IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:	Juhyung Son, et al.	Attorney Docket No. 39843-0200IP1
U.S. Patent No.:	10,687,281	
Issue Date:	June 16, 2020	
Appl. Serial No.:	16/016,520	
Filing Date:	June 22, 2018	
Title:	WIRELESS COMMUNICATION METHOD AND WIRELESS COMMUNICATION TERMINAL, WHICH USE DISCONTINUOUS CHANNEL	

DECLARATION OF R. MICHAEL BUEHRER

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

Date: May 19, 2025 By: _____

R. Michael Buehrer

SAMSUNG 1003

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I. ASSIGNMENT

1. I have been retained on behalf of Samsung Electronics Co., Ltd. ("Samsung") to offer technical opinions related to 10,687,281 ("the '281 patent") (SAMSUNG-1001). I understand that Samsung is requesting that the Patent Trial and Appeal Board ("PTAB" or "Board") to institute an *inter partes* review ("IPR") proceeding of the '281 patent.

2. I have been asked to provide my independent analysis of the '281 patent based on the prior art publications cited in this declaration.

3. I am not and never have been, an employee of Samsung. I received no compensation for this declaration beyond my normal hourly compensation based on my time actually spent analyzing the '281 patent, the prior art publications cited below, and issues related thereto, and I will not receive any added compensation based on the outcome of any IPR or other proceeding involving the '281 patent.

II. QUALIFICATIONS AND BACKGROUND INFORMATION

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

5. My qualifications are summarized here and explained in more detail in my curriculum vitae, which is attached as Appendix A to this report. Appendix A also includes a list of my publications and the cases in which I have testified at

deposition, hearing, or trial within the past four years.

6. I earned a B.S. and M.S. in Electrical and Computer Science from the University of Toledo in 1991 and 1993, respectively, and a Ph.D in Electrical Engineering from Virginia Polytechnic Institute and State University in 1996.

7. I am currently a Professor in Bradley Department of Electrical and Computer Engineering at Virginia Polytechnic Institute and State University (also known as "Virginia Tech"). I was formerly (2014-2022) the Director of *Wireless @ Virginia Tech* a comprehensive research group focused on wireless technologies. I worked in the Mobile and Portable Radio Research Group from August 2001 to August 2005. This research group expanded and became *Wireless @ Virginia Tech* in 2005. I have been a member of that group since its inception and served as the director from 2014-2022.

8. Prior being promoted to Professor of Electrical and Computer Engineering at Virginia Tech in 2012, I was an Associate Professor at Virgina Tech from August 2006 to August 2012, a Visiting Researcher at the Laboratory for Telecommunication Sciences (LTS) from August 2009 to December 2009, and an Assistant Professor at Virgina Tech from August 2001 to August 2006. I have supervised over 60 Ph.D. and M.S. graduate students to the completion of their degrees and a number of undergraduate students during the course of my career. Prior to that, I worked as a Member Technical Staff at Bell Laboratories from

August 1996 to August 2001, and was promoted to Distinguished Member of Technical Staff in 1999.

9. My area of expertise is wireless communications, radar and geolocation as well as general digital data transmission including in cellular, nearfield, and local wireless networks. As such, I regularly teach undergraduate and graduate students taking my courses from the level of sophomore to Ph.D. and participating in my research group which conducts research in wireless communication, radar and geolocation. I regularly teach a sophomore level course on Signals and Systems, a junior level course titled Introduction to Communication Systems, a senior level course on digital communications, and two graduate level courses on digital communications and multi-channel communications. I have also taught courses on spread spectrum communciations, information theory and machine learning applied to communications.

10. I have received numerous awards for research and teaching, including the Military Communications (MILCOM) Lifetime Award for Technical Achievement (2023), National Spectrum Consortium (NSC) Vanu Bose Best Paper Award at IEEE MILCOM (2023 and 2021), Fred W. Ellersick Award for the Best Paper in the Unclassified Technical Program at IEEE MILCOM (2023 and 2010), and Bell Lab President's Silver Award for outstanding research contributions.

11. I have published over 300 articles in top conferences and journals in

the areas of wireless communications and antennas. Many of my results are highly cited, and I have received multiple "Best Paper" Awards. My research has been cited over 13,000 times. I have also written more than fifteen books or book chapters in the field of wireless communications and geolocation.

12. I am a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), so recognized due to my work in wideband wireless communications and geolocation. I am a member of multiple IEEE societies including the Communications Society, Vehicular Technologies Society, and Signal Processing Society.

13. I was an organizer for IEEE DySPAN 2024 Conference. I served as the Technical Program Chair for the Signal Processing for Communications Symposium at the 2017 IEEE International Conference on Communications. I also recently served as the Technical Program Chair at the IEEE Vehicular Technology Conference and also as the Special Session co-Chair for the 2023 IEEE Radar Conference. I have also served on the technical program committees of several other conferences and workshops in my field.

14. I have also served as Area Editor for *IEEE Transactions on Wireless Communications* (2017 – 2022), Guest Lead Editor for *IEEE Journal on Special Topics in Signal Processing*, and Associate Editor in several IEEE journals, including *IEEE Wireless Communications Letters* (2010 – 2014), *IEEE*

Transactions on Communications (2009 – 2014), *IEEE Transactions on Wireless Communications* (2005 – 2012, 2015 – 2017, *IEEE Transactions on Vehicular Technologies* (2005 – 2009).

15. I am a named inventor on eighteen US patents. These patents are in the field of wireless communications and geolocation. Among others, the patents provide details for estimating the location of a wireless terminal based on its radio-frequency, methods for diversifying transmissions, transmission channel estimation and compensation based thereon, cellular communication systems.

16. My curriculum vitae, included with this declaration, includes a list of publications on which I am a named author. It contains further details regarding my experience, education, publications, and other qualifications to render an expert opinion in connection with this proceeding.

17. My analysis here is based on my years of education, research, and experience, as well as my investigation and study of relevant materials, including those cited in this Declaration.

18. I may rely upon these materials, my knowledge and experience, and/or additional materials to rebut arguments raised by the Patent Owner. Further, I may consider additional documents and information in forming any necessary opinions, including documents that may not yet have been provided to me.

19. My analysis of the materials produced in this proceeding is ongoing,

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

20. In writing this Declaration, I have considered my own knowledge and experience, including my work experience in the field of wireless and digital data communications and my experience in working with others involved in this field. Moreover, I have considered my knowledge and experience derived from serving on standards committees and organizing technology-based conferences, including those organized by the Institute of Electrical and Electronics Engineers (IEEE).

21. Counsel (Fish & Richardson) has informed me that I should consider these materials through the lens of one of ordinary skill in the art related to the '281 patent at the time of the earliest possible priority date of the '281 patent, and I have done so during my review of these materials. I have been informed by Counsel to use the date of December 24, 2015 ("Earliest Filing Date"), as the earliest possible priority date for Grounds 2A-2B and to use the date of May 14, 2016 ("Critical Date") as the priority date for Grounds 1A-1B and 2C-2D. However, as I explain below in § VIII.B, it is my opinion that the '281 patent's claims are not entitled to a priority claim before May 14, 2016. Thus, I also consider these materials through the lens of one of ordinary skill in the art related

to the ’281 patent as of May 14, 2016 as noted below in § III.

22. I have no financial interest in the outcome of this proceeding. I am being compensated for my work as an expert on an hourly basis. My compensation is not dependent on the outcome of these proceedings or the content of my opinions.

23. My opinions, as explained below, are based on my education, experience, and expertise in the fields relating to the ’281 patent. Unless otherwise stated, my testimony below refers to the knowledge of one of ordinary skill in the art as of the earliest possible priority date; however, my testimony would not change if a later priority date (e.g., May 14, 2016) is used. Any figures that appear within this document have been prepared with the assistance of Counsel and reflect my understanding of the ’281 patent and the prior art discussed below.

III. OVERVIEW OF CONCLUSIONS FORMED

24. This declaration explains the conclusions that I have formed based on my analysis of all of the considered materials and my personal experience. As explained in § VIII.B, claims 1-14 of the ’281 patent are not entitled to a priority claim before May 14, 2016. Thus, in my opinion, the Challenged Claims are rendered obvious by the prior art combinations described in Grounds 1A-1B and 2C-2D by May 14, 2016. However, as illustrated in Grounds 2A-2B, the Challenged Claims are additionally rendered obvious by prior art combinations by

the earliest possible priority date (i.e., based on the earliest-filed Korean priority application) (December 24, 2015) as well.

25. To summarize the conclusions I have formed, based upon my knowledge and experience and my review of the prior art references listed above, I believe that:

- Josiam renders obvious claims 1-5, 7-12, and 14 of the ’281 patent by May 14, 2016 (Ground 1A);
- Josiam combined with Kim renders obvious claims 1-7 and 13 of the ’281 patent by May 14, 2016 (Ground 1B);
- Bharadwaj combined with Li renders obvious claims 1-3, 7-10, and 14 of the ’281 patent by December 24, 2015 (Ground 2A);
- Bharadwaj and Li combined with Chen renders obvious claims 1-5, 7-12, and 14 of the ’281 patent by December 24, 2015 (Ground 2B);
- Bharadwaj and Li combined with Kim renders obvious claims 6 and 13 of the ’281 patent by May 14, 2016 (Ground 2C); and
- Bharadwaj, Li, and Chen combined with Kim renders obvious claims 6 and 13 of the ’281 patent by May 14, 2016 (Ground 2D).

26. In support of these conclusions, I provide an overview of the references in § IX and more detailed comments regarding the obviousness of claims 1-14 of the ’281 patent in § X.

IV. LEVEL OF ORDINARY SKILL IN THE ART

27. In my opinion, as relevant to this proceeding, a person of ordinary skill in the art ("POSITA") would have had a Bachelor's degree in electrical engineering, computer engineering, computer science, or a related field, and at least 3 years of experience in the research, design or development of wireless communication devices, systems, and/or networks, or the equivalent. For Grounds 1A-1B and 2C-2D, I have considered a POSITA as of the Critical Date and, for Grounds 2A-2B, I have considered a POSITA as of the Earliest Filing Date. Increased educational experience can make up for less work experience, and vice versa.

28. Further, all portions of this declaration are from the vantage point of a POSITA as of the date noted for each ground.

29. Based on my experiences, I have a good understanding of the capabilities of a POSITA. Indeed, I have taught, participated in organizations, and worked closely with many such persons over the course of my career. Based on my knowledge, skill, and experience, I have an understanding of the capabilities of a POSITA. For example, from my industry experience, I am familiar with what a POSITA would have known and found predictable in the art. From teaching and supervising my graduate students, I also have an understanding of the knowledge that a person with this academic experience possesses. Furthermore, I possess

those capabilities myself.

V. LEGAL STANDARDS

A. Terminology

30. I have been informed by Counsel and understand that the best indicator of claim meaning is its usage in the context of the patent specification as understood by one of ordinary skill. I further understand that the words of the claims should be given their plain meaning unless that meaning is inconsistent with the patent specification or the patent's history of examination before the Patent Office. Counsel has also informed me, and I understand that, the words of the claims should be interpreted as they would have been interpreted by one of ordinary skill at the time of the invention was made (not today). The '281 patent claims priority to the eight Korean priority applications listed below. *See* § VIII.B.

31. The '281 patent was filed June 22, 2018, and claims priority to, among other documents, Korean Priority Application No. 10-2015-0186871 filed December 24, 2015 ("Earliest Filing Date"). As I explain below in § VIII.B, it is my opinion that the Challenged Claims are not entitled to a priority date earlier than May 14, 2016, however. As such, I refer to May 14, 2016 as the "Critical Date" in this proceeding.

B. Legal Standards

32. I have been informed by Counsel and understand that documents and materials that qualify as prior art can render a patent claim unpatentable as being

anticipated or obvious.

33. I am informed by Counsel and understand that all prior art references are to be looked at from the viewpoint of a person of ordinary skill in the art at the time of the invention, and that this viewpoint prevents one from using his or her own insight or hindsight in deciding whether a claim is anticipated or rendered obvious.

34. I have been informed by Counsel and understand that for a claim to be entitled to the priority date of an earlier filing, the priority document must explicitly, implicitly, or inherently convey to one of ordinary skill in the art that the inventor had possession of the full scope of the invention. I understand that a limitation is inherently described if a POSITA would have understood that the description requires that limitation. I further understand that while the words of the claim need not appear verbatim in the description, it is insufficient that the undisclosed subject matter would have been obvious to a POSITA.

C. Anticipation

35. I understand that patents or printed publications that qualify as prior art can be used to invalidate a patent claim as anticipated or as obvious.

36. I understand that, once the claims of a patent have been properly construed, the second step in determining anticipation of a patent claim requires a comparison of the properly construed claim language to the prior art on a

limitation-by-limitation basis.

37. I understand that a prior art reference "anticipates" an asserted claim, and thus renders the claim invalid, if all limitations of the claim are disclosed in that prior art reference, either explicitly or inherently (i.e., necessarily present).

D. Obviousness

38. I understand that even if a patent is not anticipated, it is still invalid if the differences between the claimed subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a POSITA.

39. I have been informed by Counsel and understand that a claim is unpatentable for obviousness and that obviousness may be based upon a combination of references. I am informed by Counsel and understand that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. However, I am informed by Counsel and understand 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.

40. I am informed by Counsel and understand that when a patented invention is a combination of known elements, a court determines whether there was an apparent reason to combine the known elements in the fashion claimed by

the patent at issue by considering the teachings of prior art references, the effects of demands known to people working in the field or present in the marketplace, and the background knowledge possessed by a person having ordinary skill in the art.

41. I am informed by Counsel and understand that a patent claim composed of several limitations is not proved obvious merely by demonstrating that each of its limitations was independently known in the prior art. I am informed by Counsel and understand that identifying a reason those elements would be combined can be important because inventions in many instances rely upon building blocks long since uncovered, and claimed discoveries almost of necessity will be combinations of what, in some sense, is already known. I am informed by Counsel and understand that it is improper to use hindsight in an obviousness analysis, and that a patent's claims should not be used as a "roadmap."

42. I am informed by Counsel and understand that an obviousness inquiry requires consideration of the following factors: (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any so called "secondary considerations" of non-obviousness, which include: (i) "long felt need" for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) "copying" of the claimed invention by others.

43. I have been informed by Counsel and understand that an obviousness evaluation can be based on a single reference or a combination of multiple prior art references. I understand that the prior art references themselves may provide a suggestion, motivation, or reason to combine, but that the nexus linking two or more prior art references is sometimes simple common sense. I have been informed by Counsel and understand that obviousness analysis recognizes that market demand, rather than scientific literature, often drives innovation, and that a motivation to combine references may be supplied by the direction of the marketplace.

44. I have been informed by Counsel and understand that if a technique has been used to improve one device, and a person of ordinary skill at the time of invention would have recognized that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill.

45. I have been informed by Counsel and understand that practical and common sense considerations should guide a proper obviousness analysis, because familiar items may have obvious uses beyond their primary purposes. I have been informed by Counsel and understand that a person of ordinary skill looking to overcome a problem will often be able to fit together the teachings of multiple prior art references. I have been informed by Counsel and understand that

obviousness analysis therefore takes into account the inferences and creative steps that a person of ordinary skill would have employed at the time of invention.

46. I have been informed by Counsel and understand that a proper obviousness analysis focuses on what was known or obvious to a person of ordinary skill at the time of invention, not just the patentee. Accordingly, I understand that any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed.

47. I have been informed by Counsel and understand that a claim can be obvious in light of a single reference, without the need to combine references, if the elements of the claim that are not found explicitly or inherently in the reference can be supplied by the common sense of one of skill in the art.

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

49. I have been informed by Counsel and understand that in an *inter*

partes review, "the petitioner shall have the burden of proving a proposition of unpatentability," including a proposition of obviousness, "by a preponderance of the evidence." 35 U.S.C. §316(e).

VI. MATERIALS CONSIDERED

50. My analysis and conclusions set forth in this declaration are based on my educational background and experiences in the field (*see* § II). Based on my knowledge and experience, I believe that I am considered to be an expert in the field. Also, based on my knowledge and experience, I understand and know of the capabilities of persons of ordinary skill in the field around the Critical Date (for Grounds 1A-1B and 2C-2D) or the Earliest Filing Date (for Grounds 2A-2B), and I taught, participated in organizations, and worked closely with many such persons in the field during that time frame.

51. As part of my independent analysis for this declaration, I have considered the following: the background knowledge/technologies that were commonly known to persons of ordinary skill in this art (*see* § IV); my own knowledge and experiences gained from my work experience in the field of the '281 patent and related disciplines; and my experience in working with others involved in this field and related disciplines.

52. In addition, I have analyzed the following publications and materials:

- SAMSUNG-1001 U.S. Patent No 10,687,281 to Son et al. ("the '281 patent")
- SAMSUNG-1002 Excerpts from the Prosecution History of the '281 patent
- SAMSUNG-1004 Complaint, *Wilus Institute of Standards and Technology Inc., v. Samsung Electronics Co., Ltd., et al*., 2-24-cv-00746 (EDTX) filed September 11, 2024
- SAMSUNG-1006 Certified Translation of Korean Priority Application No. 10-2015-0186871 (filed Dec. 24, 2015)
- SAMSUNG-1007 Certified Translation of Korean Priority Application No. 10-2016-0004471 (filed Jan. 13, 2016)
- SAMSUNG-1008 Certified Translation of Korean Priority Application No. 10-2016-0005835 (filed Jan. 18, 2016)
- SAMSUNG-1009 Certified Translation of Korean Priority Application No. 10-2016-0026683 (filed Mar. 4, 2016)
- SAMSUNG-1010 Certified Translation of Korean Priority Application No. 10-2016-0030006 (filed Mar. 13, 2016)
- SAMSUNG-1011 Certified Translation of Korean Priority Application No. 10-2016-0059182 (filed May 14, 2016)
- SAMSUNG-1012 Certified Translation of Korean Priority Application No. 10-2016-0062422 (filed May 20, 2016)

- SAMSUNG-1013 Certified Translation of Korean Priority Application No. 10-2016-0083756 (filed Jul. 1, 2016)
- SAMSUNG-1014 US Patent Publication No. 2017/0006608A1 ("Josiam")
- SAMSUNG-1015 US Provisional Application No. 62/187,301 ("Josiam July 1, 2015 Provisional")
- SAMSUNG-1016 US Provisional Application No. 62/277,780 ("Josiam Jan. 12, 2016 Provisional")
- SAMSUNG-1017 US Provisional Application No. 62/328,106 ("Josiam Apr. 27, 2016 Provisional")
- SAMSUNG-1018 US Patent Publication No. 2018/0375632A1 ("Kim")
- SAMSUNG-1019 Certified Translation of US Provisional Application No. 62/311,929 ("Kim Provisional")
- SAMSUNG-1021 US Patent Publication No. 2017/0181129A1 ("Bharadwaj")
- SAMSUNG-1022 US Provisional Application No. 62/270,562 ("Bharadwaj Provisional")
- SAMSUNG-1023 US Patent Publication No. US2017/0041171 ("Li")
- SAMSUNG-1024 US Provisional Application No. 62/200,368 ("Li Provisional")
- SAMSUNG-1025 US Patent Publication No. 2016/0330058A1 ("Chen")

- SAMSUNG-1026 Aug. 2016 IEEE 802.11ax Draft Specification
- SAMSUNG-1027 IEEE 802.11-15/0132r13 ("December 2015 802.11ax Specification Framework")
- SAMSUNG-1028 IEEE 802.11-15/0132r15 ("March 2016 802.11ax Specification Framework")
- SAMSUNG-1029 IEEE 802.11-16/0024r1 ("March 2016 Draft 802.11ax Specification")
- SAMSUNG-1030 Evgeny Khorov et al., *A Tutorial on IEEE 802.11ax High Efficiency WLANs*, 21 IEEE Comms. Surveys & Tutorials 197 (2019)
- SAMSUNG-1031 Sanghyun Kim et al., *Wider-Bandwidth Operation of IEEE 802.11 for Extremely High Throughput: Challenges and Solutions for Flexible Puncturing*, 8 IEEE Access 213840 (2020).
- SAMSUNG-1032 Yunbo Li et al., *Non-Contiguous Channel Bonding in 11ax* (Jan. 17, 2016) IEEE 802.11-16/0059r1
- SAMSUNG-1033 IEEE 802.11ac-2013 Specification
- SAMSUNG-1034 Joonsuk Kim et al., *HE-SIG-B Structure* (Jul. 11, 2015) IEEE 802.11-15/0821r2
- SAMSUNG-1035 Katsuo Yunoki & B. Zhao, *Considerations on HE-SIG-A/B* (Jul. 15, 2015) IEEE 802.11-15/827r2

- SAMSUNG-1036 Yunbo Li et al., *BW Indication for Non-Contiguous Channel Bonding* (May 15, 2016) IEEE 802.11-16/0635r2
- SAMSUNG-1037 Kaushik Josiam et al., *HE-SIG-B Mapping and Compression* (Nov. 9, 2015) IEEE 802.11-15/1315r1
- SAMSUNG-1038 Kaushik Josiam et al., *HE-SIG-B Compression Mode* (Mar. 14, 2016) IEEE 802.11-15/0349r1
- SAMSUNG-1039 Suhwook Kim et al., *Efficient Wider Bandwidth Operation* (Sep. 11, 2013) IEEE 802.11-13/1058r0
- SAMSUNG-1040 Jinsoo Ahn et al., *OFDMA Non-Contiguous Channel Utilization* (Mar. 10, 2015) IEEE 802.11-15/0353r1
- SAMSUNG-1041 US Patent Publication No. 2018/0279371A1 ("Li-371")
- SAMSUNG-1042 US Provisional Application No. 62/244,603 ("Li-371 Provisional")
- SAMSUNG-1043 Jiayin Zhang et al., *Preamble Structure for 11ax System* (Jan. 2015) IEEE 802.11-15/0101r1
- SAMSUNG-1044 Jianhan Liu et al., *SIG-A Structure in 11ax Preamble* (Jul. 11, 2015) IEEE 802.11-15/0822r2
- SAMSUNG-1045 Hongyuan Zhang et al., *BW Field in HE-MU Format* (Jul. 25, 2016) IEEE 802.11-16/0898
- SAMSUNG-1046 US Patent No. 8,971,213 B1 ("Hart")

- SAMSUNG-1047 Fed. Commc'ns Comm., *Revision to Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band* (Feb. 20, 2013)
- SAMSUNG-1048 Andreas F. Molisch, *Wireless Communications* (2nd ed. 2011)

53. My analysis and conclusions set forth in this declaration are based on the perspective of a POSITA.

VII. TECHNOLOGY OVERVIEW

54. In this section I provide an overview of the relevant technology and state of the technical community before the December 24, 2015, which is the Earliest Filing Date of the '281 patent. This description is not intended to be exhaustive, but to provide sufficient background to support and contextualize my analysis below.

A. 802.11a/b/g

55. In the late 90's wired internet connections were ubiquitous, but wireless access to the internet was rare. Simultaneously, laptop computers were rapidly growing in popularity. The two trends spurred a demand for local wireless connections between portable computers and the internet. As a result of that demand, two standards were developed for Wireless Local Area Networks (WLANs): 802.11 (by IEEE) and HIPERLAN (by ETSI). In the intervening years

802.11 has become wildly successful and important, while HIPERLAN has become essentially extinct.

