).¹ I have been ask to consider whether certain references disclose or suggest the limitations found in U.S. Pat. No. 10,531,443 (“’443 patent”) which I reference as the “challenged patent” in this declaration as discussed in detail below. My opinions are set forth below.
2. I am being compensated at my rate of \$550 per hour for my services. No part of my compensation depends on my opinions or the outcome of this proceeding. I have no financial interest in any of the parties to this proceeding.
3. In my analysis below, I generally refer to the ’443 patent for citations unless otherwise noted.
4. Unless otherwise indicated, the emphasis in quotations has been added.

II. BACKGROUND AND QUALIFICATIONS

5. My complete qualifications and professional experience are described in my Curriculum Vitae, a copy of which can be found in Appendix B to this Declaration.

¹ Where appropriate, I refer to exhibits that I understand are to be attached to the petition for Inter Partes Review of the challenged patent.

Declaration of Dr. Mark P. Mahon

6. The following is a brief summary of my relevant qualifications and professional experience
7. I am a Teaching Professor in the School of Electrical Engineering and Computer Science at Pennsylvania State University, University Park, PA (“Penn State” or “PSU”). I have worked on telecommunications and wireless networks, including Z-Wave, Bluetooth, Zigbee, Wi-Fi, NFC, AMPS, IS-95, CDMA2000, GSM, EDGE, UMTS/WCDMA, LTE, and 5G cellular systems since 1988.
8. I received my B.S. in Electronics Engineering from the University of Scranton in 1987. I received my M.S. in Electrical Engineering and Ph.D. in Acoustics from Penn State in 1991 and 2001, respectively.
9. In 1988, after I received my bachelor’s degree, I joined the Central Intelligence Agency (CIA) while pursuing my M.S. degree at Penn State part-time. My first job at the CIA involved designing and testing systems to automatically capture and characterize telecommunication signals and emissions from various wireless and computer networking devices.
10. I returned to Penn State in early 1990 to pursue graduate research full-time and complete my M.S. degree. My graduate research work focused on wideband beamforming and adaptive signal processing. After completing my M.S. degree in EE in 1991, I accepted a full-time faculty research position at the Applied Research Lab at PSU, primarily working on classified programs, and began working on diverse

Declaration of Dr. Mark P. Mahon

radio frequency and acoustic sensor systems including wireless communications and small wireless networks for acoustic tracking, source localization, and feature extraction.

11. I began pursuing my Ph.D. part-time in 1993 while continuing my faculty research position. In 1997, as part of my faculty research position, I began working on classified programs focused on mathematical analytical modeling of cellular communication networks and the development of hardware and software systems to test against cellular networks. My role was to develop the algorithms and write the code running on a specially developed embedded system. For this work, I received a letter of recognition as the “genius behind the VELA software algorithms” from the Director of National Reconnaissance Office (NRO) Systems Engineering and Technology Office. As part of this same work, I was extensively involved in protocol and signaling analysis as well as researching model-specific performance and unique functional characteristics associated with individual mobile devices. The work involved testing dozens of handsets from many manufacturers in controlled and real-world environments against network simulators and live operational networks for each research project.

12. In 2000 my research extended into utilizing non-orthogonal wavelets for improving detection and localization of cellular handsets from high altitude sensor systems. In 2001, I completed my Ph.D. and my research focused on the utilization of advanced

Declaration of Dr. Mark P. Mahon

communication signals for wideband characterization and remote sensing of propagation channels.

13. Beginning in 1997 my cellular communications research work focused on CDMA, GSM, EDGE, UMTS, LTE, and 5G cellular systems primarily under grants sponsored principally by the Department of Defense. This classified research work required 3GPP protocol analysis and development of real-time embedded hardware and software systems capable of interacting with cellular networks and cellular handsets. A large portion of my work was directed at architectures, protocols, software, and signaling.

14. I have been working on classified projects since 1988. Before 1998, because the work was not deemed highly classified, I was able to publish eight journal and conference papers prior to 2000. Between 1999 and 2015, however, I was allowed to publish only one article in an unclassified symposium and published and presented about a dozen articles in classified settings. This is because during this period, the vast majority of my research was highly classified. As a result, nearly all of my research results were summarized in classified reports and not available to the general public. Further, because the U.S. government owns any intellectual property resulting from the sponsored research work, I did not pursue or file patent applications.

15.. In 2015, I transferred to the School of Electrical Engineering and Computer Science at Penn State as a teaching faculty member. In that role, I have continued teaching

Declaration of Dr. Mark P. Mahon

graduate and undergraduate courses, guiding Ph.D. and M.S. students in communication and mobile networking (including LTE and 5G cellular networks), and pursuing research in this and related areas. Since 2015, I have been an author on seven refereed papers as listed in my curriculum vitae (CV) (attached as Exhibit A).

16. Because of my decades of research and my continuing work at Penn State, I have intimate knowledge of telecommunication networks, including the technology involved in the patents in this case. I have been highly recognized as an expert in such systems within the research community. I was recognized twice by the National Reconnaissance Office with commendation letters for work dealing with detecting cellular signals in low signal to noise ratio environments. The U.S. government awarded me over \$12M in grants between 2003 and 2015 for projects focused on mobile communication devices and networks, in which I served as a Principal Investigator (PI), Co- PI, and/or technical lead.

17. Additionally, during my research career, I interacted extensively with computer scientists and engineers responsible for the design, development, and testing of telephony and data networking systems and testbeds. As a research faculty member, I oversaw engineers and computer scientists that executed many joint projects with development organizations. These interactions exposed me to a wide range of computer scientists and engineers working on telecommunication network technologies. Since 2011, I have been teaching undergraduate and graduate classes

Declaration of Dr. Mark P. Mahon

in communication and mobile networking and am familiar with the curricula being taught to electrical engineers and computer scientists. The interactions with a wide range of computer scientists and engineers working on telecommunication network technologies and the familiarity with the classes taught to electrical engineers and computer scientists have allowed me to have a good understanding of the level of skills possessed by a person of ordinary skill in the field of cellular technology.

18. I have extensive experience with mobile networks in general and LTE and 5G specifically. While most of my research efforts between 1998 and 2015 were highly classified, I can state that they included detailed investigation of network architectures, signaling, and functional behavior. A typical research effort would involve studying 3GPP, 3GPP2, IEEE, and other protocol standards to fully comprehend all aspects of L1, L2, and L3 requirements including timing, bit-level construction of the control and user plane messages, and timing characteristics for a given standard as well as functional behavior of network components and user equipment.

19. From 2006 through 2015 my research focused specifically on LTE. My research continues to this day, although I am no longer operating in a classified environment. During this time, I investigated the performance and functional differences of many varied network and handset devices to see how differing signaling and hardware configurations (including MIMO) and environmental factors influenced the behavior

Declaration of Dr. Mark P. Mahon

of user equipment in a given network environment. This included how diversity techniques (transmit and receive), synchronization, timing, and signal to interference plus noise ratio (SINR) for a given device would affect specific functional aspects including elements of the receiver structure, decoding and demodulation performance, calculation of parameters used by the device for making decisions and deriving parameters reported to the network.

20. As part of my research work, I built several custom CDMA, GSM, UMTS, and LTE platforms that implemented specific network-side and user equipment-side functionality including custom signal generation and processing structures, particularly the signal processing chains on both the transmit and receive sides. This equipment was developed using network simulation hardware in a laboratory environment and was later tested with corresponding networks in both controlled and fully operational environments. Implementing the transmit and receive chains for custom built protocol-enabled equipment required me to gain an intimate understanding of the relevant 3GPP protocol specifications and the underlying structures. Since 2015, I have been primarily focused on guiding graduate students pursuing research including using code domain non-orthogonal multiple access (NOMA) combined with MIMO sparse coding multiple access to minimize latency and maximize user density in grant free Internet of Things (IoT) environments. Additionally, I am guiding my graduate students in pursuing research in optimized

Declaration of Dr. Mark P. Mahon

distributed processing algorithms, implementation of block chain coding techniques to improve handover security, and edge computing resource allocation in 4G (LTE)/5G (NR) networks.

21. Much of the classified research work I performed also led to similar approaches for other wireless protocols including IEEE 802.11 and 802.15 (e.g., Zigbee, Bluetooth, and UWB), HART, and other short-range standards as well as HF radio and Wi-MAX.

III. MATERIALS REVIEWED

22. The opinions contained in this Declaration are based on the documents I reviewed, my professional judgment, as well as my education, experience, and knowledge regarding cellular networking systems.

23. I have reviewed all of the documents referenced in this Declaration. I have reviewed the challenged patent and its prosecution history. I have listed the reviewed materials in in Appendix A to this Declaration.

IV. LEGAL STANDARDS

24. I am not an attorney and offer no legal opinions. My analysis and opinions are based on my expertise in this technical field and on the instructions that counsel has given me for the legal standards relating to patentability as outlined in the rest of this section. I have applied these principles in reaching the opinions set forth herein do not provide any legal opinions in this Declaration. I have been informed and

Declaration of Dr. Mark P. Mahon

understand that certain legal standards are to be applied by technical experts in forming opinions regarding the meaning and validity of patent claims.

25. I understand and the standard that I have used throughout my declaration is that, in this proceeding, a patent claim may be deemed unpatentable as “anticipated” if it is shown by a preponderance of the evidence that each and every feature of the claim is found in a single prior art reference or rendered “obvious” if, in view of a prior art reference or a combination of prior art references, it would have been obvious to a person of ordinary skill in the art (“POSITA”) at the time of the invention, taking into account the following four issues: (1) the scope and intent of the prior art, (2) the differences between the prior art and the claim under consideration, (3) the level of ordinary skill in the art, and (4) any secondary evidence bearing on obviousness.

26. Counsel has informed me that legal principles regarding unpatentability of a claim due to obviousness have been addressed by the U.S. Supreme Court and that, while not absolute, the principles relating to a “motivation,” “suggestion,” or “teaching” in the prior art to combine references are useful in analyzing whether an invention is obvious. Counsel has also informed me that the suggestion or motivation may be either explicit or implicit and may come from knowledge generally available to a POSITA, from the nature of the problem to be solved, or from a combination of these factors. The test for an implicit motivation, suggestion, or teaching is what the combined teachings, knowledge of a POSITA, and the nature of the problem to be

Declaration of Dr. Mark P. Mahon

solved as a whole would have suggested to those of ordinary skill in the art. The analysis is not focused on the specific problem solved by the invention, but the general problem that confronted the inventor prior to the invention.

27. Counsel has further informed me that the U.S. Supreme Court has clarified that additional principles may also be applied in such an analysis. Some of those principles are set forth below.

28. I have been informed by counsel that it is no longer always required to present evidence of an explicit teaching, suggestion, or motivation to combine prior art references for purposes of determining whether an invention is obvious. Prior art can be combined based on several factors including: an express teaching, suggestion, or motivation from the prior art itself, or from a reasoned explanation of an expert or other witness.

29. I have been informed that a patent claim composed of several elements is not proved obvious merely by demonstrating that each of its elements was independently known in the prior art. In evaluating whether such a claim would have been obvious, I may consider whether there is a reason that would have prompted a person of ordinary skill in the field to combine the elements or concepts from the prior art in the same way as in the claimed invention.

30. To determine whether there was an apparent reason to combine the known elements in the way a patent claims, it will often be necessary to look to interrelated teachings

Declaration of Dr. Mark P. Mahon

of multiple pieces of prior art, to the effects of demands known to the design community or present in the marketplace, and to the background knowledge possessed by a POSITA. Also, in determining obviousness, one must be aware of the distortion caused by hindsight bias and be cautious of arguments relying upon hindsight reasoning. An obviousness argument cannot be sustained by mere conclusory statements. Instead, it must be some articulated reasoning with some rational underpinnings to support the legal conclusion of obviousness.

31. In an obviousness analysis, it is my understanding that there are “secondary considerations” that should be analyzed if they apply. I am told that these considerations include (a) whether the prior art teaches away from the claimed invention, (b) whether there was a long felt but unresolved need for the claimed invention, (c) whether others tried but failed to make the claimed invention, (d) skepticism of experts, (e) whether the claimed invention was commercially successful, (f) whether the claimed invention was praised by others, and (g) whether the claimed invention was copied by others.

32. I have also been informed that in order for evidence of secondary considerations to be significant, there must be a sufficient relationship between the claimed invention and the evidence of secondary considerations. I understand that this relationship serves to provide a link between the merits of the claimed invention and the evidence of secondary considerations provided.

Declaration of Dr. Mark P. Mahon

33. I have been informed by counsel that the Board construes claims according to the so-called “Phillips” standard. Under the Phillips standard, terms in a claim are given their ordinary and customary meaning, consistent with the patent’s specification, as understood by a POSITA. I have been informed by counsel that what is to be considered includes the claims, the patent specifications and drawings, and the prosecution history, including any art listed by the examiner or the Applicant. I have been informed by counsel that information external to the patent, including expert and inventor testimony and unlisted prior art, are to be considered if ambiguities remain. However, expert testimony may be useful in helping to explain the technology.

34. I have been informed and understand that a patent claim is not patentable as obvious if the differences between the patent claim and the prior art are such that the claimed subject matter as a whole would have been obvious at the time the claimed invention was made to a person having ordinary skill in the relevant art.

35. In analyzing the relevance of the differences between the claimed invention and the prior art, I have been informed that I must consider the impact of such differences on the obviousness or non-obviousness of the invention as a whole, not merely some portion of it. The person of ordinary skill faced with a problem is able to apply their experience and ability to solve the problem and also look to any available prior art to help solve the problem.

36.I have been informed and understand that there are recognized, exemplary rationales for combining or modifying references to show the obviousness of claimed subject matter. Some of the rationales include the following: combining prior art elements according to known methods to yield predictable results; simple substitution of one known element for another to yield predictable results; use of a known technique to improve a similar device (method or product) in the same way; applying a known technique to a known device (method or product) ready for improvement to yield predictable results; choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; known work in one field of endeavor may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations are predictable to one of ordinary skill in the art; and some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art teachings to arrive at the claimed invention.

V. LEVEL OF ORDINARY SKILL

37.It is my understanding that a person of ordinary skill in the art (“POSA” or “POSITA”) is a hypothetical person who is used to analyze the prior art without the benefit of hindsight. I have been instructed that the level of ordinary skill may be reflected by the prior art of record, and that a person of ordinary skill in the art to which the claimed subject matter pertains would have the capability of understanding

Declaration of Dr. Mark P. Mahon

the scientific and engineering principles applicable to the pertinent art. I have been instructed that there are multiple factors that may be considered in determining the level of ordinary skill in the art may include: 1) type of problems encountered in the prior art; 2) prior art solutions to those problems; 3) rapidity with which innovations are made; 4) sophistication of the technology; and 5) educational level of active workers in the field. I also understand that a POSITA is also a person of ordinary creativity, not an automaton. They would be able to fit the teachings of multiple patents together like a puzzle and have the capability of understanding the scientific and engineering principles applicable to the pertinent art.

38. I have been asked to provide a definition for the level of ordinary skill in the art in the field of the challenged at the time the priority application was filed. As stated in the challenged '443 patent, “[t]he present disclosure relates generally to communication systems. More specifically, the present disclosure relates to physical uplink control channel (PUCCH) format adaptation for 5th generation (5G) new radio (NR).” EX-1001, 1:17-20.

39. In my opinion, a POSITA as of the claimed priority date of the challenged patent would have been familiar with wireless communications networks, equipment, and integrated circuit chips, and would have had at least a working knowledge of communication protocols used in LTE and 5G radio access networks (“RAN”). A POSITA would have had (1) the equivalent of an undergraduate degree in Electrical

Declaration of Dr. Mark P. Mahon

Engineering or a related field; and (2) at least two years of experience in design, development, and/or testing of wireless telecommunication systems. In a similar vein, a POSITA would also have familiarity with the wireless standards and protocols related to data transmission and network management. It is also my opinion that more education could supplement practical experience or vice versa. For example, such knowledge could be acquired by a mixture of training and work experience such as a Master's degree in Electrical Engineering with less work experience.

40. When forming my opinions herein, I analyzed and applied the prior art and claim constructions from a POSITA's perspective at the invention's time.

41. I understand that a POSITA is presumed to have knowledge of all references that are sufficiently related to one another and to the pertinent art and to have knowledge of all arts reasonably pertinent to the particular problem that the claimed invention addresses.

42. All of my opinions in this declaration are from the perspective of a POSITA, as I have defined it above and during the relevant time frame, *i.e.*, on or around date of the priority application. During this time frame, I possessed at least the qualifications of a person of ordinary skill in the art, as defined above, and I am capable of addressing the issues from the perspective of such a person. My opinions in this declaration reflect how a POSITA would have understood the claims and the

Declaration of Dr. Mark P. Mahon

specification of the challenged patent, the prior art to the patent, and the state of the art on or around the priority date.

43. This paragraph intentionally left blank.

44. This paragraph intentionally left blank.

VI. TECHNICAL BACKGROUND AND STATE OF THE ART

45. The following section describes aspects of the state of the art for wireless systems as of the date of the priority application. This description is in addition to the description of the specific prior art references discussed in the “Overview of the Prior Art” section below.

A. Cellular And Wireless Technology

46. Mobile communications were originally developed for military purposes. The idea transitioned to the commercial world primarily through the development of cellular communication systems which were deployed beginning in the early 1980s. In mobile cellular telecommunications systems, user equipment (often abbreviated “UE”) transmit signals to and receive signals from a network of base stations. Over the past 40 years, mobile communication technologies have advanced tremendously with significant new developments appearing approximately every 10 years. To distinguish among the significant evolutions that have occurred over time, mobile communication technologies are generally divided into generations via industry consensus and is typically associated with a new air interface and network

architecture. The first generation (1G) analog transmission technology emerged in the 1980s, followed by second generation (2G) digital systems in the early 1990s, which were followed by third generation (3G) networks and fourth generation (4G) systems, culminating with the most recent fifth-generation (5G) of cellular technology, which is also called new radio or “NR.”

47. In 1998, the Third-Generation Partnership Project (3GPP) was formed as a consortium of several national and regional standardization organizations, manufacturers, operators, and market organizations. Since its formation, 3GPP has prepared the technical specifications for 3G Wideband Code Division Multiple Access or “WCDMA,” 4G Long Term Evolution or “LTE,” and 5G NR.

48. In what follows, I will provide an overview of digital communications and packet switched networks, wireless LANs and cellular telephony. These technologies are relevant to the accused system and the asserted claims.

B. Digital Communications and Packet Switched Networks

49. A digital communication system supports the transmission and reception of information that has been represented using binary signals - strings of zeros and ones.² If the original information is analog - a voice or an image, for example - then

² I note that some systems, such as FAX machines, use signal sets with hundreds to thousands of possible values, as opposed to just zeros and ones. Such systems are digital in that they have discrete signals, as opposed to the continuously varying analog systems.

the transmitter will first have to digitize the image. In order to reproduce the transmitted information at the receiving end, the receiver must know how to interpret the received bits. In the case of digitized voice, for example, the receiver must know how to break up the stream of bits into 8-bit blocks, so that those blocks can be used to create a signal with the appropriate amplitude at the appropriate time. Digital systems make this possible by organizing the transmitted bits into "packets."³

50. Packets are contiguous collections of bits in which the position of the bit within the packet indicates how the bit is to be interpreted. Figure A below shows a generic packet that has been divided up into "fields." If one knows the packet format, one can partition a string of bits into the appropriate fields and interpret the bits accordingly.

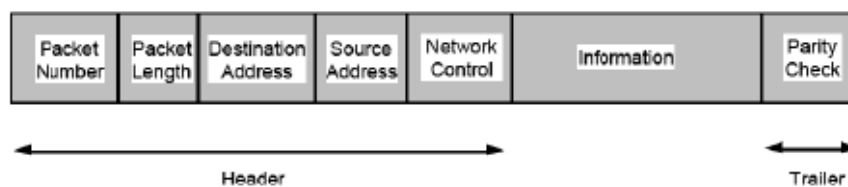


Figure A: A Generic Packet

51. The "Information" field in the packet in Figure A represents the actual message - the voice or image that is being transmitted. The rest of the fields of the packet constitute "overhead" - additional information that the network uses to reliably transfer the packet from its source to its destination.

³ Some systems use the term "frames," while others use "cells." There are distinctions than can be drawn between frames, cells, and packets, but they are not necessary here. I will use the term "packet" in a general sense.

52. Packets are self-contained in that they contain all of the information that is needed to get the packet through the network. The packets that make up a message may thus take different routes between source and destination. More importantly, packets from different messages may share the same wire. In the network in Figure B, packets being sent from A and D are labeled "1", while those from B to C are labeled "2". Note that 1's and 2's can share the same path. The switches in this network must thus switch from packet to packet, as opposed to creating a circuit and leaving it in place for an entire conversation. Such networks are called "packet-switched" networks. The Internet consists of many interconnected packet-switched networks.

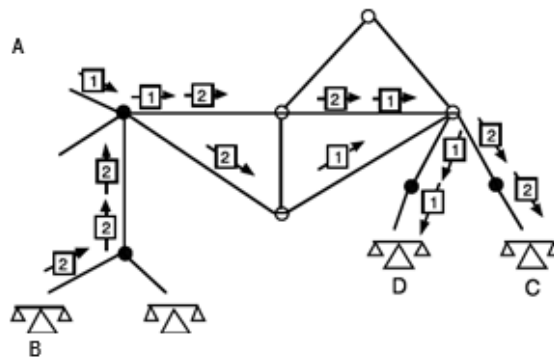


Figure B: A Packet-Switched Network

C. Local Area Networks (LANs)

53. A local area network generally consists of a group of communication nodes in a given, geographically confined, area that share a common communication medium. The nodes (i.e. "computers and/or devices") may be remote terminals, computers, printers, sensors, or some other, similar device, while the communication medium

may consist of a single wire, a collection of wires, or one or more radio channels. Given the restrictions of LAN technology, a given LAN may interconnect the computers on the floor of a building or possibly several floors; to cover larger distances requires switching and, potentially, wide area networking technologies.

54. One of the principal problems arising with local area networks is the need to share the common communication resource. Scheduling is one means of doing so, but this can be extremely inefficient if it isn't known when or how often each user will need to transmit. Polling is a second means. Polling is a protocol in which nodes may only transmit when expressly asked to do so by a controlling node. "Random access" algorithms provide yet another option. In random access systems, individual users request and use network resources as needed. A small network can thus support a very large number of users as long as those users only need the resources a small percentage of the time.

55. There have been a variety of random access algorithms developed over the years, beginning with the ALOHA system, developed at the University of Hawaii in the late 1960's and early 1970's. In the ALOHA system users transmit whenever they wish. If two users transmit at the same time, they are said to have "collided." Both users then wait a random amount of time and then retransmit. The "random" element is important, as the goal is to have the two users select different retransmission times, thus avoiding another collision.

56. In the mid 1970's a more sophisticated approach, Carrier Sense Multiple Access (CSMA) was developed. In CSMA, the network users listen to the medium before transmitting. If the medium is in use, then the users wait and transmit at a later time. The simple act of listening before talking greatly improves the performance of the random access system.

57. Perhaps the best known of the CSMA system is Ethernet (often referred to by the name of the associated standard, 802.3). In Ethernet local area networks, the users share a common collection of wires. The users may transmit whenever they wish, but before each transmission, the users must listen to the channel. Ethernet also uses collision detection (CD), and is generally referred to as a CSMA/CD technology. Even with carrier sensing, there may still be collisions due to time delays on the channel. In CSMA/CD protocols, once the users realize that they have collided, they stop transmitting immediately. This allows other users to use the channel. Ethernet is now standardized, though there are many versions. The most important version is the IEEE 802.3 standard for local area networks.

58. There are many other networking technologies available for the creation of local area networks. While it is possible to join a pair of Ethernet networks, for example, to form a larger network, it is generally not possible to simply connect two networks that use different networking technologies and have them function properly. A given networking technology is like a mono-lingual speaker. If two different networks are

to communicate, some form of translation is necessary. For example, 802.11 uses a different packet structure than a 3G cellular network. The two cannot communicate directly.

D. An Overview of 802.11 Local Area Networks

59.802.11 is a wireless LAN standard that was developed by the Institute of Electrical and Electronic Engineers (IEEE) in the 1990's. 802.11 allows for two different types of networks: independent and infrastructure. In independent networks, wireless terminals, or stations, communicate directly with each other. Figure C (taken from the 802.11 specification) shows two independent networks, or Basic Service Sets (BSSs). In the figure, each BSS consists of a pair of stations (STAs), though in general a BSS can consist of dozens or even hundreds of stations.

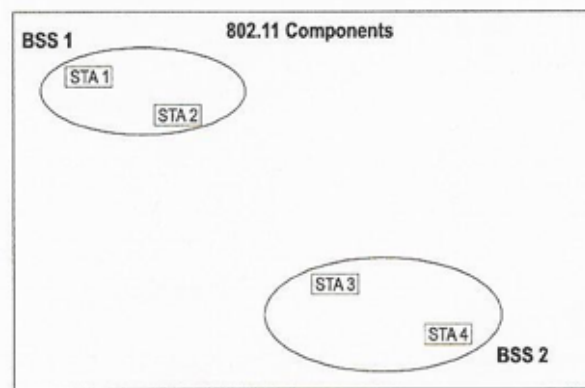


Figure C: 802.11 Independent Basic Service Set

60.The specification notes that independent networks are often referred to as ad hoc networks.

Figure 1 shows two IBSSs. This mode of operation is possible when IEEE

802.11 stations are able to communicate directly. Because this type of IEEE 802.11 LAN is often formed without pre-planning, for only as long as the LAN is needed, this type of operation is often referred to as an ad hoc network.

802.11 Specification, 1999, pg. 10

61. Ad hoc networks are distinguished from infrastructure networks which use relatively permanent access points as the basis for wireless communication.

62. The access points (APs) can connect remote users to gateways for access to other networks. In an 802.11 infrastructure, the remote stations must associate with an access point before they can communicate with any other remote station (or, through the access point, to other networks). Remote stations may still communicate with each other, but all traffic has to be routed through the access point with which the transmitting station has associated. An exemplary infrastructure network is shown below in Figure C. The lines indicate the only paths over which communication can take place.

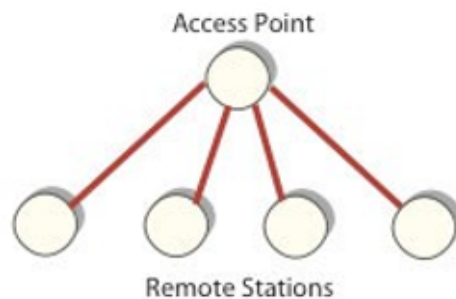


Figure E: 802.11 Infrastructure Network

63. When entering an infrastructure network, a station will first listen for a beacon in an attempt to determine which APs are present. Once an AP has been identified and selected, the station will initiate the “association service.”

A STA learns what APs are present and then requests to establish an association by invoking the association service.

ANSI/IEEE Std 802.11, 1999 Edition, pg. 19

64. The association service consists of the exchange of a pair of packets; these particular packets are examples of management frames. The station sends an “association request” frame to the AP, and the AP responds with an “association response” frame.

5.7.2 Association

For a STA to associate, the association service causes the following messages to occur:

Association request

— *Message type: Management*

— *Message subtype: Association request*

— *Information items:*

- *IEEE address of the STA initiating the association*
- *IEEE address of the AP with which the initiating station will associate*
- *ESS ID*

— *Direction of message:*

From STA to AP Association response

— *Message type: Management*

— *Message subtype: Association response*

— *Information items:*

- *Result of the requested association. This is an item with values “successful” and “unsuccessful.”*
- *If the association is successful, the response shall include the association*

identifier (AID).

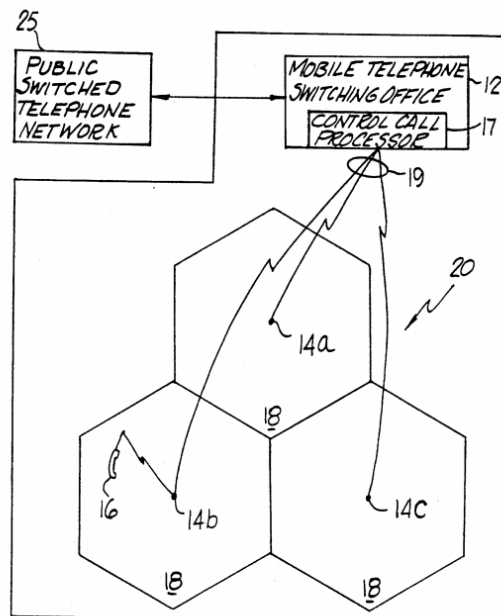
- *Direction of message: From AP to STA*

ANSI/IEEE Std 802.11, 1999 Edition, pg. 25

65. This paragraph left intentionally blank.

E. Cellular Networking Technology

66. A cellular network is a mobile network that provides services by using a large number of transceiver base stations with limited power, each covering only a limited area. This limited area is called a cell. In this way a large geographic area, like a coast-to-coast network in the U.S., can be covered by a number of cells with a general structure like the below:⁴



⁴ U.S. Patent No. 5,295,180 to Vendetti, et al ("Vendetti"), 1:10-29, Fig. 1.

67. A typical cellular network includes many components that facilitate end-to-end communications between subscribers and between subscribers and callers on other networks including landlines. At a high level, a cellular network can be divided into two main parts: the Radio Access Network, or “RAN,” to which wireless devices connect, and the Core Network.

1. The Radio Access Network

68. As the name implies, the Radio Access Network is the wireless portion of the cellular network and includes the base stations and mobile/cell phones. The size of each cell radius and its transmission power range is typically predetermined by the cellular carrier as part of its network radio plan and is based on a number of different factors that include the geographic area to be covered, the typical number of cell (mobile) phone users, and the type of voice and data to be supported.

69. One important characteristic of a cellular network is the control of the base station and mobile phone transmittal power. The basic concept for efficient network operation is that the base stations and the mobile phones not transmit at a power level greater than what is needed for efficient communication.

70. When a U.S. cellular network operator’s radio plan is complete, it typically includes hundreds of cells that are of many different sizes. Each cell is given a unique identity and is configured with various information by the cellular operator. One piece of important information for each cell includes the list of its neighbor cells. This

information is critical for a mobile to use when it is moving out of the range of a cell that it is using and needs to switch to another cell.

2. The Core Network

71. The Core Network connects to the base stations and has many different types of network elements (computer systems) that perform the many different functions that are necessary for a cellular network to operate correctly. The Core Network also provides the voice and data connections between the mobile phones and other voice and data networks. The base stations in the RAN are connected to the Core Network using trusted private network type connections that are managed by the cellular network operator.