56. The original 802.11 standard (known as WiFi 1) employed spread spectrum technology (spreading was initially a requirement for the unlicensed ISM band), similar to 3G cellular. However, it was quickly realized that the requirement for spreading in the 2.4 GHz unlicensed frequency band was too restrictive as it limited data rates to 1-2Mbps (or 11Mbps when CCK was introduced). As a first step to higher data rates, an OFDM physical layer was introduced for use in the 5 GHz U-NII frequency band which provided up to 54Mbps. This version of 802.11 was known as 802.11b or WiFi 2. The tantalizingly high data rate provided by WiFi 2 was slightly tempered by the fact that the propagation loss at 5 GHz is significantly higher than at 2.4 GHz, which limited the range in the 5GHz band. The solution to this problem was the removal of the spreading requirement in the 2.4 GHz band, which lead to the use of the OFDM physical layer at 2.4 GHz allowing both the higher 54Mbps data rate and lower propagation losses (i.e., longer range). This version of 802.11 was known as 802.11g or WiFi 3.

B. 802.11a/g Physical Layer

57. The OFDM physical layer modulates the carrier in the frequency domain by placing modulation symbols (BPSK, QPSK, 16-QAM or 64-QAM) on

sub-carriers through the use of the IFFT (Inverse Fast Fourier Transform) and transmitting the symbols in parallel. To perform this frequency domain modulation, 802.11a/g utilized a 64-point IFFT (i.e., a maximum of 64 sub-carriers), of which 52 were used, within a bandwidth of 20MHz (corresponding to a 312.5kHz spacing between subcarriers). The bottom six subcarriers, the top five subcarriers and the DC (middle) subcarrier were set to zero (i.e., nulled). By zeroing the edge carriers, the signal was kept within a specified spectral mask that mitigates interference from and to other 20MHz channels. Nulling the DC carrier eases implementation by eliminating a DC value after down-conversion. Of the 52 subcarriers used by the system, 48 carried data and four carried pilots for channel estimation. The 20MHz channels can be placed in the 2.4GHz unlicensed ISM band at 14 different locations, although only three simultaneous channels can be used. Specifically, in this band Channels 1, 6 and 11 can be used simultaneously without mutual interference.

58. The 5GHz U-NII band has significantly more bandwidth and allows for eight simultaneous 20MHz channels in the lower/middle band and four channels in the upper band as shown below.

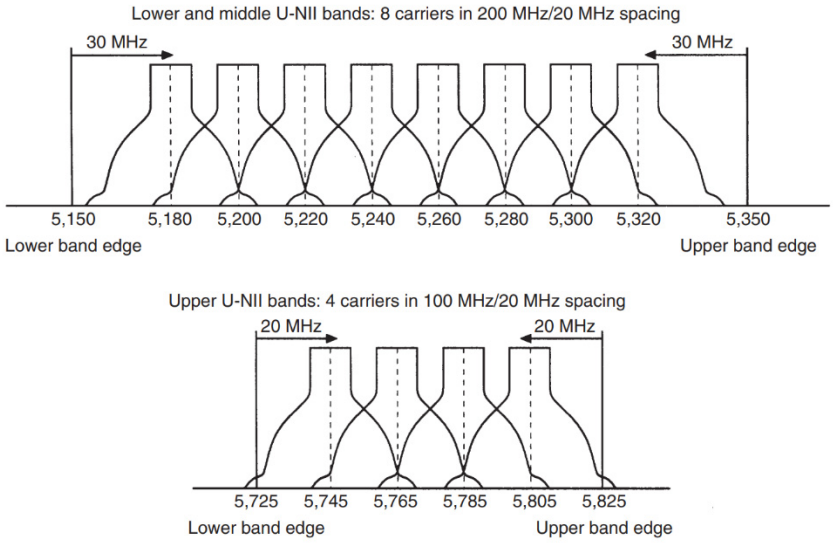


Figure 29.2 802.11a channel plan.
Reproduced with permission from IEEE 802.11 © IEEE.

SAMSUNG-1048, Fig. 29.2

59. When sending information, 802.11 transmits that information in the form of *packets* which are termed Physical Layer Protocol Data Units (PPDUs). Each 802.11a/g PPDU contains (in addition to the data being transmitted) a Physical Layer Convergence Procedure (PLCP) preamble and header. The preamble is used by the receiver for synchronization and channel estimation. The header contains signaling information that aids in demodulation of the data. In particular, the preamble contains a Short Training Field (STF) comprised of 10 known 0.8µs symbols (as shown below) that are used for coarse frequency estimation and Automatic Gain Control. The STF is followed by an 8µs Long Training Field (LTF) which contains two OFDM symbols (each modulated with

the same known sequence) and a guard interval. The LTF is used for finer timing synchronization as well as finer frequency offset estimation. The preamble is followed by a PCLP header known as the SIGNAL field. The SIGNAL (or SIG) field contains information about the data rate used, the length of the data, and a parity check bit. The signaling information is coded with a rate ½ code and uses BPSK modulation. The relationship between the three fields can be seen more clearly in the figure below.

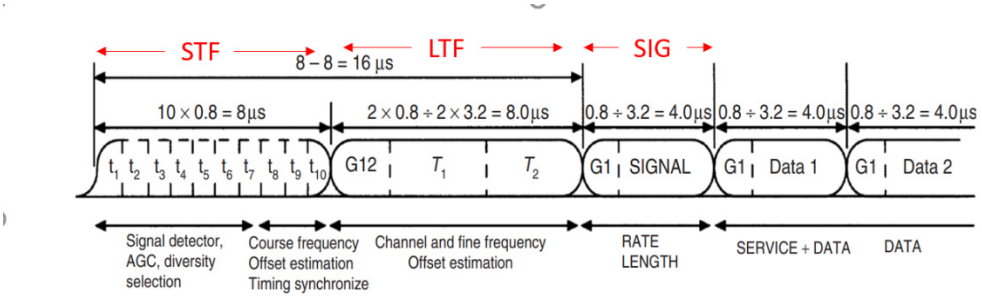


Figure 29.6 Orthogonal frequency division multiplexing training structure.

SAMSUNG-1048, Fig. 29.6

C. 802.11a/g MAC Layer

60. Unlike cellular systems where the majority of wireless access is scheduled, 802.11-based systems use a form of random access for nearly all wireless access. The MAC (Medium Access Control) layer in 802.11a/g is responsible for managing access to the shared wireless medium. It is designed to ensure efficient and fair access to the medium across multiple devices.

61. The 802.11 MAC is sometimes called the Distributed Coordination

Function (DCF) and is fundamentally based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA). DCF ensures fair access to the medium by allowing devices to transmit only when the channel is clear (i.e., not being used). This can be thought of as a radio version of what we teach our children, *i.e.*, "listen before speaking." Unlike CSMA/CD (Collision Detection) in Ethernet, CSMA/CA does not detect collisions, but instead prevents them. CSMA/CA requires devices "listen" to the channel before transmitting (sometimes called clear-channel assessment) to determine if the channel is idle or busy. If the channel is idle, the transmitter waits for a short time (known as the DIFS or Distributed Interframe Space) before sending data. If the channel is busy, the device enters a random backoff (i.e, waiting) period to avoid collisions. The backoff period is calculated using an exponential backoff algorithm, increasing the wait time after each failed attempt. A description of this DCF mechanism is shown below.

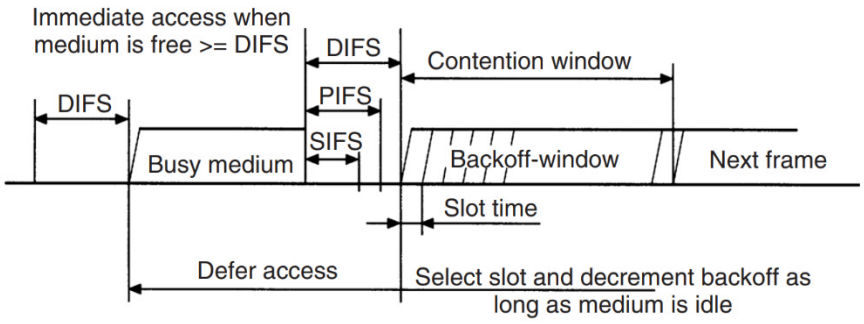


Figure 29.14 Basic access method.

SAMSUNG-1048, Fig. 29.14

62. DCF can optionally use RTS/CTS (Request to Send / Clear to Send) to reserve the channel before transmission. This helps address the "hidden node" problem, where two devices cannot sense each other, but could still interfere with each other. This approach is used to reduce collisions when packet sizes exceed a set threshold. In the RTS/CTS procedure, a station that wants to send data first sends an RTS frame to the access point (AP) or receiving device. The RTS frame contains information such as the duration of the upcoming transmission. If the channel is free, the AP (or receiver) responds with a CTS frame, signaling that the sender can proceed. The CTS frame also alerts nearby stations to defer their transmissions for the specified duration. Once the CTS is received, the sender transmits the data frame without further channel contention. After receiving the data, the recipient sends an ACK frame to confirm successful transmission.

63. As alluded to above, DCF defines different Interframe Spaces (IFS) to prioritize transmissions. DIFS is used before starting a new transmission. SIFS (Short Interframe Space) is used for high-priority responses like acknowledgements (ACKs). Each frame transmission is acknowledged (ACK) by the receiver. If no ACK is received, the sender retransmits after a backoff period.

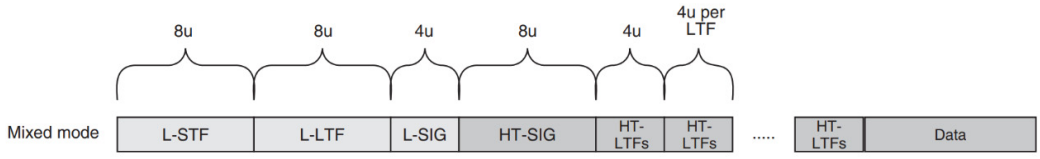
D. 802.11n

64. 802.11n (WiFi 4) was developed in the mid 2000's with the goal of dramatically increasing throughput. It was thus termed *High Throughput or HT*

and ratified in 2009. 802.11n incorporated several techniques to increase data rates offering up to 600Mbps. In particular, 802.11n introduced spatial multiplexing (a technique already incorporated into cellular in HSPA+ and 4G LTE) and wider bandwidth channels. Spatial multiplexing allows multiple parallel streams to be transmitted on the same bandwidth by using multiple antennas at the transmitter and receiver. In addition to spatial multiplexing, 802.11n increased throughput through the use of 40MHz channels by using a process called *channel bonding*. When channel bonding is supported, the AP advertises a *Primary Channel* which is 20MHz wide and a *Secondary Channel* that is also 20MHz wide directly above or below the primary channel. By doubling the bandwidth, the data rate could be increased dramatically.

65. In order to support the new features of 802.11n, a new preamble and new signaling header were required. However, in order to maintain backwards compatibility with other 802.11a/b/g devices, 802.11n both maintained the legacy preamble/header as well as adding a new preamble/header. Specifically, the PPDU begins with a Legacy STF (L-STF), followed by a Legacy LTF (L-LTF), and a Legacy SIG (L-SIG) field. The legacy header/preamble is followed by a High Throughput SIG (HT-SIG) field and High Throughput LTF (HT-LTF) fields for each spatial layer. The HT-SIG field contains information specific to 802.11n devices, including modulation and coding, multiple antenna information among

others.



SAMSUNG-1048, Fig. 29.9 (excerpt)

66. When 802.11n uses a 40MHz channel through channel bonding, data is sent not only across two channels, but also on the sub-carriers in-between the two channels, as well as the previously nulled DC carrier. More specifically, when 802.11n uses 20MHz, it uses a 64-subcarrier IFFT placing information on 56 of the 64 subcarriers (note that this is an increase of four subcarriers from 802.11a/g) including 52 data values and four pilot values. However, when a 40MHz channel is used, a 128-point IFFT is used with information placed on 114 subcarriers (108 data and 6 pilots) as illustrated below.

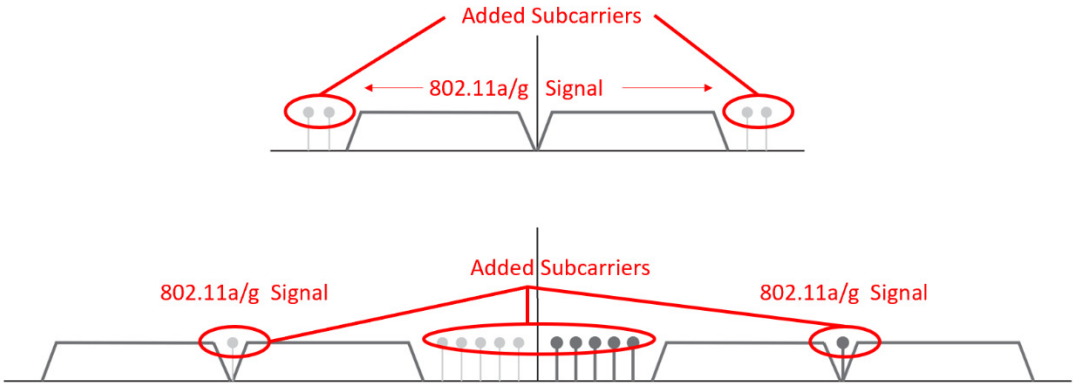


Figure 29.8 20-MHz and 40-MHz subcarriers.

SAMSUNG-1049, Fig. 29.8 (annotated)

67. When channel bonding is performed, the preamble/header fields are not spread across 40MHz. Instead, the legacy fields as well as the HT-SIG field is sent twice, once in each 20MHz channel. This allows legacy devices in either channel to read the legacy fields as well as 20MHz HT terminals to read the HT-SIG field. The channel bandwidth of WiFi increased in the next two generations through increased use of channel bonding as shown in the table below.

WiFi Generation	Channel Bandwidth
802.11a/b/g	20MHz
802.11n	20MHz, 40MHz
802.11ac	20MHz, 40MHz, 80MHz, 160MHz
802.11ax	20MHz, 40MHz, 80MHz, 160MHz

E. 802.11ac

68. Even with the improved data rates of 802.11n, it was clear that higher data rates would be needed. WiFi 5 or 802.11ac was developed to increase the throughput over 802.11n. To accomplish this, WiFi 5 increased the bandwidth to include 80MHz and 160MHz bandwidths, added 256-QAM modulation, increased the number of spatial multiplexing streams to eight, and added Multi-user MIMO, a technique employed in the cellular standard known as LTE Advanced. Similar to 802.11n, channels consisting of 40 MHz or wider always require a primary 20

MHz wide subchannel. Additionally, 80 MHz channels have a primary 40 MHz (which includes the primary 20 MHz) subchannel and a secondary 40 MHz subchannel. The same applies to 160 MHz and 80 + 80 MHz channels, which consist of primary and secondary 80 MHz subchannels.

69. Increasing bandwidth was again done using channel bonding. For bandwidths of 20MHz and 40MHz bandwidths, the approach was the same as that used in 802.11n. For 80MHz bandwidths, a 256-point IFFT was used. Of the 256 possible subcarriers, subcarriers -128 through -123 and 123 through 127 are nulled to avoid interference to adjacent channels, and three subcarriers near DC (-1, 0, 1) are also nulled. Additionally, of the 242 subcarriers that are used, eight are used as pilot tones. The remaining subcarriers are used for data transmission.

70. The approach for 160MHz is slightly different. There are two possible approaches: transmitting on two disjoint (i.e., non-contiguous) 80MHz bands or one contiguous 160MHz band. However, the subcarrier structure (i.e., which ones are used and which are not used) doesn't change, regardless of which of the two approaches is applied. The number of used subcarriers is exactly double the number used for 80MHz, i.e., 484 (468 for data, 16 for pilots) out a total possible 512.

F. Channel Bonding

71. As discussed above IEEE 802.11ac defines frequency channels for

bandwidths of 20, 40, 80 and 160 MHz, as illustrated below:

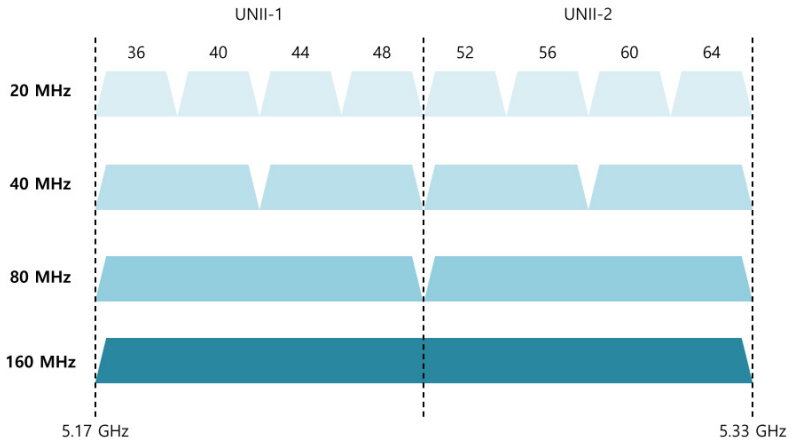


FIGURE 1. Channelization of IEEE 802.11 for various bandwidths in the 5 GHz band.

SAMSUNG-1031, Fig. 1

72. In an 802.11, a basic service set (BSS), consisting of an access point and its associated stations, selects a primary 20 MHz channel where all stations of the BSS exchange basic control frames including beacon frames and perform a backoff procedure for channel access. The frequency channels are classified into two categories :

• Primary channel: A channel that includes the primary 20 MHz channel. It is possible for the primary channel to have 20, 40, 80, or 160 MHz bandwidth.

• Secondary channel: A channel that is adjacent to a primary channel that bonds with the primary channel to form another primary channel of the

next wider bandwidth. It is possible for the primary channel to have 20, 40, or 80 MHz bandwidth.

73. In 802.11ac networks, once a BSS determines its P20 (Primary 20MHz channel), a set of secondary channels to be bonded with a primary channel for a wider bandwidth is immediately determined. The set is created such that only a contiguous bandwidth (corresponding to one of the primary channels) including the BSS P20 is used at any given time, as shown below. This approach is called *contiguous channel bonding* and makes signaling easier since there are only four possible configurations. The figure below illustrates usable channels under contiguous channel bonding when the P20 of the BSS is the third of the 20MHz channels from the left.

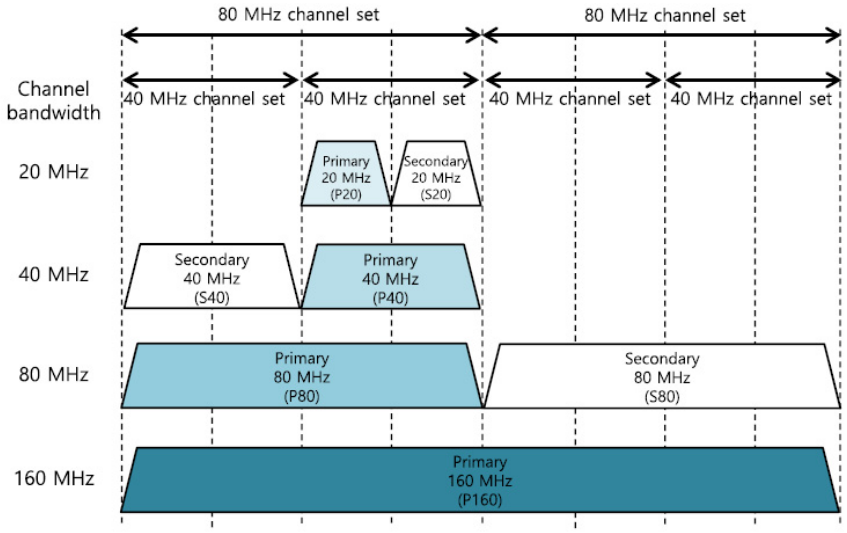


FIGURE 2. Contiguous channel bonding rule when the primary 20 MHz channel is the third (from the left) of the 20 MHz channels.

SAMSUNG-1031, Fig. 2

74. Wideband operation when using contiguous channel bonding is performed as follows. First, as a station of a BSS completes a backoff procedure (i.e., the backoff counter reaches zero) after the point coordination function interframe space (PIFS, 25μs in 5 GHz), the station performs CCA in the S20 channel to check the availability of a 40 MHz bandwidth (P40). In the Figure above, S20 is to the right of P20. If it is sensed idle, the availability of the 40 MHz bandwidth (P40) is confirmed. The procedure is repeated for the next wider secondary channel until the secondary channel is sensed busy or the maximum operation bandwidth is reached.

75. The preamble of a transmitted frame conveys the information of its transmission bandwidth so that after a receiving station reads the bandwidth subfield, it immediately knows how to tune its band filter using a predefined channel-bonding rule in conjunction with the P20 location. Thus, contiguous channel bonding simplifies the operational logic, requiring only signaling of a single two-bit subfield (i.e., the transmission bandwidth).

G. 802.11ax

76. For the next version of 802.11, it was determined that higher efficiency and higher throughput would be goals. By December 24, 2015 (i.e., the Earliest Filing Date of the ’281 patent), many of the details for 802.11ax were known. For example, a four-fold increase in the throughput as compared to

802.11ac was desired. Further, it was known that improving both the system and user throughput requires the improved use of channel resources and to achieve this some new wireless technologies such as dynamic CCA, OFDMA (orthogonal frequency-division multiple access), and advanced multiple-antenna techniques may be used. These improvements mimicked many of the techniques employed in cellular systems.

77. WiFi 6 (802.11ax) was developed to improve overall efficiency, and is thus known as WiFi High Efficiency (HE). To help increase throughput, WiFi 6 introduced 1024-QAM. To increase efficiency, several changes were made. First, the subcarrier spacing was reduced by a factor of four (78.125kHz as compared to 312.5kHz). This reduced subcarrier spacing (and thus longer OFDM symbol length) reduced the relative overhead due to the cyclic prefix. Additionally, OFDMA was added and the larger number of subcarriers allowed for more flexible implementation of OFDMA.

H. OFDMA

78. By the Earliest Filing Date, Orthogonal Frequency Division Multiple Access (OFDMA) was a well-known technique for transmitting to multiple receivers in conjunction with OFDM. Additionally, it had already been proposed to add OFDMA to 802.11ax. OFDMA assigns groups of subcarriers (known as Resource Units or RUs) to different receivers so that in one OFDM symbol, data

can be sent to multiple users. This is analogous to the concept of Resource Blocks that had been used in cellular since 2008. The smallest RU consists of 26 subcarriers, although RUs of 52, 106, 242, 484, and 996 are also possible.

79. The rationale for the use of OFDMA in WiFi is that the very wide channels (80 MHz, 80+80 MHz and 160 MHz) introduced by 802.11ac suffer from frequency selective interference, which can vary from one receiver to another and can significantly impair the practically achievable rates. With OFDMA, adjacent subcarriers (tones) are grouped together into a resource unit (RU) and a sender can choose the best RU for each particular receiver, which actually results in higher Signal-to-Interference-plus-Noise Ratio (SINR), Modulation and Coding Scheme (MCS) and throughput. Moreover, since the efficiency of high data rates degrades when a STA has little data to transmit, advanced aggregation techniques aimed to reduce channel access, acknowledgment (ACK) and preamble-induced overhead become useless. Allocating narrow RUs for such STAs is an efficient remedy. Within the framework of OFDMA in 802.11ax, a bandwidth is divided into RUs, each of which is a group of contiguous subcarriers and allocated to a station such that multiple users can be served simultaneously.

I. Signaling

80. As discussed above, the SIGNAL (or SIG) field in 802.11a/b/g was used to convey important information to the receiver about the PPDU.

Specifically, the SIG field in 802.11a/b/g contained 24 bits which were encoded with a rate ½ convolutional code to arrive at 48 total information bits sent in a single OFDM symbol. The 24 signaling bits were comprised of

- 4 bits to convey the transmission data rate
- 12 bits to convey the PSDU length
- 1 bit parity check
- 6 Tail bits for the convolutional decoder
- 1 bit reserved for future use.

81. When 802.11n was developed, the SIG field was maintained for backwards compatibility, but renamed the Legacy SIG (L-SIG). An new SIG field was also added to provide the extra information associated with the new capabilities provided by 802.11n. This SIG field was known as the High Throughput SIG (HT-SIG) and was two OFDM symbols lon. Each OFDM symbols contained 24 signaling bits which were convolutionally encoded with a rate ½ code. The 48 bits were used to in the following manner:

- 7 bits to indicate modulation and coding scheme
- 1 bit to indicate 20 MHz or 40 MHz bandwidth
- 16 bits to indicate the length of the data packet
- 1 bit indicates whether frequency smoothing is recommended for channel estimation
- 1 bit to indicate if the PPDU is a sounding PPDU
- 1 bit to indicate with the data is part of a data aggregation tansmission
- 2 bits to indicate the use and type of STBC
- 1 bit to indicate the use of convolutional or LDPC encoding
- 2 bits to indicate the number of spatial streams
- 1 bit to indicate the short or long Guard Interval
- 8 bits for error detection of the HT-SIG field

- 6 Tail bits for the convolutional decoder
- 1 bit reserved for future use

82. Thus, the amount of signaling tripled from 802.11a/b/g to 802.11n. Since signaling is both necessary (to convey formatting, especially as additional features are introduced), but wasteful (since it consumes precious resources), there is a trade-off when using signaling. The standard developers thus seek efficient ways to provide the necessary signaling.

83. When 802.11ac was introduced, for backwards compatibility it also required the transmission of the L-SIG, which was not changed from the 802.11n L-SIG. Like 802.11n, 802.11ac added two separate SIG fields known as Very High Throughput SIG-A (VHT-SIG-A) and VHT-SIG-B. The former contained most of the information needed for detecting/decoding the packet. The latter was used for MU-MIMO information, although it is also transmitted in the SU-MIMO case just to maintain consistency in the two transmissions. VHT-SIG-A was two OFDM symbols long and contained 48 signaling bits. The use of the bits is similar to 802.11n with a few notable exceptions: (1) the packet length was not included, (2) a Group ID and Association ID were added which allowed a receiver to determine quickly if the packet is intended for it, (3) the number of spatial streams was signaled in the MU-MIMO case, and the payload size was not included in either VHT-SIG-A (SU or MU). Instead, the payload size is moved to the new VHT-SIG-B field which also included user-specific information in the MU-MIMO

case.

VIII. THE '281 PATENT

A. Overview of the '281 Patent

84. The '281 patent generally relates to "a wireless communication method and a wireless communication terminal using a non-contiguous channel," and more particularly to a method of indicating "non-contiguous channel allocation information via at least one of a subfield of HE-SIG-A and a subfield of HE-SIG-B of [a] received packet." SAMSUNG-1001, Abstract, 3:43-45. The '281 describes three ways to signal non-contiguous channel allocation information:

> First, the non-contiguous channel allocation information may be indicated via the bandwidth field of the HE-SIG-A. The bandwidth field may indicate specific non-contiguous channel allocation information through a predetermined index. . . .
>
> [Second], the non-contiguous channel allocation information may be indicated via the RA field of the HE-SIG-B. The RA field may indicate a specific resource unit not assigned to a user through a predetermined index. For example, the RA field may indicate that a resource unit of a multiple of a 20 MHz channel, i.e. 242-tone, 484-tone or 996-tone, is not assigned to a user. . . .
>
> [Third], the non-contiguous channel allocation information may be indicated by carrying a null STA ID in a specific user field of the HE-SIG-B. . . .

Id., 34:27-47.

85. The '281 patent states that non-contiguous channel allocation information may be signaled "solely via subfield(s) of the HE-SIG-A" (*id*., 38:53-16), "solely via subfield(s) of the HE-SIG-B" (*id*., 39:17-25), or "via a

combination of the subfield(s) of the HE-SIG-A and subfield(s) of the HE-SIG-B" (*id*., 39:26-51). According to the '281 patent, "the bandwidth field [of HE-SIG-A] may indicate the total bandwidth information through which the PPDU is transmitted and some channel information to be punctured within the total bandwidth . . . [and] additional puncturing information may be indicated via the RA field of the HE-SIG-B." *Id*., 41:36-39.

86. For example, "when the bandwidth field indicates puncturing of the S20 channel in the total bandwidth of 160 MHz or 80+80 MHz (e.g., the second channel configuration in FIG. 33(d)), the resource unit allocation field may indicate additional puncturing the S80 channel." *Id*., 41:66-42:4. "Channels in which puncturing is indicated as described above are not assigned to [a] user." *Id*., 42:5-6.

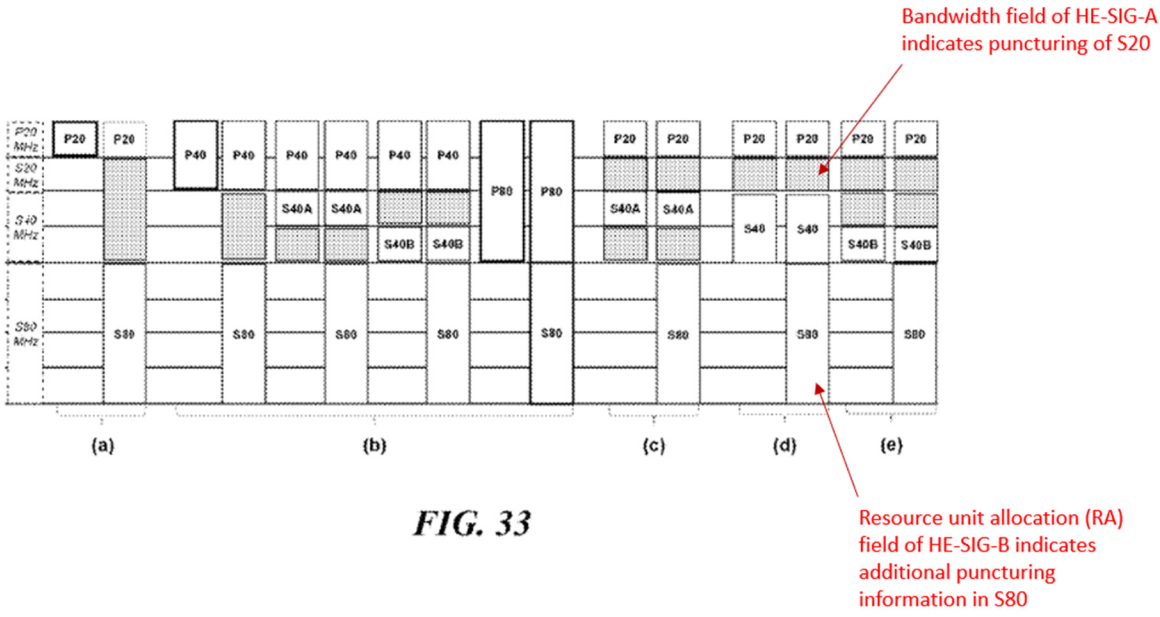


FIG. 33

SAMSUNG-1001, Fig. 33 (annotated)

B. Priority Claims

87. The ’281 patent claims priority to eight Korean priority applications shown below.

Korean App. No.	Filing Date
10-2015-0186871 (SAMSUNG-1006)	12/24/2015
10-2016-0004471 (SAMSUNG-1007)	1/13/2016
10-2016-0005835 (SAMSUNG-1008)	1/18/2016
10-2016-0026683 (SAMSUNG-1009)	3/4/2016
10-2016-0030006 (SAMSUNG-1010)	3/13/2016
10-2016-0059182 (SAMSUNG-1011)	5/14/2016
10-2016-0062422 (SAMSUNG-1012)	5/20/2016
10-2016-0083756 (SAMSUNG-1013)	7/1/2016

SAMSUNG-1001, [0001]; *see* SAMSUNG-1005 (original priority applications); SAMSUNG-1006-SAMSUNG-1013 (certified translations of Korean priority applications). However, as I explain below, claims 1-14 of the ’281 patent are not entitled to a priority claim before May 14, 2016.

88. The ’281 patent includes only two independent claims, claims 1 and 8. The subject matter recited in at least limitations [1.9] and [8.6] of the independent claims are not supported by the five Korean priority applications filed before May

14, 2016 (SAMSUNG-1006-SAMSUNG-1010).

89. It is my opinion that a POSITA reviewing these documents would not have reasonably concluded that the inventors of the ’281 patent had possession of the subject matter recited in the last limitation of claims 1 and 8, which each require “wherein the bandwidth field of the HE-SIG-A indicates channel information to be punctured within the bandwidth, and the resource unit allocation field indicates ***additional puncturing information*** for the unassigned resource unit within the bandwidth.” Nor would a POSITA have reasonably concluded that the inventors of the ’281 patent had possession of the subject matter recited in claims 6-7 and 13-14, which recite more specific requirements for the puncturing information that is already unsupported by SAMSUNG-1006 to SAMSUNG-1010. That is, claims 6-7 and 13-14 require the bandwidth field to indicate certain puncturing information (e.g., for claim 6, “puncturing of one of two 20 MHz channels in a secondary 40 MHz channel within a bandwidth of 80 MHz or puncturing of at least one of two 20 MHz channels in a secondary 40 MHz channel within a bandwidth of 160 MHz or 80+80 MHz”; for claim 7, “puncturing of a secondary 20 MHz channel within a bandwidth of 160 MHz or 80+80 MHz or puncturing of at least one of two 20 MHz channels in a secondary 40 MHz channel within a bandwidth of 160 MHz or 80+80 MHz”) and the resource unit allocation field to indicate certain additional puncturing information (e.g., for claim 6,

"indicates which 20 MHz channel in the secondary 40 MHz channel is punctured"; for claim 7, "indicates additional puncturing in a secondary 80 MHz channel").

90. While some of these documents appear to discuss indicating non-contiguous channel allocation information using the three ways I mentioned above (i.e., using the bandwidth field of the HE-SIG-A or the resource unit allocation or user-specific fields of the HE-SIG-B) (*see, e.g.*, SAMSUNG-1010, [264]-[266]), none of these documents explicitly, implicitly, or inherently discloses using both the bandwidth field of the HE-SIG-A and the resource unit allocation field of the HE-SIG-B to indicate channel puncturing information as the claim elements require.

91. Moreover, a POSITA would have understood the embodiments described in these documents as disclosing that unused channels may be indicated in either HE-SIG-A or HE-SIG-B fields—but not both. For example, in the two embodiments described in the March 13, 2016 document for indicating non-contiguous channel allocation using HE-SIG-B fields, the document states, "In this case, the BW subfield of HE-SIG-A indicates ***only the BW of the entire PPDU*** originally configured by the AP, thereby specifying the overall data tone and DC tone configuration and positioning." SAMSUNG-1010, [278], [288]. In my opinion, a POSITA would have understood this disclosure to mean that the bandwidth field indicates only the total PPDU transmission bandwidth (like in

802.11ac), and any unused channels within the bandwidth are indicated via the subfields of HE-SIG-B.

92. At best, any disclosure that could plausibly support the subject matter of claims [1.9] and [8.6] is not introduced until May 14, 2016. That priority application (SAMSUNG-1011) introduces the following disclosure, which is absent from any earlier priority application:

> The signaling method for non-contiguous BW PPDU transmission may be implemented in one of the following ways: SIG-A-only signaling, SIG-B-only signaling, or cooperative signaling between SIG-A and SIG-B.
>
> . . .
>
> [I]n the cooperative signaling method between SIG-A and SIG-B, a portion of the non-contiguous PPDU bandwidth configuration information is first transmitted via SIG-A, and the remaining additional information is signaled via SIG-B.

SAMSUNG-1011, [323], [326].

93. Because a POSITA would not have reasonably concluded that the inventors had possession of the claimed subject matter in [1.9] and [8.6] in SAMSUNG-1006 to SAMSUNG-1010 and because claims 2-7 and 9-14 depend from either claim 1 or 8, all of the ’281 patent’s claims are not entitled to a priority date earlier than May 14, 2016. Additionally, claims 6-7 and 13-14 are independently not entitled to a priority date earlier than May 14, 2016, because a POSITA would not have reasonably concluded that the inventors had possession of the subject matter of claims 6-7 and 13-14 in SAMSUNG-1006 to SAMSUNG-

1010.

C. Prosecution History of the '281 Patent

94. During prosecution, the '281 patent was rejected as anticipated by Hedayat (US10,219,271) and as obvious over Hedayat, Josiam, and Yang (US2016/0366666). SAMSUNG-1002, 57-67. Specifically, the examiner found that Hedayat anticipated limitations equivalent to those in recited in [1.pre]-[1.8], [2]-[3], [8.pre]-[8.5], and [9]-[10]. *Id.*, 59-61. The examiner relied on Josiam as teaching that the "information of the unassigned resource unit is obtained through resource unit arrangement information indicated by the resource unit allocation field of the HE-SIG-B and a Null STA ID contained in a user field corresponding to a specific resource unit in the resource unit arrangement," as required by claims 4-5 and 11-12.[1] *Id.*, 62-63. The examiner relied on Yang as teaching that "the bandwidth field of the HE-SIG-A indicates channel information to be punctured within the bandwidth, and the resource unit allocation field indicates additional puncturing information for the unassigned resource unit within the bandwidth," as

[1] The preambles of claims 5 and 11 recite dependence on claims 1 and 8, respectively. But claims 1 and 8 do not recite "a specific resource unit" as required by claims 5 and 11. The examiner treated claims 5 and 11 as depending on claims 4 and 10, respectively. *See* SAMSUNG-1002, 62-63. Counsel has asked me to do the same here.

required by limitations [1.9] and [8.6] and claims 6-7 and 13-14 of the '281 patent. *Id.*, 63-66.

95. Applicant responded by amending the pending independent claims to include the limitations in [1.9] and [8.6], which relate to channel puncturing. *Id*., 39-42. Applicant argued that the combination of Hedayat and Yang did not render obvious the channel puncturing limitations. *Id.*, 44-50. Applicant did not address the examiner's findings with respect to Josiam. *Id.*, 49-50. Additionally, neither the examiner nor Applicant considered whether Josiam teaches the subject matter recited in the independent claims. *Id*., 43-50, 57-67.

96. After Applicant's amendments, the examiner allowed the claims, noting that:

> The independent claims are directed towards resource allocation and configuration of HEW (High Energy Wireless LAN) systems. The ***independent claims require that information on an unassigned resource unit is conveyed in a particular fashion: a bandwidth subfield of a HE- SIGA field indicates the bandwidth used, and channel information about particular channel(s) to be punctured within this bandwidth; a RU allocation subfield of a HE-SIGB field includes further information about the puncturing of the channel where the unassigned RU is; and the unassigned RU is indicated using a combination of these two subfields***. The Examiner did not find this in the prior art before the priority date such that it could be incorporated into the remainder of the claim; therefore the Examiner believes that the cited prior art is the best available, and believes that one of ordinary skill in the art would not have found it obvious to combine with another reference(s) such that the independent claims would be taught.

Id., 25-28 (emphasis added).

97. In my opinion, the examiner did not substantively consider Josiam with respect to the independent claims or any limitations other than those corresponding to claims 4-5 and 11-12. I also note that Applicant did not challenge Josiam as prior art to the '281 patent. *See generally* SAMSUNG-1002.

IX. OVERVIEW AND COMBINATIONS OF PRIOR ART REFERENCES

98. I understand that the Josiam, Kim, Bharadwaj, and Li references may rely upon provisional application filings to qualify as prior art to the '281 patent by the dates discussed below. I have reviewed the relevant provisional applications for these references.

Reference	Priority Documents
Josiam (SAMSUNG-1014)	July 1, 2015 Provisional (SAMSUNG-1015) Jan. 12, 2016 Provisional (SAMSUNG-1016) Apr. 27, 2016 Provisional (SAMSUNG-1017)
Kim (SAMSUNG-1018)	Mar. 23, 2016 Provisional (SAMSUNG-1019)
Bharadwaj (SAMSUNG-1021)	Dec. 21, 2015 Provisional (SAMSUNG-1022)
Li (SAMSUNG-1024)	Aug. 3, 2015 Provisional (SAMSUNG-1024)

99. Where I rely on those references for the prior art grounds, I have included parallel citations to these priority documents and/or explain how these priority documents support the reference by the Critical Date (for Grounds 1A-1B

and 2C-2D) or the Earliest Filing Date (for Grounds 2A-2B).

100. I also note that Josiam, Kim, and Li explicitly incorporate the disclosures of the above provisional applications by reference. *See* SAMSUNG-1014, [0002]; SAMSUNG-1018, [0001]; SAMSUNG-1024, [0001].

A. US Patent Publication No. 2017/0006608A1 ("Josiam")

101. Josiam relates to "methods to enable efficient wideband operations in [wireless] local area network[s] using OFDMA." SAMSUNG-1014, [0005]; SAMSUNG-1016, 1-6, 9-10; SAMSUNG-1017, 1-2, 7-8, 11-13. Josiam presents methods of signaling nulled (i.e., unused) resource units in a high efficiency (HE) multi-user (MU) physical layer convergence protocol (PLCP) protocol data unit (PPDU). SAMSUNG-1014, [0145]-[0168], [0294]-[0305]; SAMSUNG-1016, 9-12; SAMSUNG-1017, 8-15. Josiam explains that "when a segment of the bandwidth is sensed busy," e.g., another station is using a particular channel, "the [resource units (RUs)] spanning the channel sensed busy are unused and left empty." SAMSUNG-1014, [0139]; SAMSUNG-1017, 8. Specifically, "the tones corresponding to [a] channel segment being used [by others] are nulled" and "a PHY preamble is not carried in the channel being nulled." SAMSUNG-1014, [0154]; SAMSUNG-1017, 11.

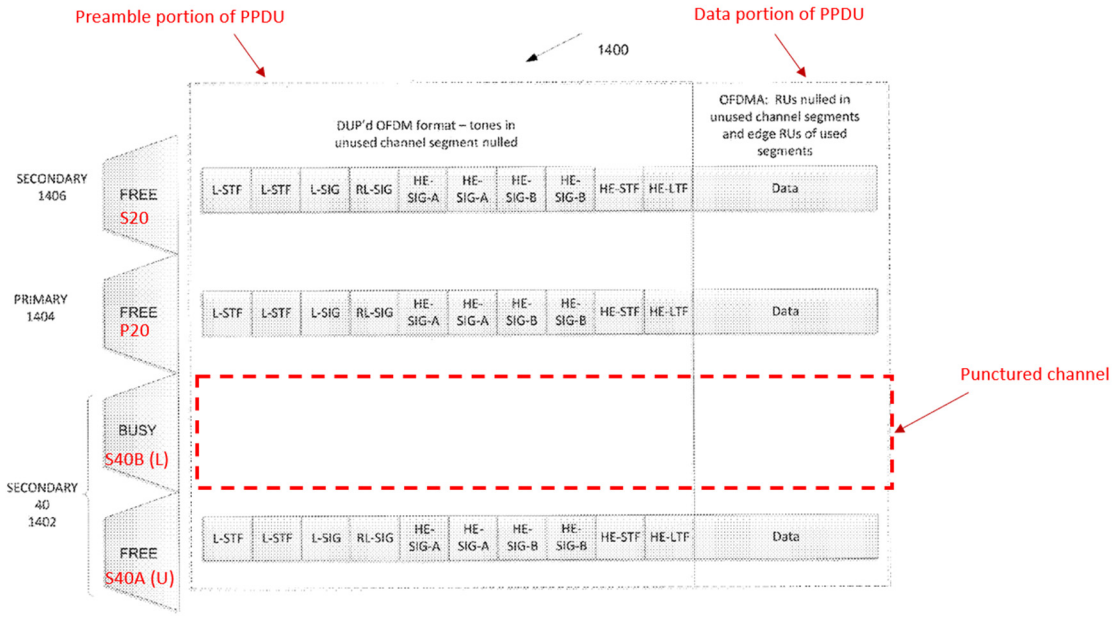


FIG. 14

SAMSUNG-1014, Fig. 14 (annotated); SAMSUNG-1017, 12

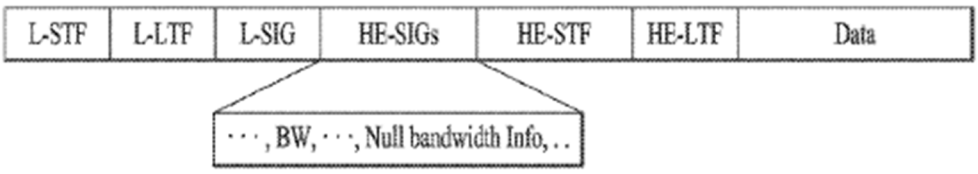
102. Josiam discloses a method for splitting signaling of a nulled channel between HE-SIG-A and HE-SIG-B in 80 and 160 (80 + 80)MHz PPDUs. SAMSUNG-1014, [0145]-[0168]; SAMSUNG-1017, 8-16. Josiam teaches that "[s]ome segments that are unused in the primary 80 MHz are indicated by the bandwidth signaling in HE-SIG-A." SAMSUNG-1014, [0164]; SAMSUNG-1017, 14. Additional signaling of "the use or disuse of a 20 MHz segment in both 80 MHz and 160 MHz PPDU" may be transmitted using the "RU signaling field of the HE-SIG-B common field." SAMSUNG-1014, [0156]; SAMSUNG-1017, 12.

B. US Patent Publication No. 2018/0365632A1 ("Kim")

103. Kim relates to "a method and apparatus for enabling efficient data transmission on a non-contiguous channel." SAMSUNG-1018, [0001];

SAMSUNG-1019, 7. Kim describes "a method of receiving a signal, which is received by an STA (station) operating in a wireless LAN (WLAN) system using a multi user (MU) scheme, includ[ing] the steps of receiving a radio frame in which a signaling (SIG) field including control information and a data field for transmitting data are included, and processing the received radio frame." SAMSUNG-1018, [0020]; SAMSUNG-1019, 14-15. Kim explains that "an 11ax radio frame may include HE-SIG A and HE-SIG B as HE-SIG fields." SAMSUNG-1018, [0092]; SAMSUNG-1019, 28.