3. First Generation Cellular Telephony

72. Mobile communications were originally developed for military purposes. The idea transitioned to the commercial world primarily through the development of cellular communication systems which were deployed beginning in the early 1980s. Some of the first- generation (1G) cellular systems were Advanced Mobile Phone System (AMPS), Nordic Mobile Telephone (NMT), and the British Total Access Communication System (TACS). These analog systems were based upon Frequency Modulated (FM) radio channels and only carried user's voice signals. The 1G systems did not provide user information confidentiality since the signals could be easily listened to by using standard commercial radio receivers tuned to the correct

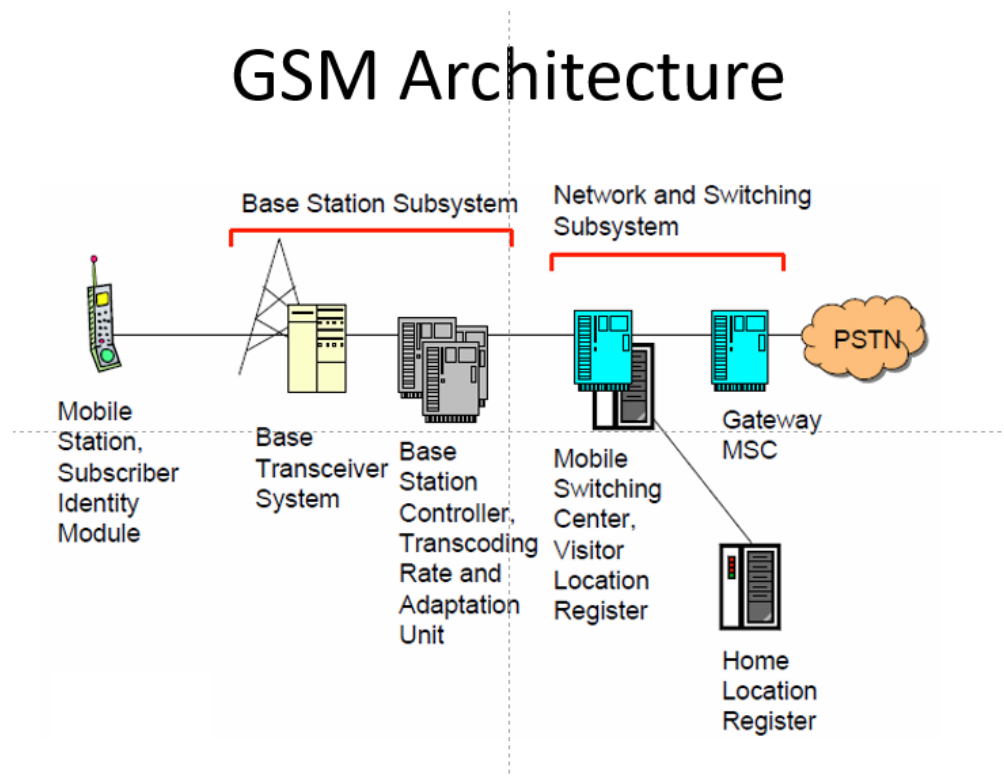
frequency carrying the user's voice signal. Additionally, device credentials such as the telephone number could be copied due to the utilization of this non-protected radio interface and Signaling System (SS7) messages in the core network. These and other security vulnerabilities were addressed in subsequent generation mobile communication systems.

4. 2nd Generation Cellular Telephony

73. Second-generation (2G) systems such as the Global System for Mobile communications (GSM) were deployed beginning in the early 1990s and were designed, in part, to address the obvious security flaws of the 1G systems. 2G systems introduced digital modulation techniques, encryption of signals and voice communications and established user authorization and authentication procedures. The European Telecommunications Standards Institute (ETSI) was the primary entity responsible for developing the first GSM standards. As part of this development work the idea of using a Subscriber Identity Module (SIM) card to protect important user and network information was introduced. A SIM is a smart card consisting of an integrated circuit chip and memory embedded into a plastic card. The first GSM SIM cards were commercially available in 1991 and they are used to store network and user-specific information used as part of the ETSI-defined security procedures.

74. Second generation GSM networks generally consist of four basic subsystems – the Mobile Station (MS), the Base Station Subsystem (BSS), the Network and Switching

Subsystem (NSS), and the Home Location Register (HLR). The MS communicates over one or more wireless links with the BSS. The BSS consists of one or more Base Transceiver Stations (BTSs – the cell towers and radio transceivers) and a Base Station Controller, as shown below.⁵



6

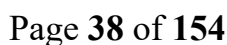
⁵ See Xuan, Ohio State Course Materials concerning “Mobile Handset Cellular Network,” available at web.cse.ohio-state.edu/~xuan/courses/694/694_CELLULAR_NETWORK.ppt.

⁶ See web.cse.ohio-state.edu/~xuan/courses/694/694_CELLULAR_NETWORK.ppt at Slide 16.

75. The figure below is taken from an early draft of the GSM standard, GSM 03.02, Version 3.1.4, February 1992. The figure depicts the interaction between the SS7 signaling network and the telephone network. A mobile handset is shown on the bottom right of the diagram, interfacing with the Mobile Switching Center (MSC) through the Base Station Subsystem (BSS). The Home Location Register (HLR) and Visitor Location Register (VLR) are interrogated through switching points (SP) that provide the information needed for call setup and roaming. The VLR is a database that is part of the MSC, and which contains the location of the active mobile stations.

7

⁷ See web.cse.ohio-state.edu/~xuan/courses/694/694_CELLULAR_NETWORK.ppt at Slides 12-25.



5. GPRS and Data Calls

77. The original (“phase one”) GSM standard provided for 9.6 kbps data services. These data services were provided through circuit-switched traffic channels, in much the same way that a modem uses the PSTN to create a data connection. As the demand for Internet connectivity grew, service providers realized that 9.6 kbps was far too slow. The first significant attempt to increase data rates focused on combining multiple traffic channels. The result was “high-speed circuit switched data” (HSCSD), which supported data rates of 40 - 50 kbps, depending on the coding used.
78. Once again, however, it was found that these services were simply too slow. Part of the problem lay in the mismatch between data applications and circuit-switched transport mechanisms. The economy of scale in packet switching was not available in a circuit-switched system, as once a circuit was dedicated to a user session, it could not be used by another party regardless of the activity level. The next step in providing high-speed data services was a step away from circuit switching to focus on packet switch transport – General Packet Radio Service (GPRS) was the result.
79. GPRS was developed to provide packet switched data communication services within GSM cellular networks. GPRS is often referred to as “2.5 generation cellular,” acknowledging its advance over the circuit-switched data systems provided by 2nd generation GSM networks. GPRS was added to the GSM standard in 1997, and has remained a part of the standard through the transition to third generation systems.

80. GPRS requires that two additional nodes – the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN) – be added to the original GSM network architecture. These two new nodes are described as follows in the GSM specification.

The Serving GPRS Support Node (SGSN), which is at the same hierarchical level as the MSC, keeps track of the individual MSs' location and performs security functions and access control. The SGSN is connected to the base station system with Frame Relay. The Gateway GSN (GGSN) provides interworking with external packet switched networks, and is connected with SGSNs via an IP-based GPRS backbone network.

GSM 03.60, version 7.4.1, 1998, at 13.⁹

81. In addition to the two new network nodes, GPRS requires modifications to several of the pre-existing 2nd generation GSM network elements. A Packet Control Unit (PCU) is added to the base station controller (BSC). GPRS subscriber information is added to the HLR. The SMS-GMSCs and the SMS-IWMSCs are upgraded to support packet switched transport through the SGSN. The MSC/VLR may be upgraded to better support GPRS and non-GPRS services, such as SGSN-supported paging of packet switched calls, and combined voice and data location updates. The packet control unit in the BSC is connected to one or more SGSNs using frame relay; as

⁹ Available at https://www.etsi.org/deliver/etsi_en/301300_301399/301344/07.04.01_60/en_301344v070401p.pdf.

discussed above, frame relay is a transport technology for wide area networks. The GGSN is connected to one or more SGSNs through an IP backbone network. The GPRS Tunneling Protocol (GTP) has been designed for routing packets between the SGSNs and the GGSNs.

6. 3rd Generation Cellular Systems

82. Beginning in 1999, third generation (3G) cellular network technology protocol standards were published by 3GPP, Release 99. The 3G network technology was known as Universal Mobile Telecommunications Service (UMTS) and was built upon a Wideband Code Division Multiple Access (WCDMA) air interface. A major design goal of 3G technology was enabling and ensuring comprehensive global roaming which made it possible for a user to utilize the global system anywhere in the world. A simplified version of the 3GPP Release 99 architecture is shown below:

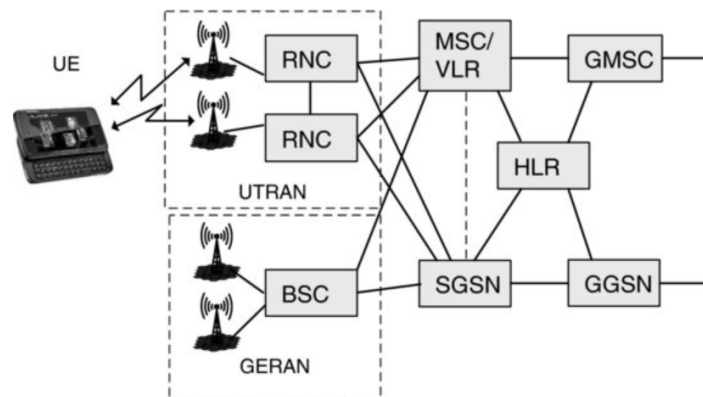


Figure 1. The 3G Release 99 system architecture.

Forsberg, “LTE Security” (2nd ed.).

83. The 3G network architecture has three main components: User Equipment (UE), the UMTS Terrestrial Radio Access Network (UTRAN), and the Core Network (CN). The UE is actually composed of two components: the Mobile Equipment (ME) and the Universal SIM (USIM). The ME is the hardware and software that make up what the average consumer thinks of as a ‘cell phone’ – the screen, the battery, antennas, processor chips, etc., however the USIM is an application running on the Universal Integrated Circuit Card (UICC) which is ‘plugged into’ the UE and was referred to as the ‘SIM card’ in 2G systems. In the figure above, the network elements labeled ‘MSC/VLR’ and ‘SGSN’ are two important components of the global roaming network architecture. The Mobile Switch Center (MSC) controls the location area around the cell tower for circuit switched connections while the Visitor Location Register (VLR) holds a list of users in that area. The Serving GPRS Support Node (SGSN) performs an equivalent function of the combined MSC/VLR for packet switched connections. Additionally, the Home Location Register (HLR) is typically deployed as an integrated element with the Authentication Center (AuC). The HLR maintains a list of subscribers for the home serving network and the AuC holds the permanent security information associated with those same subscribers as well as performing other security related functions.

84. Beginning in 2004, the Third Generation Partnership Project (3GPP) commenced a study into the long-term evolution of UMTS (the current cellular network architecture at the time) which resulted in LTE. The goals were primarily high data rates, low latency, and an architecture that could evolve and adapt with developments in technology and built upon an all packet-based network. LTE (Long-Term Evolution) is a term that refers to the 4th Generation (4G) of the cellular network architecture. As the name suggests, LTE evolved from the 3G network architecture and represented a significant departure in design, functionality, and performance from its predecessor.

85. At a high-level the LTE network architecture, like UMTS, consists of three main components: the UE, the RAN which is the interface over which the UE and the main network communicate, and the evolved packet core (EPC) which communicates with other networks and the broader electronic world. The latter two components (RAN and EPC) are referred to as the evolved packet system (EPS). Additionally, the LTE RAN, since it represents an evolution of the previous generation's radio access network (UMTS – RAN), is also called the Evolved-UMTS RAN (E-UTRAN). A high-level architecture diagram of LTE is presented below.

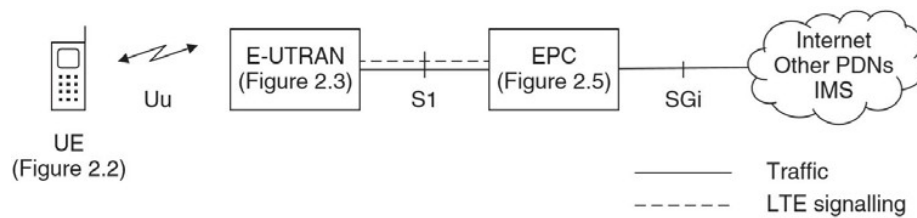


Figure 2.1 High-level architecture of LTE

Cox, "An Introduction to LTE: LTE, LTE-Advanced, SAE, VoLTE, and 4G Mobile Communications" (2nd ed.) at p. 22.

86. The first release of the 3GPP protocol standards defining LTE was termed Release 8 (R8). This release provides the foundation for LTE and introduces all of the major requirements and specifications that network operators, network equipment, chip set, and handset manufacturers use to design, develop, test, and deploy their products. The features and requirements in R8 address key enablers for LTE: signaling efficiency, spectrum flexibility and efficiency, capacity enhancements, and multi-antenna techniques. R8 also provides the basis for subsequent releases which followed.

87. LTE's core network (CN) consists of several types of nodes (devices to provide the functionality and packet-switching required to operate the network). The mobility management entity (MME) is a key control plane (carries LTE signaling) node and is responsible for establishing and releasing a service connection to a UE or other end users, signaling, mobility (users moving from cell to cell), and security. The serving gateway (S-GW) is a user-plane (carries user data) node that connects the EPC to the RAN and serves as the mobility anchor (as a UE moves from cell to cell the S-GW

keeps track of the data connection between multiple cells and is responsible for the smooth handoff when switching service areas). Two other main nodes are the home subscriber system (HSS) which contains subscriber information and the packet data network (PDN) gateway (P-GW) which connects the EPC to the internet or other networks. A few of the LTE architecture CN nodes are pictured below.

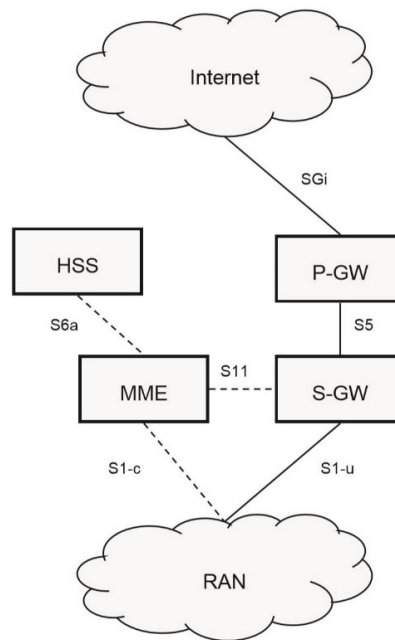


Figure 4.1 Core Network Architecture

Dahlman, "4G, LTE-Advanced Pro and The Road to 5G", (3rd ed.).

F. Mobile Devices / Smartphones

88.A mobile phone or cellular phone is a portable telephone which makes or receives calls through a cell site base station or other transmitting tower. Radio waves at

Declaration of Dr. Mark P. Mahon

specific frequencies (or “radio frequencies”) are used to transfer signals in analog or digital form to and from the cell phone.

89. In order to be able to communicate with a cellular network using radio frequency transmissions, a mobile device needs, at a minimum, a transceiver and an antenna to which it is connected. An antenna converts an electric signal to the radio wave (transmitter) and vice versa (receiver).¹⁰ A transceiver is a combination of a transceiver and a receiver and it generates a reference signal in both receive mode and transmit mode for various frequency bands.¹¹

90. While there existed before the advent of cellular service devices that have been called “mobile phones” or similar, it was really the introduction of the cellular technology described above that made widespread adoption of mobile telephones economically feasible.

91. Motorola was the first company to produce a handheld mobile phone in 1973, the Motorola DynaTAC.¹²

¹⁰ Rong Wang, PhD, “How Do Cell Phones Work?,” *Pong Pulse* (December 20, 2014) (available at <https://pongcase.com/blog/cell-phones-work/>).

¹¹ U.S. Patent No. 6,912,376 to Smith et al. (filed December 27, 1999).

¹² Peter Ha, “Motorola DynaTAC 8000x,” *Time* (October 25, 2010) (available at http://content.time.com/time/specials/packages/article/0,28804,2023689_2023708_2023656,00.html).

92. Subsequently in the 1980s, with the introduction of the first analog cellular systems (including AMPS, discussed above), the first commercially available mobile phone in the U.S., the DynaTAC 8000X, launched.¹³

93. With the introduction of the second generation of cellular networks occurring in the United States in the 1990s, advances in mobile telephone technologies occurred as well. While the traditional first generation analog cellular networks had provided more extensive coverage than the new, second generation digital networks, the use of digital circuit switched transmissions enabled quicker network signaling, thereby decreasing the amount of dropped calls and increasing call quality. As a result, 2G networks experienced significant growth in mobile phone usage. Other improvements included increase battery life and computer chip technology which allowed for a shift away from the larger “brick” phones towards smaller, lighter handheld devices. This second generation of mobile phones also eventually included the ability to communicate via SMS or text messages and to access media content on mobile phones (such as ring tones).

94. The introduction of third generation cellular networks in the 2000s marked a significant advancement over 2G networks, providing a wider range of services, advanced network capacity, and increased information transfer rates. Due to

¹³ *Id.*

increased network bandwidth, 3G devices could support transmission of voice and data.

95. Furthermore, the higher connection speeds of third generation technology also made web browsing and streaming of radio and television content possible. As of the mid-2000s, there was widespread availability of 3G cellular coverage, and accordingly a higher concentration of cellular phones.

96. “Smartphones” are a particular class of mobile phones and multi-purpose mobile computer devices. They are generally characterized by their hardware capabilities and the fact that they have mobile operating systems that facilitate wider software, internet, and multimedia functionality, alongside core functions such as voice calls and text messaging. Smartphones typically include various sensors that can be leveraged by their software, such as a magnetometer, proximity sensors, barometer, gyroscope and accelerometer, and support wireless communications protocols such as Bluetooth, Wi-Fi (802.11), and satellite navigation.

97. This paragraph left intentionally blank.

98. This paragraph left intentionally blank.

G. MIMO

99. Analytical models for Multiple Input Multiple Output (MIMO) systems were first introduced in the context of multipair telephone cable systems in 1970 by Kaye and George in a paper published on the “Transmission of Multiplexed PAM Signals Over

Declaration of Dr. Mark P. Mahon

Multiple Channel and Diversity Systems”. See *IEEE Transactions on Communication Technology*, Vol. Com-18, No. 5, October 1970, pp. 520 – 526. This paper extended an optimum receiver design for pulse amplitude-modulated (PAM) signals over a single channel to a general case of M multiplexed PAM signals over random-time and frequency-dispersive multichannel systems with I inputs and N outputs (See Fig. 2 below). *Id.* at Abstract.

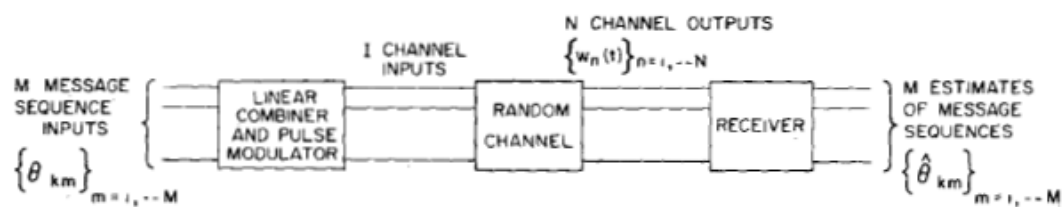


Fig. 2. General form of communication system.

100.

101. *Id.* at pp. 521.

102. Subsequently in 1974, a journal article which presented “[a] formula [] derived for the capacity of a multi-input, multi-output linear channel” describing an analytic expression for information capacity of MIMO channels with discrete-time signals and perfect channel state information was published. See Brandenburg and Wyner, *The Bell System Technical Journal*, Vol. 53, No. 5, May-June 1974. This led to several subsequent information theoretic papers dealing with optimizing channel capacity for MIMO systems.

103. An early reference to the application of MIMO techniques specifically in the context of cellular communications may be found in a 1987 paper on the capacity

Declaration of Dr. Mark P. Mahon

limits in systems with diversity in a Rayleigh fading environment. See Winters, *Journal on Selected Areas in Communications*, “On the Capacity of Radio Communications with Diversity in a Rayleigh Fading Environment”, Vol. SAC-5, No. 5, June 1987, pp. 871 – 878. Winters is specifically addressed to “radio communication system[s] ... such as a mobile radio or indoor wireless system, the communication channels between multiple transmit and/or receive antennas”. “Thus, communication systems, with appropriate signal processing techniques, can use antenna diversity (e.g., space, direction, or polarization) to establish independent channels within the same bandwidth between the transmitters and receivers, thereby achieving large capacity”. *Id.* at pp. 871. The figure below from Winters shows a base station with multiple antennas (multiple input) to multiple remote devices which constitute multiple receive antennas (multiple output).

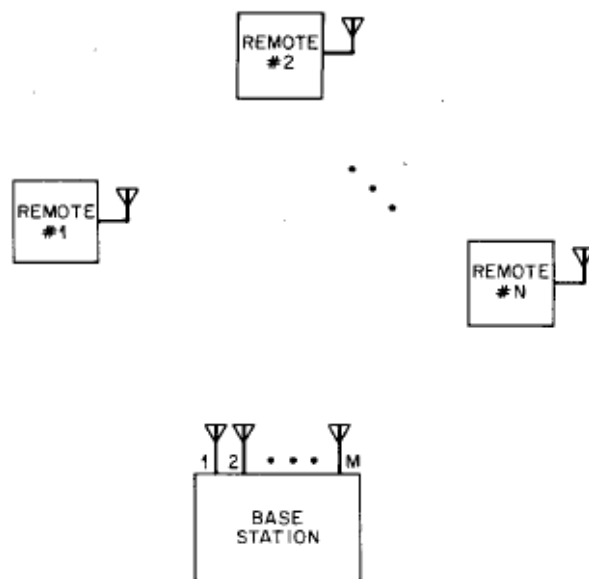


Fig. 1. Radio system consisting of a base station with M antennas and N remotes, each with one antenna.

104.

105. *Id.* at pp. 872.

106. Winters references spatial diversity in a paper he authored in 1984, “Optimum Combining in digital Mobile Radio with Cochannel Interference,” which appeared in the *IEEE Journal on Selected Areas in Communications*, Vol. SAC-2, No. 4, July 1984, pp. 528 – 539. This paper mainly focuses on receive diversity; “[p]revious studies of mobile radio systems [] have considered space diversity only for combating multipath fading ... [h]owever, in most systems the same interfering signals are present at each of the receiving antennas. Thus, the received signals can be combined to suppress these interfering signals...”. *Id.* at pp. 528. Winters also mentions what a POSITA would understand as transmit diversity in the context of discussing multipath effects at the receive antennas: “Similarly, at the receive antennas, the signal phases from two different transmit antennas are independent when the transmit antennas are more than a half of a wavelength apart”. *Id.* at pp. 530. There is nothing novel about Winters’ reference to the effects of multipath fading in the context of transmit diversity in a MIMO system where the author is focused on an optimum receiver design. A POSITA would have been knowledgeable about space diversity (transmit and receive) to improve the quality and reliability of a wireless link. In discussing multiple antenna techniques, Cox states, “The most familiar is diversity processing, which increases the received signal power and reduces the amount of fading by using multiple antennas at the transmitter, the receiver or both. **Diversity**

processing has been used since the early days of mobile communications ...”.

See Cox at pp. 87 (emphasis added).

107. As a specific example of transmit diversity, Adachi published a paper in 1979 entitled, “Transmitter Diversity for Digital FM paging System”, IEEE Transactions on Vehicular Technology, Vol. VT-28, No. 4, November 1979, pp. 333 – 338. “Multipath fading is one of the most serious problems for the signal transmission in mobile radio. To combat this problem, the application of transmitter diversity to a digital paging system is described. The method is to transmit two digital FM paging signals with different modulation indices, each of which is modulated by an identical binary signal, from separate antennas.” *Id.* at Abstract. A POSITA would understand the transmission system disclosed in this paper to be a transmit diversity system where the same data (“identical binary signal”) is transmitted from two or more antennas (“separate antennas”) enabling an improved combined signal at the receive antenna. Referencing transmit diversity, Adachi states, “In Section II, it is shown that the same action obtained with the well-known selection diversity can be achieved ...”. *Id.* at pp. 333. And, “This is the same result with the well-known selection diversity which selects the branch with the higher received signal envelope.” *Id.* at pp. 334. “*Selection diversity* is a more sophisticated version of switched diversity, where the system can monitor the signal level on all of the antennae simultaneously, and select the specific branch exhibiting the highest SNR at any given time ... as seen

in Figure 3.5.” Blogh and Hanzo, *Third-Generation Systems and Intelligent Wireless Networking*, pp. 127-128.

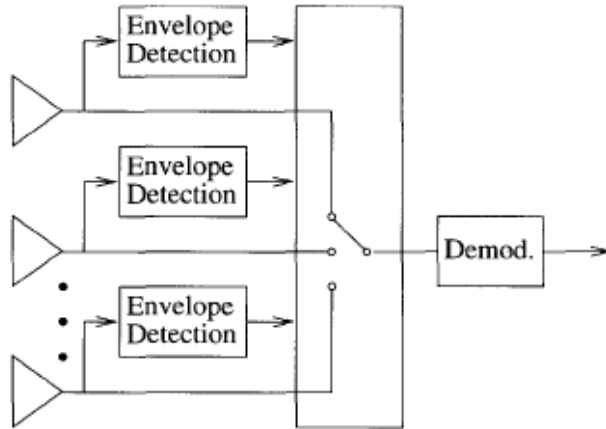
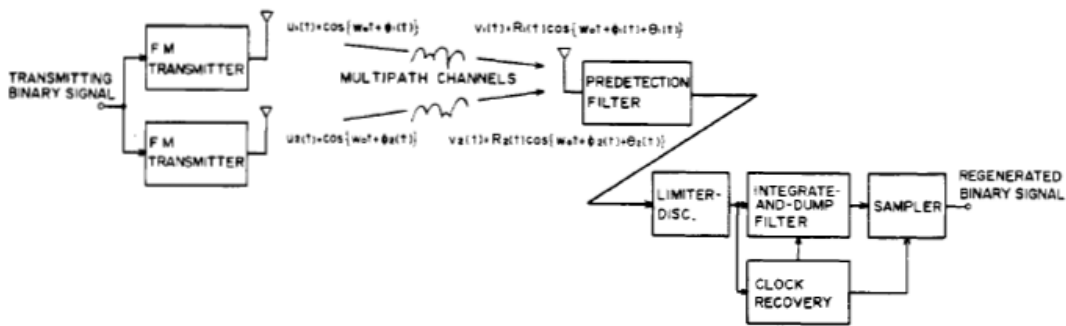


Figure 3.5: Selective-diversity combining.

108.

109. *Id.* at pp. 128.

110. It would be clear to a POSITA that Adachi is disclosing a transmit diversity system where the receiver optimizes received signal power by effectively selecting the received signal which propagated over the path (beam) that results in a maximum received signal power as shown in Fig. 1. Thus, both transmit diversity and receive diversity were well known for several decades preceding the priority date of the ‘235 patent.



111.

112. Adachi at pp. 334.

113. By the early 2000's, diversity techniques in mobile communication systems had become well entrenched. "Diversity is another technique used to compensate for fading channel impairments, and is usually implemented by using two or more receiving antennas. The evolving 3G common air interfaces also use transmit diversity, where base stations may transmit multiple replicas of the signal on spatially separated antennas or frequencies. As with an equalizer, diversity improves the quality of a wireless link without altering the common air interface, and without increasing the transmitted power or bandwidth [] [and] is usually employed at both the base station and mobile receivers." See Rappaport at Chapter 7, *Introduction*.

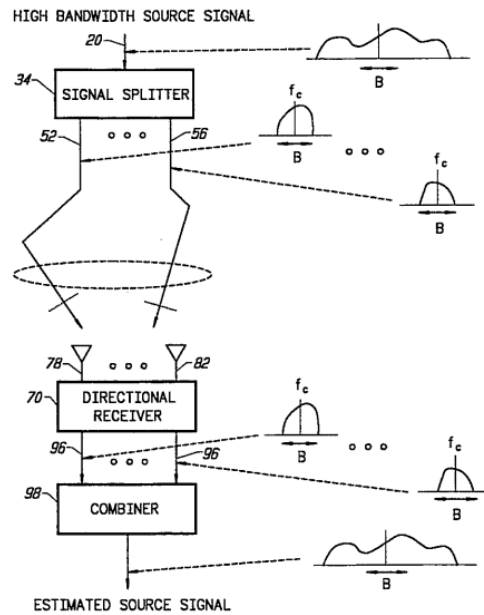
114. Spatial multiplexing which involves "Deploying multiple antennas at both the transmitter and the receiver of a wireless system" was known since the early 1990's when it was shown "to yield extraordinary bit rates []." See Bocskei, et al., *IEEE Conference Record of the Thirty-Third Asilomar Conference on Signals, Systems, and Computers*, 24-27b October, 1999, Vol. 2, pp. 1127 – 1132. In 1992 Paulraj and

Declaration of Dr. Mark P. Mahon

Kailath filed a provisional application for a patent entitled “Increasing Capacity in Wireless Systems Using Distributed Transmission/Directional Reception (DTDR)” which issued as US005345599 on September 6, 1994. The patent discloses “A method and apparatus for increasing the capacity of wireless broadcasts communications system for a central studio to a plurality of users in a service area ... Given a source signal whose information rate exceeds the practical information carrying capacity of the available broadcast channel bandwidth, the invention increases the effective capacity of the broadcast system to effectively communicate such a source signal. The high-rate signal is split into several low-rate signals such that each can be accommodated within the allocated bandwidth. These low-rate signals are transmitted from spatially separated transmitters, all radiating into the service area in the same frequency channel. Each receiver uses a plurality of antennas to receive these multiple cochannel signals that arrive from different directions-of-arrival.” See US005345599 at Abstract. Thus this patent discloses a method and apparatus for a MIMO spatial multiplexing system.

115.

Declaration of Dr. Mark P. Mahon



116.

117. See US005345599 at face.

118. In the fall of 1996, *Bell Labs Technical Journal* presented an article, “Layered Space-Time Architecture for Wireless Communication in a Fading Environment When Using Multi-Element Antennas”, Foschini, Autumn 1996. The paper discloses a MIMO system for increasing the capacity (throughput) in a Rayleigh fading environment, “[the system] use[s] (n_T, n_R) to express the number of antenna elements at the transmitter and receiver. An (n, n) analysis shows that despite the n received waves interfering randomly, capacity grows linearly with n and is enormous.” See *Bell Labs Technical Journal* at pg. 41. The paper presents a “new” architecture with an equal number of antennas at the transmitter and receiver (MIMO) and coined the term of art, “layered space-time architecture” which “targets application in future

Declaration of Dr. Mark P. Mahon

generations of fixed wireless systems, bringing high bit rates to the office and home.