FIG. 15

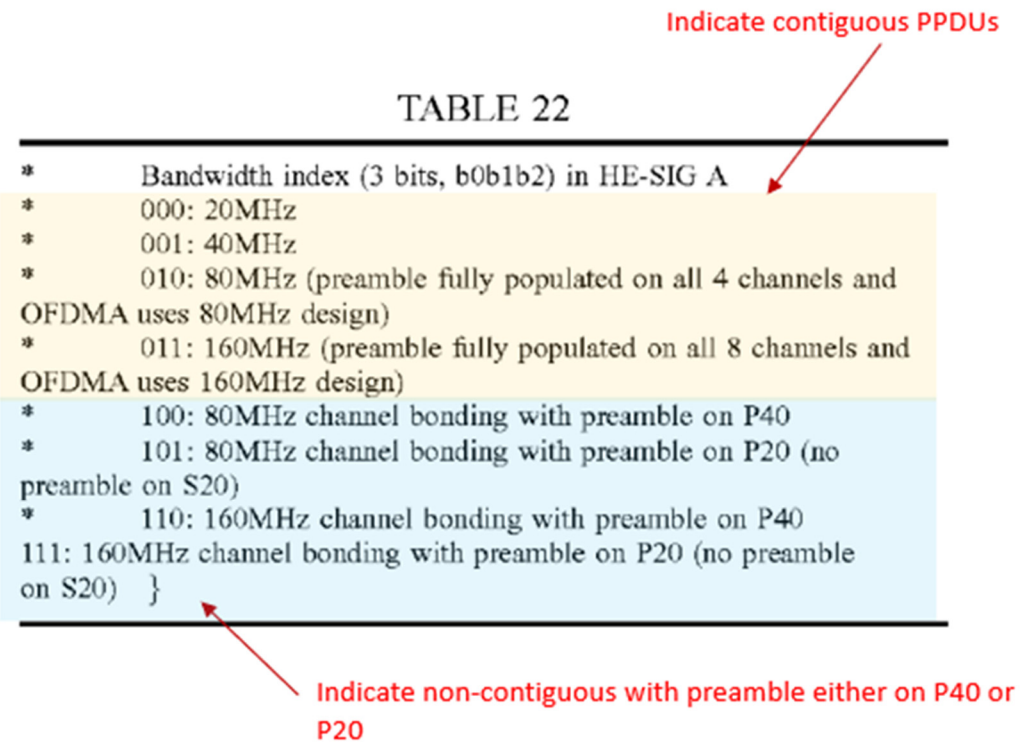


SAMSUNG-1018, Fig. 15; SAMSUNG-1019, Fig. 15

104. Kim teaches including "information on an unused bandwidth and information on a null indicator (e.g., null bandwidth/channel/sub-channel information or non-contiguous bandwidth/channel/subchannel information) in a HE-SIG-B field. . . . In particular, the present invention proposes that the HE-SIG field includes bandwidth information indicated whether or not the whole bandwidth corresponds to 20, 40, 80, or 160 (or 80+80)MHz and information on a null indicator indicating a channel region not used for transmitting data among the

whole bandwidth." SAMSUNG-1018, [0087]-[0088]; SAMSUNG-1019, 21-22.

105. Kim discloses indicating "primary channel information (information indicating whether or not a BW includes primary 20 or primary 40) is included in HE-SIG-A and detail[ed] null bandwidth information (or non-contiguous channel allocation information) is included in HE-SIG-B." SAMSUNG-1018, [0143]-[0159]; SAMSUNG-1019, 42-49. For example, Kim teaches that the bandwidth field of HE-SIG-A may be a 3-bit bandwidth index. SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44. The first four entries correspond to contiguous 20, 40, 80, and 160MHz PPDUs. *Id.* The remaining four entries indicate channel bonding with the preamble either on P40 or P20 (no preamble on S20). *Id.*



SAMSUNG-1018, Table 22 (annotated); SAMSUNG-1019, 43-44

106. When non-contiguous channel bonding is indicated (i.e., the bandwidth field is set to one of the last four entries), "detail[ed] null bandwidth information (or non-contiguous channel information) can be included in the HE-SIG-B common part." SAMSUNG-1018, [0146]; SAMSUNG-1019, 43. Kim further teaches that, "among the reserved values in the RU allocation field, a specific value indicates that the 242 RU corresponding to that channel is Null, allowing the STA to determine which 242 RU is Null based on this value." SAMSUNG-1018, [0155]-[0156], [0158]-[0159]; SAMSUNG-1019, 46-49. As

one example, when the BW index in HE-SIG A is 101, "the RU allocation field included in HE-SIG B of CH 1 for CH3 indicates that the 242-tone RU corresponding to CH3 is null." SAMSUNG-1018, [0159]; SAMSUNG-1019, 49.

C. Combination of Josiam and Kim

107. In Josiam-Kim, a bandwidth and content channel indication scheme for the bandwidth field of HE-SIG-A, per Josiam, would be modified to include four contiguous PPDU options and four non-contiguous PPDU options, per Kim. SAMSUNG-1014, [0154]-[0168]; SAMSUNG-1017, 12-15; SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44.

108. In the combination, a 3-bit bandwidth index, per Josiam, would include four contiguous options and four non-contiguous options that indicate, for each bandwidth of 80 or 160 (or 80 + 80)MHz, whether the S20 channel is transmitted, per Kim. SAMSUNG-1014, [0154]-[0168]; SAMSUNG-1017, 12-15; SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44.

TABLE 22

* Bandwidth index (3 bits, b0b1b2) in HE-SIG A
* 000: 20MHz
* 001: 40MHz
* 010: 80MHz (preamble fully populated on all 4 channels and OFDMA uses 80MHz design)
* 011: 160MHz (preamble fully populated on all 8 channels and OFDMA uses 160MHz design)
* 100: 80MHz channel bonding with preamble on P40
* 101: 80MHz channel bonding with preamble on P20 (no preamble on S20)
* 110: 160MHz channel bonding with preamble on P40
111: 160MHz channel bonding with preamble on P20 (no preamble on S20) }

SAMSUNG-1018, Table 22

	P20	S20	S40A (U-20)	S40B (L-20)	S80				PPDU Bandwidth
000	Used								20 MHz
001	Used	Used							40 MHz
010	Used	Used	Used	Used					80 MHz
011	Used	Used	Used	Used	Used	Used	Used	Used	160 MHz
100	Used	Used							80 MHz
101	Used	Punc							80 MHz
110	Used	Used	Channel use indicated by RU signaling field of HE-SIG-B						160 MHz
111	Used	Punc							160 MHz
HE-SIG-B Content Channel	1	2	1	2	1	2	1	2	

109. If the S20 channel is transmitted, then a receiving station may read both HE-SIG-B content channels from the primary 40MHz (P20 and S20), per Josiam. SAMSUNG-1014, [0164]; SAMSUNG-1017, 13-15. If the S20 channel is not transmitted (e.g., the channel is busy and must be punctured), then a POSITA would have recognized several known or obvious methods to transmit HE-SIG-B

information for the channels that ordinarily fall into HE-SIG-B content channel 2, discussed below.

110. For example, HE-SIG-B content channel 1 could carry HE-SIG-B information for all channels in the bandwidth (per Josiam). SAMSUNG-1014, [0161], [0166]; SAMSUNG-1017, 12-15. Alternatively, the HE-SIG-B content channel 1 could include a channel bonding field in the common field that indicates which channels are being used, and the HE-SIG-B content channel 1 could carry information for the channels according to the default mapping plus any additional used channels that would otherwise be carried in the HE-SIG-B content channel 2 (per Kim). SAMSUNG-1018, [0143]-[0159], Tables 23-24; SAMSUNG-1019, 42-49. Even more simply, a POSITA would have understood that bandwidth configurations in which both S20 and S40B are not transmitted could be proscribed, and thus at least one channel carrying each HE-SIG-B content channel would always be present in the P80.

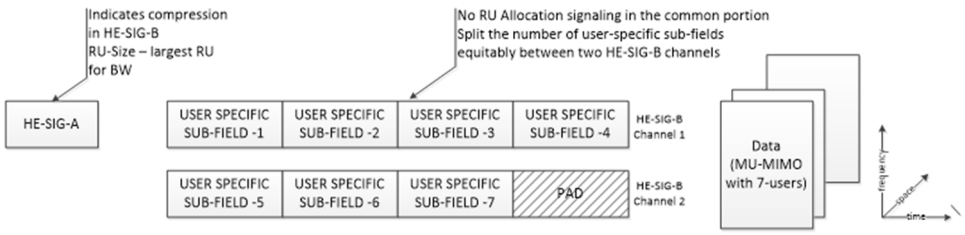
111. The Josiam-Kim combination would have been obvious to a POSITA for several reasons. First, a POSITA would have been motivated to modify Josiam's methods to include separate indications for contiguous and non-contiguous PPDUs, per Kim. In my opinion, a POSITA would have been motivated to include separate indications for contiguous bandwidths to (1) enable HE-SIG-B compression mode to be used for full bandwidth MIMO transmissions

and (2) make non-contiguous channel bonding optional for operating environments where the benefit of non-contiguous channel bonding is low.

112. By May 14, 2016, an HE-SIG-B compression mode was introduced for full bandwidth MU-MIMO, in which resource unit allocation signaling information is no longer transmitted in the HE-SIG-B field because the entire bandwidth will be used for MU-MIMO. SAMSUNG-1029, 131-132; SAMSUNG-1037, 14-15; SAMSUNG-1038, 11-13; SAMSUNG-1021, [0129]; SAMSUNG-1022, [0075]. In this mode, "[a]ll required signaling fields for full bandwidth MU-MIMO are carried in HE-SIG-A and the user specific sub-fields." SAMSUNG-1038, 12. This "improves efficiency by saving HE-SIG-B overhead" when "11ac-style MU-MIMO over the whole bandwidth is used." SAMSUNG-1037, 15.

HE-SIG-B Compression for MU-MIMO

- For MU-MIMO over the entire BW, 1 bit in HE-SIG-A indicates compression.
  - No RU signaling information transmitted in HE-SIG-B
    - RU Size is set to the largest RU for the BW (20MHz – 242 tone RU, 40 – 484, 80– 996, 160 – 2x996)
  - The user specific sub-fields are split equitably between the two HE-SIG-B Channels for efficient load-balancing
    - For k user MU-MIMO PPDU, $1, \ldots \left\lceil \frac{k}{2} \right\rceil$ user specific sub-fields in HE-SIG-B channel 1 and $\left\lceil \frac{k}{2} \right\rceil + 1, \ldots, k$ user specific sub-fields in HE-SIG-B channel 2
    - Pad to end contents in both channels at same OFDM symbol



SAMSUNG-1037, 14

113. However, Josiam's method does not include bandwidth indications for full bandwidth (i.e., contiguous) 80 and 160 MHz transmissions. SAMSUNG-1014, [0155]-[0166], Table 1; SAMSUNG-1017, 12-15. Instead, in Josiam's system, a full bandwidth 80 or 160MHz transmission is indicated by signaling the total PPDU bandwidth and the availability of both P20 and S20 through the bandwidth field of HE-SIG-A and by including non-null values in the corresponding resource unit allocation fields for the remaining channels. *Id*. But when full bandwidth MU-MIMO mode is used, no resource unit allocation fields are transmitted because the entire indicated bandwidth is used. SAMSUNG-1037, 14-15; SAMSUNG-1038, 11-13. A POSITA would have understood that one obvious solution would have been to include the four contiguous options from 802.11ac and use the remaining four options for non-contiguous operation, per Kim. SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44. Moreover, a POSITA would have understood that, by retaining the bandwidth signaling options from 802.11ac, implementation details for full bandwidth MU-MIMO may be reused from previously developed 802.11ac receivers. SAMSUNG-1037, 15; SAMSUNG-1038, 12; SAMSUNG-1033, 259-261, 293-295; SAMSUNG-1029, 91-93, 131-132; SAMSUNG-1043, 8-9, 13.

114. A POSITA would have also been motivated to include separate indications for contiguous and non-contiguous bandwidth operation to the reduce

physical layer design complexity and encoding/decoding complexity in less dense operating environments. Specifically, a POSITA would have recognized that, when the probability of the channel being busy is low, the benefit of non-contiguous channel bonding can be small. SAMSUNG-1039, 3-10. For example, in scenarios with relatively low interference levels (e.g., residential areas with low-density housing), the need for non-contiguous bonding would be minimal. *Id.* This is because the only there would only be a single WiFi network within range, and thus no other network to cause interference would be in range. *Id.*

115. In such cases, a POSITA would have understood that the additional complexity required to implement non-contiguous channel bonding would not be justified. Specifically, a POSITA would have understood that the benefits of non-contiguous channel bonding should be considered against the added burdens put on the physical layer design. SAMSUNG-1040, 7-12 ("Non-contiguous channel support with PHY restriction might be required . . . ***Complexity and AP/STA capability needs to be considered***."). A POSITA would have also understood that more complex processing may be needed to encode and decode non-contiguous PPDUs. SAMSUNG-1040, 8 ("***STAs' capability for non-contiguous channel support might vary***[.] CCA, contention and back-off and other channel access schemes might be required to be re-defined for non-contiguous channel[.]"). For example, a POSITA would have recognized that it may be desirable to revert to the

existing contiguous channel bonding scheme from 802.11ac to reduce the number of clear channel assessments required, with each extra assessment consuming additional power. SAMSUNG-1041, [0043]-[0050]; SAMSUNG-1042, [0030]-[0036].

116. A POSITA would have understood that, by retaining the four existing contiguous channel bonding options from 802.11ac and including the new non-contiguous channel bonding options as four separate options of a 3-bit bandwidth field, the non-contiguous channel bonding modes may be made optional. Thus, in less dense operating environments, the existing contiguous channel bonding scheme may be used. *Id.* A POSITA would have also understood that having four contiguous options maintains a level of backwards compatibility with previous version of 802.11 as well as SU operation. SAMSUNG-1043, 8-9, 13; SAMSUNG-1033, 259-261; SAMSUNG-1029, 91-93. This further allows for implementation details to be reused from previously developed 802.11 receivers and reused between SU and MU modes. *Id.*; SAMSUNG-1044, 12 ("HE-SIG-A is encoded [the] same as VHT-SIG-A in 11ac, therefore there is ***no extra implementation and verification works needed***."); SAMSUNG-1021, [0112] (noting that the use of similar formats of HE-SIG-A may "increase simplicity of implementation"); SAMSUNG-1022, [0062].

117. A POSITA would have found the Josiam-Kim combination obvious

and predictable given that the combination merely reflects the simple substitution of one set of indications of a 3-bit bandwidth field in HE-SIG-A for another set of indications of a 3-bit bandwidth field in HE-SIG-A, where both sets of indications include information of the total bandwidth of the PPDU and puncturing information for the S20 channel. SAMSUNG-1014, [0154]-[0168]; SAMSUNG-1017, 12-15; SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44.

118. Additionally, the Josiam-Kim bandwidth and content channel indication scheme for the bandwidth field of HE-SIG-A would have been obvious to try. Indeed, a POSITA would have understood that there was a need to indicate which channels were used or unused in the preamble of an HE MU PPDU when non-contiguous PPDUs are transmitted and that there was insufficient space in the HE-SIG-A field to indicate all possible channel combinations. SAMSUNG-1014, [0150]-[0156]; SAMSUNG-1017, 12-14; SAMSUNG-1023, [0028]-[0031]; SAMSUNG-1024, [0023]-[0028]; SAMSUNG-1035, 5; SAMSUNG-1036, 13-15.

119. It was known in the art that this information may be split between HE-SIG-A and HE-SIG-B fields to reduce the signaling burden in HE-SIG-A, specifically by using the HE-SIG-A to indicate the total bandwidth of the PPDU and whether certain channels in the primary 80MHz carrying the HE-SIG-B content channel 2 are transmitted. SAMSUNG-1014, [0150]-[0156]; SAMSUNG-

1017, 12-14; SAMSUNG-1021, [0131]-[0132], [0138]; SAMSUNG-1022, [0076]-[0078]; SAMSUNG-1034, 9; SAMSUNG-1035, 9; SAMSUNG-1036, 13-14. Within the eight values of a 3-bit bandwidth field, a POSITA would have appreciated that two of the values should correspond to contiguous 20 and 40MHz PPDUs. This is because the P20 channel is required (SAMSUNG-1023, [0027]; SAMSUNG-1024, 8), and if other channels are not available, only a 20MHz PPDU would be transmitted. A POSITA would have recognized a finite number of predictable ways to indicate the remaining combinations of HE-SIG-B content channel 2 locations across 80 and 160MHz bandwidths using the remaining six indices. One obvious and predictable solution would have been to use four values of the 3-bit field to indicate the existing contiguous bandwidth options carried over from 802.11ac (and used in 80.211ax for single-user HE PPDUs), and the remaining four values to indicate the use of the S20 channel in non-contiguous 80 and 160MHz bandwidths, as taught by Kim. SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44; SAMSUNG-1033, 259-261; SAMSUNG-1029, 91-93; SAMSUNG-1036, 13-15.

120. Indeed, in the 802.11ax draft specification dated March 2, 2016, Table 26-16—which lists the variables included in HE-SIG-A of a MU PPDU—states that the number of bits would be greater than or equal to two. SAMSUNG-1029, 91-93. With two bits representing four modes being "[s]et to 0 for 20 MHz, 1 for

40 MHz, 2 for 80 MHz, 3 for 160 MHz and 80+80 MHz." *Id.*

NOTE—The HE-SIG-A field contents for the HE extended range SU PPDU may be subject to change.

The HE-SIG-A field of an HE MU PPDU contains the fields listed in Table 26-16.

Table 26-16 - Fields in the HE-SIG-A for a HE MU PPDU

Two Parts of HE-SIG-A	Bit	Field	Number of Bits	Description
	TBD	DL/UL	1	Indicates whether the HE MU PPDU is UL or DL. This field indicates DL for TDLS. NOTE—The TDLS peer can identify the TDLS frame by To DS and From DS fields in the MAC header of the 11ax MPDU.
	TBD	BSS Color	6	The BSS Color field is an identifier of the BSS
	TBD	Spatial Reuse	TBD	TBD
	TBD	TXOP Duration	TBD	Indicates the remaining time in the current TXOP. Details TBD.
	TBD	Bandwidth	≥ 2	Set to 0 for 20 MHz, 1 for 40 MHz, 2 for 80 MHz, 3 for 160 MHz and 80+80 MHz
	TBD	SIGB MCS	3	Indication the MCS of HE-SIG-B. Set to 0 for MCS0 Set to 1 for MCS1 Set to 2 for MCS2 Set to 3 for MCS3 Set to 4 for MCS4

SAMSUNG-1029, Table 26-15 (annotated)

121. For these reasons, a POSITA would have found the Josiam-Kim combination obvious and predictable.

D. US Patent Publication No. 2017/0181129A1 ("Bharadwaj")

122. Bharadwaj relates to "[m]ethods, apparatuses, and computer readable media for supporting preamble design aspects of high efficiency WLANs." SAMSUNG-1021, [0007]; SAMSUNG-1022, [0004]. Bharadwaj discloses a "WLAN protocol data unit 200," which includes a preamble having HE-SIG-A and HE-SIG-B fields. SAMSUNG-1021, [0098]-[0101]; SAMSUNG-1022, [0048]-[0051].

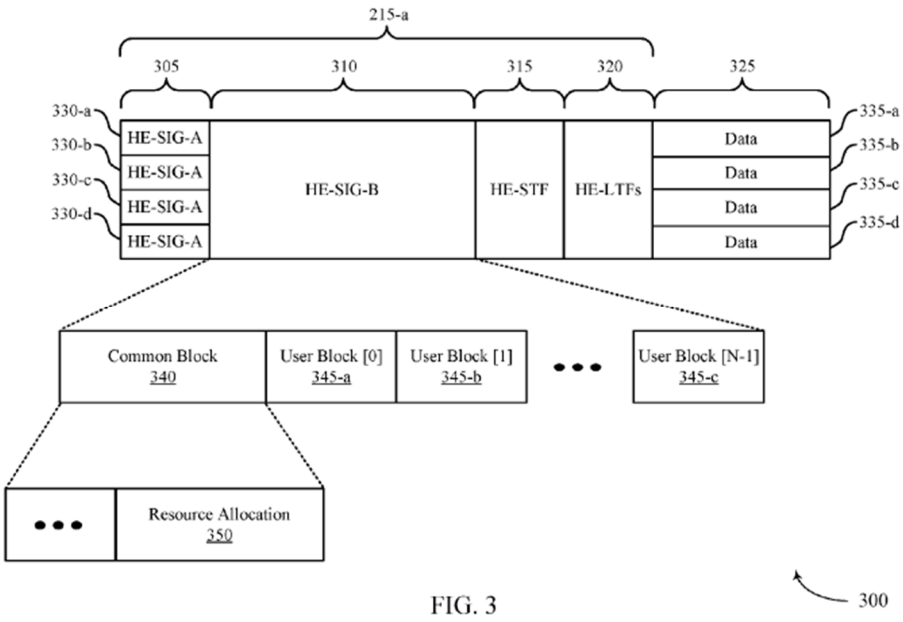


FIG. 3

SAMSUNG-1021, Fig. 3; SAMSUNG-1022, Fig. 3

123. Bharadwaj discloses a method of indicating puncturing of 20MHz subchannels using the HE-SIG-A and HE-SIG-B fields. SAMSUNG-1021, [0130]-[0132], [0138]-[0142]; SAMSUNG-1022, [0076]-[0081]. Specifically, Bharadwaj describes two ways to indicate a punctured channel, depending on which channels are being punctured. *Id.*

124. First, Bharadwaj teaches that, when a secondary 20MHz channel is punctured, two different indicators may be included in HE-SIG-A. SAMSUNG-1021, [0131]-[0132], [0138]; SAMSUNG-1022, [0076]-[0078]. For example, "information/contents of the SIG-B that was found in the secondary 20 MHz channel may be transmitted on the primary 20 MHz channel. In such case an indication of the puncturing of the 20 MHz channel may be signaled in the SIG-A

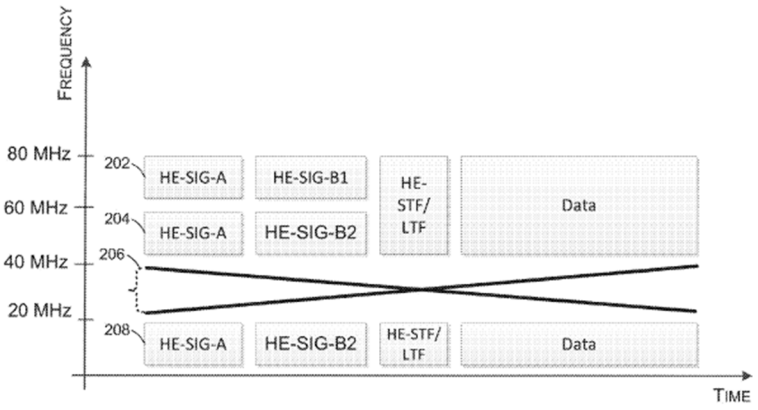
field, for example by including an indicator." SAMSUNG-1021, [0132]; SAMSUNG-1022, [0077]. Alternatively, "information/contents of the SIG-B that was found in the secondary 20 MHz channel may be decoded from a 4th 20 MHz channel. In such case an indication of the SIG-B decoding may be signaled in the SIG-A field, for example by including an indicator." SAMSUNG-1021, [0138]; SAMSUNG-1022, [0078].