The architecture might also be used in future wireless local area networks (LAN)

applications for which it promises extraordinarily high bit rates.” Id.

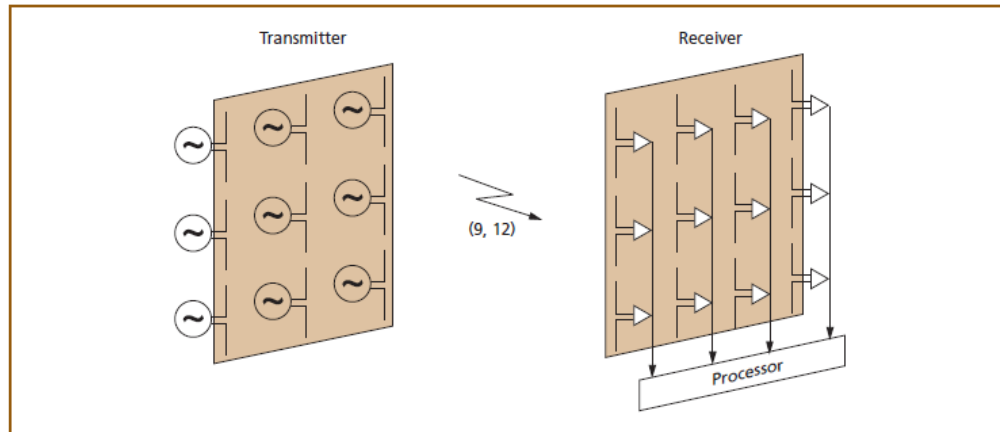


Figure 1.
Shorthand notation (n_T, n_R) for the number of transmit antennas n_T and receive antennas n_R (dipole antennas shown).

119.

120. Id at pp. 43.

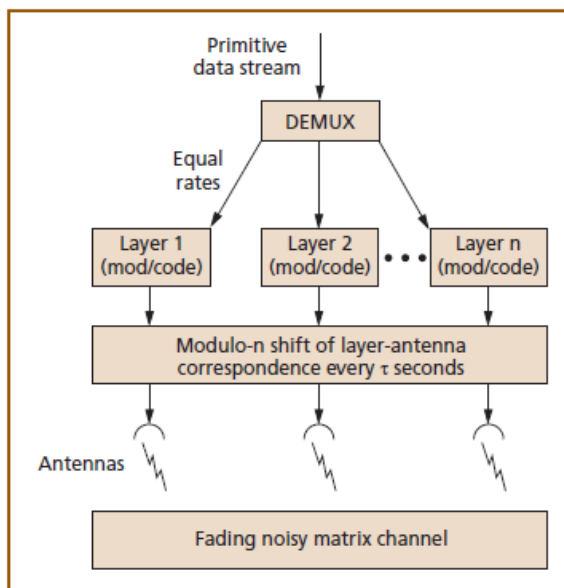


Figure 4.
Transmission process using space-time layering.

121.

122. Id at pp. 46.

123. By the late 1990's and early 2000's a POSITA would be very familiar with the concept of spatial multiplexing to transmit multiple data streams simultaneously in a MIMO system to significantly increase data throughput rates compared to single input single output and diversity systems. As presented in Bolcskei regarding spatial multiplexing systems "have been shown to have the potential of achieving extraordinary bit rates." "In the following M_T and M_R denote the number of transmit-and-receive antennas, respectively. Using single-carrier modulation, M_T different data streams are sent simultaneously from the M_T transmit antennas, pass through a time-dispersive matrix channel, and arrive at the M_R receive antennas." See Bolcskei at Abstract, pp. 1128.

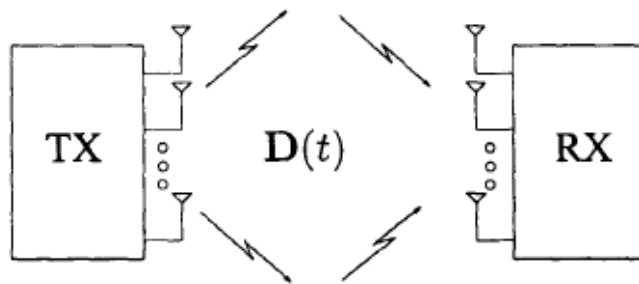


Fig. 1. Space-time coding modem.

124.

125. Id at pp. 1128.

126. In addition to MIMO systems in which a transmitter and receiver both have multiple antennas (that is, one radio on each side controlling the transmit and receive signal processing) being well known to a POSITA by the early 2000's, he/she would

also be knowledgeable of so called, Multiuser MIMO systems (MU-MIMO). In MU-MIMO, multiple radios control multiple antennas.

127. In the *IEEE Wireless Communications and Networking Conference*, 23-28 September, 2000, Vol. 3, pp. 426 – 430, Wong, et al., published “Optimizing the Spectral Efficiency of Multiuser MIMO Smart Antenna Systems”. “In this paper, we consider the maximization of spectral efficiency of a multiuser MIMO system for downlink communications (one base to many mobiles) ... [e]ach mobile (user) in the system incorporates an array of n_R antennas and in general transmits $K_m \geq$ space-time subchannels, in the same frequency spectrum and time slot.” See Wong at Abstract. In this paper the authors presented a technique that maximizes the spectral efficiency of the system in the context of the downlink. “...we consider the downlink (base station to many mobiles) communications for wireless systems where smart antennas are employed at both the BS and all MS.” Id. at pp.426. The presented MU-MIMO system consists of a single base station with multiple antennas transmitting to multiple mobile stations, each with multiple antennas as shown in Fig. 1 below. A POSITA would understand that the proposed system is a downlink MU-MIMO system where the receivers are all separate radios controlling their own multiple antennas.

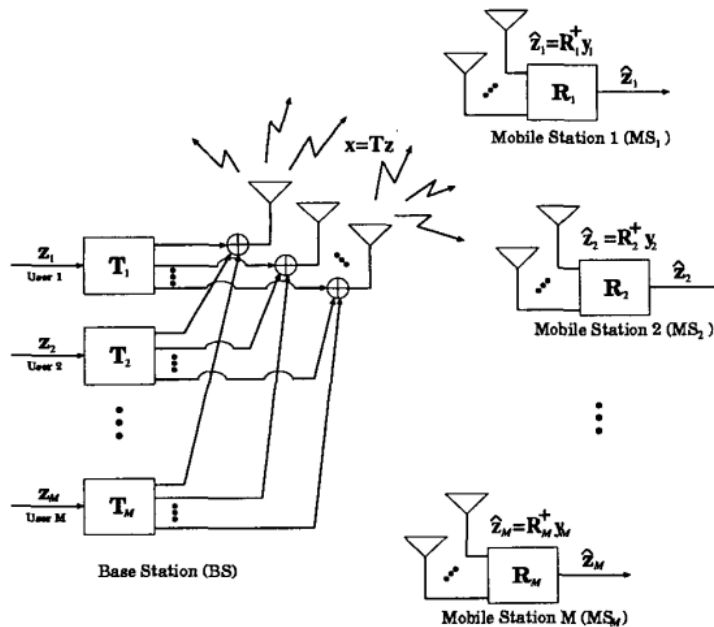


Fig. 1. System configuration of a multiuser MIMO system.

- 128.
129. Id. at pp. 430.
130. Likewise, Rousseaux, et al., published “A Blind Multi-User MIMO Transceiver using Code Modulation in a Multipath Context,” in the *14th International Conference on Digital Signal Processing Proceedings*, 1-3 July, 2002, Vol. 2, pp. 267 – 270. This paper was also focused on “... multi-user systems where both the base station and the users have multiple antennas” in a “wideband context” using “OFDM ... and related block transmission techniques that use a cyclic prefix.” Id. at pp. 267.
131. In US005345599 discussed above, a POSITA would also understand that the disclosed system where “The high-rate signal is split into several low-rate signals ... [and] [t]hese low-rate signals are transmitted from spatially separated transmitters, all radiating into the service area in the same frequency channel. Each receiver uses a

plurality of antennas to receive these multiple cochannel signals”, discloses a downlink MU-MIMO system where multiple data streams are transmitted by separate radios (base stations) to be received by a device using multiple antennas. See US005345599 at Abstract. “Fig. 5 shows operation of a representative receiving station. A receiving station located within the service area will receive all d signals in the same frequency channel. Receiving stations use a receive array that contains m subarrays (or elements)”. See US005345599 7:49-53.

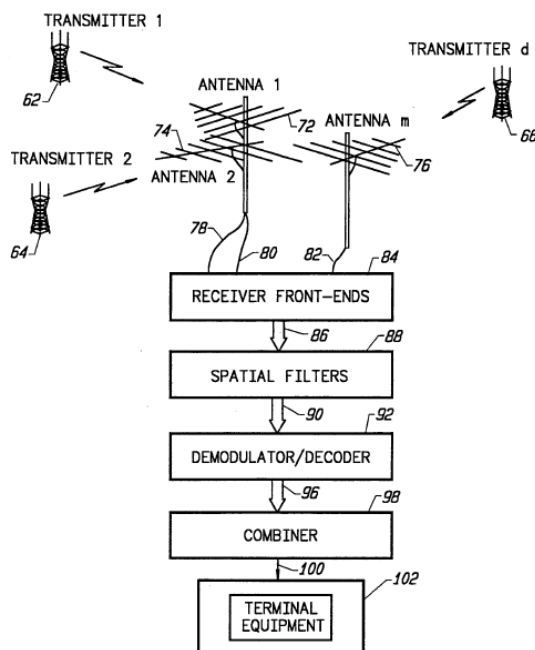
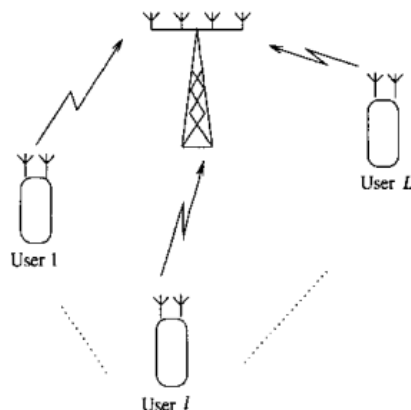


FIG. 5

132.

133. Other papers presented uplink MU-MIMO systems where mobile stations with multiple antennas transmit data up to the base station which uses multiple antennas to receive the spatially multiplexed data from the multiple mobile stations. In the

paper, “Multiuser MIMO Systems and Interference Avoidance”, *IEEE International Conference on Acoustics, Speech, and Signal Processing*, 6-10 April, 2003, pp. 828 – 831, Popescu and Rose present “A general signal space formulation” used to make “the approach applicable to any MIMO system model regardless of the choice of basis functions.” They further state, “We also note that the approach is general and applicable to any MIMO system model.” See Popescu and Rose at Abstract, pp. 828. The authors present an application of interference avoidance techniques “to multiuser MIMO systems such as those associated with the uplink of a wireless system in which users and the base station are equipped with multiple antennas.” Id. at pp. 828.



134. **Fig. 1. Multiuser MIMO system in which users and the base station are equipped with antenna arrays for transmission/reception.**

135. By 2004, many papers discussing uplink MU-MIMO were known to a POSITA, such as “Transceiver Optimization for Multiuser MIMO Systems”, Serbetli and Yener, *IEEE Transactions on Signal Processing*, Vol. 52, No. 1, January 2004, pp. 214 – 226.. “We consider the uplink of a multiuser system where the transmitters as

well as the receiver are equipped with multiple antennas. Each user multiplexes its symbols”. See Serbatli and Yener at Abstract. “We consider the uplink of a single cell synchronous system with K users. The receiver employs N_R antennas. We assume that the i th user multiplexes a fixed number of data streams M_i through its N_T transmit antennas employing an $N_T \times M_i$ linear transmitter F_i in one symbol period (Fig. 1).” Id. at pp. 215.

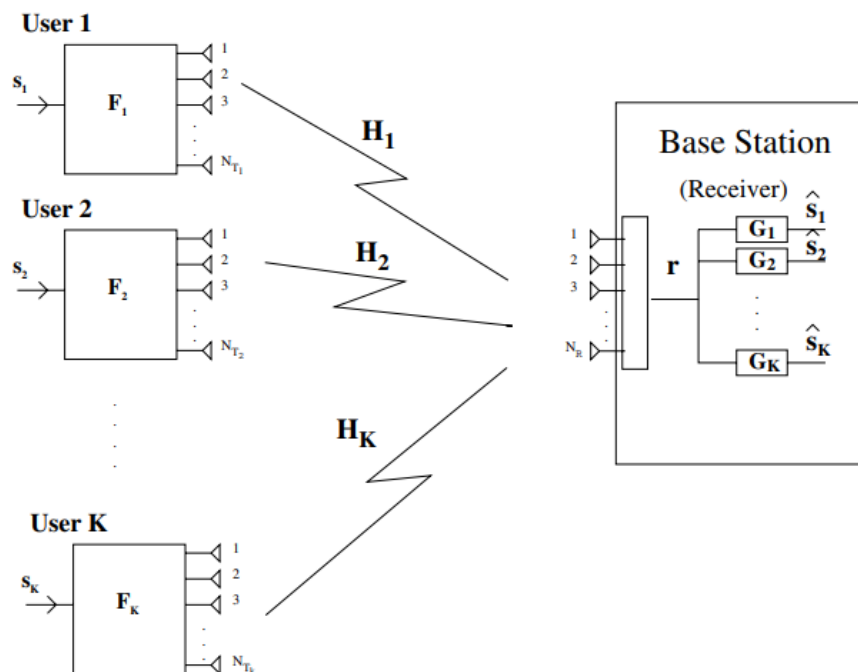


Fig. 1. System model of multiuser MIMO system.

136.

137. Beamforming or spatial filtering has been an active topic of research and application since the late 19th century. An early version of a beamformer was the Perrin array (designed by and named after Sergeant Jean Perrin) deployed during WWI. This was an acoustic array used by the French army to detect enemy aircraft

Declaration of Dr. Mark P. Mahon

using two subarrays of six hexagonal sensors in each subarray. The picture below shows Perrin's array. The two main receivers (equivalent to acoustic antennas) were separated by a fixed distance which provided the operators with the ability to spatially filter signals arriving at the sensor based upon the overlap of the receiver's sensitivity patterns (i.e., the spatial responsiveness to a given direction of arrival) to determine the elevation angle of the enemy plane.

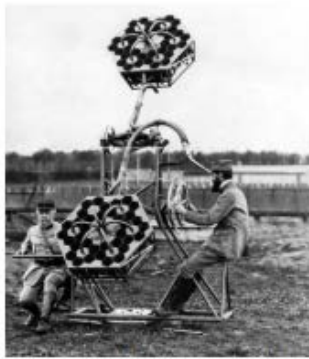


Figure 1: Acoustic array developed by Sergeant Jean Perrin (right) and used by the French Army during WWI to detect enemy aircraft.

138.

139. Heilman, et al.

140. The early days of beamforming were dominated by acoustic (in air and underwater) applications primarily until the mid-20th century when radio antennas came on to the scene during WWII.

141. “*Beamforming* is the name given to a wide variety of array processing algorithms that, by some means, focus the array’s signal-capturing abilities in a given direction. Based on the analogy of a flashlight, the mainlobe of an array’s directivity pattern is called a *beam*[]. Just as one might point a telescope or a radar dish, a beamforming

algorithm ‘points’ the array’s spatial filter toward desired directions but algorithmically rather than physically...**the signal processing algorithms developed for these conventional beamforming algorithms date from the early days of array processing and are well understood.**” See Johnson and Dudgeon pp. 112 (emphasis added).

142. The fundamental concepts of using multiple antenna elements (acoustic or RF) to form an array which are used to spatially focus the transmit signal (transmit beam) or spatially filter the received signal (receive beam) have not changed significantly because it was the well-understood physics that permitted the original construction of the arrays. For example, the basic idea of using two subarrays (as in Perrin’s array) with overlapping receive sensitivity patterns to combine the arriving signal in a way that permitted higher resolution spatial filtering than could be obtained if the subarrays were used individually was well understood during the early part of the 20th century.

143. The simplest and oldest form of a beamforming algorithm is the so called, delay-and-sum beamforming. “The underlying idea is quite simple: If a propagating signal is present in an array’s aperture, the sensor outputs, delayed by appropriate amounts and added together, reinforce the signal with respect to noise or waves propagating in different directions.” Id.

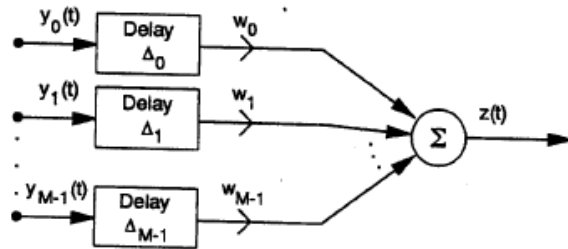


Figure 4.2 The beamformer's output $z(t)$ consists of adding together the sensors' outputs after a delay (and an amplitude weight) has been applied to each. The delays can be chosen to maximize the array's sensitivity to waves propagating from a particular direction or location in space.

144.

145. Id.

146. In array signal processing, the simple delay-and-sum beamforming is, in reality modified by characteristics of the sensors themselves and by various filtering operations that may be performed on the received signals. "For all these reasons, we must consider each sensor's output to be a filtered version of the local wavefield. Combining these filtered outputs to form a beam is known as *filter-and-sum beamforming*." Id. at pp. 128.

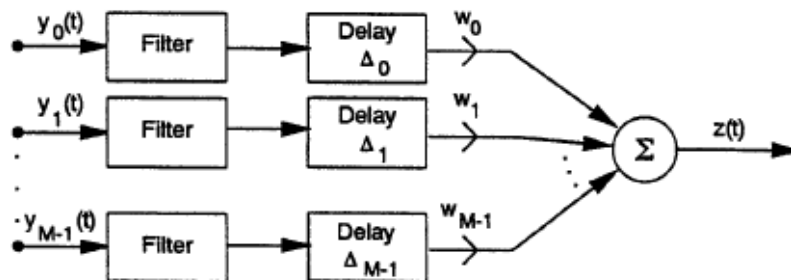


Figure 4.8 The configuration of the filter-and-sum beamformer consists of linear filters preceding the delay-and-sum beamforming stage. The transfer functions of these filters are usually identical and select the range of frequencies corresponding to the signal of interest.

147.

148. Id.

149. Combining and using subarrays has also been known (as illustrated above) since the early days of the beamforming and they have been used to provide higher

Declaration of Dr. Mark P. Mahon

sensitivity (i.e., increased spatial filtering) as well as to perform averaging, cancellation, and other array functionality. “The simple concept of the filter-and-sum beamformer can be generalized to include spatial filtering of sensor signals. This filtering occurs when the sensors are **not omnidirectional**, having greater sensitivity to waves propagating in certain directions. We find this solution when the sensors are continuous apertures, as in the case of telescopes[] or World War I listening devices[], or consist of small subarrays, as in the case of some sonar and seismic arrays.” Id. at 131 (emphasis added).

150. Additionally, using subarrays (as in the Perrin beamformer) has been a method used to obtain high resolution (as above) or to form other desired outcomes, such as averaging data statistics. One example is spatial averaging. In this case “a regular linear array of M sensors can be decomposed into component regular linear subarrays having M_S sensors. If the subarrays are spatially disjoint, then we can average over nonoverlapping subapertures... The trick is to *overlap* the subarrays, compute the spatial correlation matrix for each, and average these to form a spatial correlation matrix that uses the data provided by the entire array.”

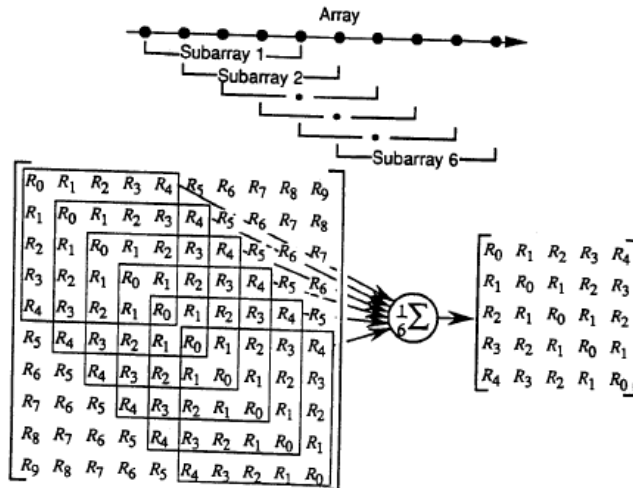


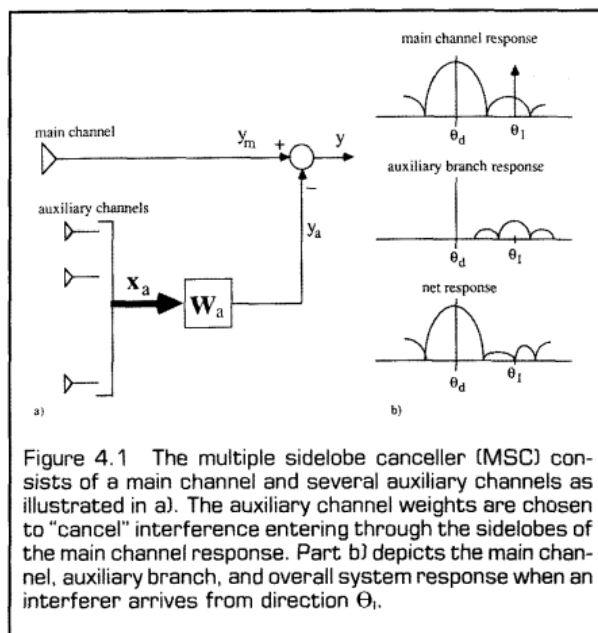
Figure 4.35 A regular linear array of M sensors can be conceptually decomposed into $M - M_s + 1$ subarrays each having M_s sensors. Here, spatial correlation matrices are computed for each of the six subarrays formed from a ten-sensor array. These matrices, which are submatrices of the array's spatial correlation matrix, are then averaged to form a smaller spatial correlation matrix. In this way, time-bandwidth product is gained at the expense of aperture.

151.

152. Id. at pp. 188.

153. The above illustrates that a single array is separated into six logical subarrays which together create nine combinations of subarray overlapped regions. This concept has been used throughout the history of beamforming. The same concepts may be applied to circular arrays or arrays covering 360 degrees. If, for example, the array depicted above was reshaped into a circular array, each subarray would cover approximately 160 degrees with 120 degrees of overlap in each sector associated with each subarray of one or more subarrays. The figure above also indicates that it was well known that the overlap could be handled by processing the data of the subarrays in various ways to obtain the high resolution or specific desired performance behavior of the overall array.

154. Another example of using subarrays to obtain specific behavior from a set of arrays is the well-known multiple sidelobe canceller (MSC). “The multiple sidelobe canceller (MSC) is perhaps the earliest statistically optimum beamformer. An MSC consists of a ‘main channel’ and one or more ‘auxillary channels’”. See Veen and Buckley, “Beamforming: A Versatile Approach to Spatial Filtering”, *IEEE Signal Processing Magazine*, April 1988 at pp. 13-14. The main channel can be a high gain antenna (as in a single highly directional antenna covering a sector of a cell) or an array whose output is processed to achieve the same angular coverage. In the MSC it is the sidelobes of the two subarrays that overlap and the resulting signals are processed in such a way to perform a specific function (sidelobe cancellation).



155.

156. Id.

157. The MSC uses multiple subarrays or a combination of a highly directional antenna and an array to combine the outputs of the two arrays to obtain improved spatial performance for the overall system.

158. Additionally, a POSITA at the priority date of the '235 patent would be knowledgeable about various antenna configurations and sectorized designs for used for wireless communication systems. An example of various antenna design considerations can be found in Kalinichev, "Analysis of Beam-Steering and Directive Characteristics of Adaptive Antenna Arrays for Mobile Communications", IEEE Antennas and Propagation Magazine, Vol. 43, No. 3, June 2001, pp. 145-152.

159.

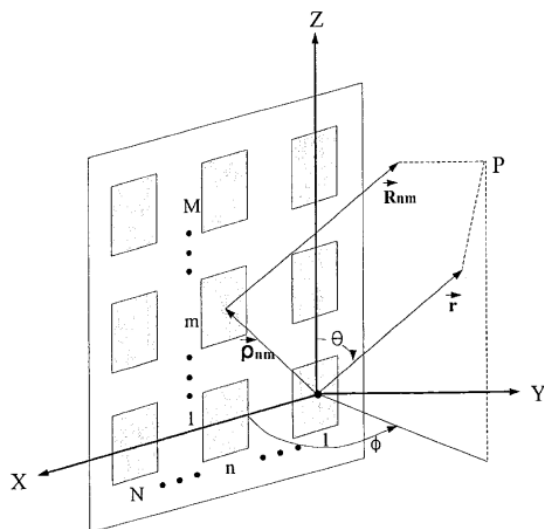


Figure 2. A planar array, consisting of N vertical linear subarrays of M patch radiators. The subarrays are placed in one plane, and are equally spaced.

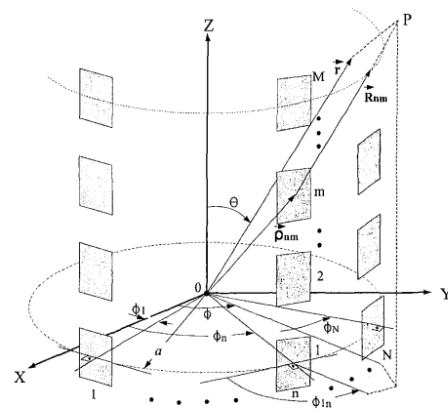


Figure 1. A circular array, consisting of N vertical linear subarrays of M patch radiators. The subarrays are situated along a circular arc of radius a , and have azimuth coordinates ϕ_n , $n = 1, \dots, N$.

160.

161. Id. at pp. 146-147.

Declaration of Dr. Mark P. Mahon

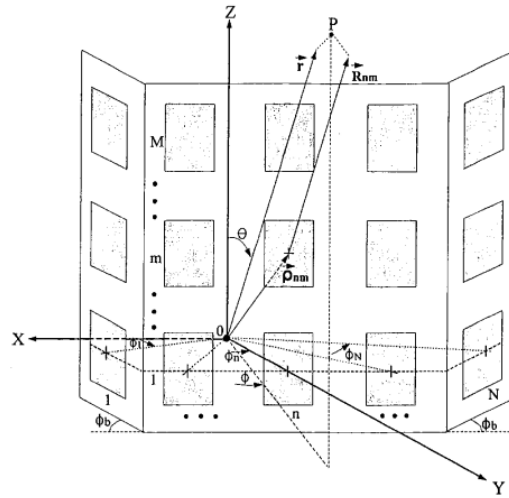


Figure 3a. A three-segment array, consisting of N vertical subarrays of M patch radiators.

162.

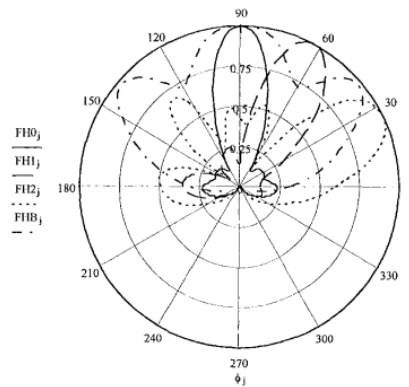


Figure 4a. The azimuth (H-plane) normalized patterns in polar (dimensionless) coordinates for the five-subarray circular array, with $a = 0.95\lambda$, $\Delta\phi = 30^\circ$: $\phi_0 = 90^\circ$ (solid line), $\phi_0 = 60^\circ$ (dashed line), and $\phi_0 = 15^\circ$ (dotted line). Also shown is the synthesized broad-beam pattern (dash-dotted line) with a 136° 3 dB beamwidth.

163. *Id.* at pp. 148 and 149.

164. This paragraph left intentionally blank.

165. This paragraph left intentionally blank.

166. This paragraph left intentionally blank.

167. This paragraph left intentionally blank.

H. General Related Knowledge

168. The following section further describes the state of the art for wireless systems as of the priority date as known to a POSITA.

1. Radio Channels in a Mobile Wireless Communication System

169. As the '443 Patent acknowledges, a group known as the 3rd Generation Partnership Project (“3GPP”) defines global technical specifications and reports for present and future wireless communication systems. EX-1001, 3:22-27. These standards are used by equipment manufacturers – both for network equipment, such as base stations (“BS”), and end-user devices, referred to as user equipment (“UE”) – to ensure that the devices may communicate with one another. EX-1001, 3:22-36.

170. In a typical cellular communication system, a BS communicates with various UEs over radio channels to provide the various UEs with access to the network. EX-1010, 4:36-42. These radio channels are referred to as physical channels, and may be categorized either as downlink physical channels, which refer to information sent from the BS to the UE, or uplink physical channels, which refer to information sent from the UE to the BS. EX-1010, 6:45-7:39. The physical channels may further be categorized as shared channels, which are available to carry user data, or control channels, which are used to carry control information. EX-1010, 6:45-7:39. Thus, there are four primary physical channels: physical downlink shared channel (“PDSCH”); physical downlink control channel (“PDCCH”); physical uplink shared

channel (“PUSCH”); and physical uplink control channel (“PUCCH”). EX-1010, 6:45-7:39.

171. This paragraph left intentionally blank.

2. Hybrid-ARQ Acknowledgements (“HARQ-ACK”)

172. Over these shared physical channels, blocks of data, referred to as a transport block (“TB”) are sent, which are composed of many code blocks (“CBs”). EX-1010, 31:16-17. These CBs may be further grouped into code block groups (“CBGs”), such that a TB may comprise one or more CBGs. EX-1010, 31:16-37. After decoding, each CB is checked for correctness with a cyclic redundancy check (“CRC”). EX-1010, 11:12-30. CRC is a sequence of bits attached to a CB in the transmitter prior to encoding and is used for error detection. EX-1010, 16:33-54. The CRC is checked in the receiver after the decoder to confirm whether or not the transmitted CB has been successfully received. EX-1010, 16:33-54. If the CRC attached to the CB matches the one calculated by the receiver, the CB is considered to be error free. EX-1010, 16:33-54.

173. Following CRC, a hybrid automatic repeat request (HARQ) indicator is sent from the receiver device to the transmitter device to indicate a positive acknowledgement (ACK) or negative acknowledgement (NACK) of data sent using the shared channels. EX-1010, 16:9-17:3. Upon receiving the ACK signal, the transmitter device transmits

the next block of data (*i.e.*, new data), but if the NACK signal is received, the transmitter device retransmits the data. EX-1010, 16:9-17:3.