125. Next, Bharadwaj explains that, when "other 20 MHz channels are punctured," i.e., not the secondary 20MHz channel, "an HE-SIG-B design may be different." SAMSUNG-1021, [0139]-[0142]; SAMSUNG-1022, [0079]-[0082]. For example, "a special or dedicated [resource unit] allocation bit sequence may be used to indicate that a 20 MHz channel is punctured. The indication may be made by adding an additional entry in a [resource unit] allocation table." SAMSUNG-1021, [0141]-[0142]; SAMSUNG-1022, [0081]-[0082]. In this case, "an explicit indication of the punctured 20 MHz channel may not be needed" in the HE-SIG-A field. SAMSUNG-1021, [0140]; SAMSUNG-1022, [0081].

E. US Patent Publication No. US2017/0041171 ("Li")

126. Li relates "to systems and methods for wireless communications and, more particularly, to a bandwidth and sub-channel indications system in wireless communications." SAMSUNG-1023, [0002]; SAMSUNG-1024, [0001]. Li describes a high efficiency preamble including HE-SIG-A and HE-SIG-B fields.

SAMSUNG-1023, [0023]; SAMSUNG-1024, [0020], Fig. 1. Li explains that, in some cases, one or more 20MHz subchannels of a frequency band may need to be "removed or punctured out (e.g., subchannel 206) because the subchannel may be unusable," e.g., due to interference from "adjacent channels, noise, obstacles, etc." SAMSUNG-1023, [0026]; SAMSUNG-1024, [0010], [0024].



SAMSUNG-1023, Fig. 2; SAMSUNG-1024, Fig. 3

127. According to Li, "a transmitting device may need to signal [to] the receiving device which 20 MHz subchannels are used (e.g., 20 MHz subchannels 202, 204 and 208)." SAMSUNG-1023, [0027]; SAMSUNG-1024, [0025]. Li teaches "a bandwidth subchannel indication system may allocate one or more indication bits of the HE-SIG-A field to be used as an indication of the bandwidth of the transmission and/or an indication of the subchannels that are used and/or not used for the transmission." SAMSUNG-1023, [0030]-[0032]; SAMSUNG-1024, [0025]-[0030].

128. Li explains that the primary 20MHz channel is always used (because stations listen on the prearranged P20 channel), and thus for a 160MHz channel, "a transmitting device may need to utilize around 7 bits to indicate the presence of the 7 secondary 20 MHz subchannels." SAMSUNG-1023, [0027]-[0028]; SAMSUNG-1024, [0025]-[0026]. But, as Li explains, "utilizing 7 bits within the HE-SIG-A field may incur additional overhead in the HE-SIG-A field." SAMSUNG-1023, [0028]; SAMSUNG-1024, [0026]. Thus, Li proposes using a 4-bit bandwidth indication in HE-SIG-A "that accounts for a subset of useful configurations." SAMSUNG-1023, [0030]-[0033] ; SAMSUNG-1024, [0025]-[0031].

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	P	S1	S2	S3	S4	S5	S6	S7
1	X							
2	X	X						
3	X		X					
4	X	X	X					
5	X			X				
6	X	X		X				
7	X		X	X				
8	X	X	X	X				
9	X	X	X	X	X	X	X	X
10	X		X	X	X	X	X	X
11	X	X		X	X	X	X	X
12	X	X	X		X	X	X	X
13	X	X	X	X		X	X	X
14	X	X	X	X	X		X	X
15	X	X	X	X	X	X		X
16	X	X	X	X	X	X	X	

SAMSUNG-1023, Fig. 3; SAMSUNG-1024, 9

F. Combination of Bharadwaj and Li

129. In Bharadwaj-Li, the bandwidth field of HE-SIG-A would indicate both the bandwidth of the PPDU and a subset of channel puncturing configurations (per Li) and the resource unit allocation field of the HE-SIG-B common field would indicate additional puncturing information through a special RU allocation sequence (per Bharadwaj). SAMSUNG-1021, [0130]-[0132], [0138]-[0142]; SAMSUNG-1022, [0076]-[0081]; SAMSUNG-1023, [0030]-[0032]; SAMSUNG-1024, [0025]-[0030]. In the combination, the bandwidth field of HE-SIG-A would take the form of an index, which maps to the total bandwidth of the PPDU and a subset of channel configurations (per Li) with the subset of channel configurations indicating whether the S20 or S40B channels are transmitted (per Bharadwaj). *Id.* In this sense, the indications described in paragraphs [0132] and [0138] of Bharadwaj take the form of index values of the bandwidth field of HE-SIG-A. *Id.*

130. As one obvious example, the bandwidth field (per Bharadwaj) would be expanded by one bit to indicate both the total bandwidth of the PPDU and a subset of "useful configurations" of used channels (per Li). SAMSUNG-1021, [0111]; SAMSUNG-1022, [0061]; SAMSUNG-1023, [0027]-[0031]; SAMSUNG-1024, [0025]-[0028]. Within the subset of channel configurations indexed by the bandwidth field, two configurations (depicted below as (b) and (c)) indicating the availability of S20 and S40B, per Bharadwaj, would be included for both 80 and

160MHz PPDUs. SAMSUNG-1021, [0131]-[0132], [0138]; SAMSUNG-1022, [0076]-[0078].

131. With the remaining four indices, a POSITA would have found it obvious to include indications for 20 and 40MHz (in which non-contiguous channel bonding is not used) and indications for 80 and 160MHz with no puncturing of the secondary 40MHz (depicted below as (a)). SAMSUNG-1021, [0131]; SAMSUNG-1022, [0076]. The use of other channels would be indicated using a special RU allocation bit sequence in a corresponding resource unit allocation field in the HE-SIG-B common field, per Bharadwaj." SAMSUNG-1021, [0141]-[0142]; SAMSUNG-1022, [0081]-[0082].

<table>
<tr><th></th><th>P20</th><th>S20</th><th>S40A (U-20)</th><th>S40B (L-20)</th><th colspan="4">S80</th><th>PPDU Bandwidth</th></tr>
<tr><td>20</td><td>Used</td><td colspan="7" rowspan="2"></td><td>20 MHz</td></tr>
<tr><td>40</td><td>Used</td><td>Used</td><td>40 MHz</td></tr>
<tr><td>80(a)</td><td>Used</td><td>Used</td><td colspan="2" rowspan="2"></td><td colspan="4" rowspan="2"></td><td rowspan="3">80 MHz</td></tr>
<tr><td>80(b)</td><td>Used</td><td>Punc</td><td>Used</td></tr>
<tr><td>80(c)</td><td>Used</td><td>Punc</td><td>Used</td><td>Punc</td><td colspan="4" rowspan="2"></td></tr>
<tr><td>160(a)</td><td>Used</td><td>Used</td><td colspan="3" rowspan="3"></td><td colspan="4" rowspan="3">Channel use indicated by RU signaling field of HE-SIG-B</td><td rowspan="3">160 MHz</td></tr>
<tr><td>160(b)</td><td>Used</td><td>Punc</td><td>Used</td></tr>
<tr><td>160(c)</td><td>Used</td><td>Punc</td><td>Punc</td></tr>
<tr><td>HE-SIG-B Content Channel</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td>1</td><td>2</td><td></td></tr>
</table>

132. A POSITA would have found it obvious to use the bandwidth field of HE-SIG-A to indicate the total bandwidth of the PPDU and some channel puncturing information (per Li) and use the resource unit allocation field of the

HE-SIG-B common field to indicate additional puncturing information (per Bharadwaj) for several reasons. First, given that the relied upon portions of Bharadwaj (i.e., those supported by the Bharadwaj Provisional) do not explicitly teach where in the HE-SIG-A field the indications of unused S20 and S40B channels are carried, a POSITA would have looked to known methods of indicating channel use in HE-SIG-A, such as a joint bandwidth and subchannel indication (per Li).

133. Moreover, a POSITA would have been motivated to indicate both the bandwidth of the PPDU and the use of the S20 and S40B channels using the same field to save space in HE-SIG-A. For example, if the indications described in Bharadwaj paragraphs [0132] and [0138] were included in a separate field of HE-SIG-A, a POSITA would have understood that at least two additional bits would be used to indicate three options for the location of HE-SIG-B content channel 2:

(1) no HE-SIG-B content channel 2 transmitted, information is copied on HE-SIG-B content channel 1 (SAMSUNG-1021, [0132]; SAMSUNG-1022, [0077]);

(2) HE-SIG-B content channel 2 is located in the fourth 20MHz channel (S40B) (SAMSUNG-1021, [0138]; SAMSUNG-1022, [0078]), and

(3) neither of the above applies and the HE-SIG-B content channel 2 is located in S20 (SAMSUNG-1021, [0131]; SAMSUNG-1022, [0076]).

134. It would have been obvious to a POSITA to include information of the location of the second HE-SIG-B content channel (per Bharadwaj) as channel configurations in a bandwidth and subchannel indication field (per Li) to save one bit in the bandwidth field of HE-SIG-A. SAMSUNG-1021, [0131]-[0132], [0138]; SAMSUNG-1022, [0076]-[0078]; SAMSUNG-1023, [0027]-[0031]; SAMSUNG-1024, [0025]-[0028]. A POSITA would have had a reasonable expectation of success in the combination given that the known elements in the combination perform known functions. Moreover, the Bharadwaj-Li combination would have been predictable considering that it was known in the art that the bandwidth field of HE-SIG-A in a multi-user PPDU may be extended to indicate additional information. SAMSUNG-1027, 6-8. Indeed, the December 2015 Draft IEEE 802.11ax Framework noted that the bandwidth field of HE-SIG-A may be larger than the two bits used for the bandwidth field in a single user transmission "to take advantage of OFDMA." SAMSUNG-1027, 6-8.

Table 2 - HE-SIG-A field for an HE MU PPDU

Field	Length (bits)	Description	Encoding
DL/UL	1		
BSS Color	6	Base station identifier.	
Spatial Reuse	TBD		
TXOP Duration	TBD	Indicates the remaining time in the current TXOP. See [14].	
Bandwidth	≥ 2	May accommodate more than in SU case to take advantage of OFDMA	
SIGB MCS	3	See [15].	MCS0, MCS1, MCS2, MCS3, MCS4, MCS5 Other MCS TBD
SIGB DCM	1		
SIGB Number Of Symbols	4	Support about 16 users using MCS0 per BCC	
SIGB	≥ 1	Differentiates full bandwidth MU-	

SAMSUNG-1029, 6-7 (annotated)

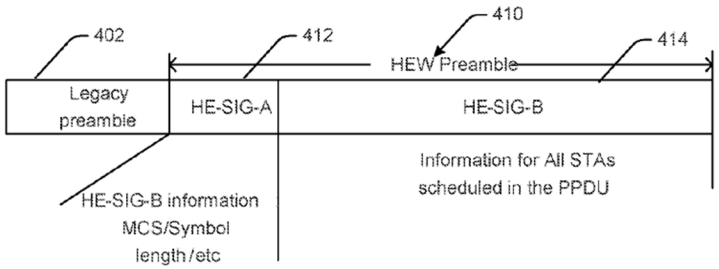
135. A POSITA would have further understood that the combination reflects the use of a known technique—e.g., a bandwidth and subchannel indication system (per Li)—to improve a similar method—e.g., a method of indicating some channel puncturing information using an indication in HE-SIG-A and additional puncturing information through a special RU allocation sequence (per Bharadwaj)—to arrive at an improved and predictable method of indicating channel puncturing information using the bandwidth field of HE-SIG-A and the resource unit allocation field of HE-SIG-B. SAMSUNG-1023, [0030]-[0032]; SAMSUNG-1024, [0025]-[0030]; SAMSUNG-1021, [0130]-[0132], [0138]-[0142]; SAMSUNG-1022, [0076]-[0081].

136. Along the same lines, a POSITA would have understood that the

combination reflects the simple substitution of one known method (e.g., a two-bit field that indicates PPDU bandwidth) for another (e.g., a three-bit bandwidth field that indicates PPDU bandwidth and channel puncturing information) to arrive at the predictable result of a bandwidth field that indicates bandwidth and some channel puncturing information. SAMSUNG-1021, [0111]; SAMSUNG-1022, [0061]; SAMSUNG-1023, [0030]-[0032]; SAMSUNG-1024, [0025]-[0030].

G. US Patent Publication No. 2016/0330058A1 ("Chen")

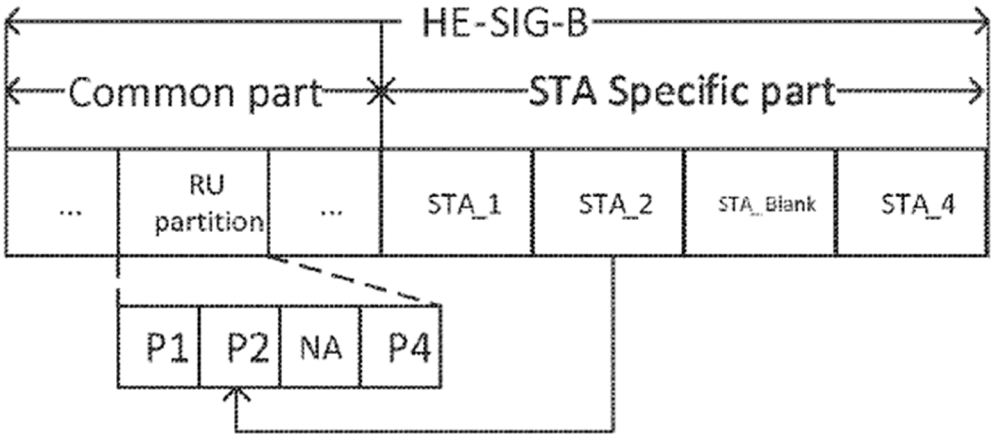
137. Chen relates to "resource unit (RU) allocation in high efficiency (HE) Wi-Fi preambles," particularly in IEEE 802.11ax or High-Efficiency WLAN. SAMSUNG-1025, [0002]-[0003]. Chen discloses "identifying an RU for transmitting and receiving data based at least in part on a received PPDU." SAMSUNG-1025, [0101]-[0104]. Chen's PPDU includes HE-SIG-A and HE-SIG-B fields. *Id*., [0035], [0076], [0101]-[0104], Fig. 4.



SAMSUNG-1025, Fig. 4

138. Chen further discloses methods for identifying an unassigned resource unit. SAMSUNG-1025, [0090]-[0093], Figs. 12-14. For example, Chen teaches

that, "[i]f one RU is not allocated or is skipped, AP 110 may assign a special (e.g., blank or null) PAID which is not decodable by or known to any of the scheduled STA. As a result, all of the STAs 140 will skip that RU. FIG. 13 depicts a datagram illustrating an example HE-SIG-B 1300 portion indicating a sequence of RU allocation information with an unallocated RU." SAMSUNG-1025, [0092].



SAMSUNG-1025, Fig. 13

H. Combination of Bharadwaj, Li, and Chen

139. In Bharadwaj-Li-Chen, Bharadwaj-Li includes a method of indicating an unassigned resource unit using a null station ID in a user field corresponding to the resource unit not assigned to a user, per Chen. SAMSUNG-1021, [0101]-[0104], [0117], Figs. 3, 5; SAMSUNG-1022, [0051]-[0054], [0067], Fig. 3, 5; SAMSUNG-1025, [0090]-[0093], Figs. 12-14. In the combination, the resource unit allocation field partitions a specific 20MHz subchannel into multiple resource units, per Bharadwaj. SAMSUNG-1021. [0104], [0117]; SAMSUNG-1022,

[0054], [0067]. A specific resource unit within the 20MHz data region may be indicated as an unassigned resource unit using a null station ID, per Chen. SAMSUNG-1025, [0090]-[0093], Fig. 13.

140. A POSITA would have found it obvious to use a null station ID in the user field corresponding to a specific resource unit indicated by the resource unit allocation field, as Chen teaches, for several reasons. First, a POSITA would have been motivated to include a method of indicating additional unassigned resource units (beyond entirely nulled channels), for example, resource units on the edge of a nulled channel. In my opinion, a POSITA would have understood that it may be helpful to null resource units in an unpunctured channel adjacent to a punctured channel. *Id*.; SAMSUNG-1014, [0139], [0143], [0147], Figs. 11-13; SAMSUNG-1015, 8-11. Specifically, a POSITA would have understood that resource units in the segment adjacent to a punctured channel may be nulled, i.e., not assigned to a user, to ensure compliance with spectral masks and out of band emission requirements. *Id*. As one example, "when 20MHz at the edge of a[n] 80MHz PPDU is nulled as shown [below], the spectral mask requirement for the band adjacent to the nulled segment can be defined by the tightest of spectral masks corresponding to bandwidths greater than or equal to than being nulled." SAMSUNG-1014, [0143]; SAMSUNG-1015, 9.

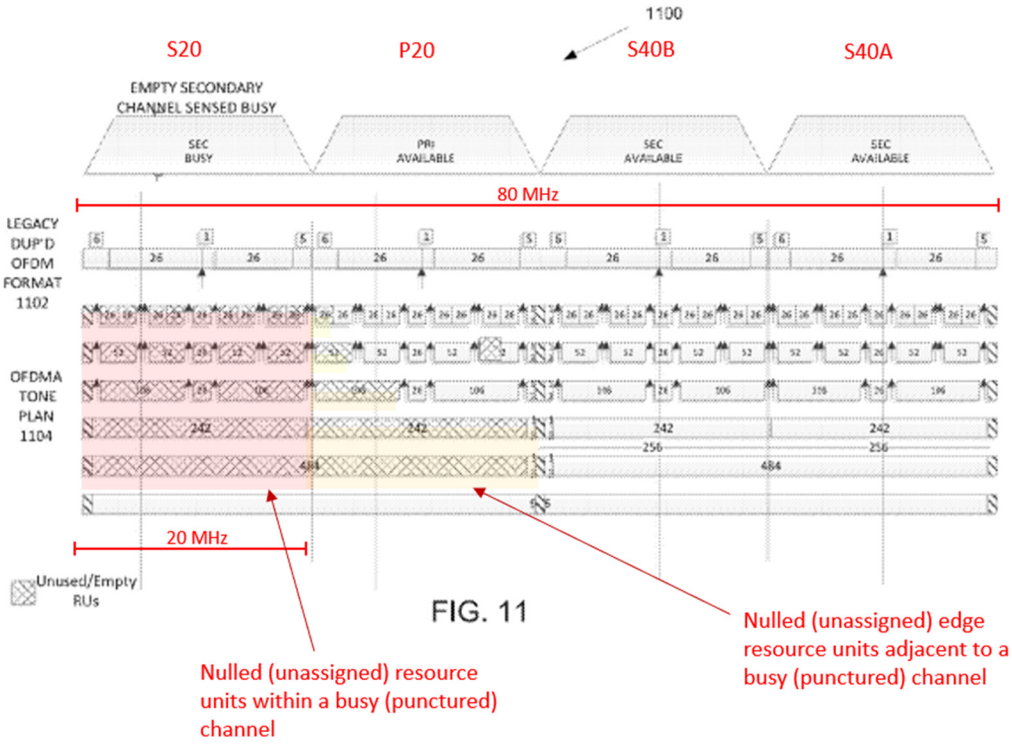


FIG. 11

SAMSUNG-1014, Fig. 11 (annotated); SAMSUNG-1015, Fig. 9

141. A POSITA would have understood Chen's method of indicating an unassigned resource unit using a null station ID as a known, predictable solution to indicate additional unassigned resource units, such as edge resource units in a used channel adjacent to a punctured busy channel. SAMSUNG-1025, [0090]-[0093]. Thus, it would have been obvious to a POSITA to use Chen's method to further indicate information of an unassigned resource unit, such as a resource unit adjacent to a busy channel, in Bharadwaj-Li. Moreover, a POSITA would have had a reasonable expectation of success in combining Chen with Bharadwaj-Li given that the known elements in the combination merely perform the same functions and would have also found the combination predictable for similar

reasons to those discussed above.

142. A POSITA would have further understood that the combination reflects the use of a known technique—e.g., indicating an unassigned resource unit using a null station ID in a user specific field corresponding to the unassigned resource unit (per Chen)—to improve a similar method—e.g., a method of indicating some channel puncturing via the bandwidth field of HE-SIG-A and the resource unit allocation field of HE-SIG-B (per Bharadwaj-Li)—to arrive at an improved and predictable method of indicating information of an unassigned resource unit (e.g., an unassigned resource unit on the edge of a punctured channel) using a null station ID in a user field (e.g., Bharadwaj's user block 345) corresponding to the unassigned resource unit. SAMSUNG-1021, [0101]-[0104], [0117], Figs. 3, 5; SAMSUNG-1022, [0051]-[0054], [0067], Fig. 3, 5; SAMSUNG-1025, [0090]-[0093], Figs. 12-14.

I. Combination of Bharadwaj, Li, and Kim

143. In Bharadwaj-Li-Kim, Bharadwaj-Li's bandwidth and subchannel indication in HE-SIG-B would be modified to include four contiguous PPDU options and four non-contiguous PPDU options that indicate, for each bandwidth of 80 or 160 (or 80 + 80) MHz, whether the S20 channel is transmitted, per Kim. SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44; *see* § IX.F.

TABLE 22

* Bandwidth index (3 bits, b0b1b2) in HE-SIG A
* 000: 20MHz
* 001: 40MHz
* 010: 80MHz (preamble fully populated on all 4 channels and OFDMA uses 80MHz design)
* 011: 160MHz (preamble fully populated on all 8 channels and OFDMA uses 160MHz design)
* 100: 80MHz channel bonding with preamble on P40
* 101: 80MHz channel bonding with preamble on P20 (no preamble on S20)
* 110: 160MHz channel bonding with preamble on P40
111: 160MHz channel bonding with preamble on P20 (no preamble on S20) }

SAMSUNG-1018, Table 22

	P20	S20	S40A (U-20)	S40B (L-20)	S80				PPDU Bandwidth
000	Used								20 MHz
001	Used	Used							40 MHz
010	Used	Used	Used	Used					80 MHz
011	Used	Used	Used	Used	Used	Used	Used	Used	160 MHz
100	Used	Used	Channel use indicated by RU signaling field of HE-SIG-B						80 MHz
101	Used	Punc							80 MHz
110	Used	Used							160 MHz
111	Used	Punc							160 MHz
HE-SIG-B Content Channel	1	2	1	2	1	2	1	2	

144. If the S20 channel is transmitted, then a receiving station may read both HE-SIG-B content channels from the primary 40MHz (P20 and S20), per Bharadwaj. SAMSUNG-1021, [0131]; SAMSUNG-1022, [0076]. If the S20 channel is not transmitted (e.g., the channel is busy and must be punctured), then a POSITA would have recognized several known or obvious methods to transmit HE-SIG-B information for the channels that ordinarily fall into HE-SIG-B content

channel 2. SAMSUNG-1021, [0131]; SAMSUNG-1022, [0076].