174. This paragraph left intentionally blank.

3. DCI Decoding

175. To support the transmission of downlink and uplink transport channels Downlink Shared Channel (DL-SCH) and Uplink Shared Channel (UL-SCH) control signaling is required. EX-1010, 10:56-11:11. This control signaling enables a UE to successfully receive, demodulate, and decode the DL-SCH. EX-1010, 10:56-11:11. The Downlink Control Information (DCI) is transmitted through the PDCCH and includes information about the DL-SCH resource allocation (the set of resource blocks containing the DL-SCH), transport format and information related to the DL-SCH HARQ. EX-1010, 10:56-11:11.

176. To form the PDCCH payload the DCI undergoes channel coding: addition of a CRC attachment followed by convolutional coding and rate matching according to PDCCH format capacity. EX-1010, 11:12-30. The coded DCI bits (*i.e.*, PDCCH payload), are then mapped to Control Channel Elements (“CCEs”) according to the PDCCH format. EX-1010, 11:12-58. These coded bits are then converted to complex modulated symbols. Finally, the modulated symbols are interleaved and mapped to physical Resource Elements (“REs”). EX-1010, 11:12-58.

177. After performing deinterleaving, deprecoding, symbol combining, symbol demodulation and descrambling at the receiver, the UE is required to perform blind decoding of the PDCCH payload as it is not aware of the detailed control channel structure, including the number of control channels and the number of CCEs to which each control channel is mapped. EX-1010, 12:4-15. Multiple PDCCHs can be transmitted in a single subframe which may and may not be all relevant to a particular UE. EX-1010, 12:4-15. The UE finds the PDCCH specific to it by monitoring a set of PDCCH candidates (a set of consecutive CCEs on which a PDCCH could be mapped) in every subframe. EX-1010, 12:4-26. The UE uses its Radio Network Temporary Identifier ("RNTI") to try and decode candidates. EX-1010, 11:12-30. The RNTI is used to demask a PDCCH candidate's CRC. EX-1010, 11:12-30. If no CRC error is detected the UE determines that PDCCH carries its own control information. EX-1010, 11:12-30.

178. This paragraph left intentionally blank.

4. Search Space Configurations

179. Once the DCI message is generated and channel coded according to the required DCI and PDCCH format, PDCCH multiplexing, scrambling, modulation, precoding, interleaving and layer mapping are performed to form complex symbols. These complex symbols are now ready to be mapped onto REs. EX-1010, 11:12-58. The REs are defined in terms of REGs/CCEs allocated to a transmission. EX-1010, 11:12-

58. The number of CCEs allocated is given by the PDCCH format. EX-1010, 11:12-58. The control region of a subframe is a collection of CCEs and can contain PDCCHs for multiple UEs thus the UE has to monitor a large area to extract its own control information. EX-1010, 11:12-58. As the UE is not explicitly informed of the detailed control channel structure it has to blindly attempt to decode the control region. EX-1010, 11:12-12:15. Unfortunately, this may impose a substantial burden on the UE as at large bandwidths the control region may be very large. This may exceed practical hardware limitations and lead to increased cost and/or reduced performance of the UE.
180. To simplify the decoding task at the UE, the whole control region is sub-divided into common and UE-specific search spaces which the UE should monitor (attempt to decode each of the PDCCHs). EX-1010, 11:59-12:3. Each space comprises 2, 4 or 6 PDCCH candidates whose data length depends on the PDCCH format; each PDCCH must be transmitted on 1, 2, 4 or 8 CCE(s) ($1 \text{ CCE} = 9 \text{ REGs} = 9 \times 4 \text{ REs} = 72 \text{ bits}$). EX-1010, 11:31-12:3.
181. The PDCCH candidates consist of consecutive CCEs. EX-1010, 11:31-12:3. The candidates within the PDCCH candidate set do not have to be unique, especially for smaller bandwidths. EX-1010, 11:31-12:3. The common and UE-specific search spaces can overlap with each other. EX-1011, 1:26-2:3. The size of search space is determined by the number of PDCCH candidates and the size of CCE aggregation

- level. EX-1011, 1:26-2:3. That is, the size of the search space is integer times the size of CCE aggregation level or the number of PDCCH candidates. EX-1011, 1:26-2:3.
182. The common search space (“CSS”) carries the common control information and is monitored by all UEs in a cell. EX-1011, 1:26-2:3. The number of CCE aggregation levels supported by the common search space is limited to two i.e. 4 and 8 as compared to the UE-specific search space where four CCE aggregation levels are possible. EX-1011, 1:26-2:3. This reduces the burden on UE for decoding common control information compared to decoding UE-specific control information. The common control space is used to carry important initial information including paging information, system information and random access procedures. EX-1011, 1:26-2:3.
183. When searching the common control space the decoder always starts decoding from the first CCE. EX-1011, 1:26-2:3. This restriction further simplifies the common search. The decoding is done on every possible PDCCH candidate set for given PDCCH format until it successfully decodes the PDCCH present in CSS. EX-1011, 1:26-2:3.
184. The UE-specific search space (“USS”) carries control information specific to a particular UE and is monitored by at least one UE in a cell. EX-1012, 9:10-10:19. Unlike the CSS, the starting location of the USS may be varied for each subframe or UE. EX-1012, 9:10-10:19. The starting location of the USS is determined in every subframe using a hash function. UE. EX-1012, 9:10-10:19.

185. In the USS the UE finds its PDCCH by monitoring a set of PDCCH candidates (a set of consecutive CCEs on which PDCCH could be mapped) in every subframe. EX-1012, 9:10-10:19. If no CRC error is detected when the UE uses its RNTI to demask the CRC (16-bit value also refers as C-RNTI) on a PDCCH, the UE determines that PDCCH carries its own control information. EX-1012, 9:10-10:19. The PDCCH candidate sets correspond to different PDCCH formats. EX-1012, 9:10-10:19. There are 4 PDCCH formats: 0, 1, 2 or 3. EX-1012, 9:10-10:19. If the UE fails to decode any PDCCH candidates for a given PDCCH format it tries to decode candidates for other PDCCH formats. EX-1012, 9:10-10:19. This process is repeated for all possible PDCCH formats until all directed PDCCHs are successfully decoded in USS. EX-1012, 9:10-10:19.

186. This paragraph left intentionally blank.

5. U.S. Patent No. 10,735,170

187. U.S. Patent No. 10,735,170 (“’170 Patent”) to Yang et al. summarizes the state of the art as of the date of the earliest alleged priority date for the ’443 Patent. The ’170 Patent was filed on August 6, 2015 and issued on August 4, 2020. EX-1010. The ’170 Patent “provides an HARQ-ACK feedback method and device,” whereby UE “detects downlink grant downlink control information and performs HARQ-ACK feedback for downlink data corresponding to the downlink control information.” EX-1010, Abstract.

188. The '170 Patent explains that “[a] UE of the present invention detects DL grant DL control information and performs HARQ-ACK feedback for DL data corresponding to the DL control information.” EX-1010, 2:17-20. Accordingly, the '170 Patent discloses “a method of performing acknowledgement/negative acknowledgement (ACK/NACK) feedback by a user equipment (UE), comprising: detecting downlink control information (DCI) for a cell configured in an unlicensed band; and receiving downlink (DL) data through a physical downlink shared channel (PDSCH) according to the DCI.” EX-1010, 2:24-29.

189. To perform this method, the '170 Patent explains that UE comprises “a radio frequency (RF) unit configured to receive or transmit a signal and a processor configured to control the RF unit.” EX-1010, 2:36-38. “The processor may be configured to control the RF unit to receive downlink (DL) data through a physical downlink shared channel (PDSCH) according to the DCI” and “to transmit ACK or NACK as the ACK/NACK information according to a result of decoding the DL data.” EX-1010, 2:40-51.

190. The '170 Patent explains that when a transport block for one data transmission transmitted through the PDSCH may be further segmented into a plurality of code blocks or code block groups. EX-1010, 31:16-21. In such instances, and with respect to the HARQ-ACK feedback transmission, the '170 Patent explains that rather than transmitting HARQ-ACK on a transport block basis, it may be desirable to also

configure/transmit the HARQ-ACK feedback transmission “on a code block basis or on a code block group basis, for effective retransmission and error recovery.” EX-1010, 31:16-21.

191. Accordingly, as clear in the '170 Patent, as of the date of the earliest alleged priority date for the '443 Patent, it was well known to a POSITA that a UE was configured to receive downlink (DL) data, such as a TB comprising a plurality of CBs or CBGs, through a physical downlink shared channel (PDSCH) according to the DCI received through a physical downlink control channel (PDCCH) and transmit HARQ-ACK information according to a result of decoding the DL data on a TB, CB or CBG basis.

6. Summary

192. Accordingly, and as discussed above, it was well known to a POSITA as of the claimed priority date of the challenged patent that base stations (“BSs”) (also occasionally abbreviated as “gNBs”) were configured to communicate with user equipment (“UE”) over physical uplink and downlink channels such as PUSCH, PUCCH, PDSCH, and PDCCH. Moreover, a POSTIA as of the claimed priority date of the challenged patent was well aware that BSs would transmit data in the form of a transport block (“TB”) to the UE over PDSCH and that the transmitted TBs were further broken down by code blocks (“CBs”) and code block groups (“CBGs”). Upon receipt of the TB comprising CBs and CBGs, the cyclic redundancy check (“CRC”)

transmitted with the TB would be checked by the UE to confirm whether or not the transmitted data had been successfully received, and the UE would then transmit a HARQ-ACK back to the BS to indicate whether the data had been successfully received or not. Moreover, because TBs are relatively large, it was well known to a POSITA as of the claimed priority date of the challenged patent that transmitting one HARQ-ACK bit per TB was inefficient and that it was more efficient to transmit HARQ-ACK bits per CB or CBG.

VII. OVERVIEW OF THE CHALLENGED PATENT

A. Priority Date

193. I have been instructed that for the purposes of this IPR, to assume the priority date for the challenged patent is June 15, 2017 (the filing date of Provisional Application No. 62/520,520 to which the challenged patent claims priority).

194. My analysis herein would not change regardless of whether the priority date is June 15, 2017 (the filing date of the provisional application) or June 14, 2018 (the filing date of the non-provisional application).

B. Overview Of The Content Of The Challenged Patent

195. The Challenged Claims are directed to techniques for improving wireless communications between a base station and user equipment for 5th generation (“5G”) cellular communications.

196. Before turning to the specific improvements alleged in the Challenged Claims, it may be useful to first discuss cellular networks more generally. A cellular network

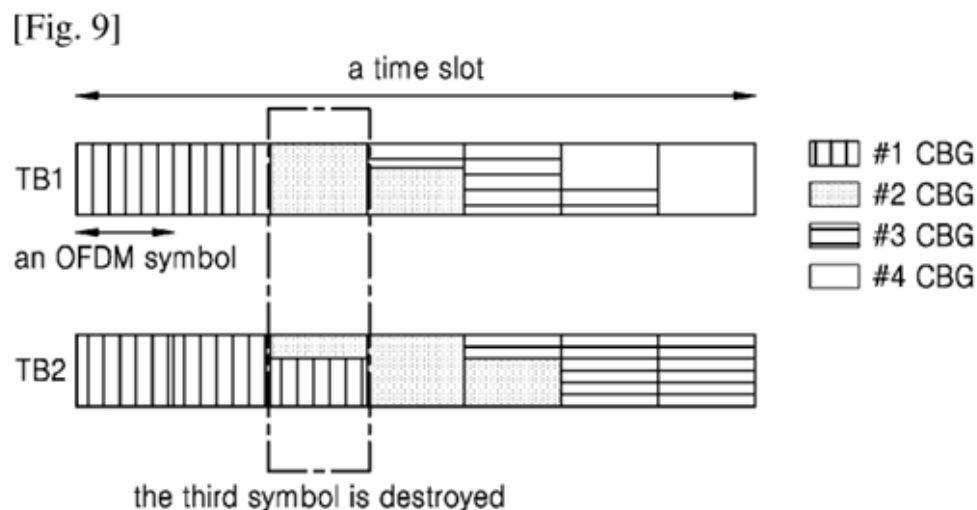
(sometimes referred to as a mobile network) is a radio network distributed over land areas called cells. Each cell is served by at least one fixed-location transceiver, referred to as a base station (“BS”). The BS provide the cell with network coverage that can be used for the transmission of voice, data, and other types of content. When joined together these cells provide radio coverage over a wide geographic area creating a cellular network. This enables a large number of user equipment (“UE”), such as cells phones, to communicate with each other anywhere in the network via the BS.

197. Communications from the BS to the UEs are sent as blocks of data. To ensure that the blocks have been received by the UE, the UE sends back an acknowledgement of reception of that block. If the acknowledgement indicates a successful transmission, then the processing continues, however, if the acknowledgement indicates a failed transmission, then the BS re-transmits the same block to the UE again. This concept of BS transmissions followed by UE acknowledgements (and possible BS re-transmissions) has been known and used throughout the history of wireless communications.

198. The ’443 patent relates to a specific improvement in this known sequence. In 4G LTE systems, the BS would transmit the blocks of data in transport blocks (“TBs”). The UE would then send back an acknowledgement to the BS for each TB. The

problem is that TBs are fairly large (up to 3824 bits). So, if only 1 bit out of 3824 bits failed in a transmission, the BS had to re-send the entire TB.

199. To mitigate this inefficiency, in 5G, the TBs were broken up into smaller units of data called code block groups (“CBGs”). For example, take Figure 9 of Wang (shown below) illustrating two TBs, each subdivided into various CBGs:



200. EX-1004, Fig. 9.

201. By subdividing each TB into various CBGs, the UE can now evaluate each CBG for successful transmission, and can then send back an acknowledgement for each CBG. If retransmission is needed as a result of an unsuccessful initial transmission, the BS now only needs to re-transmit one of the smaller CBGs rather than the entire TB.

202. In the transition from LTE to 5G, a BS retained its ability to send one acknowledgement bit for the entire TB, but now added the ability to send individual

bits for each CBG within a TB. Thus, this case is partially about breaking up larger blocks into smaller sub-blocks and being able to send acknowledgements on a more refined basis for each CBG within each TB.

203. The Challenged Claims of the '443 patent include criteria for the BS to determine whether to send an acknowledgement for the entire TB or the individual CBGs. The transmissions from the BS to the UE can be either “common,” such that they are meant to be received by all UEs in the cell or “user-specific,” such that they are meant only for a particular UE within the cell. These transmissions are referenced as being in a “common search space” (“CSS”) or a “UE-specific search space” (“USS”).

204. The '443 patent claims the permutation of using (1) the 1-bit acknowledgement per TB for CSS transmissions and (2) using the 1-bit acknowledgement per CBG for USS transmissions. However, the '443 patent notably does not teach any particular advantage to selecting this one permutation of different acknowledgements.

205. The '443 patent uses specific terminology to describe this basic and known process above. Specifically, the BS sends a physical downlink shared channel (“PDSCH”) message to a UE which includes code block groups (“CBGs”) of a transport block (“TB”), and in return, receives CBG based hybrid-ARQ acknowledgements (“HARQ-ACK”) feedback. The control channel format and resource for HARQ-ACK feedback may be determined by the scheduling space for CBG-based HARQ-ACK, such that if a PDSCH is scheduled in common search

space (“CSS”), the UE will report only one HARQ-ACK bit per TB, but if the PDSCH is scheduled in UE-specific search space (“USS”), the UE will report HARQ-ACK bits for all CBGs received. EX-1001, 2:61-3:3.

206. The following series of annotated Figures 1 graphically depicts Challenged Claim 3. As shown in annotated Figure 1 below, the BS (outlined and highlighted in yellow) includes both sending circuitry (outlined in red) to send downlink channels, like a PDSCH, that include CBGs of a TB and receiving circuitry (outlined in blue) to receive CBG based HARQ-ACK:

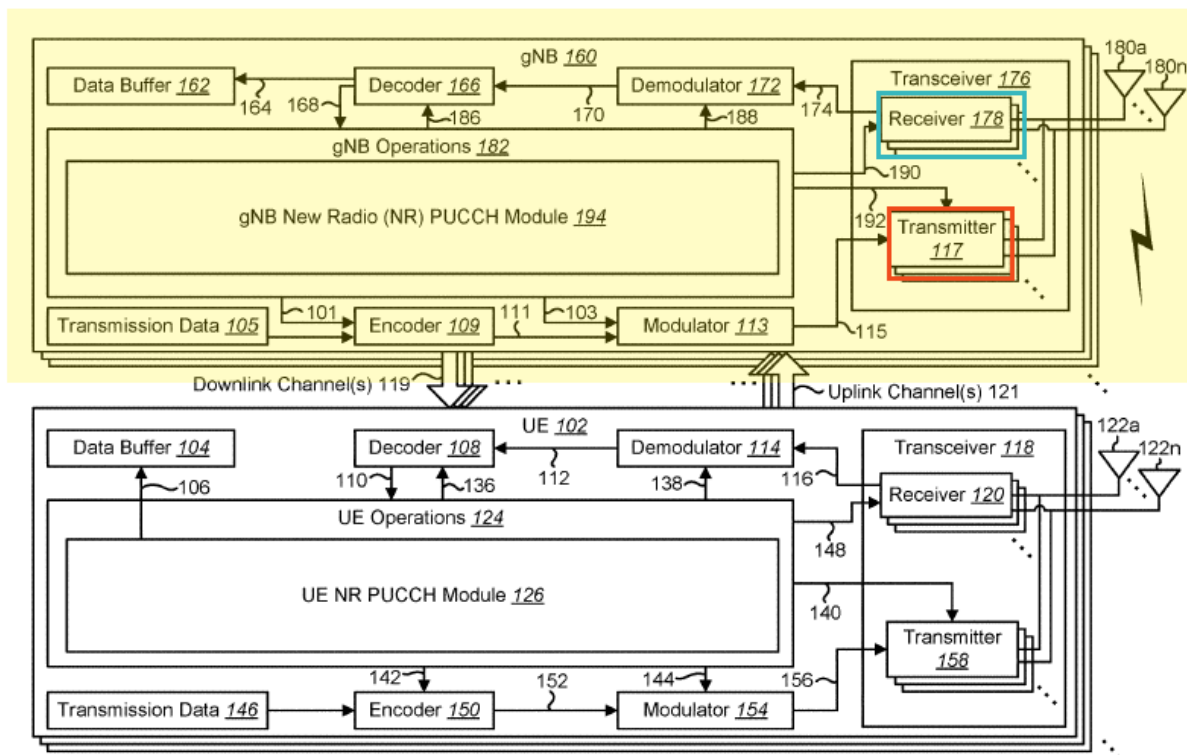


FIG. 1

207. EX-1001, Fig. 1.¹⁴

208. The CBG-based HARQ-ACK feedback may then be configured based upon the scheduling space, such that if a PDSCH (green arrow) is scheduled in CSS the UE may report (purple arrow) only one bit per TB (EX-1001, 2:63-66; *see also* EX-1001, 5:61-6:3), but if the PDSCH (green arrow) is scheduled in USS the UE may report (purple arrow) HARQ-ACK bits for all transmitted CBGs (EX-1001, 2:66-3:2; *see also* EX-1001, 5:61-6:3):

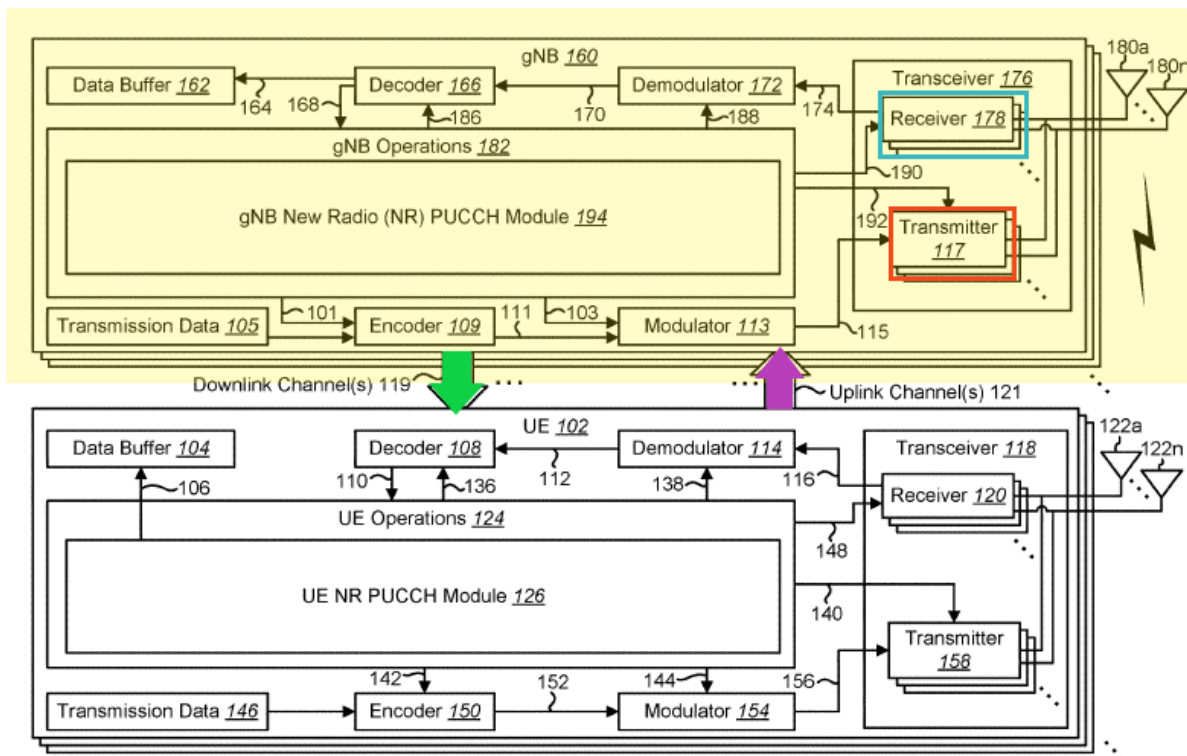


FIG. 1

209. EX-1001, Fig. 1.

¹⁴ Unless otherwise noted, all emphasis and annotations herein have been added.

210. All of the concepts described and claimed in the '443 Patent, including performing HARQ-ACK feedback on a CB or CBG basis rather than a TB basis and using (1) the 1-bit HARQ-ACK feedback per TB for CSS transmissions and (2) using the 1-bit HARQ-ACK feedback per CBG for USS transmissions were known to a POSITA long prior to the '443 Patent.

211. This paragraph left intentionally blank.

C. Prosecution History

212. The '443 Patent issued from U.S. Pat. App. No. 16/008,492 filed June 14, 2018 claiming priority through continuation applications to U.S. Provisional Pat. App. No. 62/520,520 filed June 15, 2017.

213. I have reviewed the prosecution history related to the Challenged Claims. I discuss portions of it below.

214. During prosecution, the (then-pending) claims issued without rejection. *See generally* EX-1002. In the examiner's statements of reasons for allowance contained within the notice of allowance, the examiner cited U.S. Patent Publication No. 2019/0245648 to Jo et al. and U.S. Patent Publication No. 2019/0230685 to Park et al., but noted that neither reference, individually or in combination, taught the limitations of the Challenged Claims. EX-1002, pp. 6-7. The examiner emphasized that the claims required a system configured to change the number of HARQ-ACK bits sent in response to PDSCH information that identifies either a common search

Declaration of Dr. Mark P. Mahon

space (CSS) or a UE-specific search space (USS), which was not found in either Jo or Park individually or in combination. EX-1002, pp. 6. Specifically, the examiner stated:

the cited prior art fails to teach individually or in combination, for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), the transmitting circuitry is configured to report one HARQ-ACK bit for the transport block, and for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), the transmitting circuitry is configured to report HARQ-ACK bits of all CBGs.

215. EX-1002, pp. 6.

216. The Examiner's statements of reasons for allowance reflect the only distinction over the prosecution prior art for the Challenged Claims.

217. The primary references cited herein (Wang, EX-1004 in Ground 1 and Yang, EX-1005 in Ground 2) each focus on, and teach, precisely this concept which was allegedly missing from the prior art during prosecution: configuring CBG-based HARQ-ACK feedback based upon scheduling space (either CSS or USS). First, consider Wang, which serves as the basis for Ground 1. Wang expressly summarizes this concept, explaining that:

the single bit HARQ-ACK feedback method is adopted by the DCI in the common search space (CSS) fixedly while the multi-bit HARQ-

Declaration of Dr. Mark P. Mahon

ACK feedback method is adopted by the DCI in a user-specific search space (USS) fixedly.

218. EX-1004, 12:53-57. Wang's disclosure of differentiating HARQ-ACK bit reporting based upon search space configuration is precisely what was alleged to be missing from the prior art during the prosecution of the '443 Patent.

219. Next, consider Yang, which serves as the basis for Ground 2. Like Wang, Yang also summarizes the exact concept of differentiating HARQ-ACK bit reporting based upon search space configuration, which was allegedly missing from the prior art during prosecution. Yang explains that:

for DL/UL data transmission scheduled through DCI (or TM-dedicated DCI format set/used for specific TM only) transmission based not on CSS but on USS, a CBG-unit retransmission scheduling and per-CBG A/N [(HARQ-ACK)] feedback configuration operation is applicable/configurable. On the other hand, for DL/UL data (and/or Msg3/4) transmission scheduled through CSS based DCI (or TM-common DCI format) transmission, a TB-unit retransmission scheduling and per-TB (TB level) A/N feedback operation is applicable/configurable (i.e., TB-level A/N feedback is configured).

220. EX-1005, 37:63-38:6. Accordingly, like Wang, Yang's disclosure of differentiating HARQ-ACK bit reporting based upon search space configuration is precisely what was alleged to be missing from the prior art during the prosecution of the '443 Patent.

221. Thus, both Wang and Yang independently render obvious the Challenged Claims as detailed in Grounds 1 and 2 respectively, *infra*. The Challenged Claims recite and were allowed based upon their recitation of the known concept of differentiating HARQ-ACK bit reporting based upon search space configuration. Both Wang and Yang independently describe the precise method of differentiation of HARQ-ACK bit reporting based upon search space configuration that is claimed in the Challenged Claims – which was the sole basis of patentability during prosecution.

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VIII. OVERVIEW OF THE PRIOR ART

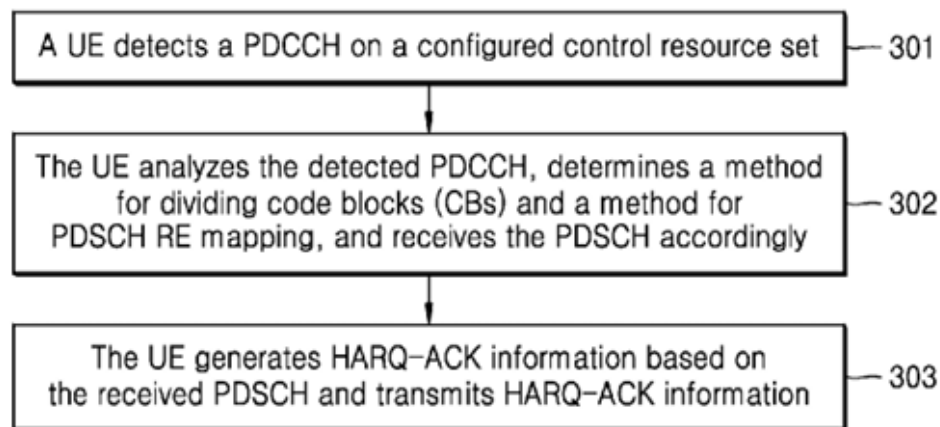
A. Wang

223. U.S. Patent No. 11,206,108 (“Wang”) was filed on January 3, 2018, issued on December 21, 2021, and claims priority to Chinese Application No. 201710288177.X (“Wang Foreign Priority Application”) filed April 27, 2017. I have been advised that Wang qualifies as prior art under §102(a)(2) which is consistent with my understanding of how certain references qualify as “prior art” for purposes of invalidity analyses. Wang was not cited nor applied by the Examiner during prosecution of the challenged patent.

224. Wang discloses a method for enhancing the performance of data transmission within a wireless communications network. To achieve this objective, Wang discloses a UE detecting a PDCCH on a configured control resource set, determining

by the UE a method for dividing CBs and a method for rate matching of a PDSCH, and receiving the PDSCH according to the PDCCH and generating, by the UE, HARQ-ACK information according to the PDSCH and transmitting the HARQ-ACK information to a BS. EX-1004, 3:11-21. Figure 3 of Wang, reproduced below, depicts that at step 301, a UE detects a PDCCH from a BS on a configured control resource set configured by the base station. EX-1004, 7:20-27. At step 302, the UE analyzes the detected PDCCH, determines a method for dividing CBs depending on a DCI carried by the received PDCCH so that the data may be decoded and the like, performs PDSCH RE mapping and receives the PDSCH accordingly. EX-1004, 7:28-56. Finally, at step 303, the UE generates HARQ-ACK information based on the received PDSCH and transmits the HARQ-ACK information to the BS. EX-1004, 7:57-59.

[Fig. 3]



225. EX-1004, Fig. 3.

226. Based upon the difference between the various DCI carried by the received PDCCH, Wang recognizes that in some instances it may be desirable to implement a single bit HARQ-ACK feedback method, while in other instances it may be desirable to adopt a multi-bit HARQ-ACK feedback method. EX-1004, 12:48-57. Specifically, Wang suggests adopting the single bit HARQ-ACK feedback method for a DCI in a CSS, while utilizing the multi-bit HARQ-ACK feedback method for a DCI in USS. EX-1004, 12:48-57.

227. The Wang Foreign Priority Application contains the same disclosure. Specifically, the Wang Foreign Priority Application explains that the HARQ-ACK feedback is divided into two situations: single-bit or multi-bit. EX-1007, pp. 13 (“[p]referably, the HARQ-ACK information is divided into two situations of single-bit HARQ-ACK or multi-bit HARQ-ACK information”). With respect to the single-bit HARQ-ACK feedback situation, the Wang Foreign Priority Application explains that “the HARQ-ACK information is that one-bit HARQ-ACK information is fed back to one TB.” EX-1007, pp. 13. Conversely, with respect to the multi-bit HARQ-ACK feedback situation, the Wang Foreign Priority Application explains that “the UE may feed back HARQ-ACK information to each CBG.” EX-1007, pp. 25. The Wang Foreign Priority Application discloses that one method to differentiate between the single-bit or multi-bit HARQ-ACK feedback methods, is based upon DCI and search space configurations. EX-1007, pp. 13 (“whether or not the single-bit or multi-

Declaration of Dr. Mark P. Mahon

bit HARQ-ACK information is generated is determined according to one or more of the following parameters: ... a DCI format; ... a downlink control channel search space”). Specifically, such that “the DCI in the common search space (CSS) is fixedly subjected to the single-bit HARQ-ACK feedback method, ... [while] the DCI in a user specific search space (USS) is fixedly subjected to the multi-bit HARQ-ACK feedback method.” EX-1007, pp. 26. This method of differentiating between a single-bit HARQ-ACK feedback situation and a multi-bit HARQ-ACK feedback situation disclosed in the Wang Foreign Priority Application is illustrated in Figure 3 below, which is substantively identical to Figure 3 of Wang depicted above:

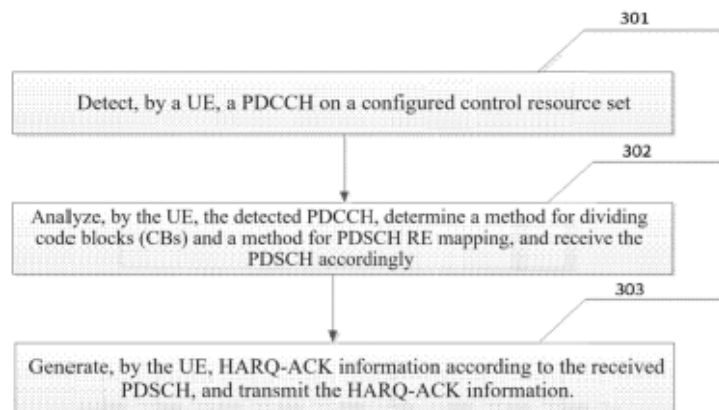


FIG. 3

228. EX-1007, Fig. 3.

229. Accordingly, and as will be discussed subsequently in more detail, both Wang and the Wang Foreign Priority Application teach all elements found in the Challenged Claims – using the same technology relied upon by the '443 specification and priority documents.

230. This paragraph left intentionally blank.

B. Yang

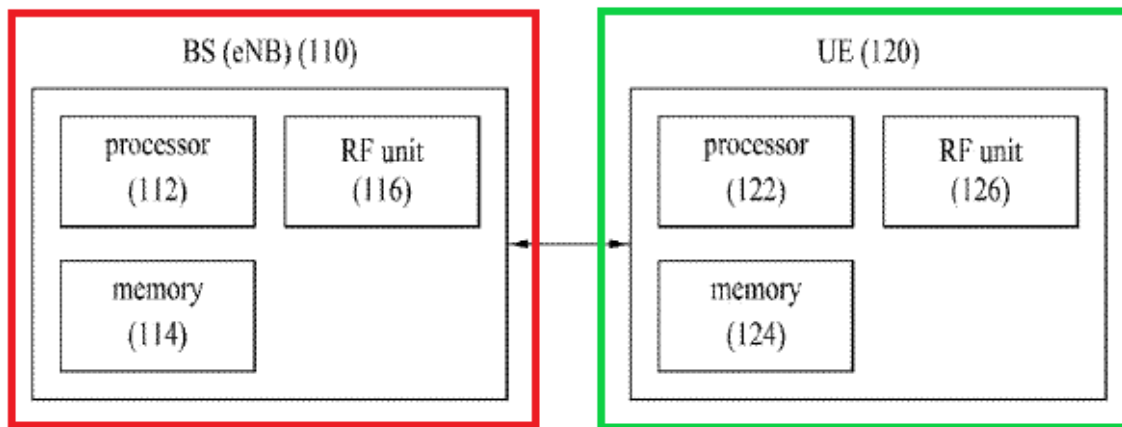
231. U.S. Pat. No. 11,012,221 (“Yang”) was filed on March 8, 2018, issued on May 18, 2021, and claims priority to U.S. Provisional Application No. 62/501,048 (“’048 Application”) filed May 3, 2017. I have been advised that Yang is prior art under §102(a)(2) which is consistent with my understanding of how certain references qualify as “prior art” for purposes of invalidity analyses. Yang was not cited nor applied by the Examiner during prosecution of the challenged patent.

232. Yang discloses a method and apparatus for use within a wireless communication system for receiving a first transport block including a plurality of code blocks from the base station through a physical layer channel, and transmitting HARQ-ACK payload including HARQ-ACK information on the first transport block to the base station. EX-1005, Abstract. Preferably, a code block-based CRC is attached to each of the code blocks, a transport block-based CRC is attached to the first transport block, and the HARQ-ACK payload includes a plurality of HARQ-ACK bits corresponding to M code block groups for the first transport block. EX-1005, Abstract.

233. Figure 18 of Yang, reproduced and annotated below, shows a BS and a UE applicable to the wireless communication system of Yang. EX-1005, 38:55-56. The BS (outlined in red) includes a processor 112, a memory 114, and an RF unit 116.

EX-1005, 38:61-62. The RF unit 116 is connected to the processor 112, and transmits and/or receives RF signals from the UE 120. EX-1005, 38:66-67. The UE (outlined in green) also includes a processor 122, a memory 124, and an RF unit 126. EX-1005, 38:67-39:1. The RF unit 126 is connected to the processor 122, and transmits and/or receives RF signals from the BS 110. EX-1005, 39:2-7.

【FIG. 18】



234. EX-1005, Fig. 18.

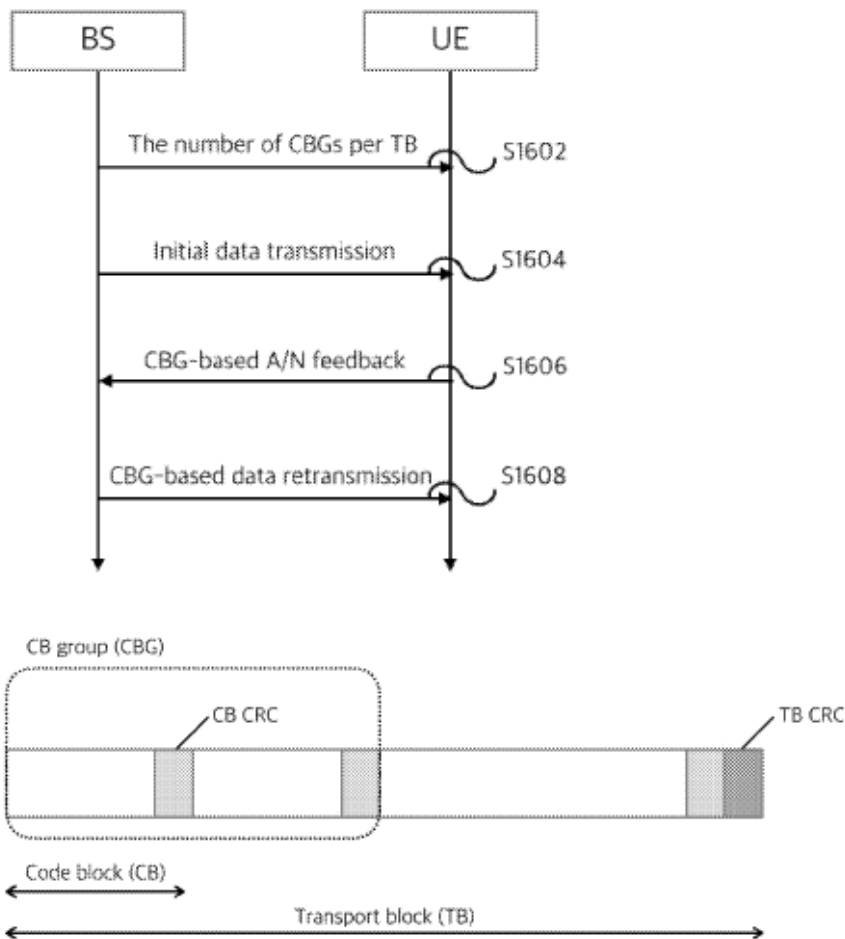
235. Figure 16 of Yang, reproduced below, illustrates the signal transmitting process disclosed in Yang. EX-1005, 21:16-17. At S1602, a UE receives information on the number of M CBGs per TB from a BS. EX-1005, 21:18-21. Thereafter, at S1604, the UE can receive the initial transmission of data, including a TB made up of a plurality of CBs that can be grouped into one or more CBGs, from the BS on PDSCH. EX-

Declaration of Dr. Mark P. Mahon

1005, 21:21-25. Next, at S1606, the UE can feedback CBG-based HARQ-ACK¹⁵ information on the data to the BS. EX-1005, 21:29-31. Finally, at S1608, based upon the CBG-based HARQ-ACK information received, the BS can perform retransmission to the UE. EX-1005, 21:31-32.

¹⁵ Yang uses “A/N” to abbreviate “HARQ-ACK.” EX-1005, 16:59-61 (“the present invention proposes a method of configuring CBG, a method of configuring *HARQ-ACK (hereinafter abbreviated A/N) feedback*”).

【FIG. 16】



236. EX-1005, Fig. 16.

237. The '048 Application contains the same disclosure. Specifically, the '048 Application proposes a method “wherein the (retransmission) scheduling is performed in the unit of CB or of CB group (CBG) and the HARQ-ACK feedback is configured/transmitted in the unit of CB/CBG. More specifically, a method for configuring a CBG, a method for configuring HARQ-ACK (that is, A/N) feedback.” EX-1009, pp. 66. The method proposed in the '048 Application is implemented in a

typical wireless communication system, comprising a UE and a BS. EX-1009, pp. 66.

238. Accordingly, and as will be discussed in more detail below, both Yang and the '048 Application teach all elements found in the Challenged Claims – using the same technology relied upon by the '443 specification and priority documents.

239. This paragraph left intentionally blank.

IX. CLAIM CONSTRUCTION

240. I have been instructed solely for purposes of this IPR, that each claim term in the Challenged Claims be given its plain and ordinary meaning in this proceeding and that no specific construction of any claim term is required because the prior art relied on in this Petition meets each of the claim terms under any reasonable construction.

X. THE CHALLENGED CLAIMS OF THE '443 PATENT ARE OBVIOUS OVER WANG

A. Challenged Claims.

1. Detailed Application of Wang

a. Claim 3

[3.0] A base station (gNB), comprising:

241. To the extent the preamble is limiting, Wang discloses¹⁶ this element.

¹⁶ As used throughout this Petition, “discloses” encompasses what a reference would teach, suggest, or render obvious to a POSITA.

242. As an initial matter, a POSITA would understand that a base station in a wireless network architecture could be abbreviated by a number of different acronyms, such as gNB, eNB, node-b, BS or other. Nevertheless, a POSITA would understand the base station of the Challenged Claims to simply be a device that communicates with wireless communication devices, such as UE. EX-1001, 1:32-33.

243. Wang discloses a base station for use in a wireless communication system for transmitting and receiving signals to a UE. EX-1004, 5:60-62.

In a wireless communication system, downlink transmission refers to *transmitting a signal from a base station to a UE (user equipment)*. A downlink signal includes a data signal, a control signal, and a reference signal (pilot). Here, *the base station transmits downlink data in a physical downlink shared channel (PDSCH), or transmits downlink control information in a downlink control channel. Uplink transmission refers to transmitting a signal from the UE to the base station*. An uplink signal also includes a data signal, a control signal and a reference signal. Here, *the UE transmits uplink data in a physical uplink shared channel (PUSCH), or transmits uplink control information in a physical uplink control channel (PUCCH)*. *The base station* may dynamically schedule the PDSCH transmission and PUSCH transmission of *the UE* through a physical downlink control channel (PDCCH).

244. EX-1004, 5:50-6: 8;¹⁷ *see also* EX-1004, 37:33-34 (“***A terminal*** for transmitting and receiving data...”); EX-1004, 38:35-36 (“***A base station*** for transmitting and receiving data...”).

245. Thus, Wang discloses both a base station and a user equipment for use in a wireless communication system. Accordingly, Wang discloses this element.

246. The Wang Foreign Priority Application also discloses this element. Similar to Wang, the Wang Foreign Priority Application discloses a base station for use in a wireless communication system for transmitting and receiving signals to a user equipment. EX-1007, pp. 9.

In wireless communication systems, downlink transmission refers to transmitting of signals from ***a base station to user equipment (UE)***. Downlink signals include data signals, control signals, and reference signals (pilot frequency). Here, ***the base station transmits downlink data over a physical downlink shared channel (PDSCH), or transmits downlink control information over a downlink control channel. Uplink transmission refers to transmitting of signals from the UE to base station.*** Uplink signals also include data signals, control signals, and reference signals. Here, ***the UE transmits uplink data over a physical uplink shared channel (PUSCH), or sends uplink control information over a physical uplink control channel (PUCCH). The base station*** may dynamically schedule the PDSCH and PUSCH

¹⁷ All emphasis added unless otherwise stated.

transmissions of *the UE* via a physical downlink control channel (PDCCH).

247. EX-1007, pp. 9.

248. Accordingly, Wang discloses claim element 3.0.

[3.1] sending circuitry configured to send a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and

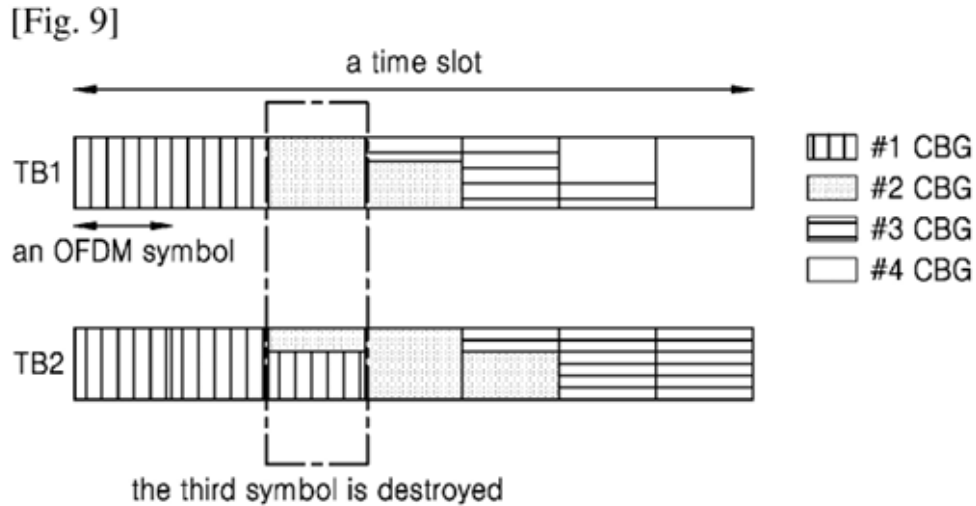
249. Wang discloses this element. Specifically, Wang discloses a base station with sending circuitry configured to send downlink transmissions, including “downlink data in a physical downlink shared channel (PDSCH)” for reception by a UE. EX-1004, 5:64-65; *see also* 6:5-6 (“[t]he *base station* may dynamically schedule the *PDSCH transmission*”); 23:23-24 (“[t]he *base station transmits a TB, which is divided into 4 CBGs*”). A POSITA would understand that a base station that transmits data over a PDSCH would include sending circuitry to effectuate that downlink transmission. The entire purpose of a base station is to communicate with user equipment via different physical channels which are transmitted over radio signals using sending circuitry, such as a transceiver. Accordingly, it would be clear to any POSITA that any base station for use within a wireless communication system possesses sending circuitry and that sending circuitry would be used to transmit a PDSCH.

250. Wang further discloses that the PDSCH transmitted by the base station includes a TB, which may further comprise CBGs. EX-1004, 4:61-65; *see also* 36:54-55 (“***the PDSCH includes code block groups (CBGs) or a transport block***”). Wang elaborates, explaining that within that TB, the:

TB may be divided into multiple CBs firstly and then the multiple CBs are grouped into several CBGs; alternatively, ***the TB may be divided into multiple CBGs*** firstly, and each CBG may be further divided into one or more CBs. In particular, when data is retransmitted, the base station may retransmit the entire TB, or may only retransmit a portion of the CB or CBG of the current TB or a portion of modulation symbols on the OFDM symbols.

251. EX-1004, 7:46-53.

252. Figure 9 of Wang, depicted below, is a schematic diagram illustrating CB/CBG mapping of the PDSCH of the two TBs according to an embodiment of Wang. As seen below, the TBs transmitted via PDSCH may comprise multiple CBGs:

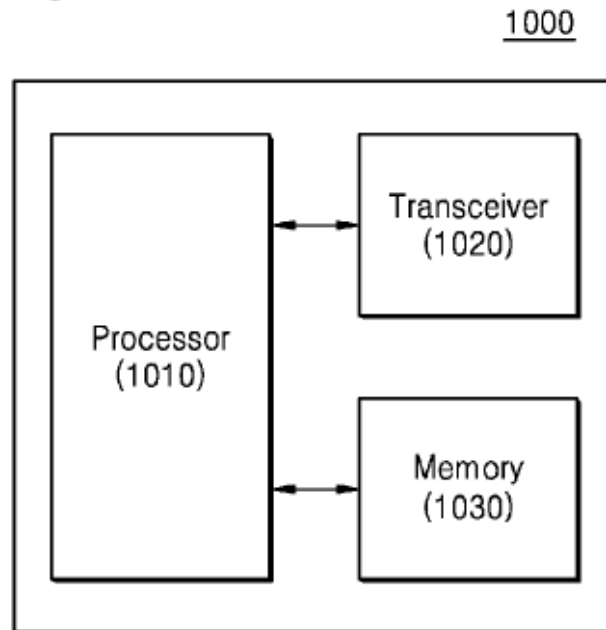


253. EX-1004, Fig. 9.

254. Accordingly, Wang discloses a base station with sending circuitry configured to send a PDSCH that includes CBGs of a TB.

255. Wang further discloses that following transmission of a PDSCH that includes CBGs of a TB by the base station, the PDSCH is received by the UE. Figure 10 of Wang, depicted below, is a schematic diagram illustrating a UE according to an embodiment of Wang. As seen below, the UE includes “a processor 1010, a transceiver 1020 and a memory 1030.” EX-1004, 35:34-35. “The transceiver 1020 may be connected to the processor 1010 and transmit and/or receive a signal.” EX-1004, 35:63-64. “The signal may include control information and data.” EX-1004, 35:64-65. “The processor 1010 may control the transceiver to receive the PDSCH according to the PDCCH.” EX-1004, 35:51-53.

[Fig. 10]



256. EX-1004, Fig. 10; *see also* EX-1004, 7:28-31 (“the UE ... *receives the PDSCH* accordingly”). A POSITA would understand Wang’s disclosure of a transceiver 1020 connected to the processor 1010 to *receive signals*, including receiving the PDSCH, to be receiving circuitry.

257. Moreover, a POSITA would understand that the UE receiving a PDSCH would entail receiving circuitry. Similar to the above, the entire purpose of a user equipment is to communicate with a base station via different physical channels which are received over radio signals using receiving circuitry, such as a transceiver. Accordingly, it would be clear to any POSITA that any user equipment for use within a wireless communication system possesses receiving circuitry and that receiving circuitry would be used to receive a PDSCH.

258. Accordingly, Wang discloses both a (1) base station with sending circuitry configured to send a PDSCH that includes CBGs of a TB; and a (2) UE with receiving circuitry configured to receive a PDSCH that includes CBGs of a TB.

259. The Wang Foreign Priority Application also discloses a base station with sending circuitry configured to send downlink transmissions, including “downlink data over a physical downlink shared channel (PDSCH)” for reception by a UE. EX-1007, pp. 9 (“downlink transmission refers to *transmitting of signals from a base station to user equipment (UE)*”); EX-1007, pp. 9 (“*the base station transmits* downlink data over a physical downlink shared channel (PDSCH)”); EX-1007, pp. 17 (“[a]nalyze, by *the UE... and receive the PDSCH* accordingly”). The PDSCH transmitted by the base station includes a TB, and that TB may further include CBGs. EX-1007, pp. 15 (“*receiving the PDSCH includes: receiving the retransmitted CB, CBG*, or OFDM symbols which are affected in a fast retransmission time window, or receiving the whole retransmitted TB in the fast retransmission time window”); *see also* EX-1007, pp. 42 (“[t]he *base station transmits a TB, which is divided into 4 CBGs*”).

260. Like Figure 9 of Wang, Figure 9 of the Wang Foreign Priority Application also illustrates the CBGs of two TBs transmitted via PDSCH:

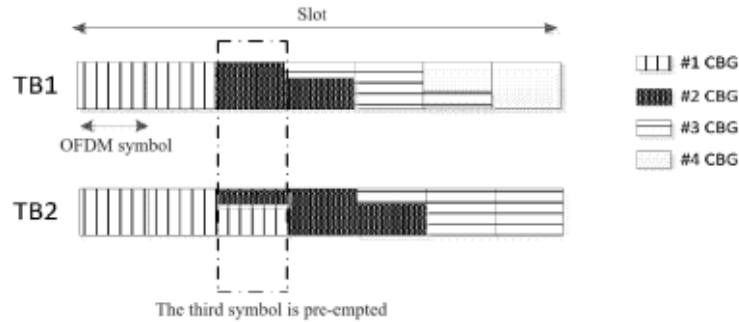


FIG. 9

261. EX-1007, Fig. 9.

262. Wang thus discloses or render obvious claim element 3.1.

[3.2] receiving circuitry configured to receive CBG based HARQ-ACK, wherein

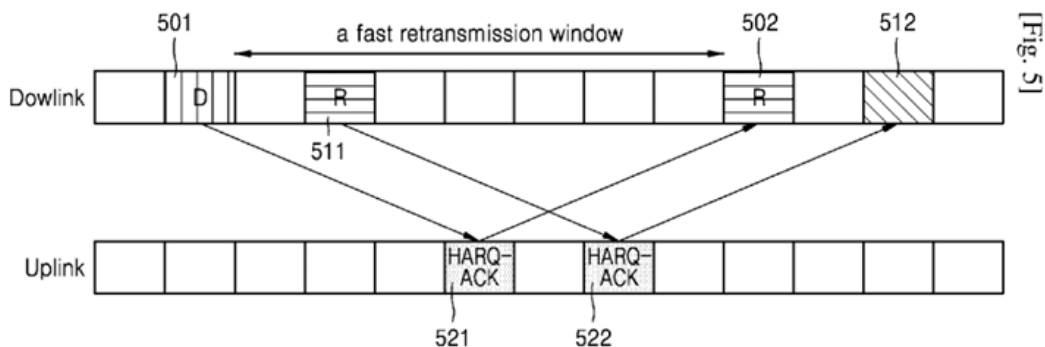
263. Wang discloses the element. Specifically, Wang discloses a base station that may “receiv[e] HARQ-ACK information of each CBG.” EX-1004, 12:13-14 (“*after receiving HARQ-ACK information of each CBG, the base station* may only retransmit CBGs received by the UE incorrectly still, so that utilization of the downlink resources is improved”); *see also* EX-1004, 38:35-43 (“*A base station for transmitting and receiving data, the base station comprising...at least one processor configured to execute the stored instructions to...receive, from the terminal, HARQ-ACK information generated according to the PDSCH*”).

264. Wang goes on to explain that the processor of the UE is configured to execute stored instructions to “generate HARQ-ACK information according to the PDSCH and *control the transceiver to transmit the HARQ-ACK information.*” EX-1004, 5:37-46; *see also* EX-1004, 7:57-59 (“[t]he *UE* generates HARQ-ACK information

based on the received PDSCH and *transmits the HARQ-ACK information*”). The HARQ-ACK feedback transmitted by the UE is CBG based. EX-1004, 12:13-14 (“after receiving HARQ-ACK information of each CBG”); EX-1004, 12:18-19 (“the UE may feed back the HARQ-ACK information for each CBG separately”).

265. A POSITA would understand that a base station that receives HARQ-ACK information would include receiving circuitry to effectuate that reception of the HARQ-ACK transmission. The entire purpose of a base station is to communicate with user equipment via different physical channels which are transmitted over radio signals using sending and receiving circuitry, such as a transceiver. Accordingly, it would be clear to any POSITA that any base station for use within a wireless communication system possesses receiving circuitry and that receiving circuitry would be used to receive a HARQ-ACK transmission.

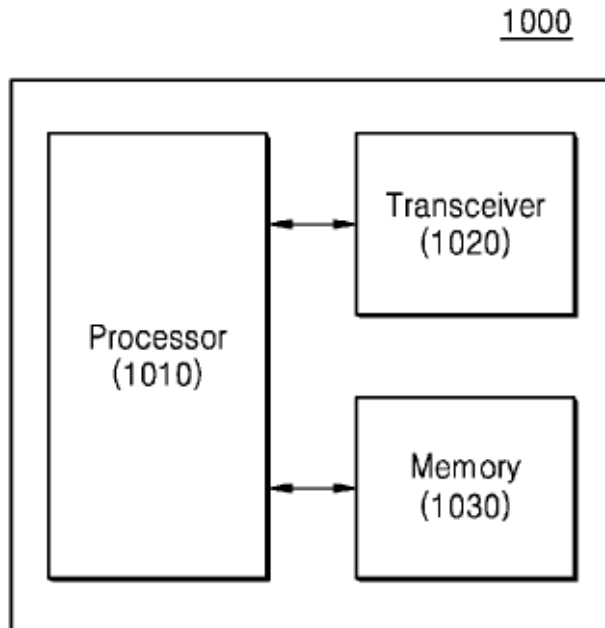
266. Figure 5 of Wang, depicted below, is a schematic diagram illustrating a fast HARQ retransmission based upon the affected CBG (EX-1004, 16:20-38):



267. EX-1004, Fig. 5.

268. Figure 10 of Wang, , depicted below, is a schematic diagram illustrating a UE according to an embodiment of Wang. As seen below, the UE includes “a processor 1010, a transceiver 1020 and a memory 1030.” EX-1004, 35:34-35. “The transceiver 1020 may be connected to the processor 1010 and transmit and/or receive a signal.” EX-1004, 35:63-64. “The signal may include control information and data.” EX-1004, 35:64-65. “The transceiver 1020 may transmit a signal output from the processor 1010 through the wireless channel.” EX-1004, 35:67-36:2. “The processor 1010 may generate HARQ-ACK information according to the PDSCH.” EX-1004, 35:53-54. “*The processor 1010 may control the transceiver to transmit the HARQ-ACK information.*” EX-1004, 35:54-56.

[Fig. 10]



269. EX-1004, Fig. 10; *see also* EX-1004, 7:57-59 (“[t]he UE ... *transmits the HARQ-ACK* information”).

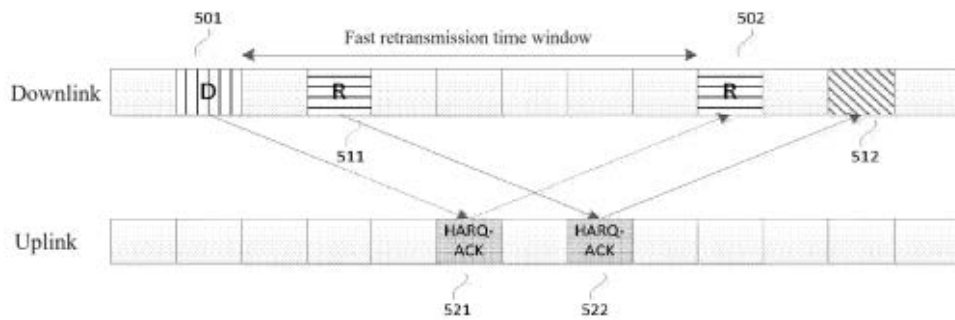
270. A POSITA would understand Wang’s disclosure of a transceiver 1020 connected to a processor 1010 to *transmit a signal output*, including HARQ-ACK information, to be transmitting circuitry. The entire purpose of a UE is to communicate with a base station via different channels which are transmitted over radio signals using sending and receiving circuitry, such as a transceiver. Accordingly, it would be clear to any POSITA that any UE for use within a wireless communication system possesses transmitting circuitry and that transmitting circuitry would be used to transmit a HARQ-ACK transmission.

271. Accordingly, Wang discloses both (1) a base station with receiving circuitry configured to receive CBG based HARQ-ACK; and (2) a UE with transmitting circuitry configured to transmit CBG based HARQ-ACK.

272. The Wang Foreign Priority Application supports this disclosure in Wang, explaining that the UE is responsible for generating “and transmitting the HARQ-ACK information.” EX-1007, pp. 12. The UE “is configured to generate HARQ-ACK information according to the detected PDSCH” and the “HARQ-ACK transmitting module is configured to transmit the HARQ-ACK information.” EX-1007, pp. 16; *see also* EX-1007, pp. 18 (“[g]enerate, by the UE, HARQ-ACK information according to the received PDSCH, and transmit the HARQ-ACK

information”). The HARQ-ACK is CBG based. EX-1007, pp. 25 (“the UE may feed back the HARQ-ACK information to each CBG”). The Wang Foreign Priority Application goes on to explain that the HARQ-ACK is received by the base station, such that “after the base station received HARQ-ACK information for each CBG, the CBG that is not properly received by the UE may be only retransmitted.” EX-1007, pp. 25.

273. The Wang Foreign Priority Application also contains Figure 5, depicted below, and illustrating a fast HARQ retransmission based upon the affected CBG:



274. EX-1007, Fig. 5.

275. Accordingly, a POSITA would understand the Wang Foreign Priority Application to disclose both (1) a base station with receiving circuitry configured to receive CBG based HARQ-ACK; and (2) a UE with transmitting circuitry configured to transmit CBG based HARQ-ACK.

276. Wang thus discloses or render obvious claim element 3.2.

[3.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), the receiving

circuitry is configured to receive one HARQ-ACK bit for the transport block,

277. Wang discloses the element. More specifically, Wang discloses differentiating between CBG based HARQ-ACK feedback corresponding to the search space that the PDSCH is scheduled in:

[p]referably, the HARQ-ACK information is single bit HARQ-ACK information for one TB or multi-bit HARQ-ACK information for one TB, and *the HARQ-ACK information is determined to be the single bit HARQ-ACK information or the multi-bit HARQ-ACK information according to one or more of the following parameters:* business type; DCI format; system parameters; downlink control channel resource set; and *downlink control channel search space.*

278. EX-1004, 3:57-65; *see also* EX-1004, 7:57-59 (“[t]he UE generates HARQ-ACK information based on the received PDSCH and transmits the HARQ-ACK information”).

279. More specifically, Wang discloses utilizing one HARQ-ACK bit for the TB when the PDSCH is scheduled in a CSS. EX-1004, 12:50-57 (“In particular, the single bit HARQ-ACK feedback method is adopted by the DCI in the common search space (CSS) fixedly”); *see also* EX-1004, 12:35-36 (“it is a default operation to feed back single bit HARQ-ACK information for one TB”).

280. The Wang Foreign Priority Application supports this disclosure in Wang. Specifically, the Wang Foreign Priority Application explains that “the HARQ-ACK

information is divided into two situations of single-bit HARQ-ACK or multi-bit HARQ-ACK information for each transport block.” EX-1007, pp. 13. And that the HARQ-ACK information is generated by the UE “according to the received PDSCH.” EX-1007, pp. 18 (“[g]enerate, by the UE, HARQ-ACK information according to the received PDSCH, and transmit the HARQ-ACK information”). The Wang Foreign Priority Application goes on to explain that one way to determine whether to use single-bit or multi-bit HARQ-ACK feedback is based upon search space configurations, such that “DCI in a common search space (CSS) feeds back one-bit HARQ-ACK information to one TB.” EX-1007, pp. 13.