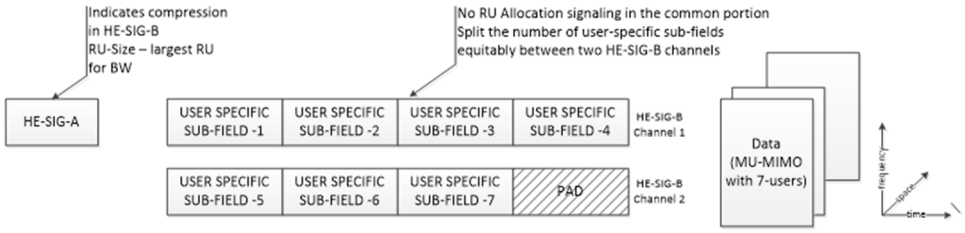
145. For example, HE-SIG-B content channel 1 could carry HE-SIG-B information for all channels in the bandwidth (per Bharadwaj). SAMSUNG-1021, [0132]; SAMSUNG-1022, [0077]. Alternatively, the HE-SIG-B content channel 1 could include a channel bonding field in the common field that indicates which channels are being used, and the HE-SIG-B content channel 1 could carry information for the channels according to the default mapping plus any additional used channels that would otherwise be carried in the HE-SIG-B content channel 2 (per Kim). SAMSUNG-1018, [0143]-[0159], Tables 23-24; SAMSUNG-1019, 42-49. Even more simply, bandwidth configurations in which both S20 and S40B are not transmitted could be proscribed, and thus at least one channel carrying each HE-SIG-B content channel would always be present in the P80.

146. The Bharadwaj-Li-Kim combination would have been obvious to a POSITA for several reasons. First, a POSITA would have been motivated to modify Bharadwaj-Li to include separate indications for contiguous and non-contiguous PPDUs, per Kim. In my opinion, a POSITA would have been motivated to include separate indications for contiguous bandwidths to (1) enable HE-SIG-B compression mode to be used for full bandwidth MIMO transmissions and (2) make non-contiguous channel bonding optional for operating environments where the benefit of non-contiguous channel bonding is low.

147. By May 14, 2016, an HE-SIG-B compression mode was introduced for full bandwidth MU-MIMO, in which resource unit allocation signaling information is no longer transmitted in the HE-SIG-B field because the entire bandwidth will be used for MU-MIMO. SAMSUNG-1029, 131-132; SAMSUNG-1037, 14-15; SAMSUNG-1038, 11-13; SAMSUNG-1021, [0129]; SAMSUNG-1022, [0075]. In this mode, "[a]ll required signaling fields for full bandwidth MU-MIMO are carried in HE-SIG-A and the user specific sub-fields." SAMSUNG-1038, 12. This "improves efficiency by saving HE-SIG-B overhead" when "11ac-style MU-MIMO over the whole bandwidth is used." SAMSUNG-1037, 15.

HE-SIG-B Compression for MU-MIMO

- For MU-MIMO over the entire BW, 1 bit in HE-SIG-A indicates compression.
  - No RU signaling information transmitted in HE-SIG-B
    - RU Size is set to the largest RU for the BW (20MHz – 242 tone RU, 40 – 484, 80– 996, 160 – 2x996)
  - The user specific sub-fields are split equitably between the two HE-SIG-B Channels for efficient load-balancing
    - For k user MU-MIMO PPDU, $1, \ldots \left\lceil \frac{k}{2} \right\rceil$ user specific sub-fields in HE-SIG-B channel 1 and $\left\lceil \frac{k}{2} \right\rceil + 1, \ldots, k$ user specific sub-fields in HE-SIG-B channel 2
    - Pad to end contents in both channels at same OFDM symbol



SAMSUNG-1037, 14

148. However, the Bharadwaj-Li combination does not include bandwidth indications for full bandwidth (i.e., contiguous) 80 and 160 MHz transmissions.

SAMSUNG-1014, [0155]-[0166], Table 1; SAMSUNG-1017, 12-15. Instead, in Bharadwaj-Li, a full bandwidth 80 or 160MHz transmission is indicated by signaling the total PPDU bandwidth and the availability of both P20 and S20 through the bandwidth field of HE-SIG-A and by including non-null values in the corresponding resource unit allocation fields for the remaining channels. *Id*. But when full bandwidth MU-MIMO mode is used, no resource unit allocation fields are transmitted because the entire indicated bandwidth is used. SAMSUNG-1037, 14-15; SAMSUNG-1038, 11-13. A POSITA would have understood that one obvious solution would have been to include the four contiguous options from 802.11ac and use the remaining four options for non-contiguous operation, per Kim. ; SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44. Moreover, a POSITA would have understood that, by retaining the bandwidth signaling options from 802.11ac, implementation details for full bandwidth MU-MIMO may be reused from previously developed 802.11ac receivers. SAMSNG-1037, 15; SAMSUNG-1038, 12; SAMSUNG-1033, 259-261, 293-295; SAMSUNG-1029, 91-93, 131-132; SAMSUNG-1043, 8-9, 13.

149. A POSITA would have also been motivated to include separate indications for contiguous and non-contiguous bandwidth operation to the reduce physical layer design complexity and encoding/decoding complexity in less dense operating environments. Specifically, a POSITA would have recognized that,

when the probability of the channel being busy is low, the benefit of non-contiguous channel bonding can be small. SAMSUNG-1039, 3-10. For example, in scenarios with relatively low interference levels (e.g., residential areas with low-density housing), the need for non-contiguous bonding would be minimal. *Id.* This is because the only there would only be a single WiFi network within range, and thus no other network to cause interference. *Id.*

150. In such cases, a POSITA would have understood that the additional complexity required to implement non-contiguous channel bonding would not be justified. Specifically, a POSITA would have understood that the benefits of non-contiguous channel bonding should be considered against the added burdens put on the physical layer design. SAMSUNG-1040, 7-12 ("Non-contiguous channel support with PHY restriction might be required . . . ***Complexity and AP/STA capability needs to be considered***."). A POSITA would have also understood that more complex processing may be needed to encode and decode non-contiguous PPDUs. SAMSUNG-1040, 8 ("***STAs' capability for non-contiguous channel support might vary***[.] CCA, contention and back-off and other channel access schemes might be required to be re-defined for non-contiguous channel[.]"). For example, a POSITA would have recognized that it may be desirable to revert to the existing contiguous channel bonding scheme from 802.11ac to reduce the number of clear channel assessments required, with each extra assessment consuming

additional power. SAMSUNG-1041, [0043]-[0050]; SAMSUNG-1042, [0030]-[0036].

151. A POSITA would have understood that, by retaining the four existing contiguous channel bonding options from 802.11ac and including the new non-contiguous channel bonding options as four separate options of a 3-bit bandwidth field, the non-contiguous channel bonding modes may be made optional. Thus, in less dense operating environments, the existing contiguous channel bonding scheme may be used. *Id.* A POSITA would have also understood that having four contiguous options maintains a level of backwards compatibility with previous version of 802.11 as well as SU operation. SAMSUNG-1043, 8-9, 13; SAMSUNG-1033, 259-261; SAMSUNG-1029, 91-93. This further allows for implementation details to be reused from previously developed 802.11 receivers and reused between SU and MU modes. *Id.*; SAMSUNG-1044, 12 ("HE-SIG-A is encoded [the] same as VHT-SIG-A in 11ac, therefore there is ***no extra implementation and verification works needed***."); SAMSUNG-1021, [0112] (noting that the use of similar formats of HE-SIG-A may "increase simplicity of implementation"); SAMSUNG-1022, [0062].

152. A POSITA would have found the Bharadwaj-Li-Kim combination obvious and predictable given that the combination merely reflects the simple substitution of one set of indications of a 3-bit bandwidth field in HE-SIG-A for

another set of indications of a 3-bit bandwidth field in HE-SIG-A, where both sets of indications include information of the total bandwidth of the PPDU and puncturing information for the S20 channel. SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44; *see* § IX.F.

153. Additionally, the Bharadwaj-Li-Kim bandwidth and content channel indication scheme for the bandwidth field of HE-SIG-A would have been obvious to try. Indeed, a POSITA would have understood that there was a need to indicate which channels were used or unused in the preamble of an HE MU PPDU when non-contiguous PPDUs are transmitted and that there was insufficient space in the HE-SIG-A field to indicate all possible channel combinations. SAMSUNG-1023, [0028]-[0031]; SAMSUNG-1024, [0023]-[0028]; SAMSUNG-1035, 5; SAMSUNG-1036, 13-15.

154. It was known in the art that this information may be split between HE-SIG-A and HE-SIG-B fields to reduce the signaling burden in HE-SIG-A, specifically by using the HE-SIG-A to indicate the total bandwidth of the PPDU and whether certain channels in the primary 80MHz carrying the HE-SIG-B content channel 2 are transmitted. SAMSUNG-1021, [0131]-[0132], [0138]; SAMSUNG-1022, [0076]-[0078]; SAMSUNG-1034, 9; SAMSUNG-1035, 9; SAMSUNG-1036, 13-14. Within the eight values of a 3-bit bandwidth field, a POSITA would have appreciated that two of the values should correspond to

contiguous 20 and 40MHz PPDUs. This is because the P20 channel is required (SAMSUNG-1023, [0027]; SAMSUNG-1024, 8), and if other channels are not available, only a 20MHz PPDU would be transmitted. A POSITA would have recognized a finite number of predictable ways to indicate the remaining combinations of HE-SIG-B content channel 2 locations across 80 and 160MHz bandwidths using the remaining six indices. One obvious and predictable solution would have been to use four values of the 3-bit field to indicate the existing contiguous bandwidth options carried over from 802.11ac (and used in 80.211ax for single-user HE PPDUs), and the remaining four values to indicate the use of the S20 channel in non-contiguous 80 and 160MHz bandwidths, as taught by Kim. SAMSUNG-1033, 259-261; SAMSUNG-1029, 91-93; SAMSUNG-1036, 13-15; *see* §§ IX.B, IX.F.

155. Indeed, in the 802.11ax draft specification dated March 2, 2016, Table 26-16—which lists the variables included in HE-SIG-A of a MU PPDU—states that the number of bits would be greater than or equal to two. SAMSUNG-1029, 91-93. With two bits representing four modes being "[s]et to 0 for 20 MHz, 1 for 40 MHz, 2 for 80 MHz, 3 for 160 MHz and 80+80 MHz." *Id.*

NOTE—The HE-SIG-A field contents for the HE extended range SU PPDU may be subject to change.

The HE-SIG-A field of an HE MU PPDU contains the fields listed in Table 26-16.

Table 26-16 - Fields in the HE-SIG-A for a HE MU PPDU

Two Parts of HE-SIG-A	Bit	Field	Number of Bits	Description
	TBD	DL/UL	1	Indicates whether the HE MU PPDU is UL or DL. This field indicates DL for TDLS. NOTE—The TDLS peer can identify the TDLS frame by To DS and From DS fields in the MAC header of the 11ax MPDU.
	TBD	BSS Color	6	The BSS Color field is an identifier of the BSS
	TBD	Spatial Reuse	TBD	TBD
	TBD	TXOP Duration	TBD	Indicates the remaining time in the current TXOP. Details TBD.
	TBD	Bandwidth	≥ 2	Set to 0 for 20 MHz, 1 for 40 MHz, 2 for 80 MHz, 3 for 160 MHz and 80+80 MHz
	TBD	SIGB MCS	3	Indication the MCS of HE-SIG-B. Set to 0 for MCS0 Set to 1 for MCS1 Set to 2 for MCS2 Set to 3 for MCS3 Set to 4 for MCS4

SAMSUNG-1029, Table 26-15 (annotated)

156. For these reasons, a POSITA would have found the Bharadwaj-Li-Kim combination obvious and predictable.

X. MANNER IN WHICH THE PRIOR ART REFERENCES RENDER THE '281 CLAIMS UNPATENTABLE

157. I provide below a chart summarizing the grounds, relevant Challenged Claims, prior art, and applied priority date present in this Section.

Ground	Claim(s)	§103	'281 Patent Priority Date Relied Upon
1A	1-5, 7-12, 14	Josiam	5/14/2016 (Critical Date)
1B	1-7, 13	Josiam, Kim	5/14/2016 (Critical Date)
2A	1-3, 7-10, 14	Bharadwaj, Li	12/24/2015 (Earliest Filing Date)
2B	1-5, 7-12, 14	Bharadwaj, Li, Chen	12/24/2015 (Earliest Filing Date)
2C	6, 13	Bharadwaj, Li, Kim	5/14/2016 (Critical Date)

Ground	Claim(s)	§103	'281 Patent Priority Date Relied Upon
2D	6, 13	Bharadwaj, Li, Chen, Kim	5/14/2016 (Critical Date)

A. Ground 1A – Josiam renders obvious claims 1-5, 7-12, and 14 by May 14, 2016

158. All of my opinions with respect to Ground 1A (§ X.A) are from the vantage point of a POSITA as of the Critical Date (May 14, 2016).

1. Claim 8

[8.pre] A wireless communication method of a wireless communication terminal, the method comprising:

159. To the extent the preamble is limiting, Josiam describes a method of "transmitting to a station (STA), a bandwidth signaling sub-field in high efficiency signal-A (HE-SIG-A) field included in a high efficiency multi-user PPDU (HE MU PPDU)." SAMSUNG-1014, Abstract; SAMSUNG-1016, 1-6, 9-10; SAMSUNG-1017, 1-2, 7-8, 11-13.

[8.1] receiving a wireless packet;

160. Josiam teaches receiving a wireless packet (e.g., HE PPDU). SAMSUNG-1014, Abstract, [0006], [0264]-[0267], Fig. 38, claim 1; SAMSUNG-1016, 1-6, 9-10; SAMSUNG-1017, 1-2, 7-8, 11-13. For example, Josiam discloses "a station (STA) in a wireless local area network (WLAN) is provided. The STA includes a transceiver configured to receive, from an access point (AP), a bandwidth signaling sub-field in high efficiency signal-A (HE-SIG-A) field

included in a high efficiency multi-user PPDU (HE MU PPDU) indicating availability of at least one content channel." SAMSUNG-1014, [0006]; SAMSUNG-1016, 1-6, 9-10; SAMSUNG-1017, 1-2, 7-8, 11-13. In view of the '281 patent's discussion of a wireless packet, a POSITA would have understood that a PPDU is a wireless packet. SAMSUNG-1023, [0015]; SAMSUNG-1046, 6:29-49; SAMSUNG-1001, 34:11-13 ("the received wireless packet may be an HE MU PPDU").

[8.2] obtaining bandwidth information indicated via a bandwidth field of HE-SIG-A of the received packet;

161. Josiam teaches obtaining bandwidth information (e.g., PPDU bandwidth) indicated via a bandwidth field of HE-SIG-A of the received packet (e.g., HE PPDU). SAMSUNG-1014, Abstract, [0006], [0154]-[0156], [0264]-[0267], Figs. 13, 38, Claim 1; SAMSUNG-1016, 3-5, 9-10; SAMSUNG-1017, 1, 8-0, 11-15. For example, Josiam teaches an HE MU PPDU including, among other fields, HE-SIG-A and HE-SIG-B fields. *Id*.

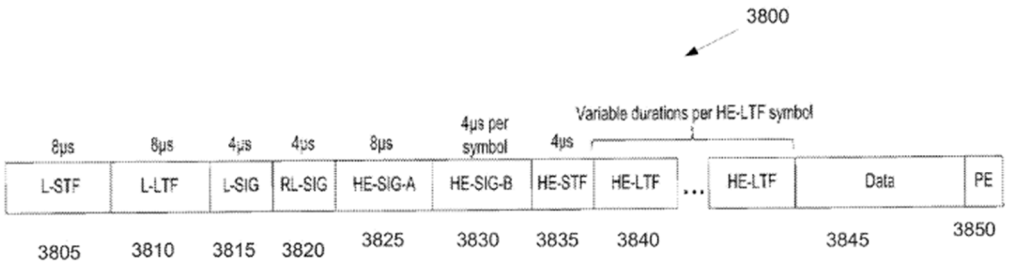


FIG. 38

SAMSUNG-1014, Fig. 38; SAMSUNG-1016, Fig. 4

162. Josiam teaches that the HE-SIG-A includes a bandwidth field that indicates the PPDU bandwidth. SAMSUNG-1014, [0154]-[0155], [0161]-[0165]; SAMSUNG-1017, 12-16. For example, Josiam discloses that a station "may use the ***indication in the bandwidth field signaled in the HE-SIG-A to decipher*** both the ***bandwidth of the PPDU*** and the location of the content channel that it may decode in the HE-SIG-B." SAMSUNG-1014, [0161], SAMSUNG-1017, 12-13.

[8.3] obtaining information of an unassigned resource unit via at least one of the bandwidth field of the HE-SIG-A and a subfield of HE-SIG-B of the received packet; and

163. As discussed below for [8.5], Josiam renders obvious that information of an unassigned resource unit is indicated via a combination of the bandwidth field of the HE-SIG-A and a resource unit allocation field in the HE-SIG-B common field ("a subfield of HE-SIG-B"). *See* [8.5]. For similar reasons, a POSITA would have understood that the information of the unassigned resource unit is obtained via at least one of the bandwidth field of HE-SIG-A and a subfield of HE-SIG-B of the received packet.

[8.4] decoding the received packet based on the bandwidth information and the information of the unassigned resource unit,

164. Josiam renders obvious decoding the received packet based on the PPDU bandwidth ("bandwidth information") and the information of the unassigned resource unit.

165. Josiam teaches decoding a received PPDU ("wireless packet"). SAMSUNG-1014, [0161] ("STA may use the indication in the bandwidth field signaled in the HE-SIG-A to decipher both the bandwidth of the PPDU and the location of the content channel that it may decode in the HE-SIG-B."), [0164]; SAMSUNG-1017, 12-14.

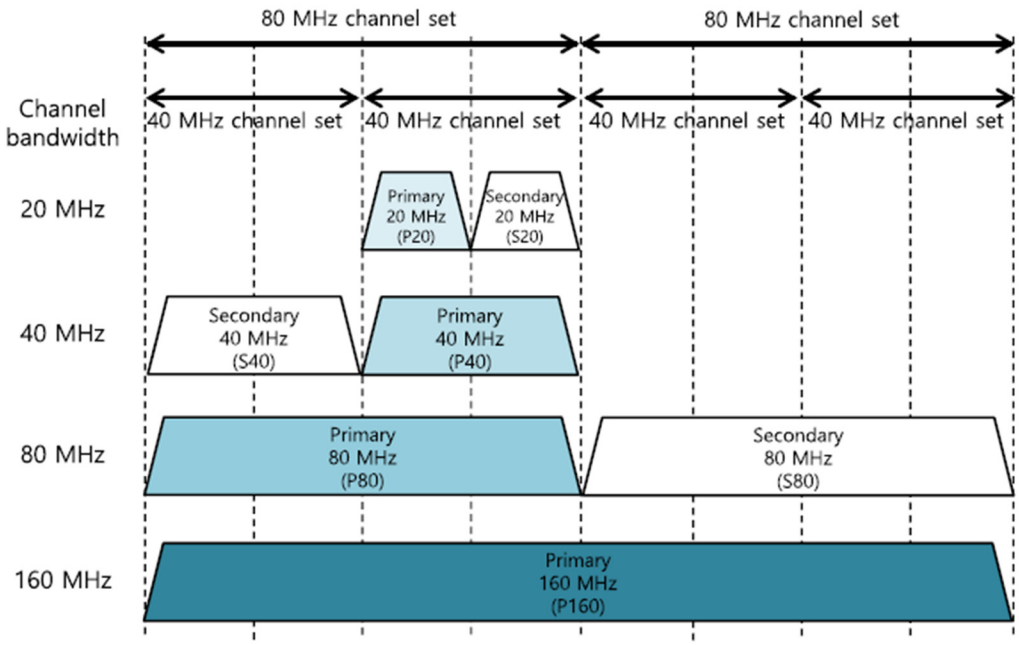
166. A POSITA would have understood that a received PPDU is decoded based on the PPDU bandwidth ("bandwidth information"). SAMSUNG-1014, [0161], [0164]; SAMSUNG-1017, 12-14. For example, Josiam teaches that the PPDU bandwidth is used to determine the length of the HE-SIG-B common field (specifically, the number of resource unit allocation fields) of the PPDU. SAMSUNG-1014, [0285]-[0287] ("***The number of RU allocation sub-fields in the HE-SIG-B common block field depends on the total PPDU bandwidth***."); SAMSUNG-1016, 6-7. Additionally, Josiam teaches that the PPDU bandwidth indicates the overall OFDMA tone plan (e.g., possible resource unit arrangements, guard tone locations, DC tone locations) of the PPDU. SAMSUNG-1014, [0133]-[0150], [0249]-[0263], Figs. 9-13, 35-37 (illustrating different OFDMA tone plans for different PPDU bandwidths); SAMSUNG-1016, 5-7, 9-10; SAMSUNG-1017, 11-15.

167. A POSITA would have also understood that the PPDU bandwidth informs a receiving station to which channels it should tune its receiver to receive

the PPDU. SAMSUNG-1023, [0027]; SAMSUNG-1024, [0025]; SAMSUNG-1031, 3-5; SAMSUNG-1034, 9; SAMSUNG-1040, 9. Specifically, a POSITA would have understood that a receiving station generally listens for incoming PPDUs on the primary 20 MHz channel, which has been prearranged between the stations within a basic service set (e.g., an AP and multiple STAs). SAMSUNG-1023, [0027] ("[T]he primary 20 MHz subchannel may be known by each device . . . in the coverage area, where each device may listen for the primary subchannel."); SAMSUNG-1024, [0025]; SAMSUNG-1031, 3-5; SAMSUNG-1034, 9 ("HE-SIG-A can deliver information about the PPDU to all STAs[.] STAs do not know about the operating bandwidth yet[.]").

168. When a station receives a PPDU on the P20 channel, it uses the bandwidth information indicated by the bandwidth field of HE-SIG-A to determine which 20 MHz channels within a frequency spectrum (e.g., the 5 GHz spectrum) may carry the PPDU. For example, if the bandwidth field indicates that the PPDU is an 80 MHz bandwidth, a receiving station would understand that the PPDU may be transmitted using the 20 MHz channel to the right of the P20 channel and two 20 MHz channels to the left of the P20 channel. SAMSUNG-1031, 3-5; SAMSUNG-1030, 15. A station then tunes its receiver to receive a waveform corresponding to the PPDU bandwidth. SAMSUNG-1045, 12 ("With or without [channel puncturing], the spectral mask should be identical as defined for the full

BW (20/40/80/160(80+80) masks), 16 ("[I]n channel puncturing modes, the transmitted waveforms only need to conform to the original 80MHz or 160MHz [spectral] masks."); SAMSUNG-1027, 23-25; SAMSUNG-1032, 11-15.



SAMSUNG-1031, Fig. 2

169. After tuning its receiver to the correct frequency, a station then uses the punctured channel information to indicate groups of tones (i.e., resource units) corresponding to an unused 20 MHz segment of the PPDU bandwidth that are not used in the transmission (e.g., because a particular 20 MHz segment of bandwidth is busy). SAMSUNG-1031, 4-15; SAMSUNG-1032, 11-15; SAMSUNG-1045, 11-17. A POSITA would have understood that a receiving station uses this information to determine that these resource units should be filtered or ignored

because no information is transmitted on them. SAMSUNG-1031, 4; SAMSUNG-1034, 9-15 ("Receiver can prepare for decoding accordingly with early identified RU structure."); SAMSUNG-1032, 12-15.