281. To the extent element 3.3 may not be explicitly disclosed in Wang, it would have been obvious to a POSITA in view of Wang as well as the state of the art as discussed above. Section, VI.H, *supra*. As disclosed in Wang and discussed throughout, it was well known prior to the priority date of the '443 Patent that TBs could be further subdivided in CBs or CBGs and that UEs could transmit HARQ-ACK bits on either a TB or CBG basis to improve the efficiency of the system and potentially prevent the need for retransmission of an entire TB whenever a NACK signal is received. Moreover, it was known that it may not always be desirable to transmit one HARQ-ACK bit per CBG in all instances, so that it may be desirable to set up a wireless system where one HARQ-ACK bit is transmitted per TB in some instances, and one HARQ-ACK bit is transmitted per CBG in other instances. To set up such a system,

a POSITA would be faced with a limited number of characteristics to use to distinguish between one HARQ-ACK transmission method and another. Accordingly, a POSITA would immediately recognize that one such distinguishing characteristic to devise such a system around is search space configuration, such that one HARQ-ACK bit is transmitted per TB in one search space configuration (*e.g.*, CSS), while one HARQ-ACK bit is transmitted per CBG in another search space configuration (*e.g.*, USS).

282. Accordingly, Wang discloses or render obvious claim element 3.3.

[3.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), the receiving circuitry is configured to receive HARQ-ACK bits of all CBGs.

283. Wang discloses this element. Specifically, Wang discloses differentiating between CBG based HARQ-ACK feedback corresponding to the search space that the PDSCH is scheduled in:

[p]referably, the HARQ-ACK information is single bit HARQ-ACK information for one TB or multi-bit HARQ-ACK information for one TB, and *the HARQ-ACK information is determined to be the single bit HARQ-ACK information or the multi-bit HARQ-ACK information according to one or more of the following parameters:* business type; DCI format; system parameters; downlink control channel resource set; and *downlink control channel search space.*

284. EX-1004, 3:57-65; *see also* EX-1004, 7:57-59 (“[t]he UE generates HARQ-ACK information based on the received PDSCH and transmits the HARQ-ACK information”).

285. More specifically, Wang discloses utilizing HARQ-ACK bits for all CBGs when the PDSCH is scheduled in a USS. EX-1004, 12:55-57 (“the multi-bit HARQ-ACK feedback method is adopted by the DCI in a user-specific search space (USS) fixedly”); *see also* EX-1004, 12:13-16 (“after receiving HARQ-ACK information of each CBG, the base station may only retransmit CBGs received by the UE incorrectly still, so that utilization of the downlink resources is improved”); EX-1004, 12:18-19 (“the UE may feed back the HARQ-ACK information for each CBG separately”).

286. The Wang Foreign Priority Application supports this disclosure in Wang. Specifically, the Wang Foreign Priority Application explains that “the HARQ-ACK information is divided into two situations of single-bit HARQ-ACK or multi-bit HARQ-ACK information of each transport block.” EX-1007, pp. 13. And that the HARQ-ACK information is generated by the UE “according to the received PDSCH.” EX-1007, pp. 18 (“[g]enerate, by the UE, HARQ-ACK information according to the received PDSCH, and transmit the HARQ-ACK information”). The Wang Foreign Priority Application goes on to explain that in the multi-bit HARQ-ACK feedback method “the UE may feed back the HARQ-ACK information to each CBG.” EX-1007, pp. 25. And that one way to determine whether to use single-bit or

multi-bit HARQ-ACK feedback is based upon search space configurations (EX-1007, pp. 13), such that “the DCI in the user specific search space (USS) is fixedly subjected to the multi-bit HARQ-ACK feedback method,” of one bit for each CBG (EX-1007, pp. 26).

287. To the extent element 3.3 may not be explicitly disclosed in Wang, it would have been obvious to a POSITA in view of Wang as well as the state of the art as discussed above. Section, VI.H, *supra*. As disclosed in Wang and discussed throughout, it was well known prior to the priority date of the '443 Patent that TBs could be further subdivided in CBs or CBGs and that UEs could transmit HARQ-ACK bits on either a TB or CBG basis to improve the efficiency of the system and potentially prevent the need for retransmission of an entire TB whenever a NACK signal is received. Moreover, it was known that it may not always be desirable to transmit one HARQ-ACK bit per CBG in all instances, so that it may be desirable to set up a wireless system where one HARQ-ACK bit is transmitted per TB in some instances, and one HARQ-ACK bit is transmitted per CBG in other instances. To set up such a system, a POSITA would be faced with a limited number of characteristics to use to distinguish between one HARQ-ACK transmission method and another. Accordingly, a POSITA would immediately recognize that one such distinguishing characteristic to devise such a system around is search space configuration, such that one HARQ-ACK bit is transmitted per TB in one search space configuration (*e.g.*,

CSS), while one HARQ-ACK bit is transmitted per CBG in another search space configuration (*e.g.*, USS).

288. Accordingly, Wang discloses or render obvious claim element 3.4.

b. Claim 5

289. Claim 5 is the method claim that corresponds to the operation of the base station claimed in claim 3 and effectively has identical limitations.

[5.0] A communication method of a base station comprising:

290. Element [5.0] is identical to element [3.0] and disclosed for the reasons cited therein.

[5.1] sending a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and

291. Element [5.1] is identical to element [3.1] and disclosed for the reasons cited therein.

[5.2] receiving CBG based HARQ-ACK, wherein

292. Element [5.2] is identical to element [3.2] and disclosed for the reasons cited therein.

[5.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), one HARQ-ACK bit for the transport block is received,

293. Element [5.3] is identical to element [3.3] and disclosed for the reasons cited therein.

[5.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), HARQ-ACK bits of all CBGs are received.

294. Element [5.4] is identical to element [3.4] and disclosed for the reasons cited therein.

c. Claim 1

295. Claim 1 an apparatus claim directed to the user equipment that communicates with the base station of claim 3. Accordingly, claim 1 is the corollary to claim 3 and effectively has identical limitations.

[1.0] A user equipment (UE), comprising:

296. Element [1.0] is written to cover the UE side of the transmission from the base station discussed in element [3.0] and disclosed for the reasons cited therein.

[1.1] receiving circuitry configured to receive a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and

297. Element [1.1] is written to cover the UE side of the transmission from the base station discussed in element [3.1] and disclosed for the reasons cited therein.

[1.2] transmitting circuitry configured to transmit CBG based HARQ-ACK, wherein

298. Element [1.2] is written to cover the UE side of the transmission from the base station discussed in element [3.2] and disclosed for the reasons cited therein.

[1.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), the transmitting circuitry is configured to report one HARQ-ACK bit for the transport block,

299. Element [1.3] is written to cover the UE side of the transmission from the base station discussed in element [3.3] and disclosed for the reasons cited therein.

[1.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), the transmitting circuitry is configured to report HARQ-ACK bits of all CBGs.

300. Element [1.4] is written to cover the UE side of the transmission from the base station discussed in element [3.4] and disclosed for the reasons cited therein.

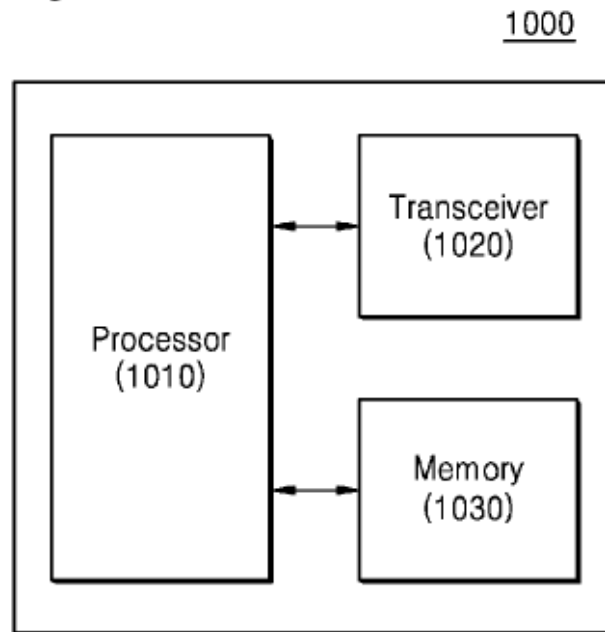
d. Claim 2

[2.0] The UE of claim 1, wherein determining circuitry configured to determine a physical uplink control channel (PUCCH) resource for transmission of the CBG based HARQ-ACK which PUCCH resource is one of a plurality PUCCH resources defined for different payload sizes.

301. Wang discloses or render obvious claim 2. More specifically, Wang discloses a UE with a processor, which “may include one or more processors.” EX-1004, 35:44-45. The processor “may detect a PDCCH on a configured control resource set,” “determine a method for dividing CBs and a method for rate matching of a PDSCH according to the PDCCH,” and “generate HARQ-ACK information according to the PDSCH.” EX-1004, 35:48-54. Moreover, “the UE transmits uplink data in a physical uplink shared channel (PUSCH), or transmits uplink control information in a physical uplink control channel (PUCCH).” EX-1004, 6:2-5. Accordingly, the UE of Wang comprises determining circuitry (*i.e.*, a processor) configured to determine a PUCCH resource for transmission of the CBG based HARQ-ACK which PUCCH is one of a

plurality of PUCCH resources defined for different payload sizes. Figure 10 of Wang, depicted below, is a schematic diagram illustrating a UE according to an embodiment of Wang. As seen below, the UE includes “a processor 1010, a transceiver 1020 and a memory 1030.” EX-1004, 35:34-35.

[Fig. 10]



302. EX-1004, Fig. 10.

303. The Wang Foreign Priority Application supports this disclosure in Wang. Specifically, the Wang Foreign Priority Application explains that the UE comprises “a PDCCH detecting and analyzing module, a PDSCH receiving module, a HARQ-ACK information generating module and an HARQ-ACK transmitting module.” EX-1007, pp. 60. “The PDCCH detecting and analyzing module is configured to detect a PDCCH of a scheduled PDSCH on a configured control resource set and analyze the

detected PDCCH.” EX-1007, pp. 60. “The PDSCH receiving module is configured to determine a method for dividing CBs and a method for rate matching of the PDSCH according to the detected PDCCH and to receive the PDSCH according to the detected PDCCH.” EX-1007, pp. 60. “The HARQ-ACK information generating module is configured to generate HARQ-ACK information according to the detected PDSCH.” EX-1007, pp. 60. Moreover, “the UE transmits uplink data over a physical uplink shared channel (PUSCH), or transmits uplink control information over a physical uplink control channel (PUCCH).” EX-1007, pp. 9.

304. Accordingly, Wang discloses or render obvious claim 2.

e. Claim 4

305. Claim 4 is the method claim that corresponds to the operation of the user equipment claimed in claim 1 and effectively has identical limitations.

[4.0] A communication method of a user equipment (UE) comprising:

306. Element [4.0] is identical to element [1.0] and disclosed for the reasons cited therein.

[4.1] receiving a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and

307. Element [4.1] is identical to element [1.1] and disclosed for the reasons cited therein.

[4.2] transmitting CBG based HARQ-ACK, wherein

308. Element [4.2] is identical to element [1.2] and disclosed for the reasons cited therein.

[4.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), one HARQ-ACK bit for the transport block is transmitted,

309. Element [4.3] is identical to element [1.3] and disclosed for the reasons cited therein.

[4.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), HARQ-ACK bits of all CBGs are transmitted.

310. Element [4.4] is identical to element [1.4] and disclosed for the reasons cited therein.

XI. THE CHALLENGED CLAIMS OF THE '443 PATENT ARE OBVIOUS OVER YANG

A. Challenged Claims.

2. Detailed Application of Yang

a. Claim 3

[3.0] A base station (gNB), comprising:

311. To the extent the preamble is limiting, Yang discloses this element.

312. As an initial matter, a POSITA would understand that a base station in a wireless network architecture, such as a 5G wireless network, could be abbreviated by a number of different acronyms, such as gNB, eNB, node-b, BS or other. Nevertheless, a POSITA would understand the base station of the Challenged Claims to simply be

a device that communicates with wireless communication devices, such as UE. EX-1001, 1:32-33.

313. Specifically, Yang discloses both (1) a base station and (2) a user equipment for use in a wireless communication system for transmitting and receiving signals to and from the two devices. EX-1005, 2:42-3:8.

provided herein is a user equipment used in a wireless communication system, including a radio frequency (RF) module and a processor configured to receive information on a number M of code block groups defined for one transport block *from a base station...*

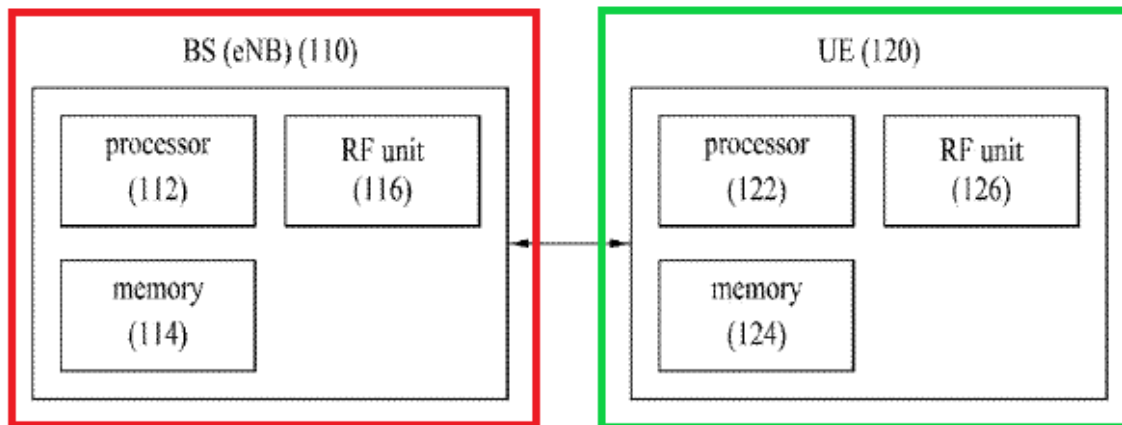
314. EX-1005, 1:61-66.

provided herein is *a base station used in a wireless communication system, the base station* including a radio frequency (RF) module and a processor configured to transmit information on a number M of code block groups defined for one transport block to *a user equipment* through an upper layer signal, transmit a first transport block including a plurality of code blocks to the user equipment through a physical layer channel, and receive Hybrid ARQ Acknowledgement (HARQ-ACK) payload including HARQ-ACK information on the first transport block from the user equipment, wherein a code block-based Cyclic Redundancy Check (CRC) is attached to each of the code blocks, wherein a transport block-based CRC is attached to the first transport block, and wherein the HARQ-ACK payload includes a plurality of HARQ-ACK bits corresponding to M code block groups for the first transport block.

315. EX-1005, 2:59-3:8.

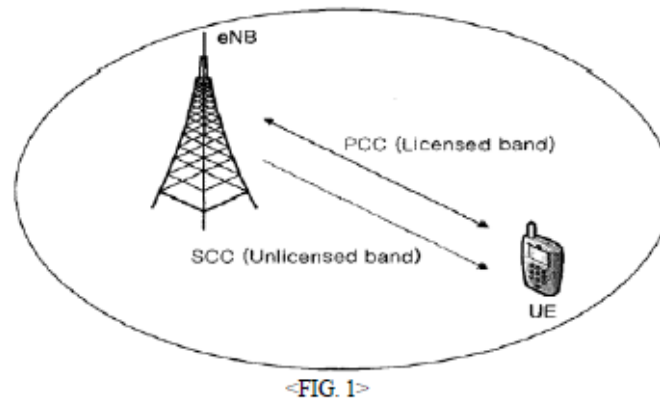
316. Figure 18 of Yang, annotated and depicted below, illustrates a BS (outlined in red) communicating with a UE (outlined in green) in a wireless communication system:

【FIG. 18】



317. EX-1005, Fig. 18.

318. The '048 Application also discloses this element. Similar to Yang, the '048 Application discloses a base station for use in a wireless communication system for transmitting and receiving signals to and from a UE. EX-1009, pp. 51 (“*an eNB may transmit signals to a UE or a UE may transmit signals to an eNB*”). Figure 1 of the '048 Application, reproduced below, depicts a BS (labeled “eNB”) in communication with a UE:



319. EX-1009, pp. 51.

320. Thus, Yang discloses claim element 3.0.

[3.1] sending circuitry configured to send a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and

321. Yang discloses this element. Specifically, Yang discloses a base station with sending circuitry configured to send a physical downlink channel that includes CBGs of a TB for receipt by a UE through the UE's receiving circuitry:

provided herein is a base station used in a wireless communication system, *the base station including a radio frequency (RF) module and a processor configured to* transmit information on a number M of code block groups defined for one transport block to a user equipment through an upper layer signal, *transmit a first transport block including a plurality of code blocks to the user equipment through a physical layer channel...*

322. EX-1005, 2:59-67. That physical layer channel may be “a physical downlink shared channel (PDSCH).” EX-1005, 4:45-46; *see also* EX-1005, 21:21-22 (“*the UE*

can receive initial transmission of data from the BS (on PDSCH)”). Yang further discloses that the data transmitted on the PDSCH by the base station includes a TB comprising CBGs. EX-1005, 21:22-25 (“the data include [*sic*] a transport block, *the transport block includes a plurality of code blocks, and a plurality of code block groups*”).

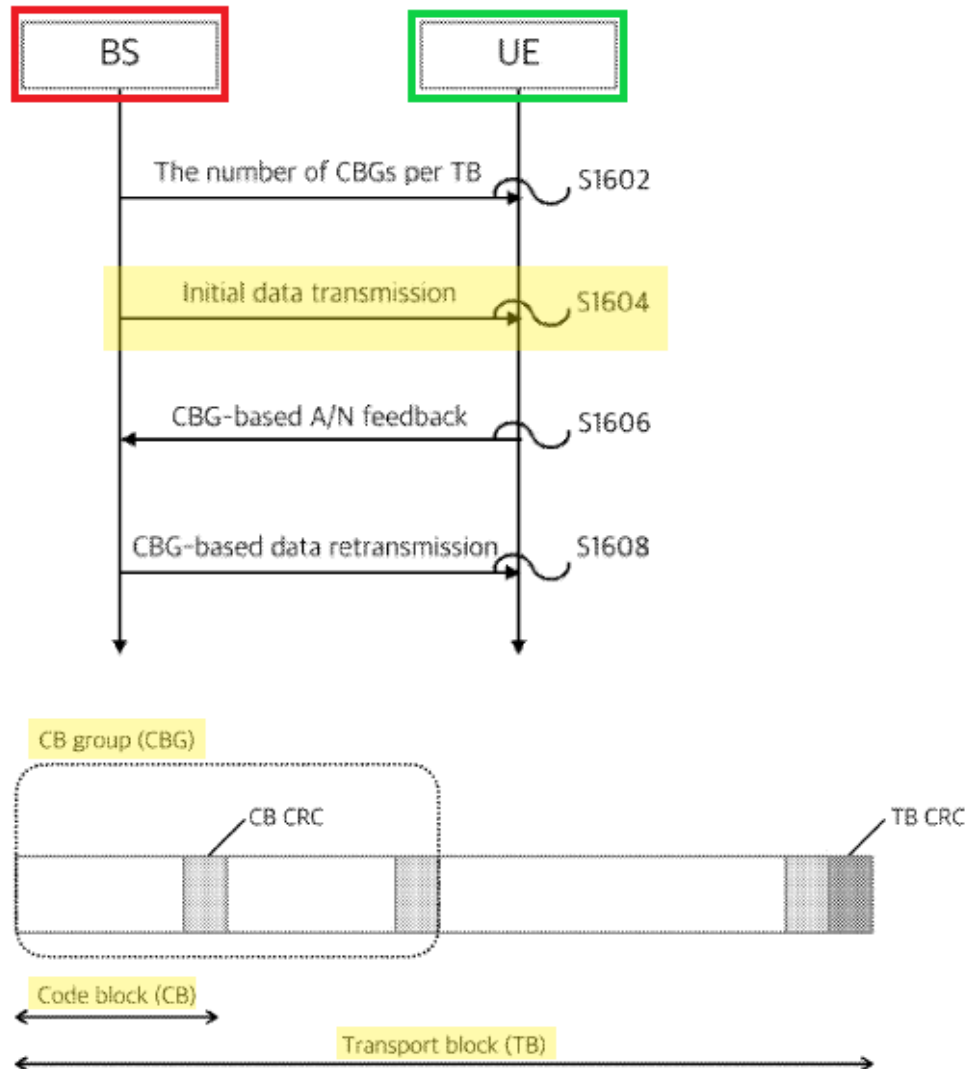
323. Yang also discloses that the UE is configured to receive a PDSCH that includes CBGs of a TB transmitted from the BS:

provided herein is *a user equipment* used in a wireless communication system, including a radio frequency (RF) module and a processor *configured to receive information on a number M of code block groups defined for one transport block from a base station through an upper layer signal, receive a first transport block including a plurality of code blocks from the base station through a physical layer channel...*

324. EX-1005, 1:61-2:1.

325. Figure 16 of Yang, annotated and depicted below, first illustrates the process in which the BS (outlined in red) transmits an “initial data transmission” to the UE (outlined in green) at “S1604” (highlighted yellow). Figure 16 also depicts the composition of that “data transmission,” showing that the “data transmission” comprises a transport block (highlighted yellow), which includes a plurality of CBs and CBGs (also highlighted yellow):

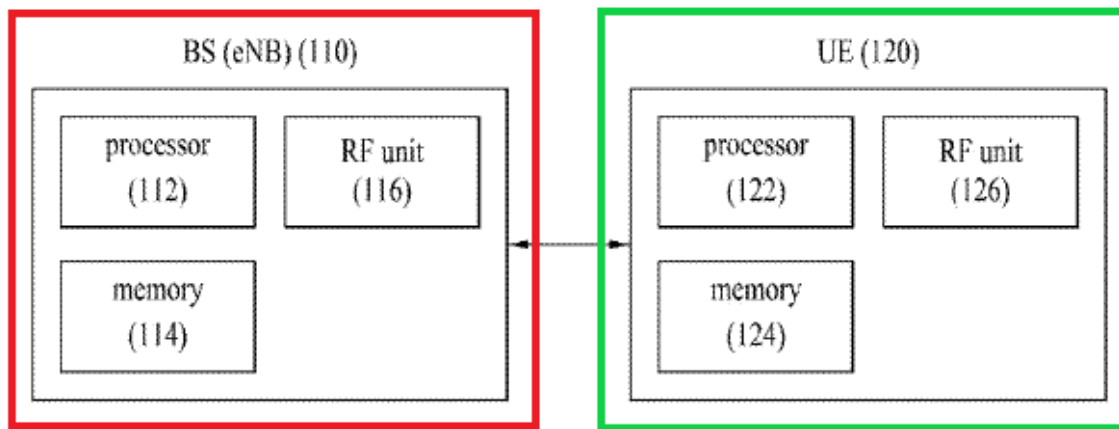
【FIG. 16】



326. EX-1005, Fig. 16.

327. The transmitting circuitry of the BS (outlined in red) (*i.e.*, the RF module and processor) and the receiving circuitry of the UE (outlined in green) (*i.e.*, the RF module and processor) are depicted in Figure 18 of Yang below:

【FIG. 18】



328. EX-1005, Fig. 18. Furthermore, Yang discloses that its invention may be “implemented by various means, for example, hardware, firmware, software, or combinations thereof” including ASICs, DSPs, and various processors. EX-1005, 39:41-51.

329. A POSITA would understand that a base station that transmits data over a PDSCH would include sending circuitry to effectuate that downlink transmission. The entire purpose of a base station is to communicate with user equipment via different physical channels which are transmitted over radio signals using sending circuitry, such as a transceiver. Accordingly, it would be clear to any POSITA that any base station for use within a wireless communication system possesses sending circuitry and that sending circuitry would be used to transmit a PDSCH. Thus, a POSITA would understand that Yang discloses a base station with sending circuitry configured to send a PDSCH that includes CBGs of a TB.

330. Moreover, a POSITA would understand that a UE that receives data over a PDSCH would include receiving circuitry to effectuate the reception of that downlink transmission. The entire purpose of a UE is to communicate with base stations via different channels which are transmitted over radio signals using receiving circuitry, such as a transceiver. Accordingly, it would be clear to any POSITA that any UE for use within a wireless communication system possesses receiving circuitry and that receiving circuitry would be used to receive a PDSCH. Thus, a POSITA would understand that Yang discloses a UE with receiving circuitry configured to receive a PDSCH that includes CBGs of a TB.

331. Accordingly, a POSITA would understand that Yang discloses both (1) a base station with sending circuitry configured to send a PDSCH that includes CBGs of a TB; and (2) a UE with receiving circuitry to receive a PDSCH that includes CBGs of a TB.

332. The '048 Application also discloses a base station with sending circuitry configured to send downlink transmissions to a UE with receiving circuitry. EX-1009, pp. 19 (“A BS 10 may include a processor 11, a memory 12, and a radio frequency (RF) unit 13... *[t]he RF unit 13 is coupled with the processor 11 and transmits and/or receives a radio signal*”); EX-1009, pp. 19 (“A UE 20 may include a processor 21, a memory 22, and a radio frequency (RF) unit 23... *[t]he RF unit 23 is coupled with the processor 21 and transmits and/or receives a radio signal*”).

Those downlink transmissions may comprise a physical downlink shared channel (PDSCH) that further comprises CBGs of a TB:

a method wherein, when the size of *DL data (that is, TB size)* becomes a fixed level or more, *the bit stream to be sent via PDSCH is divided into a plurality of CB (Code Block)* and is transmitted in a form in which channel coding and CRC are separately applied for each CB, is applied. *When reception (decoding) of even one of the plurality of CBs included in one PDSCH fails, the UE operates such that HARQ-ACK feedback corresponding to the PDSCH is reported to eNB using NACK.*

333. EX-1009, pp. 66; *see also* EX-1009, pp. 66 (“[f]or CBG described below, all CBs (constituting a single TB) can be configured as one CBG, or a portion of a plurality of CB is composed of one CBG, or each of one CBs can be configured into one CBG”).

334. A POSITA would understand this passage in the '048 Application to disclose both (1) a base station with sending circuitry configured to send a PDSCH that includes CBGs of a TB; and (2) a UE with receiving circuitry to receive a PDSCH that includes CBGs of a TB.

335. Thus, Yang discloses or renders obvious claim element 3.1.

[3.2] receiving circuitry configured to receive CBG based HARQ-ACK, wherein

336. Yang discloses the element. Specifically, Yang discloses a base station with receiving circuitry for HARQ-ACK feedback that is transmitted by a UE through transmitting circuitry:

provided herein is a base station used in a wireless communication system, *the base station including a radio frequency (RF) module and a processor configured to... receive Hybrid ARQ Acknowledgement (HARQ-ACK) payload including HARQ-ACK information* on the first transport block from the user equipment, wherein a code block-based Cyclic Redundancy Check (CRC) is attached to each of the code blocks, wherein a transport block-based CRC is attached to the first transport block, and wherein the HARQ-ACK payload includes a plurality of HARQ-ACK bits corresponding to M code block groups for the first transport block.

337. EX-1005, 2:59-3:8. Through the RF module and processor (*i.e.*, the receiving circuitry), the base station of Yang may receive “CBG-based (code block group-based) A/N information.” EX-1005, 21:29-31.

338. Yang further discloses a UE with transmitting circuitry configured to transmit the CBG-based HARQ-ACK feedback:

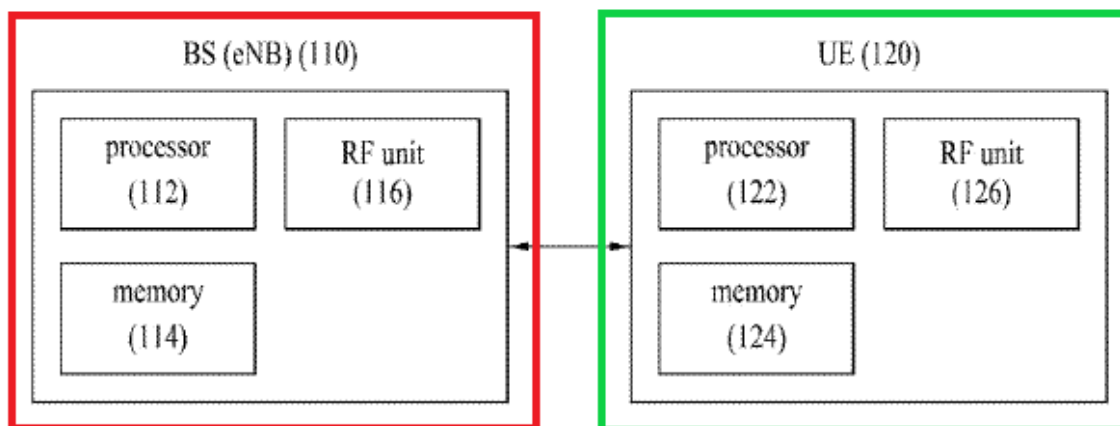
provided herein is *a user equipment used in a wireless communication system, including a radio frequency (RF) module and a processor configured to* receive information on a number M of code block groups defined for one transport block from a base station through an upper layer signal, receive a first transport block including a plurality of code

blocks from the base station through a physical layer channel, and ***transmit Hybrid ARQ Acknowledgement (HARQ-ACK) payload including HARQ-ACK information on the first transport block to the base station***, wherein a code block-based Cyclic Redundancy Check (CRC) is attached to each of the code blocks, wherein a transport block-based CRC is attached to the first transport block, ***and wherein the HARQ-ACK payload includes a plurality of HARQ-ACK bits corresponding to M code block groups for the first transport block***.

339. EX-1005, 1:61-2:10. Through the RF module and processor (*i.e.*, the transmitting circuitry), the UE of Yang may transmit “CBG-based (code block group-based) A/N information.” EX-1005, 21:29-31.

340. The transmitting circuitry of the UE (outlined in green) (*i.e.*, the RF module and processor) and the receiving circuitry of the BS (outlined in red) (*i.e.*, the RF module and processor) are depicted in Figure 18 of Yang below:

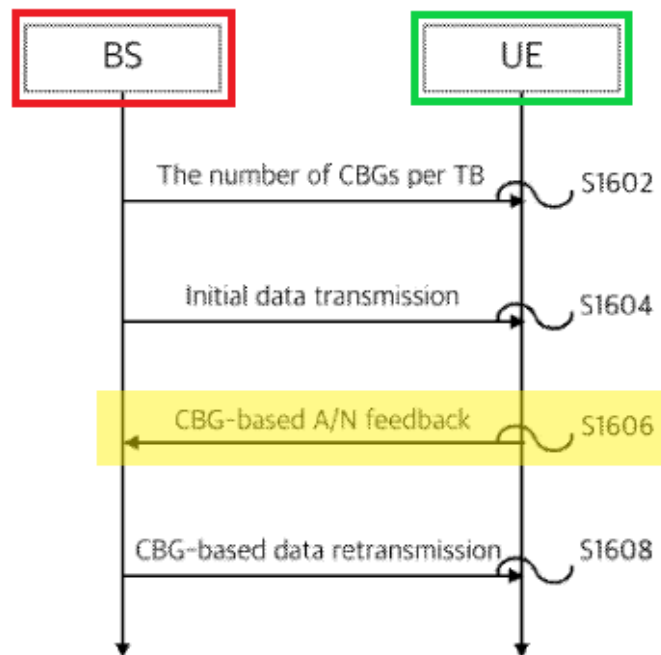
【FIG. 18】



341. EX-1005, Fig. 18.

342. As shown in annotated Figure 16 of Yang below, following the “initial data transmission” in “S1604”, the BS (outlined in red) receives “CBG-based [HARQ-ACK] feedback” at “S1604” (highlighted yellow) via its RF module that is transmitted by the UE (outlined in green):

【FIG. 16】



343. EX-1005, Fig. 16.

344. As noted in [3.1] above, Yang’s implementations include various forms of circuitry that would implement the receiving circuitry. EX-1005, 39:41-51.

345. A POSITA would understand that a base station that receives HARQ-ACK information would include receiving circuitry to effectuate that reception of the

HARQ-ACK transmission. The entire purpose of a base station is to communicate with user equipment via different physical channels which are transmitted over radio signals using sending and receiving circuitry, such as a transceiver. Accordingly, it would be clear to any POSITA that any base station for use within a wireless communication system possesses receiving circuitry and that receiving circuitry would be used to receive a HARQ-ACK transmission.

346. Further, a POSITA would understand that a UE that transmits HARQ-ACK information would include transmitting circuitry to effectuate the HARQ-ACK transmission. The entire purpose of a UE is to communicate with a base station via different channels which are transmitted over radio signals using sending and receiving circuitry, such as a transceiver. Accordingly, it would be clear to any POSITA that any UE for use within a wireless communication system possesses transmitting circuitry and that transmitting circuitry would be used to transmit a HARQ-ACK transmission.

347. Accordingly, Yang discloses both (1) a base station with receiving circuitry configured to receive CBG based HARQ-ACK; and (2) a UE with transmitting circuitry configured to transmit CBG based HARQ-ACK.

348. The '048 Application supports this disclosure in Yang, and discloses a base station with receiving circuitry to receive radio signals that are transmitted via transmitting circuitry of a UE. EX-1009, pp. 19 ("A BS 10 may include a processor 11, a memory

12, and a radio frequency (RF) unit 13... *[t]he RF unit 13 is coupled with the processor 11 and transmits and/or receives a radio signal*"); EX-1009, pp. 19 ("A UE 20 may include a processor 21, a memory 22, and a radio frequency (RF) unit 23... *[t]he RF unit 23 is coupled with the processor 21 and transmits and/or receives a radio signal*"). The '048 Application goes on to explain that the radio signals transmitted from the UE and received by the BS may comprise CBG based HARQ-ACK feedback:

In the present invention, in consideration of these operational properties of the new RAT system, a method is proposed, *wherin the (retransmission) scheduling is performed in the unit of CB or of CB group (CBG) and the HARQ-ACK feedback is configured/transmitted in the unit of CB/CBG*. More specifically, a method for configuring a CBG, *a method for configuring HARQ-ACK (that is, A/N) feedback*, a method for operating a reception soft buffer of UE, and a method for handling a certain mismatch situation are proposed. For CBG described below, all CBs (constituting a single TB) can be configured as one CBG, or a portion of a plurality of CB is composed of one CBG, or each of one CBs can be configured into one CBG.

349. EX-1009, pp. 66. Thus, the '048 Application supports Yang's disclosure of a base station comprising receiving circuitry configured to receive CBG-based HARQ-ACK feedback transmitted by the transmitting circuitry of a UE.

350. A POSITA would understand this passage to disclose both (1) a base station with receiving circuitry configured to receive CBG based HARQ-ACK; and (2) a UE with transmitting circuitry configured to transmit CBG based HARQ-ACK.

351. Accordingly, Yang discloses or renders obvious claim element 3.2.

[3.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), the receiving circuitry is configured to receive one HARQ-ACK bit for the transport block,

352. Yang discloses the element. Yang discloses a method of configuring CBG based HARQ-ACK feedback:

The present invention proposes a method of performing (retransmission) scheduling in unit of CB or CBG (CB group) and configuring/transmitting HARQ-ACK feedback in unit of CB/CBG, in consideration of properties of a new RAT system. Particularly, the present invention proposes a method of configuring CBG, *a method of configuring HARQ-ACK (hereinafter abbreviated A/N) feedback*, a method of operating a reception soft buffer of a UE, a method of handling a specific mismatch situation, and the like.

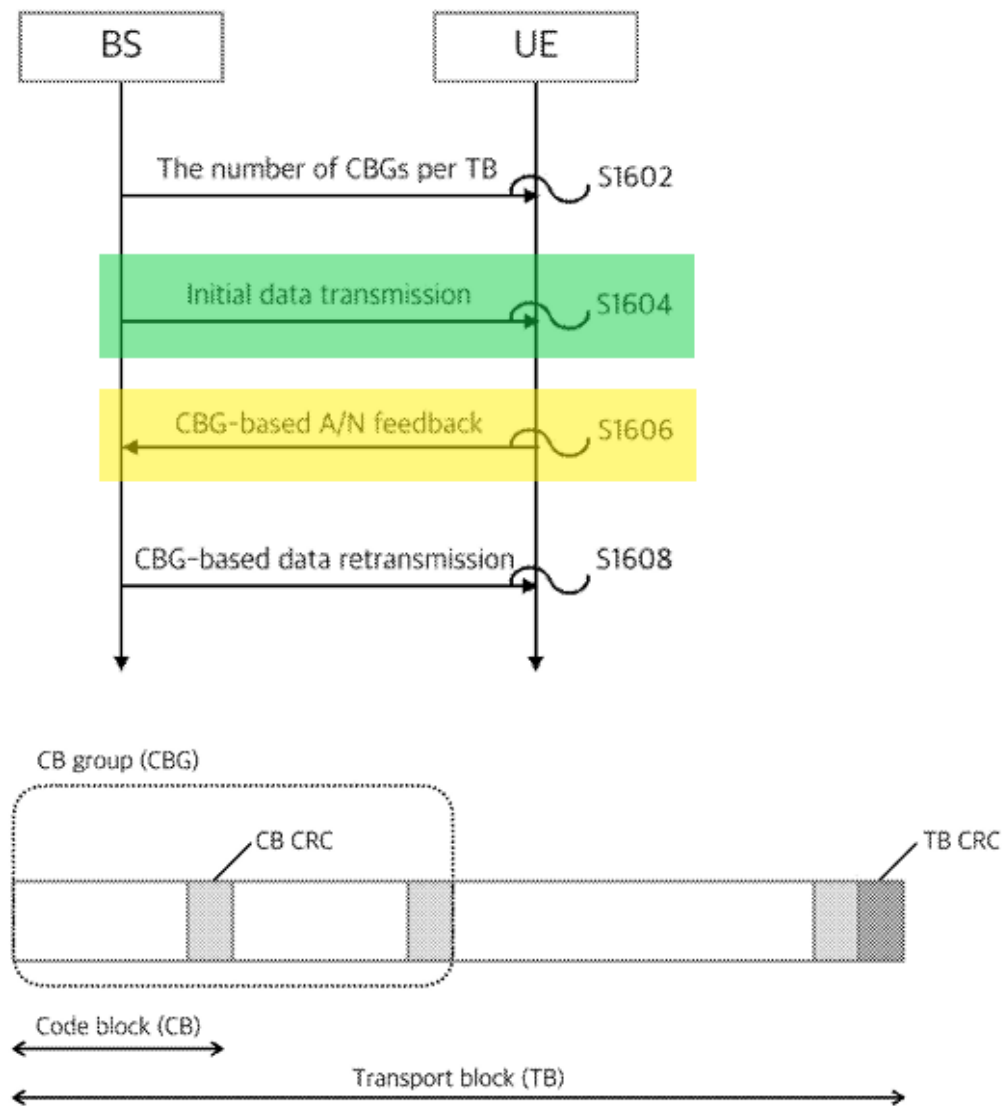
353. EX-1005, 16:55-64. The CBG based HARQ-ACK feedback received by the base stations from the UE corresponds directly with the PDSCH sent by the base station to the UE:

the UE can receive *initial transmission of data from the BS (on PDSCH)* [S1604]...[t]hereafter, the UE can feed back CBG-based (code block group-based) A/N information on the data to the BS

[S1606], and the BS can perform data retransmission based on the code block group [S1608].

354. EX-1005, 21:21-32. Thus, as seen in Figure 16 of Yang depicted below, the “CBG-based [HARQ-ACK] feedback” in S1606 (highlighted yellow), corresponds directly to the “initial data transmission” in S1604 (highlighted green), which is sent in PDSCH:

【FIG. 16】



355. EX-1005, Fig. 16.

356. More specifically, Yang discloses differentiating CBG based HARQ-ACK feedback corresponding to the search space that the PDSCH is scheduled in, such that if scheduled in CSS, a per-TB HARQ-ACK feedback method is configured:

for DL/UL data (and/or Msg3/4) transmission scheduled through CSS based DCI (or TM-common DCI format) transmission, a TB-unit retransmission scheduling and per-TB (TB level) A/N feedback operation is applicable/configurable.

357. EX-1005, 38:1-6.

358. Thus, Yang discloses utilizing one HARQ-ACK bit for the transport block when the PDSCH is scheduled in a CSS.

359. The '048 Application supports this disclosure in Yang. Specifically, the '048 Application discloses applying specific CBG-based HARQ-ACK feedback configurations based upon search space configurations. EX-1009, pp. 83-84. That HARQ-ACK feedback received by the base stations from the UE corresponds directly with the PDSCH sent by the base station to the UE. EX-1009, pp. 66 (“[w]hen reception (decoding) of even one of the plurality of CBs included in one PDSCH fails, *the UE operates such that HARQ-ACK feedback corresponding to the PDSCH is reported to eNB using NACK*”). The '048 Application goes on to explain that “TB-specific” HARQ-ACK feedback can be applied when the transmission is scheduled in a CSS. EX-1009, pp. 84 (“A/N feedback operation on a TB basis may be applied/set for DL/UL data (and/or Msg3/4) transmissions scheduled via CSS-based DCI transmissions”).

360. To the extent element 3.3 may not be explicitly disclosed in Wang, it would have been obvious to a POSITA in view of Wang as well as the state of the art as discussed

above. Section, VI.H, *supra*. As disclosed in Wang and discussed throughout, it was well known prior to the priority date of the '443 Patent that TBs could be further subdivided in CBs or CBGs and that UEs could transmit HARQ-ACK bits on either a TB or CBG basis to improve the efficiency of the system and potentially prevent the need for retransmission of an entire TB whenever a NACK signal is received. Moreover, it was known that it may not always be desirable to transmit one HARQ-ACK bit per CBG in all instances, so that it may be desirable to set up a wireless system where one HARQ-ACK bit is transmitted per TB in some instances, and one HARQ-ACK bit is transmitted per CBG in other instances. To set up such a system, a POSITA would be faced with a limited number of characteristics to use to distinguish between one HARQ-ACK transmission method and another. Accordingly, a POSITA would immediately recognize that one such distinguishing characteristic to devise such a system around is search space configuration, such that one HARQ-ACK bit is transmitted per TB in one search space configuration (*e.g.*, CSS), while one HARQ-ACK bit is transmitted per CBG in another search space configuration (*e.g.*, USS).

361. Accordingly, Yang discloses or renders obvious claim element 3.3.

[3.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), the receiving circuitry is configured to receive HARQ-ACK bits of all CBGs.

362. Yang discloses this element. As discussed above, Yang discloses a method of configuring CBG based HARQ-ACK feedback:

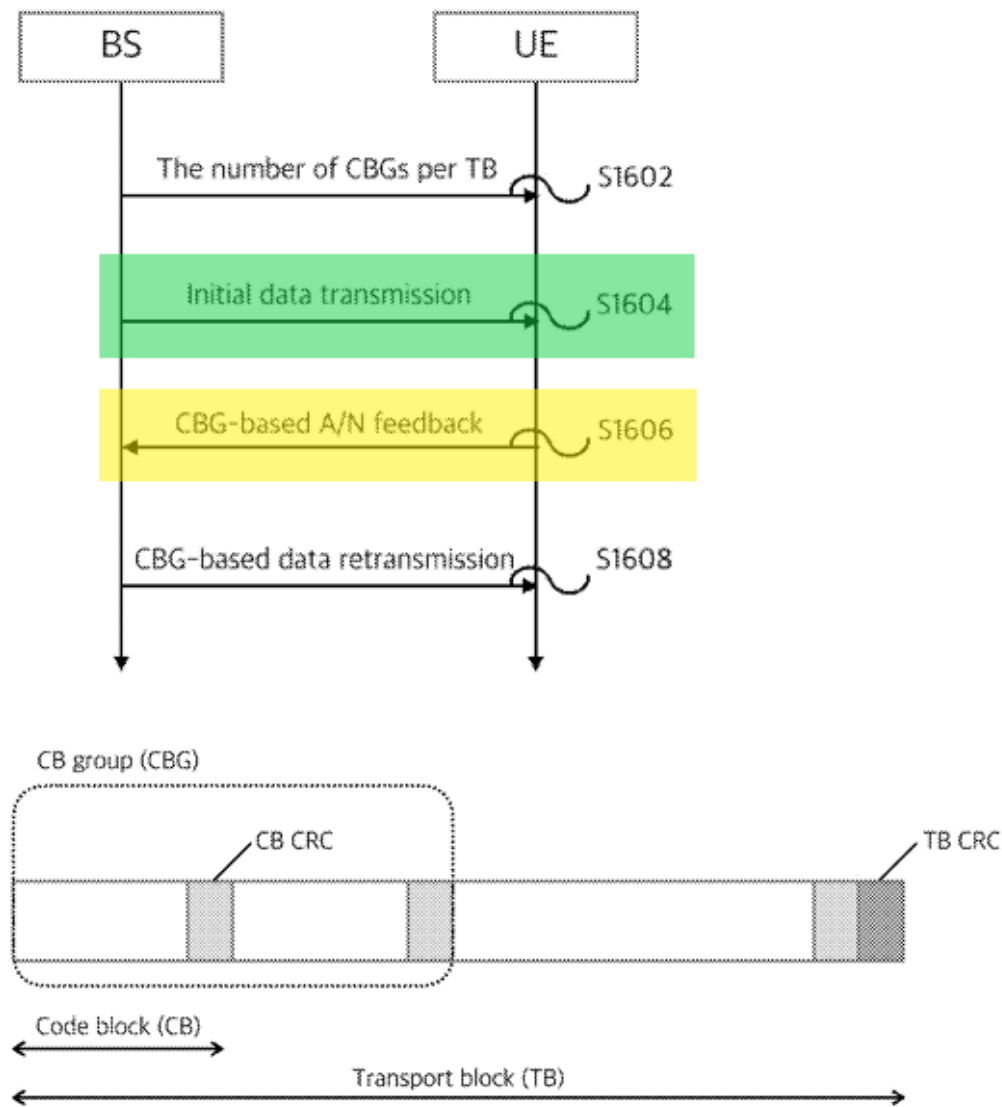
The present invention proposes a method of performing (retransmission) scheduling in unit of CB or CBG (CB group) and configuring/transmitting HARQ-ACK feedback in unit of CB/CBG, in consideration of properties of a new RAT system. Particularly, the present invention proposes a method of configuring CBG, *a method of configuring HARQ-ACK (hereinafter abbreviated A/N) feedback*, a method of operating a reception soft buffer of a UE, a method of handling a specific mismatch situation, and the like.

363. EX-1005, 16:55-64. The CBG based HARQ-ACK feedback received by the base stations from the UE corresponds directly with the PDSCH sent by the base station to the UE:

the UE can receive *initial transmission of data from the BS (on PDSCH)* [S1604]...[t]hereafter, the UE can feed back *CBG-based (code block group-based) A/N information on the data to the BS [S1606]*, and the BS can perform data retransmission based on the code block group [S1608].

364. EX-1005, 21:21-32. Thus, as seen in Figure 16 of Yang depicted below, the “CBG-based [HARQ-ACK] feedback” in S1606 (highlighted yellow), corresponds directly to the “initial data transmission” in S1604 (highlighted green), which is sent in PDSCH:

【FIG. 16】



365. EX-1005, Fig. 16.

366. More specifically, Yang discloses differentiating CBG based HARQ-ACK feedback corresponding to the search space that the PDSCH is scheduled in, such that if the PDSCH is scheduled in USS, a per-CBG HARQ-ACK feedback method is configured:

for DL/UL data transmission scheduled through DCI (or TM-dedicated DCI format set/used for specific TM only) transmission *based not on CSS but on USS, a CBG-unit retransmission scheduling and per-CBG A/N feedback configuration operation is applicable/configurable.*

367. EX-1005, 37:63-38:1.

368. Thus, Yang discloses utilizing HARQ-ACK bits for all CBGs when the PDSCH is scheduled in a USS.

369. The '048 Application supports this disclosure in Yang. Specifically, the '048 Application discloses applying specific CBG-based HARQ-ACK feedback configurations based upon search space configurations. EX-1009, pp. 83-84. That HARQ-ACK feedback received by the base stations from the UE corresponds directly with the PDSCH sent by the base station to the UE. EX-1009, pp. 66 (“[w]hen reception (decoding) of even one of the plurality of CBs included in one PDSCH fails, *the UE operates such that HARQ-ACK feedback corresponding to the PDSCH is reported to eNB using NACK*”). The '048 Application goes on to explain that “CBG-specific” HARQ-ACK feedback can be applied when the transmission is scheduled in a USS. EX-1009, pp. 83-84 (“retransmission scheduling on a CBG basis and A/N feedback configuration operation on a CBG basis may be applied/set only for DL/UL data transmissions scheduled via USS-based DCI transmissions rather than CSS”).

370. To the extent element 3.3 may not be explicitly disclosed in Wang, it would have been obvious to a POSITA in view of Wang as well as the state of the art as discussed above. Section, VI.H, *supra*. As disclosed in Wang and discussed throughout, it was well known prior to the priority date of the '443 Patent that TBs could be further subdivided in CBs or CBGs and that UEs could transmit HARQ-ACK bits on either a TB or CBG basis to improve the efficiency of the system and potentially prevent the need for retransmission of an entire TB whenever a NACK signal is received. Moreover, it was known that it may not always be desirable to transmit one HARQ-ACK bit per CBG in all instances, so that it may be desirable to set up a wireless system where one HARQ-ACK bit is transmitted per TB in some instances, and one HARQ-ACK bit is transmitted per CBG in other instances. To set up such a system, a POSITA would be faced with a limited number of characteristics to use to distinguish between one HARQ-ACK transmission method and another. Accordingly, a POSITA would immediately recognize that one such distinguishing characteristic to devise such a system around is search space configuration, such that one HARQ-ACK bit is transmitted per TB in one search space configuration (*e.g.*, CSS), while one HARQ-ACK bit is transmitted per CBG in another search space configuration (*e.g.*, USS).

371. Accordingly, Yang discloses or renders obvious claim element 3.4.

b. Claim 5

372. Claim 5 is the method claim that corresponds to the operation of the base station claimed in claim 3 and effectively has identical limitations.

[5.0] A communication method of a base station comprising:

373. Element [5.0] is identical to element [3.0] and disclosed for the reasons cited therein.

[5.1] sending a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and

374. Element [5.1] is identical to element [3.1] and disclosed for the reasons cited therein.

[5.2] receiving CBG based HARQ-ACK, wherein

375. Element [5.2] is identical to element [3.2] and disclosed for the reasons cited therein.

[5.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), one HARQ-ACK bit for the transport block is received,

376. Element [5.3] is identical to element [3.3] and disclosed for the reasons cited therein.

[5.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), HARQ-ACK bits of all CBGs are received.

377. Element [5.4] is identical to element [3.4] and disclosed for the reasons cited therein.

c. Claim 1

378. Claim 1 an apparatus claim directed to the user equipment that communicates with the base station of claim 3. Accordingly, claim 1 is the corollary to claim 3 and effectively has identical limitations.

[1.0] A user equipment (UE), comprising:

379. Element [1.0] is written to cover the UE side of the transmission from the base station discussed in element [3.0] and disclosed for the reasons cited therein.

[1.1] receiving circuitry configured to receive a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and

380. Element [1.1] is written to cover the UE side of the transmission from the base station discussed in element [3.1] and disclosed for the reasons cited therein.

[1.2] transmitting circuitry configured to transmit CBG based HARQ-ACK, wherein

381. Element [1.2] is written to cover the UE side of the transmission from the base station discussed in element [3.2] and disclosed for the reasons cited therein.

[1.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), the transmitting circuitry is configured to report one HARQ-ACK bit for the transport block,

382. Element [1.3] is written to cover the UE side of the transmission from the base station discussed in element [3.3] and disclosed for the reasons cited therein.

[1.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), the transmitting circuitry is configured to report HARQ-ACK bits of all CBGs.

383. Element [1.4] is written to cover the UE side of the transmission from the base station discussed in element [3.4] and disclosed for the reasons cited therein.

d. Claim 2

[2.0] The UE of claim 1, wherein determining circuitry configured to determine a physical uplink control channel (PUCCH) resource for transmission of the CBG based HARQ-ACK which PUCCH resource is one of a plurality PUCCH resources defined for different payload sizes.

384. Yang discloses or render obvious claim 2. More specifically, and as discussed above with respect to elements 3.1 and 3.2, and as shown in Fig. 18 of Yang, Yang discloses a UE with a processor and memory (*i.e.*, determining circuitry). EX-1005, 38:67-39:1. “The processor 112 may be configured to implement the procedures and/or methods proposed by the present invention” and “[t]he memory 124 is connected to the processor 122 and stored information related to the operations of the processor 122.” EX-1005, 39:2-5. Yang further discloses that “the UE may receive a PDCCH/PDSCH (S107) and transmit a physical uplink shared channel (PUSCH)/physical uplink control channel (PUCCH) (S108), as a general downlink/uplink signal transmission procedure.” EX-1005, 4:58-62. “Here, control information transmitted from the UE to the BS is called uplink control information (UCI).” EX-1005, 4:62-64. “The UCI may include a hybrid automatic repeat and request (HARQ) acknowledgement (ACK)/negative-ACK (HARQ ACK/NACK) signal, a scheduling request (SR), channel state information (CSI), etc.” EX-1005,

5:64-67. “The CSI includes a channel quality indicator (CQI), a precoding matrix index (PMI), a rank indicator (RI), etc.” EX-1005, 6:67-5:2. “While the UCI is transmitted through a PUCCH in general, it may be transmitted through a PUSCH when control information and traffic data need to be simultaneously transmitted.” EX-1005, 5:2-5.

385. Moreover, Yang explains that “based on the CBG number set for TB, an A/N payload size and a corresponding PUCCH format can be set.” EX-1005, 29:26-28. “For example, a PUCCH format used for CBG unit A/N transmission per TBS (total CBG number ‘M’ according to TBS) and a candidate PUCCH resource set can be set independently (differently).” EX-1005, 29:28-31. Accordingly, the UE of Yang comprises determining circuitry configured to determine a PUCCH resource for transmission of the CBG based HARQ-ACK which PUCCH is one of a plurality of PUCCH resources defined for different payload sizes.

386. The ’048 Application supports this disclosure in Yang. More specifically, the ’048 Application explains that “the A/N bit configuration of the TB unit and the A/N bit configuration of the CBG unit are configured according to whether A/N feedback is performed by semi-static (e.g., RRC) or dynamic (e.g., DCI) signaling (e.g., (initial) DL data scheduling DCI), and in the case of CBG unit A/N bit configuration, the corresponding A/N payload size (and PUCCH format for the corresponding A/N transmission) may be set via semi-static (e.g., RRC) signaling.” EX-1009, pp. 77.

The '048 Application goes on to state that “for each TB size, the number of CBs comprising the corresponding TB and the CBG configuration based thereon (e.g., the total number of CBs comprising the TB, M, and the number of CBs comprising a single CBG, N) may be determined according to a predetermined rule, and the A/N payload size and the corresponding PUCCH format may be set based on the number of CBGs set in a given TB.” EX-1009, pp. 77. “For example, the PUCCH format and the set of candidate PUCCH resources used for CBG-based A/N transmission may be independently (differently) set for each TB size (and thus the total number of CBGs M).” EX-1009, pp. 77. Accordingly, the '048 Application discloses a UE comprising determining circuitry configured to determine a PUCCH resource for transmission of the CBG based HARQ-ACK which PUCCH is one of a plurality of PUCCH resources defined for different payload sizes.

387. Accordingly, Yang discloses or renders obvious claim 2.

e. Claim 4

388. Claim 4 is the method claim that corresponds to the operation of the user equipment claimed in claim 1 and effectively has identical limitations.

[4.0] A communication method of a user equipment (UE) comprising:

389. Element [4.0] is identical to element [1.0] and disclosed for the reasons cited therein.

[4.1] receiving a physical downlink shared channel (PDSCH) that includes code block groups (CBGs) of a transport block; and

390. Element [4.1] is identical to element [1.1] and disclosed for the reasons cited therein.

[4.2] transmitting CBG based HARQ-ACK, wherein

391. Element [4.2] is identical to element [1.2] and disclosed for the reasons cited therein.

[4.3] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a common search space (CSS), one HARQ-ACK bit for the transport block is transmitted,

392. Element [4.3] is identical to element [1.3] and disclosed for the reasons cited therein.

[4.4] for the CBG based HARQ-ACK corresponding to the PDSCH which is scheduled in a UE-specific search space (USS), HARQ-ACK bits of all CBGs are transmitted.

393. Element [4.4] is identical to element [1.4] and disclosed for the reasons cited therein.

XII. SECONDARY CONSIDERATIONS DO NOT REBUT THE PRIMA FACIE CASE OF OBVIOUSNESS

394. In my opinion, secondary considerations do not rebut the prima facie case of obviousness for at least two reasons. *First*, I have not seen any evidence of any secondary consideration to date.

395. To the extent Patent Owner seeks to proffer secondary considerations evidence in this proceeding, I reserve the right to comment on such evidence.

396. *Second*, I do not believe that Patent Owner will be able to establish a nexus between any secondary consideration and the challenged claims. I have been advised that a nexus does not exist where the alleged secondary consideration results from something other than what is both claimed and novel in the claims.

397. As I explained above, there is nothing novel in the claims. Indeed, all claim elements are disclosed in the prior art. Thus, I do not see a basis for Patent Owner to assert that there is a nexus between any secondary consideration and the claims.

398. Moreover, as I have discussed before, the prosecution of the '443 patent would indicate that the purported basis for non-obvious and/or novelty was the idea of differentiating between transmitting HARQ-ACK feedback on a per TB basis and transmitting HARQ-ACK feedback on a per CBG basis based upon search space configuration of the PDSCH. However, as detailed above in Grounds 1 and 2 as well as the State of the Art, the concept of transmitting HARQ-ACK feedback on a per CBG basis to improve the efficiency of communications between the BS and UE had existed well before the alleged earliest priority date of the '443 Patent to perform the actions cited by the Examiner as the sole reason for patentability in the notice of allowance as discussed in the Prosecution History section above. More specifically, the concept of differentiating between transmitting HARQ-ACK feedback on a per TB basis and transmitting HARQ-ACK feedback on a per CBG basis based upon search space configuration of the PDSCH, as detailed above in Grounds 1 and 2 as

well as the State of the Art, existed well before the alleged earliest priority date of the '443 Patent. Thus, there would not be any nexus between any alleged secondary considerations and any patentable aspect of the claims.

XIII. CONCLUSION AND DECLARATION

399. My findings and opinions set forth in this Declaration are based on my work and examination to date. I may continue my examinations in view of additional documents or other factual evidence over the course of this proceeding that may necessitate supplementing and/or refining my opinions. I reserve the right to add to, alter, or delete my opinions and my Declaration upon discovery of additional information. I reserve the right to make such changes as necessary.

400. In signing this Declaration, I understand that the Declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I acknowledge that I may be subject to cross-examination in this case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

401. 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

Declaration of Dr. Mark P. Mahon

so made are punishable by fine or imprisonment, or both, under Section 1001, of Title
18 of the United States Code.

[SIGNATURE ON COVER PAGE]

APPENDIX A – MATERIALS RELIED UPON

Exhibit #	Description
1001	U.S. Patent No. 10,531,443 (the “’443 Patent”)
1002	Select portions of prosecution history of the ’443 Patent (“File History”)
1003	Declaration of Petitioners’ Expert Dr. Mark Mahon [This declaration herein]
1004	U.S. Pat. No. 11,206,108 (“Wang”)
1005	U.S. Pat. No. 11,012,221 (“Yang”)
1006	Chinese Pat. App. 201710288177.X (“Wang Foreign Priority Application”)
1007	English translation of the Wang Foreign Priority Application
1008	U.S. Provisional Pat. App. 62/501,048 (“’048 Application”)
1009	English translation of the ’048 Application
1010	U.S. Pat. No. 10,735,170
1011	U.S. Pat. No. 8,223,712
1012	U.S. Pat. No. 9,344,259
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Declaration of Dr. Mark P. Mahon

APPENDIX B – RÉSUMÉ

Mark P. Mahon, Ph.D.
Teaching Professor
Pennsylvania State University
School of Electrical Engineering and Computer Science
W209A Westgate Bldg.
Pennsylvania State University
University Park, PA

Highlights

Teaching faculty experienced in research and systems development in cellular and mobile wireless networks, wireless local area networks, wireless network security, mobility management, mobile data systems including networks, protocols, and applications, wideband signal processing, modulation theory, algorithms, mathematical/analytical modeling, communication, detection and estimation, and control systems. Pursues funding for and conducts advanced research in computer and mobile networks, theoretical and experimental analysis of communication systems, cellular, wireless, and mobile systems, wideband signal processing, sensors, tracking, localization, and data fusion. Experienced in hardware/software development, data acquisition, integration, and testing, field test planning, preparation, and execution. Extensive programming experience including UI, analysis tools, real-time object-oriented programming, and embedded systems code development in C, C++, python, java, Verilog, RTL, VHDL, HDL, and assembly.