170. After determining which channels may carry the PPDU, a POSITA would have understood that a receiving station uses the information of punctured channels to determine which of these channels are not transmitted, and thus the receiver can determine which channels within the PPDU bandwidth may carry resource units allocated to the station and which channels to filter or ignore because no information is transmitted on them. SAMSUNG-1031, 4; SAMSUNG-1034, 9-15; SAMSUNG-1032, 12. A POSITA would have understood that by indicating the unused subchannels, a station may limit decoding to the used 20 MHz portions, thus reducing required processing power to decode the received PPDU. SAMSUNG-1035, 11.

171. Based on Josiam's teachings relating to the use of the PPDU bandwidth of the PPDU, a POSITA would have understood that the PPDU is decoded based on the PPDU bandwidth—and, specifically, the information it provides (e.g., length of the HE-SIG-B common field, the overall OFDMA tone plan, which channels to use to receive the PPDU).

172. Josiam also renders obvious that a received PPDU ("wireless packet") is decoded based on the information of an unassigned resource unit (e.g., a nulled

resource unit) *See* [8.5]. For example, a POSITA would have understood that a station decodes a received PPDU based on its resource unit assignment. SAMSUNG-1025, [0101]-[0103], Fig. 17; SAMSUNG-1021, [0101]; SAMSUNG-1022, [0051]; SAMSUNG-1031, 4-5.

173. Specifically, Josiam teaches that a station determines its resource unit assignment by comparing the position of a user-field that matches its station ID to the resource unit arrangement indicated by the 8-bit RU allocation subfield. SAMSUNG-1014, [0279]-[0289]; SAMSUNG-1016, 4-9; *see* SAMSUNG-1025, [0090]-[0093], Figs. 12-14. In PPDUs larger than 40MHz, user fields are split between the HE-SIG-B content channels. SAMSUNG-1014, [0286]-[0287]; SAMSUNG-1016, 3-7. When a resource unit is nulled (i.e., unassigned), a POSITA would have recognized two options for adjusting the HE-SIG-B user-specific field in response to a nulled resource unit.

174. First, a POSITA would have understood that no user fields corresponding to the nulled resource unit may be transmitted. SAMSUNG-1014, [0294]-[0296]; SAMSUNG-1016, 11; SAMSUNG-1025, [0089]-[0093], Figs. 12-14; SAMSUNG-1028, 13 ("At least 1 state is reserved in the 8 bit RU allocation subfield of the HE-SIG-B common field for "***no STA-specific information field assigned by the RU allocation subfield***."). In this case, a receiving station would adjust the alignment between its position in the user-specific field and the resource

unit arrangement information based on the information of an unassigned resource unit as part of decoding a received PPDU. SAMSUNG-1014, [0294]-[0296]; SAMSUNG-1016, 11; SAMSUNG-1025, [0089]-[0093], Figs. 12-14.

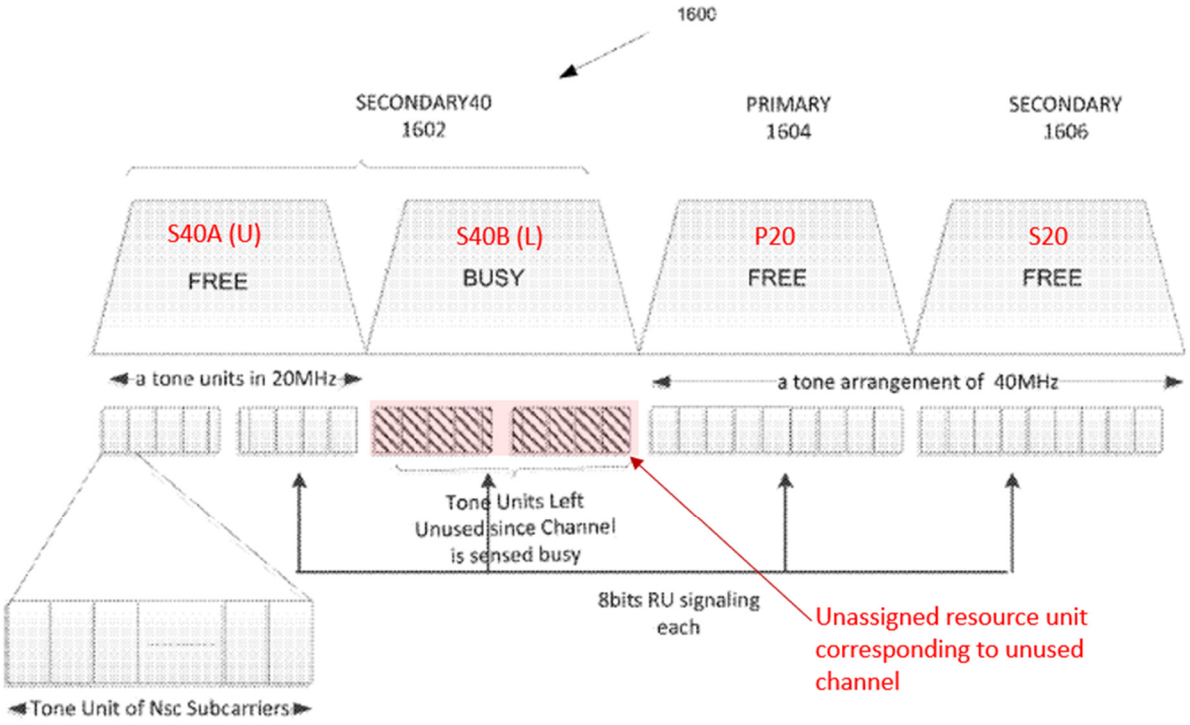
175. Second, a POSITA would have understood that a null or unassigned station ID may be included in the user field corresponding to the unassigned resource unit. SAMSUNG-1014, [0304]-[0306]; SAMSUNG-1016, 12; SAMSUNG-1025, [0089]-[0093], Figs. 12-14; SAMSUNG-1032, 14; *see* § X.A.4. Here, too, a POSITA would have understood that a receiving station uses the information of an unassigned resource unit to decode a received PPDU by skipping over the user field corresponding to the unassigned resource unit, and thus not attempt to decode the data in that resource unit. *Id.*

[8.5] wherein the information of the unassigned resource unit is indicated via a combination of the bandwidth field of the HE-SIG-A and a resource unit allocation field of the HE-SIG-B, and

176. Josiam renders obvious this limitation in at least two ways. First, as discussed below for [8.6], Josiam teaches indicating null channel information via the bandwidth field of HE-SIG-A and the RU signaling field in the HE-SIG-B common field. SAMSUNG-1014, [0155]-[0168]; SAMSUNG-1017, 12-15; *see* [8.6]. Josiam teaches that information of a null channel indicates information of an unassigned resource unit corresponding to the nulled channel because the resource units that fall under the channel segment left unused are not assigned to any user,

i.e., nulled. SAMSUNG-1014, [0139], [0151], [0154]; SAMSUNG-1017, 8 ("***Resource units of OFDMA that full [sic] under the channel segment left unused are nulled***. ***The nulling is always in units of resource units and not smaller***."); *see* SAMSUNG-1032, 11-15; SAMSUNG-1045, 11-17.

177. As one example, information of an unassigned resource unit may be indicated by the bandwidth field of HE-SIG-A indicating an 80MHz transmission and the number and location of the HE-SIG-B content channels. SAMSUNG-1014, [0155]-[0168]; SAMSUNG-1017, 12-15; *see* [8.6]. In a resource unit allocation field corresponding to a punctured channel (e.g., S40B in the illustration below), the 8-bit RU signaling information may signal that the punctured channel is unoccupied "by signaling ***an unused 242-tone RU***." SAMSUNG-1014, [0167]; SAMSUNG-1017, 15.



SAMSUNG-1014, Fig. 16 (annotated); SAMSUNG-1017, 17

178. Josiam also renders obvious that the information of an unassigned resource unit corresponding to a punctured channel is indicated via a combination of the bandwidth field of HE-SIG-A and the resource allocation field in the HE-SIG-B common field.

179. For example, Josiam teaches that a receiving station determines the number and arrangement of the resource unit allocation fields based on the total PPDU bandwidth (indicated by the bandwidth field), and a resource unit allocation field indicates a null 242-tone resource unit corresponding to a nulled channel within the PPDU bandwidth indicated by HE-SIG-A. SAMSUNG-1014, [0285]-

[0287]; SAMSUNG-1016, 6-7. As another example, Josiam teaches that the bandwidth field of HE-SIG-A indicates the number, location, and length (number of resource unit allocation fields) of the HE-SIG-B content channels, which may contain a resource unit allocation field that indicates a null 242-tone resource unit corresponding to a nulled channel within the PPDU bandwidth indicated by HE-SIG-A. SAMSUNG-1014, [0155]-[0168], [0285]-[0287]; SAMSUNG-1016, 6-7; SAMSUNG-1017, 12-15; *see* [8.4], [8.6]. I note that this mapping appears consistent with Wilus's infringement allegations. SAMSUNG-1004, 19-20.

180. Moreover, Josiam teaches that, in some instances, e.g., when S20 and/or S40B is punctured, the information of the punctured channel is indicated by *both* the bandwidth field of HE-SIG-A and the resource unit allocation field of HE-SIG-B. SAMSUNG-1014, [0167] ("In cases where a specific content channel-2 is signaled empty, the corresponding RU signaling information of the RUs that occupied the same bandwidth as the content channel signaled empty is signaled as unoccupied by transmitting the 8-bit RU signaling information. ***This information is redundant***, but this ensures the signaling structure of the HE-SIG-B remains unaltered."); SAMSUNG-1017, 15.

181. Second, Josiam teaches that the information of a nulled resource unit ("unassigned resource unit") adjacent to an unavailable channel is obtained via the bandwidth field of HE-SIG-A and the resource unit allocation field in the HE-SIG-

B common field. SAMSUNG-1014, [0139]-[0150], [0168], Figs. 10-12; SAMSUNG-1017, 8-11, 15. Josiam explains that "[s]ome RUs in the segment adjacent to the channel sensed busy, especially those that are closest to the channel segment sensed busy are also nulled to ensure compliance with spectral masks and out of band emission requirements. … [T]he amount of nulling in the used channel segment adjacent to the one being left unused depends on the type of RUs used to compose the OFDMA PPDU." SAMSUNG-1014, [0139]; SAMSUNG-1017, 8.

182. Josiam teaches that "the nulling of RUs on the edge of the occupied bands to align the tone-plan is derived based on the bandwidth signaling in the HE-SIG-A and the 8-bit RU signaling information [of the RU signaling field in the common field of HE-SIG-B]." SAMSUNG-1014, [0167]-[0168]; SAMSUNG-1017, 15. For example, Josiam teaches that, when the bandwidth field indicates puncturing of some channels (e.g., S20 and S40B) (SAMSUNG-1014, [0155]-[0166]; SAMSUNG-1017, 12-15), and the RU signaling field in the HE-SIG-B common field indicates the partitioning in used (available) channels adjacent to the punctured channel (e.g., into nine 26-tone resource units) (SAMSUNG-1014, [0138], [0156], [0165], [0168], [0281]-[0285]; SAMSUNG-1016, 5-10; SAMSUNG-1017, 6-7, 12-15), nulling of some of those resource units adjacent to the punctured channels may be "derived based on the bandwidth signaling in the HE-SIG-A [i.e., "bandwidth field"] and the 8-bit RU signaling information" in the

resource unit allocation field in HE-SIG-B common field. SAMSUNG-1014, [0168]; SAMSUNG-1017, 15; *see also* SAMSUNG-1014, [0143] ("[Nulling requirements] can be defined or implied."); SAMSUNG-1017, 9; *cf.* § X.A.4.

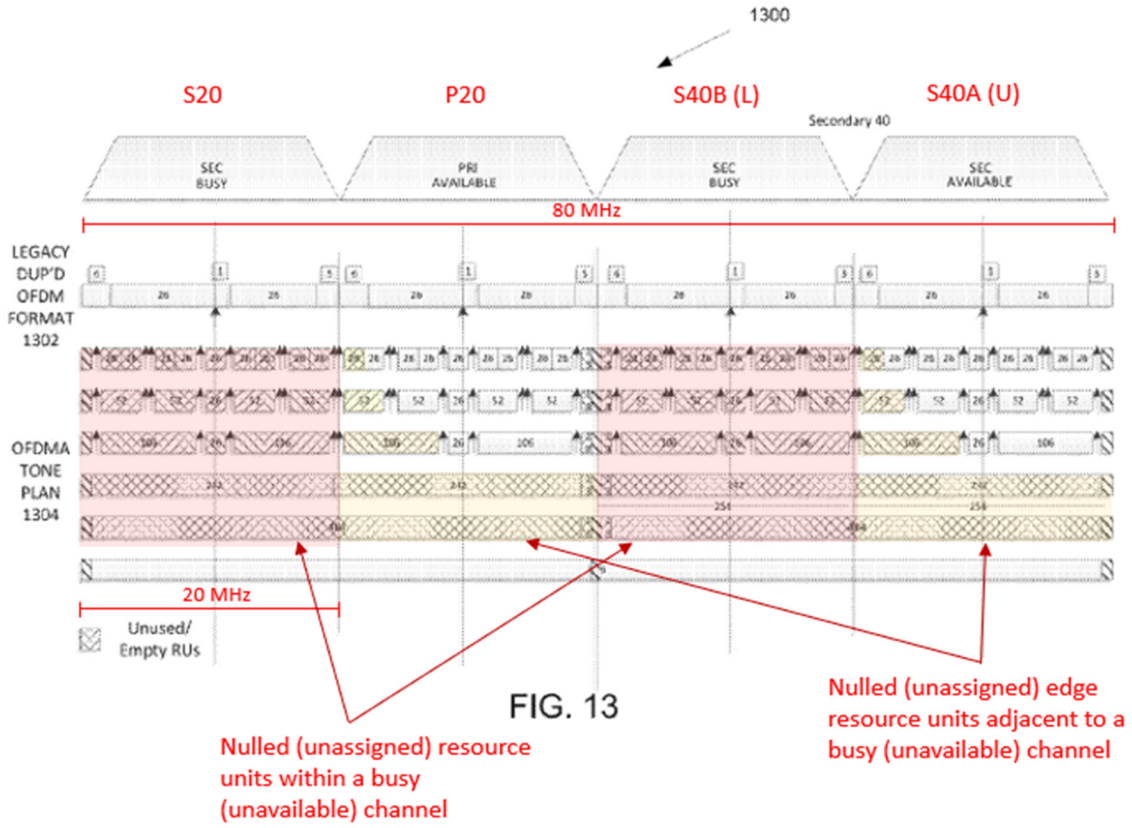


FIG. 13

SAMSUNG-1014, Fig. 13 (annotated); SAMSUNG-1017, 11

183. Moreover, as discussed below for [11], the information of a nulled edge resource unit may be additionally or alternatively obtained by way of a null station ID in the user-field of HE-SIG-B. *See* § X.A.4; SAMSUNG-1014, [0304]; SAMSUNG-1016, 12. Here, too, Josiam teaches that the information of the nulled edge resource unit ("an unassigned resource unit") is also indicated via a

combination of (1) the bandwidth field of HE-SIG-A, which indicates the number and arrangement of the resource unit allocation fields based on the total PPDU bandwidth and the number and location of the HE-SIG-B content channels (as discussed above), and (2) the RU signaling field in the HE-SIG-B common field, which indicates resource unit arrangement information. SAMSUNG-1014, [0154]-[0168], [0250]-[0287]; SAMSUNG-1016, 5-7, 9-10, 12; SAMSUNG-1017, 11-15.

[8.6] wherein the bandwidth field of the HE-SIG-A indicates channel information to be punctured within the bandwidth, and the resource unit allocation field indicates additional puncturing information for the unassigned resource unit within the bandwidth.

184. Josiam teaches a method for indicating whether one or more 20MHz channel segments that comprise an 80MHz or larger PPDU cannot be used because the channels are busy by nulling the resource unit corresponding to the busy channel. SAMSUNG-1014, [0134]-[0139]; SAMSUNG-1017, 8-11 ("Resource units of OFDMA that full [sic] under the channel segment left unused are nulled. The nulling is always in units of resource units and not smaller."). A POSITA would have understood that the channels indicated as unused within the PPDU bandwidth correspond to the claimed "channel information to be punctured" and "puncturing information." SAMSUNG-1001, 42:5-15; SAMSUNG-1030, 211; SAMSUNG-1031, 4-5; SAMSUNG-1045, 11-17.

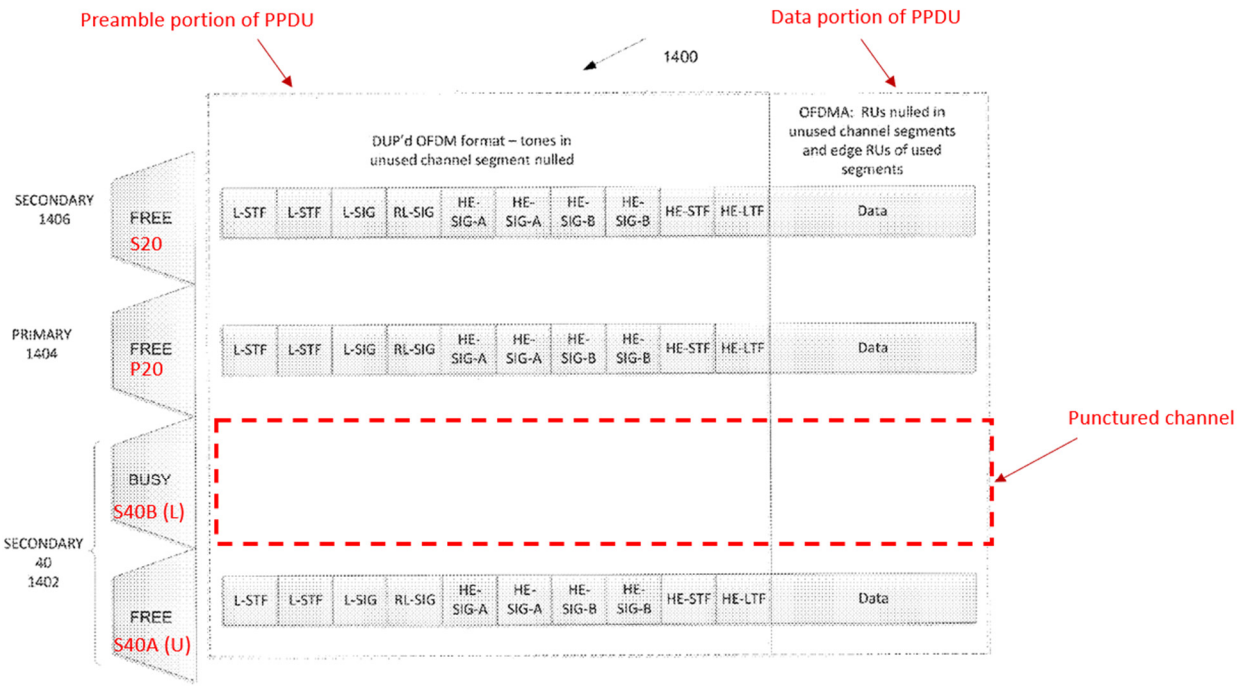


FIG. 14

SAMSUNG-1014, Fig. 14 (annotated), SAMSUNG-1017, 12

185. Josiam states that "SIG-A fields could carry the code indicating the channels being left unused" (i.e., punctured). SAMSUNG-1014, [0151]; SAMSUNG-1017, 11. However, as Josiam explains, the "bandwidth signaling is constrained in bit width to indicate all combinations of used/unused 20 MHz segments in the PPDU bandwidth." SAMSUNG-1014, [0155]; SAMSUNG-1017, 12-13. To signal the availability of each 20MHz channel in PPDU bandwidths up to 160MHz, "7 bits are needed in the bandwidth field." *Id.* But according to Josiam, "there is no room for 7 bits of bandwidth signaling in HE-SIG-A." *Id.*

186. Thus, Josiam discloses a method of splitting indication of available and unavailable channels (i.e., channels to be punctured) between HE-SIG-A and

HE-SIG-B . . . specifically using the RU signaling field [i.e., 'resource unit allocation field'] of the HE-SIG-B common field." SAMSUNG-1014, [0155]-[0168]; SAMSUNG-1017, 12-15. Josiam explains that such a method "may take advantage of the duplication structure in the HE-SIG-B to signal the unused 20 MHz segments in 80 MHz and 160 MHz PPDU." SAMSUNG-1014, [0156]; SAMSUNG-1017, 12. For example, "[s]ince the duplicated channels carry the exact same information, as long as one copy of each content channel is received (e.g., when applicable) or the ***unavailability of one of the content channels is indicated in the bandwidth field***, it may be possible to signal the use or disuse of a 20 MHz segment in both 80 MHz and 160 MHz PPDU." SAMSUNG-1014, [0161]; SAMSUNG-1017, 12-13.

187. Josiam teaches using the "bandwidth signaling sub-field [i.e., 'bandwidth field'] in HE-SIG-A field of a HE-multi-user (MU) PPDU [to] indicate[] both the PPDU bandwidth being used for OFDMA and availability of the HE-SIG-B content channels." SAMSUNG-1014, [0163]; SAMSUNG-1017, 14. As one example, Josiam proposes using a 3-bit bandwidth field, which maps "to the PPDU bandwidth and the HE-SIG-B content channel indication." SAMSUNG-1014, [0163]-[0166], Table 1; SAMSUNG-1017, 13-15.