Education

PhD. Acoustics, The Pennsylvania State University, University Park, PA 16802, 2001
M.S. Electrical Engineering, The Pennsylvania State University, University Park, PA, 16802, 1991
B. S. Electronics Engineering, The University of Scranton, Scranton, PA, 18510, 1987

Employment

July 2021 – Present: *Teaching Professor, School of Electrical Engineering and Computer Science, The Pennsylvania State University, University Park, PA 16801*

June 2018 – June 2021: *Associate Teaching Professor*

Aug. 2015 – June 2018: *Assistant Teaching Professor*

Teach graduate and undergraduate courses in computer science and electrical engineering such as communication networks, mobile networks, neural networks, programming, mathematics, and wireless security. Advise and direct graduate students' MS and PhD research in the areas of wireless and computer networks, network resource allocation and optimization techniques, ultrawide band systems, multiple antenna applications, and wireless security. Guide Schreyer Honors College students' honors theses. HackPSU and BlockChain@PSU faculty adviser, member of graduate advising committees, member of Computer Science Undergraduate Curriculum Committee, member of School of EECS Management Committee, advise undergraduate electrical engineering, computer science, computer engineering, and data science students.

2003 – Aug. 2015: *Associate Research Professor, Applied Research Laboratory, Communications, Information, and Navigation Office, The Applied Research Laboratory, The Pennsylvania State University, State College, PA* Principal Investigator, Co-Principal Investigator, Technical lead conducting research on cellular and mobile networks, computer network security, mobile communication systems, data fusion, and wideband signals and image processing with total funding over \$12M.

2002 – 2003: *Sr. Systems Engineer, Klein & Stump, Inc., 2120 Washington Blvd. #400, Arlington, VA 22204* Researcher and technical consultant working on wireless communications projects for US Special Operations Command (SOCOM) and Naval Information Warfare Activity (NIWA). Awarded \$150k SBIR for SOCOM advanced signal simulator.

1991 – 2002: *Assistant Research Professor, Applied Research Laboratory, Communication Sciences and Technology Division, The Applied Research Laboratory, The Pennsylvania State University, State College, PA 16804* Principal Investigator and researcher conducting research on cellular and mobile networks, wideband signals, tracking and localization, adaptive signal processing, acoustic propagation, sensor systems, remote sensing, and active noise control. Awarded \$750k for development of novel wavelet based wideband signal detection for high altitude sensors.

1988 – 1989: *Program Engineer, Central Intelligence Agency, Langley, VA 22101*
Assisted in the development of algorithms and signal processing systems for novel applications in the areas of RF communications and signal modulation techniques.

Detailed Research Experience:

Current ongoing research:

Resource allocation and scheduling improvements in NG networks and edge computing; Multiple Input Multiple Output antenna techniques for increased capacity in NG systems; Fast handover techniques using blockchains to reduce mobility interruption times in 5G networks; AI/NN techniques applied to network scheduling and optimization, and mobile robotics for localization and mapping; Automated object detection and 3D mapping using sonar array data. Security vulnerabilities in UWB ranging.

2015 – Present

Lead graduate and undergraduate student research in wireless communication networks, distributed video processing in cellular systems, UWB ranging, communication systems and security, software defined network security, application of game theory to cyber resiliency, wireless, machine learning, big data analytics, and artificial intelligence for mobile and computer network security and automated detection in acoustic and sonar systems.

2014 – 2015

Leading internal research and development effort on deep packet inspection for zero day and predictive detection for data networks. Technical performer developing novel deformable wavelet-based contour matching technique for automated object detection in satellite images. Acoustic tracking and identification of drones for area defense system.

2014

Developed real-time scanner for 802.15.4 (LR-WPAN) protocol deployed on software defined radio platform.

2013-2014

Technical lead on developing novel mathematical model for analyzing torpedo acoustic threat surrogate systems for US Navy. Experimental lead on disposable, adaptive, high bandwidth fiber-optic undersea communication system for US Navy.

2013

Implemented a novel matched filter receiver for a unique OFDM signal of interest to facilitate signal detection in a high co-channel interference environment of a wide field of view high altitude receiver and wideband signal set design in highly complex propagation environments for

Department of Defense (DoD).

2012-2013

Technical lead for design and implementation of a real-time transmitter/receiver on a software defined radio platform for maritime communication systems (Automatic Information System/Maritime Security).

2012

Communications/signal processing technical consultant on Maritime Domain Operations and Unmanned Surface Ship Interdiction study effort for US Navy.

2011-2012

Principal Investigator, technical and experimental lead on fiber optic undersea communication system for Advanced Submarine System Development effort for US Navy.

2011

Technical lead on mathematical analysis, algorithm development, and implementation of pattern of life signal to noise ratio analysis in high co-channel interference environment for DoD.

Trusted agent for Army Research Lab to review and critically analyze work associated with wideband signaling and passive emissions collection from cell phones. Reviewed contractor data analysis and technical briefings for scientific accuracy and rigor. Advised the sponsor on contractor testing methodologies, procedures, and analysis techniques. Technical lead implementing unique wideband acoustic communication system and specialized signal processing hardware for an acoustic system being utilized in a complex maritime environment for the DoD.

2009 – 2010

Tiger team lead for large unmanned undersea vehicle (UUV) assigned to identify platform induced electromagnetic interference with electronic payload system in the HF and acoustic regimes for the US Navy.

Developed and implemented a novel algorithm to calculate the effective force charge based on muzzle sensor data utilizing MEMS transducers and PIC controller on a portable howitzer for the US Army.

Conducted study and authored Intelligence, Surveillance, and Reconnaissance (ISR) for Unmanned/Minimally Manned Undersea Vehicle (UMUV) report presented to Defense Advanced Research Projects Agency (DARPA).

2006 – 2009

Principal Investigator for a multi-year research and FPGA-based engineering prototype development effort in the area of 3G/4G (UMTS/LTE) cellular and wireless (IEEE 802.16 and 802.11) communication systems; Effort consisted of three phases: theoretical and analytical study, proof-of-concept development, and testing, and prototype development for DoD.

2005-2006

Technical lead on Information Fusion engine integration into a sandbox enclave at Joint Interagency Task Force South (JIATF-S) to support multi-int data fusion.

2003 – 2006

Principal Investigator for multi-year Office of Secretary of Defense sponsored research program in the area of multi-intelligence data fusion as part of the overall initiative of Force Transformation; worked extensively with NGA, DIA, DISA, OSD, all military services, and some coalition components.

2002 – 2003

Pursued funding for research interests in the areas of wireless/wideband communications, wideband systems, source detection/localization, intelligent system of systems design, and data fusion; Awarded Phase I, Small Business Innovative Research contract for Portable Signal Training System by SOCOM (02-013); Technical consultant for Naval Information Warfare Center on Common for High Performance Computing Software Support Initiative's (CHSSI) Electronic Battlefield Environment (EBE) portfolio (Electromagnetic Environmental Effects Toolkit), SBIR, MERIT/TENCAP, TST programs

1998 – 2002

Researcher and principal investigator performed research in large time-bandwidth product (wavelets) source detection and localization – theoretical, analytical, and field testing; CDMA IS-95A/3G cellular communications; Developed mathematical analytical models and included code development of the CDMA air interface physical layer implementing major aspects of the CDMA protocol for test and analysis purposes; Built real-time hardware platform for deploying developed CDMA physical layer code.

1997 – 1998

Principal Investigator in charge of signal processing algorithm and code development, image acquisition and compression, telephony, and user interface design for an experimental remote, autonomous, acoustic rockslide detection for Conrail. Work included algorithm and code development utilizing embedded digital signal processing (DSP) board and development of unique algorithms for real-time monitoring of transducers to create an event detection system.

1991 – 1997

Performed fundamental research in the areas of signal processing algorithm development, acoustic atmospheric propagation, detection, source localization, beamforming, system identification, and active control; Main responsibilities include real-time code development (C, Visual C++, assembly) for signal processing systems, adaptive beamforming, and embedded processing for eight major projects during this time. Multiple DSP platform development; Active Noise Control, feature extraction, data logging and fusion, passive acoustic tracking, beamforming, and analysis for these projects

1988-1989

Assisted in the development of algorithms and signal processing systems for novel applications in the areas of RF communications and signal modulation techniques.

Case History:

Ericsson Inc. and Nokia of America v. Active Wireless Technologies, LLC. IPR2024-00xx

Consulting for petitioners Ericsson and Nokia on improvements in system information transmissions in 4G systems. Wrote declaration.

October 2023 – April 2024, Erise IP; Finnegan, DLA Piper, Husch Blackwell

BNR v. ASUSTek/Media Tek/Laird/NXP Inc. Inv. No. 337-TA-1367 (USITC). Consulting for defendant ASUS on ASUS (Qualcomm-based products) non-infringement and JDG (ASUS/Media Tek/ Laird/ NXP) on Tech DI non-infringement on WiFi wireless devices and semiconductor chips with wireless capabilities related to wireless transmission technologies. Wrote rebuttal report. BNR settled with ASUS and Media Tek; BNR withdrew complaint for NXP.

September 2023 – April 2024, McKool Smith

Daingean Technologies Ltd. v. AT&T, et al, Case No. IPR2024-00309. Consulting for petitioner AT&T. Technology related to 5G wireless transmissions. Wrote declarations. Case settled.

August 2023 – December 2023, Greenberg Traurig

Atlas Global Technologies, LLC v. Acer Incorporated, No. 2:22-cv-00259 WDTX. Consulting for defendant Acer. Technology related to wireless transmissions in WiFi networks. No reports. Settled.

August 2023 – Present, McKool Smith

Ericsson v. Lenovo/Motorola, In the Matter of Certain Mobile Phones, Components Thereof, and Products Containing Same, Inv. No. 337-TA-1375 (USITC)

Consulting for Complainant Ericsson on technology related to 5G cellular signaling technology.

August 2023 – Present, Caldwell, Cassady and Curry

Neo Wireless, LLC v. Ford, et al., Case No. 2:22-MD-03034. Consulting for plaintiff on technology related to 4G cellular radio access. Wrote infringement reports.

June 2023 – November 2023, Duane Morris

Ericsson, Inc., and Cellco Partnership D/B/A Verizon Wireless v. Woodbury Wireless LLC., IPR 2023-01364. Consulted for petitioner Verizon. IPR. The technology related to MIMO and minimization of interference. Declaration filed 10/10/23. Case settled.

January 2023 – April 2023, McKool Smith

Ericsson v. Koninklijke KPN N.V., Case No. IPR2023-00582. Consulting for Petitioner Ericsson. IPR. Technology related to neighbor cell lists in wireless systems. Declaration filed 2/17/23.

November 2022 – April 2023, Finnegan, Henderson, Farabow, Garrett & Dunner, LLP

Qualcomm, Inc. vs. FedEx, Inc., IPR 2022-00585

Consulting for patent owner FedEx. Wrote IPR declaration. Deposed 4/19/23.

Technology related to sensor information collected by tracking devices.

October 2022 – November 2023, BC Law Group, P.C.

Lionra Technologies Limited v. Apple, Inc. Case No. 6:22-cv-00351-ADA, WDTX

Consulting for patent owner Lionra. Case dismissed 11/18/23.

September 2022 – June 2023, Quinn Emanuel, LLP

Google LLC v. Sonos, Inc., Inv. No. 337-TA-1330 (USITC)

Consulting for patent owner Google. Wrote infringement and validity rebuttal reports.

Technology related to voice assistants and smart devices. Deposed 4/14/23. Testified at trial 6/20/23 and 6/23/23.

September 2022 – August 2023, BC Law Group, P.C.

Apple, Inc. vs. Speir Technologies Limited, IPR2022-01512 and -00151

Consulted for patent owner Speir on UWB localization technology. Wrote IPR declarations. Deposed 10/25/23. Case dismissed 11/18/23.

August 2022 – Present, Venable, LLP

VoIP-Pal.com, Inc. v. Verizon Communications Inc. Case No. 6:21-cv-00672, WDTX

Consulting for defendant Verizon. Wrote non-infringement report. Deposed 5/17/23.

Technology relates to VoIP in cellular networks.

July 2022 – November 2023, Quinn Emanuel Urquhart & Sullivan, LLP
Evolved Wireless LLC v. Samsung Electronics Co., Ltd., and Samsung Electronics America, Inc., Case No. 2:21-cv-00033, EDTX. Technology related to handovers in 4G networks.
Consulting for defendant Samsung. Wrote non-infringement and validity rebuttal report. Deposed 7/5/23; Testified at trial 11/14/23.

March 2022 – Dec. 2022, Knobbe, Martens, Olson & Bear, LLP
Jawbone Innovations, LLC v. Amazon.com, Inc., et al.
Consulting for petitioner Amazon re: IPR. Case stayed. No reports.
Technology related to tracking using acoustic arrays.

May 2022 – Dec. 2022, McKool Smith; Alston Bird
Ericsson Inc. and Telefonaktiebolaget LM Ericsson vs. Apple Inc., Case No. 2:21-cv-376, EDTX
Consulted for plaintiff and counter-defendant Ericsson.
Report on Essentiality and Rebuttal report (FRAND). Deposed 10/4/2022. Testified 12/7/2022. Case settled during trial.
Broad spectrum of technology related to cellular networks (core network and mobile device)

March 2022 – Dec. 2022, McKool Smith
Ericsson Inc. and Telefonaktiebolaget LM Ericsson vs. Apple Inc., Inv. No. 337-TA-1299, ITC
Consulted for Ericsson. Opening and Rebuttal report. Deposed 10/7/2022. Case settled.
Technology related to security in cellular systems.

January 2022 – March 2023, Duane Morris
Telecom Network Solutions v. AT&T Inc., et al, Case No. 2:21-cv-415 and Verizon Communications Inc., et al, Case No 2:21-cv-416, EDTX
Consulted for defendants AT&T and Verizon on Invalidity. Case settled; no reports filed.
Technology related to QoS in cellular networks.

September 2021 – December 2021, Duane Morris, LLP
KAIFI LLC v. Verizon Wireless, Case No. 2:20-cv-280-JRG, EDTX
Consulted for defendant Verizon. Wrote Non-Infringing Alternatives and Non-Infringement reports.
Deposed 12/15/21. Case settled. Technology related to cellular and WiFi enablement with cellular systems.

September 2021 – December 2021, Quinn Emanuel, LLP
L2 Mobile Technologies, LLC v. Google, Case No. 6:21-cv-358, WDTX
Consulted for defendant Google. Wrote reply Claim Construction brief. Case settled.
Technology related to control signaling in cellular systems.

August 2021 – May 2022, McKool Smith
Godo Kaisha IP Bridge 1 v. Ericsson, Case No. 2:21-cv-00213-JRG, EDTX
Consulted for defendant Ericsson. IPR and Claim Construction declarations.
Technology related to signaling in OFDM systems.

July 2021 – August 2021, Quinn Emanuel, LLP
Finesse Wireless, LLC v. Nokia, et al., Case No. 2:21-CV-00063-JRG, EDTX
Consulted for defendant Nokia on claim construction. Wrote declaration and deposed on 8/17/21.
Technology related to coding techniques in wireless systems.

June 2021 – Dec 2021, Knobbe, Martens, Olson & Bear, LLP
Vocalife LLC v. Amazon.com, Inc., et al., Case No. 2:20-cv-00401-JRG-RSP, EDTX
Consulted for defendant Amazon on claim construction. Stayed pending sister case outcome.
Technology related to echo cancelation and signal enhancement in acoustic systems.

March 2021 – Sept 2021, Wilson Sonsini

Lenovo Holding Co, Inc., et al. v. InterDigital Technology Corp.

IPR. Consulted for InterDigital. Wrote three declarations. Deposed 7/27/21.

Technology related to control signaling in cellular systems.

January 2021 – May 2021, Winston & Strawn, LLP

Ericsson, Inc. v. Samsung Electronics, Ltd., ITC

Consulted for plaintiff. Settled May 2021. No deposition. No declaration filed.

Patents dealt with antenna arrays for 5G/4G base stations, access point signaling, bearer handling.

November 2020 – June 2021, Sheppard Mullin

Hong Kong uCloudlink v. SIMO Holdings, Inc. and Skyroam, Inc., Case No. 18-cv-05031-EMC,

NDCA. Consulted for plaintiff uCloudlink on infringement and validity. Deposed (3/26/21). Case

settled. Virtual SIM technology.

August 2019 – August 2020; June 2021 – Sept 2021 McKool Smith/Irell & Manella

Optis Wireless Technology, LLC et al. v. Apple, Inc., EDTX, Civ No. 2:19-cv-66

Consulted for plaintiff Optis. Infringement and validity analysis/reports, IPR. Deposed 06/01/20 and testified at trial 8/3/20 – 8/9/20. Re-trial for damages 8/10/21 – 8/16/21.

March 2019 – May 2020 Gibson, Dunn, & Crutcher, LLP

Sol IP v. AT&T, Ericsson, Nokia, Verizon, and Sprint, EDTX, Case No. 2:18-cv-526

Consulted for defendants on patents involving LTE downlink cell search and synchronization signaling. Invalidity, non-infringement analysis/reports, claim construction. No deposition, case settled.

2016 – March 2019 Sidley Austin, LLP

Huawei v. Samsung, NDCA

Case No. 3:16-cv-02787-WHO

Consulted for plaintiff Huawei on original complaint and for defendant Huawei on counterclaims on patents involving control channel signaling, network access, and security. Assisted claim construction, IPR petition and preliminary response, wrote validity and non-infringement reports. Deposed 6/20/18, 7/19/18. Case settled.

2016 Russ, August & Kabat

Core Wireless v. Apple, Court of Northern California, Case No. 6:14-cv-752-JDL

Consulted for plaintiff on patents associated with core network signaling. Wrote infringement and validity reports and rebuttals. Performed source code review and conformance testing. Deposed (8/12/2016). Patent was dropped during down select before trial.

2015 - 2016 Hueston & Hennigan

Core Wireless v. LG Electronics, Court of Eastern Texas, Case No. 2:14-cv-911-JRG-RSP (lead case),

Case No. 2:14-cv-912-JRG-RSP (consolidated)

Consulted for plaintiff on patents on cellular user interface. Present at jury trial (3/2016) and participated in mock jury trial (2/10/2016). Wrote rebuttal expert report on validity and deposed (12/11/2015). Wrote infringement report regarding cellular protocols. Performed source code review and conformance testing. Core Wireless prevailed.

2015 Bunsow De Mory Smith & Allison

Core Wireless v. LG Electronics, Court of Eastern Texas, Case No. 2:14-cv-911-JRG-RSP (lead case),

Case No. 2:14-cv-912-JRG-RSP (consolidated) and Core Wireless v. Apple, Case No. 6:14-cv-752-JDL

Consulted for plaintiff on patents associated with core network signaling. Wrote declarations on claim construction. Prepared tutorial to be presented to court. Case handed off to Hueston & Hennigan.

Case Testimony History:

October 2023 – April 2024, Erise IP; Finnegan, DLA Piper, Husch Blackwell
BNR v. ASUSTek/Media Tek/Laird/NXP Inc. Inv. No. 337-TA-1367 (USITC). Consulting for defendant ASUS on ASUS (Qualcomm-based products) non-infringement and JDG (ASUS/Media Tek/ Laird/ NXP) on Tech DI non-infringement. Wrote on WiFi wireless devices and semiconductor chips with wireless capabilities related to wireless transmission technologies. Wrote rebuttal report. Deposed 2/8/24. BNR settled with ASUS and Media Tek; BNR withdrew complaint before hearing.

November 2022 – April 2023, Finnegan, Henderson, Farabow, Garrett & Dunner, LLP
Qualcomm, Inc. vs. FedEx, Inc., IPR 2022-00585
Consulting for patent owner FedEx. Wrote IPR declaration. Deposed 4/19/23.
Technology related to sensor information collected by tracking devices.

September 2023 – June 2023, Quinn Emanuel, LLP
Google LLC v. Sonos, Inc., Inv. No. 337-TA-1330 (USITC)
Consulting for patent owner Google. Wrote infringement and validity rebuttal reports.
Technology related to voice assistants and smart devices. Deposed 4/14/23. Testified 6/20-23/23.

September 2022 – November 2023, BC Law Group, P.C.
Apple, Inc., vs. Speir Technologies Limited, IPR2022-01512 and -00151
Consulted for patent owner Speir on UWB localization technology. Wrote IPR declarations. Deposed 10/25/23. Case dismissed 11/18/23.

August 2022 – Present, Venable, LLP
VoIP-Pal.com, Inc. v. Verizon Communications Inc. Case No. 6:21-cv-00672, WDTX
Consulting for defendant Verizon. Wrote non-infringement report. Deposed 5/17/23.
Technology relates to VoIP in cellular networks.

July 2022 – November 2023, Quinn Emanuel Urquhart & Sullivan, LLP
Evolved Wireless LLC v. Samsung Electronics Co., Ltd., and Samsung Electronics America, Inc., Case No. 2:21-cv-00033, EDTX. Technology related to handovers in 4G networks.
Consulting for defendant Samsung. Wrote non-infringement and validity rebuttal report. Deposed 7/5/23; Testified at trial 11/14/23. Jury found for defendant on all counts.

March 2022 – December 2022, McKool Smith
Ericsson Inc. and Telefonaktiebolaget LM Ericsson vs. Apple Inc., Inv. No. 337-TA-1299, ITC
Consulting for Ericsson. Opening and Rebuttal report. Deposed 10/7/2022. Testified 12/7/2022. Case settled during trial.

May 2022 – December 2022, McKool Smith; Alston Bird
Ericsson Inc. and Telefonaktiebolaget LM Ericsson vs. Apple Inc., Case No. 2:21-cv-376, EDTX
Consulting for plaintiff and counter-defendant Ericsson.
Report on Essentiality and Rebuttal report. Deposed 10/4/2022. Case settled.

September 2021 – December 2021, Duane Morris, LLP
KAIFI LLC v. Verizon Wireless, Case No. 2:20-cv-280-JRG, EDTX
Consulted for defendant Verizon. Wrote Non-Infringing Alternatives and Non-Infringement reports. Deposed 12/15/21. Case settled.

July 2021 – August 2021, Quinn Emanuel, LLP
Finesse Wireless, LLC v. Nokia, et al., Case No. 2:21-CV-00063-JRG, EDTX
Consulted for defendant Nokia on claim construction. Technology related to noise in the front-end of receiver. Deposed on 8/17/21.

March 2021 – Sept 2021, Wilson Sonsini

Lenovo Holding Co, Inc., et al. v. InterDigital Technology Corp.

IPR. Consulted for InterDigital. Technology related to control signaling in cellular systems. Wrote three declarations. Deposed 7/27/21.

November 2020 – June 2021, Sheppard Mullin

Hong Kong uCloudlink v. SIMO Holdings, Inc. and Skyroam, Inc., Case No. 18-cv-05031-EMC,

NDCA. Consulted for plaintiff uCloudlink on infringement and validity. Technology related to virtual SIM. Deposed 3/26/21.

August 2019 – August 2020; June 2021 – Sept 2021 McKool Smith/Irell & Manella

Optis Wireless Technology, LLC et al. v. Apple, Inc., EDCX, Civ No. 2:19-cv-66

SEPs – Consulted for plaintiff Optis on control channel MIMO switching, control channel information fields. Infringement and validity analysis/reports, IPR. Deposed 06/01/20 and testified at trial 8/3/20 – 8/9/20. Testified at re-trial for damages 8/10/21 – 8/16/21.

2016 – March 2019 Sidley Austin, LLP

Huawei v. Samsung, NDCA

Case No. 3:16-cv-02787-WHO

Consulted for plaintiff Huawei on original complaint and for defendant Huawei. Assisted claim construction, IPR petition and preliminary response, wrote validity and non-infringement reports. Deposed 6/20/18, and 7/19/18.

2016 Russ, August & Kabat

Core Wireless v. Apple, Court of Northern California, Case No. 6:14-cv-752-JDL

Consulted for plaintiff on patents associated with core network signaling. Wrote infringement and validity reports and rebuttals. Performed source code review and conformance testing. Deposed (8/12/2016). Patent was dropped during down select before trial.

2015 - 2016 Hueston & Hennigan

Core Wireless v. LG Electronics, Court of Eastern Texas, Case No. 2:14-cv-911-JRG-RSP (lead case), Case No. 2:14-cv-912-JRG-RSP (consolidated)

Consulted for plaintiff on patents on cellular user interface. Present at jury trial (3/2016) and participated in mock jury trial (2/10/2016). Wrote rebuttal expert report on validity and deposed (12/11/2015). Wrote infringement report regarding cellular protocols. Performed source code review and conformance testing. Core Wireless prevailed.

Teaching:

Courses:

- CSE 516 (Mobile Networks): Redesigned the course to integrate latest developments in mobile network architecture design. The course now includes signaling, control, and protocol issues unique to 4G/5G architectures addressing eMBB, mMTC, and URLLC use cases critical to IoT and future wireless network development and future NG networks.
- CSE 514 (Communication Networks)
- CSE 590 (Colloquium)
- CMPEN 462 (Wireless Communication Systems and Security): Created and designed this course to address a gap in the wireless communications area focusing on security. This course is included in the cybersecurity computational foundations minor.
- EE 456 (Introduction to Neural Networks): This course is intended to address the need for EE and CMPEN students to be exposed to the principles associated with artificial intelligence with a focus on the integration of physics-based approaches.
- CMPEN/EE 362 (Communication Networks)
- CMPSC 263 (Blockchains and Modern Web Development): This course is ‘module’ driven and

designed to provide students with a broad range of academic backgrounds an opportunity to learn about blockchains and cryptography. Under supervision, students in the Distributed Ledger Society teach the modules including theory and practice in the areas of programming, math, and cryptography.

- ACS 505 (Experimental Techniques in Acoustics)
- MATH 141 (Calculus with Analytical Geometry II)
- CMPSC 101 (Programming in C++)

Publications:

Rublein, Mehmeti, Mahon, and LaPorta, “Impact of Client Choice on Distributed Resource Allocation in Edge Computing”, *The 33rd International Conference on Computer Communications and Networks (ICCCN 2024)*, IEEE and IEEE Communication Society, July 29 – 31, 2024, Big Island, Hawaii, USA.

Rublein, Mehmeti, Mahon, and LaPorta, “Improved Methods of Task Assignment and Resource Allocation with Preemption in Edge Computing Systems”, *IEEE Transactions on Parallel and Distributed Computing*. Submitted July 2023.

Sorensen, Mahon, Mehmeti, and LaPorta, QoE-Analysis of 5G Network Resource Allocation Schemes for Competitive Multi-User Video Streaming Applications, *IEEE Conference on Vehicular Technology*, Florence, Italy, June 2023.

Sorensen, Mehmeti, Mahon, LaPorta, and Cao, “EQMS: An Improved Energy-Aware and QOE-aware Video Streaming Policy across Multiple Competitive Mobile Devices”, *Wireless Networks: The Journal of Mobile Communication, Computation and Information*, Dec. 2022.

Sorensen, Mehmeti, Mahon, Qui, Chan, Qui, and LaPorta, “Optimal Resource Allocation for Crowdsourced Image Processing”, *IEEE Transactions on Mobile Computing*. June 2022.

Sorensen, Mehmeti, Mahon, La Porta, Cao, “Mutli-User Competitive Energy-Aware and QoE-Aware Video Streaming on Mobile Devices”, *ACM Proceedings of the QoS and Security for Wireless and Mobile Networks (Q2SWinet) Symposium collocated with Modeling, Analysis, and Simulation of Wireless and Mobile Systems (MSWIM 2020)*, Alicante, Spain, Nov. 2020.

Sorensen, Mehmeti, Mahon, Qui, Chan, and LaPorta, “Optimal Resource Allocation for Crowdsourced Image Processing”, *IEEE International Conference on Sensing and Networking (IEEE SECON 2020)*, Como, Italy, June 2020.

Swanson, Mahon, Norris, and Mast, “Atmospheric Multipath Resolution Using Spread Spectrum Acoustic Signals”, *Proceedings of Meetings on Acoustics*, September 2017.

Aquaviva, Mahon, Einfalt, and LaPorta, “Optimal Cyber-Defense Strategies for Advanced Persistent Threats: A Game Theoretic Approach,” *2017 International Symposium on Reliable and Distributed Systems*, Hong Kong, China, September 27 – 29, 2017.

Young, Mahon, and Wyckoff, “Automated Information Management,” Chap. 12, *Mathematical Techniques in Multisensor Data Fusion*, Hall, David L., Artech House Inc., Mar 2004

Mahon, Sonsteby, and Wenchel, “Application of Non-Orthogonal Waveletes for Geolocation,” *Radiolocation and Direction Finding Symposium*, Southwest Research Institute, San Antonio, Texas, 2-4 Nov. 1999.

Myers, Lovette, Kilgus, Giannini, Swanson, Reichard, Mahon, Mast, "A Java-based Information System for Wayside Sensing and Control," *Proc. of the 1998 ASME/IEEE Joint Railroad Conference*, 1998, pp. 135-147.

Swanson, Mast, Mahon, "Atmospheric Multipath Resolution Using Spread Spectrum Acoustic Signals," *Proceedings of the 133rd Meeting of the ASA*, June 15-20, 1997.

Mahon, Swanson, "Acoustic Holography as an Active Control Measurement Tool," *Proceedings of Active 95, The 1995 International Symposium on Active Control of Sound and Vibration*, Newport Beach, CA, July 1995, pp. 673-684.

Mahon, Sibul, Valenzuela, "A Sliding Window Update for the Basis Matrix of the QR Decomposition," *IEEE Transactions on Signal Processing*, May 1993, pp. 1951-1953.

Mahon, Sibul, Valenzuela, "An Alternative Updating Scheme for the QR Algorithm as Applied to Adaptive Beamforming," *Proc. 25th Annual Conf. on Info. Sciences and Systems*, Johns Hopkins University, Baltimore, MD, March 1991, pp. 193-199.

Awards/Honors:

Senior Member IEEE

2001 Formal citation letter from National Reconnaissance Office (NRO) for experimental work with mobile wireless systems

2001 Formal citation letter for excellence in software development from the NRO for work associated with mobile wireless systems.

2000 Formal citation letter from NRO for development of wavelet course presented at NRO Technology Symposium

1997 Invited session chair of "Signal Processing in Acoustics: General Signal Processing," Noise-Con '97, 133rd meeting of the ASA.

1996 Simowitz Citation Acoustics Department PSU for outstanding publication by a graduate student

1995 Invited co-chair of "Transducers for Active Control of Sound and Vibration," Active 95, Active Noise Control Conference

1993 Simowitz Award Acoustics Department PSU for outstanding publication by a graduate student

1987 Dr. A. J. Cawley Award for Excellence in Electronics Engineering by Physics/EE Department University of Scranton