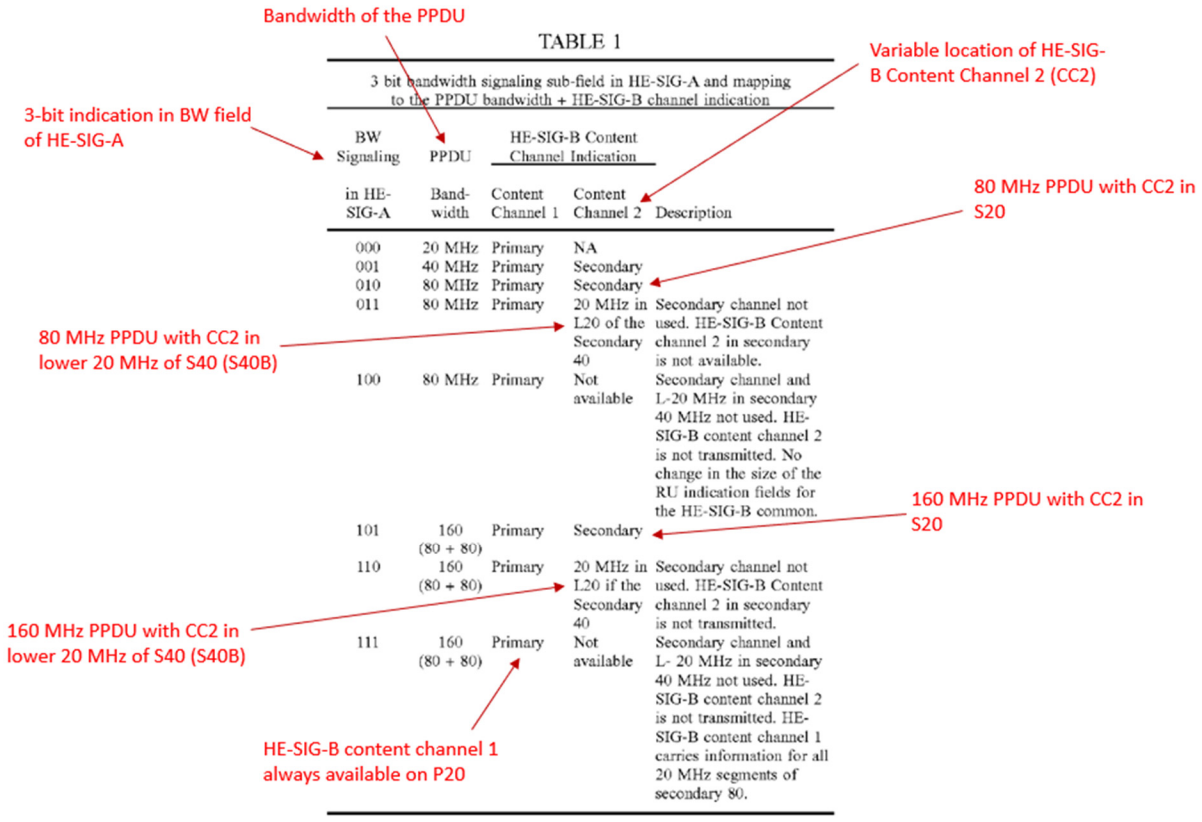


TABLE 1

3 bit bandwidth signaling sub-field in HE-SIG-A and mapping to the PPDU bandwidth + HE-SIG-B channel indication

BW Signaling in HE-SIG-A	PPDU Band-width	HE-SIG-B Content Channel Indication: Content Channel 1	HE-SIG-B Content Channel Indication: Content Channel 2	Description
000	20 MHz	Primary	NA	
001	40 MHz	Primary	Secondary	
010	80 MHz	Primary	Secondary	
011	80 MHz	Primary	20 MHz in L20 of the Secondary 40	Secondary channel not used. HE-SIG-B Content channel 2 in secondary is not available.
100	80 MHz	Primary	Not available	Secondary channel and L-20 MHz in secondary 40 MHz not used. HE-SIG-B content channel 2 is not transmitted. No change in the size of the RU indication fields for the HE-SIG-B common.
101	160 (80 + 80)	Primary	Secondary	
110	160 (80 + 80)	Primary	20 MHz in L20 if the Secondary 40	Secondary channel not used. HE-SIG-B Content channel 2 in secondary is not transmitted.
111	160 (80 + 80)	Primary	Not available	Secondary channel and L- 20 MHz in secondary 40 MHz not used. HE-SIG-B content channel 2 is not transmitted. HE-SIG-B content channel 1 carries information for all 20 MHz segments of secondary 80.

SAMSUNG-1014, Table 1 (annotated); SAMSUNG-1017, 13-15

188. Josiam explains that "[t]he bandwidth and content channel indication together tell the STA where the signaling for the OFDMA resource units is carried in the HE-SIG-B." SAMSUNG-1014, [0164]-[0166]; SAMSUNG-1017, 13-14. For example, "[w]hen the bandwidth signaling field indicates 011 (e.g., the PPDU bandwidth is 80 MHz and the secondary 20 MHz channel is not used), HE-SIG-B content channel 2 is carried in the [L][2]-20 MHz segment of the secondary 40." *Id*.

[2] Josiam states, "HE-SIG-B content channel 2 is carried in the U-20 MHz segment of the secondary 40." SAMSUNG-1014, [0165]; SAMSUNG-1017, 14-15. In my opinion, "U" is errata

"Further information on the 20 MHz segment (e.g., [U]-20) used or unused [i.e., ***additional puncturing information***] is carried in RU signaling of the HE-SIG-B common channel." *Id.*

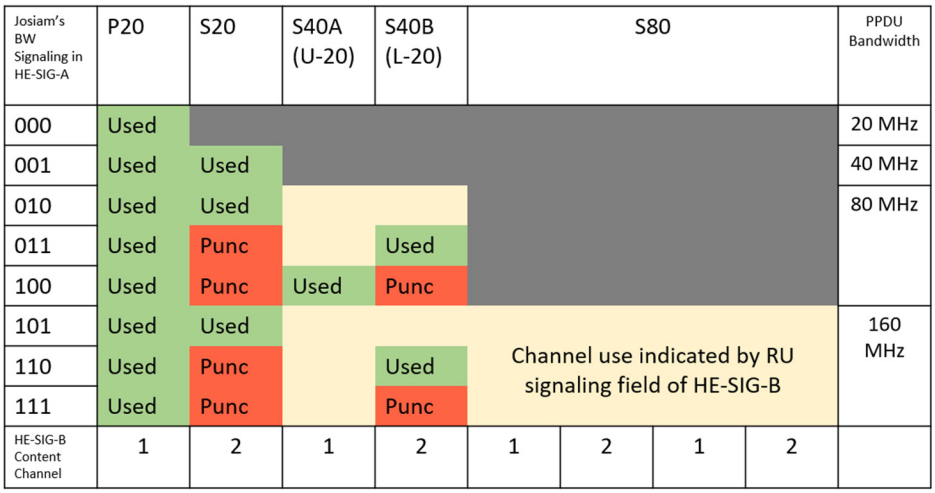
189. Josiam explains that the "8-bit RU signaling information [carried in the RU signaling field ('resource unit allocation field')] signals an unoccupied 20 MHz segment by signaling an ***unused 242 tone RU***." SAMSUNG-1014, [0167]; SAMSUNG-1017, 15.

190. Using 3 bits for the bandwidth field of HE-SIG-A, a total of eight channel configurations may be indexed. Josiam's bandwidth indication scheme includes two options for 20 and 40 MHz contiguous PPDUs. SAMSUNG-1014, [0154]-[0168], Table 1; SAMSUNG-1017, 13-15. That leaves six options remaining. As depicted below, for 80 and 160 MHz PPDUs, Josiam's scheme chooses to include three options for decoding the HE-SIG-B content channel 2: (1) decode the content channel from the secondary 20 MHz (S20), (2) decode the content channel from the lower 20 MHz of S80 (S40B), or (3) both S20 and S40B

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and should read "L" as is it does in the corresponding entry in Table 1. SAMSUNG-1014, Table 1; SAMSUNG-1016, 13-15. In Josiam's notation, the lower 40 MHz corresponds to the 20MHz channel in the S40 (S40B), which carries SIG-B content channel 2. *See* SAMSUNG-1014, Fig. 15; SAMSUNG-1017, Fig. 13.

are busy, so no content channel 2 is transmitted. *Id.* In some cases, such as indication "100," the remaining channels may be deduced considering the other bandwidth options, e.g., if S40A was additionally punctured, a 20 MHz PPDU would be indicated using "000." *Id.* In other cases, the additional unused channels are indicated using the RU signaling field of HE-SIG-B. *Id.*



191. A POSITA would have understood Josiam's method of splitting signaling between HE-SIG-A and HE-SIG-B as teaching this limitation. Specifically, Josiam teaches that the bandwidth field indicates a PPDU bandwidth and whether some of the channels in the primary 80MHz bandwidth are not available ("channel information to be punctured within the bandwidth"). SAMSUNG-1014, [0164]; SAMSUNG-1017, 14. Josiam further teaches that the RU signaling field ("resource unit allocation field") may indicate additional unavailable 20MHz segments by signaling an unused 242-tone resource unit within

the bandwidth of the PPDU (i.e., the resource unit allocation field indicates additional puncturing information for the unassigned resource unit within the bandwidth). SAMSUNG-1014, [0156], [0165]-[0167]; SAMSUNG-1017, 12-15.

192. Additionally, where the unassigned resource unit is a nulled edge resource unit, a POSITA would have understood that the additional puncturing information is for the unassigned resource unit within the bandwidth (e.g., nulled edge resource unit) because Josiam teaches that the nulled edge resource unit is adjacent to a nulled (i.e., punctured) channel indicated by the resource unit allocation field. SAMSUNG-1014, [0139]-[0150], [0168], Figs. 10-12; SAMSUNG-1017, 8-11, 15; *see* [8.5].

2. Claim 9

[9] The wireless communication method of claim 8, wherein the resource unit allocation field indicates a specific resource unit not assigned to a user through a predetermined index.

193. Josiam renders obvious that the resource unit allocation field (e.g., RU signaling field) indicates a specific resource unit not assigned to a user (e.g., an unused 242 tone resource unit) through a predetermined index (e.g., RU allocation index).

194. As discussed above for [8.6], Josiam teaches indicating that a particular 20MHz channel within a PPDU is not available "by using the RU signaling field [i.e., ***resource unit allocation field***] of the HE-SIG-B common

field." SAMSUNG-1014, [0156], [0165]-[0167]; SAMSUNG-1017, 12-15; *see* § X.A.1. For example, the "8-bit RU signaling information signals an unoccupied 20 MHz segment by signaling an unused 242 tone RU," i.e., ***a specific resource unit not assigned to a user***. SAMSUNG-1014, [0167]; SAMSUNG-1017, 15; *see also* SAMSUNG-1014, [0139]; SAMSUNG-1017, 8 ("Resource units of OFDMA that full [sic] under the channel segment left unused are nulled. ***The nulling is always in units of resource units and not smaller***.").

195. A POSITA would have understood that Josiam's 8-bit RU signaling field signals this unused 242-tone resource unit through a predetermined index. Josiam elsewhere teaches that the RU allocation field may indicate an 8-bit value corresponding to an entry in a resource unit allocation index (i.e., a predetermined index), and one such entry corresponds to a null allocation. SAMSUNG-1014, [0279], [0281], [0285]-[0286], [0294]-[0296]; SAMSUNG-1016, 5-10. For example, "the RU allocation index 11111111 signals a null allocation." SAMSUNG-1014, [0295], Table; SAMSUNG-1016, 10.

TABLE 6

8-bit indices	RU size	Number of entries	
11 0 01yyy	484	8	
11 0 10yyy	996	8	
11 0 11yyy	2*996	8	
11 1 11111	Null	1	⇦No load balancing is used
	Allocation		

SAMSUNG-1014, Table 6; SAMSUNG-1016, 10.

196. A POSITA would have understood that this RU allocation index may signal a null 242 tone resource unit corresponding to a punctured 20MHz channel, as Josiam teaches earlier. SAMSUNG-1014, [0167]; SAMSUNG-1017, 15. Indeed, this technique would have been well known to a POSITA. SAMSUNG-1027, 8-12; SAMSUNG-1028, 10-13; SAMSUNG-1023, [0044]; SAMSUNG-1024, [0038]. For example, the December 2015 802.11ax draft standard had adopted an RU allocation field in HE-SIG-B with an 8-bit value corresponding to indices in a predetermined resource unit allocation index. SAMSUNG-1027, 8-12. By March 2016, the draft standard included that "[a]t least 1 state is reserved in the 8 bit RU allocation subfield of the HE-SIG-B common field for 'no STA-specific information field assigned by the RU allocation subfield.'" SAMSUNG-1028, 10-13.

197. Alternatively, it would have been obvious for a POSITA to include

one or more special entries in the RU allocation index to indicate that a specific size resource unit is nulled. Josiam teaches that RU allocation signaling indices may indicate "RU sizes whose width span larger than 20 MHz," i.e., larger than 242-tones. SAMSUNG-1014, [0292]; SAMSUNG-1016, 9. For example, Josiam teaches that the RU allocation index may include RU sizes corresponding to 242, 484, and 996-tone resource units. SAMSUNG-1014, Table 4; SAMSUNG-1016, 6. A POSITA would have found it obvious to include entries that indicate a specific resource unit of 242-tone or larger is punctured. *See also* SAMSUNG-1016, 10 ("***[A] null allocation for each RU size can be encoded in an index individually. For example 11101000 could indicate a null allocation for a 484 tone RU, 11110000 could indicate a null allocation for a 996 tone RU and 11111000 could indicate a null allocation for a 2*996 tone RU***. When these null allocations are signaled, they signal both the RU size and the fact that there are no user fields corresponding to the RU in the HE-SIG-B content channel in which it is carried.").

198. By including null allocation indices corresponding to resource unit sizes larger than 242-tones, a single RU allocation entry may indicate that more than one 20MHz channel is punctured. SAMSUNG-1016, 10. I believe a POSITA would have found this particularly useful in a 160MHz PPDU when both S20 and S40B are punctured, and HE-SIG-B content channel 1 carries HE-SIG-B information for all 8 channels. SAMSUNG-1014, [0166]; SAMSUNG-1017, 15.

By specifying that a resource unit larger than 242-tones is punctured, multiple corresponding 20MHz channels may be indicated as punctured using the same resource unit allocation field, thus reducing signaling burden in the HE-SIG-B field. SAMSUNG-1016, 10.

3. Claim 10

[10] The wireless communication method of claim 9, wherein the specific resource unit not assigned to a user is at least one of a 242-tone resource unit, a 484-tone resource unit, and a 996-tone resource unit.

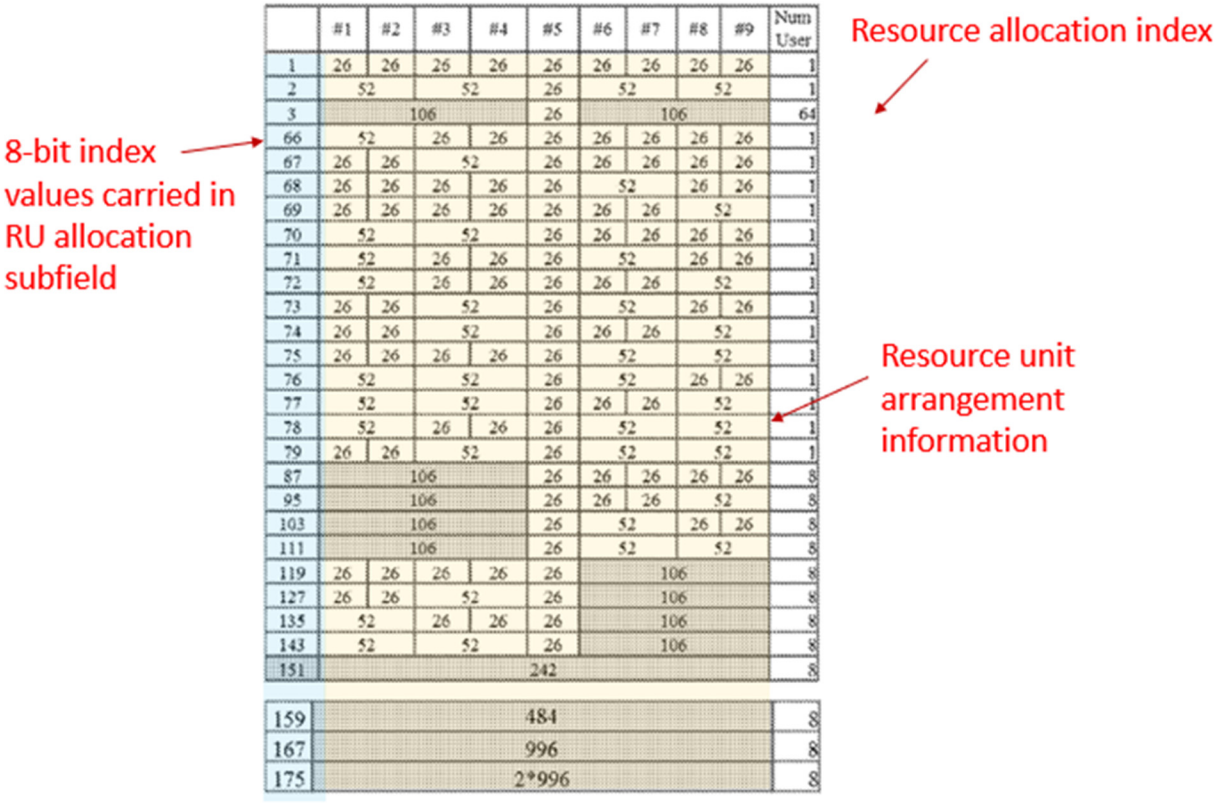
199. As discussed for [8.6] and [9], Josiam teaches that the specific resource unit not assigned to a user (e.g., an "unused 242 tone RU") is at least a 242-tone resource unit. SAMSUNG-1014, [0167]; SAMSUNG-1017, 15; *see* §§ X.A.1-2. Additionally, for the reasons discussed above for [9], it would have been obvious that the specific resource unit is a 242, 484, or 996-tone resource unit. SAMSUNG-1014, Table 4; SAMSUNG-1016, 6, 10; *see* § X.A.2.

4. Claim 11

[11] The wireless communication method of claim 8, wherein the information of the unassigned resource unit is obtained through resource unit arrangement information indicated by the resource unit allocation field of the HE-SIG-B and a Null STA ID contained in a user field corresponding to a specific resource unit in the resource unit arrangement.

200. Josiam renders obvious this limitation. As discussed for [8.5], Josiam teaches that a station may determine that a specific resource unit is assigned to the station by comparing the position of a user field that matches its station ID to resource unit arrangement information indicated by a resource unit allocation field.

SAMSUNG-1014, [0279]-[0289], Table 4; SAMSUNG-1016, 4-9; *see* § X.A.1.



	#1	#2	#3	#4	#5	#6	#7	#8	#9	Num User
1	26	26	26	26	26	26	26	26	26	1
2	52		52		26	52		52		1
3	106				26	106				64
66	52		26	26	26	26	26	26	26	1
67	26	26	52		26	26	26	26	26	1
68	26	26	26	26	26	52		26	26	1
69	26	26	26	26	26	26	26	52		1
70	52		52		26	26	26	26	26	1
71	52		26	26	26	52		26	26	1
72	52		26	26	26	26	26	52		1
73	26	26	52		26	52		26	26	1
74	26	26	52		26	26	26	52		1
75	26	26	26	26	26	52		52		1
76	52		52		26	52		26	26	1
77	52		52		26	26	26	52		1
78	52		26	26	26	52		52		1
79	26	26	52		26	52		52		1
87	106				26	26	26	26	26	8
95	106				26	26	26	52		8
103	106				26	52		26	26	8
111	106				26	52		52		8
119	26	26	26	26	26	106				8
127	26	26	52		26	106				8
135	52		26	26	26	106				8
143	52		52		26	106				8
151	242									8
159	484									8
167	996									8
175	2*996									8

SAMSUNG-1016, Fig. 8 (annotated)[3]

201. Josiam further teaches that the station ID corresponding to a specific resource unit may be set to a null station ID to indicate that the resource unit is nulled (i.e., unassigned). SAMSUNG-1014, [0304]; SAMSUNG-1016, 12. Specifically, Josiam explains that "a null allocation is indicated in the user

[3] This figure is also reproduced in SAMSUNG-1014 as Table 4 but is used here for readability purposes.

subfields," which "may be done by indicating a null STA-ID or a[] STA-ID determined [] by the AP that is not yet allocated." *Id.* Indeed, a POSITA would have understood that, by setting the station ID to a null value or an ID not assigned to any station, no stations would attempt to decode the corresponding resource unit. SAMSUNG-1025, [0089]-[0093], Figs. 12-14; SAMSUNG-1032, 14. I note that Applicant did not dispute the Examiner's finding that Josiam teaches this limitation during prosecution. SAMSUNG-1002, 62-63 (citing SAMSUNG-1014, [0304]-[0306]).

202. Here, a POSITA would have found it obvious to use Josiam's null station ID method to indicate information of an unassigned resource unit (e.g., nulled edge resource unit). As discussed above for [8.5], the information of an unassigned resource unit may be information of a nulled edge resource unit adjacent to a channel to be punctured, and this information may be "derived based on the bandwidth signaling in the HE-SIG-A and the 8-bit RU signaling information of the RU signaling field in the common field of HE-SIG-B]." SAMSUNG-1014, SAMSUNG-1014, [0168]; SAMSUNG-1017, 15; *see* § X.A.1. In addition or as an alternative to this method, a POSITA would have found it obvious to obtain information of a nulled resource unit by way of a null station ID corresponding to a specific resource unit in the RU arrangement, as taught by Josiam. SAMSUNG-1014, [0304]; SAMSUNG-1016, 12.

203. Particularly, a POSITA would have understood that, where an edge resource unit is nulled, it would have been advantageous to nonetheless include a user-field for that edge resource unit to preserve the HE-SIG-B structure and thus simplify receiver implementation. A POSITA would have understood that while information of a nulled edge resource unit may be derived from predefined rules based on the channel puncturing information, this would require additional decoding steps (and thus processing power) for a receiving station to properly decode the received PPDU. By contrast, when information of a nulled edge resource unit is indicated via a null station ID, no additional decoding steps would be needed at the receiving station. Instead, a receiving station would simply skip the unassigned resource unit because it is not assigned to that station as it does for resource units assigned to other stations. SAMSUNG-1025, [0089]-[0093], Figs. 12-14.

204. A POSITA would have been further motivated to indicate a null edge resource unit using a null station ID because it would offer more flexibility compared to relying on predefined rules to derive the null edge resource unit from the punctured channel information. For example, a POSITA would have understood that out-of-band emission requirements may vary based on a jurisdiction's regulatory requirements (such as the specific frequency sub-band, indoor versus outdoor use, and presence of military and civilian radar systems) and

that these regulations may change over time. SAMSUNG-1047, 16-17, 20-24, 31-32, 42. By indicating a nulled edge resource unit using a null station ID, the nulling requirement may be determined by the AP based on the specific operating environment. I note that Applicant did not dispute the Examiner's finding that using a null station ID "would allow flexibility in managing RU allocation." SAMSUNG-1002, 62-63.

205. A POSITA would have also found it obvious to indicate a nulled edge resource unit using a null station ID because it merely reflects the simple substitution of one known element for another, and the result would have been predictable because a receiving station behaves in the same way as if an unassigned resource unit was assigned to another station. Indeed, using a blank or null station ID to indicate a nulled or otherwise unassigned resource unit was well known in the field well before May 14, 2016. SAMSUNG-1025, [0090]-[0092]; SAMSUNG-1032, 14. For example, Chen describes two alternative methods for indicating an unassigned resource unit: using a "special (e.g. blank or null) PAID[4]"

[4] A partial AID (PAID) is a form of station ID carried in the user-specific part of HE-SIG-B. SAMSUNG-1025, [0033], [0064]; SAMSUNG-1046, 2:43-63 ("IEEE 802.11ac defines a partial AID (association identifier) field that provides an indication to the client whether or not a frame (packet) is intended for that client."). A POSITA would have understood that a null PAID

or using additional non-allocation information to indicate an unassigned resource unit and then deriving the station's correct resource unit allocation based on this information. SAMSUNG-1025, [0089]-[0093], Figs. 12-14.

206. Thus, a POSITA would have understood Josiam as rendering obvious that the information of the unassigned resource unit is obtained through resource unit arrangement information indicated by the resource unit allocation field of the HE-SIG-B and a Null STA ID contained in a user field corresponding to a specific resource unit in the resource unit arrangement.

5. Claim 12

[12] The wireless communication method of claim [11],[5] wherein the specific resource unit is at least one of a 26-tone resource unit, a 52-tone resource unit, and a 106-tone resource unit.

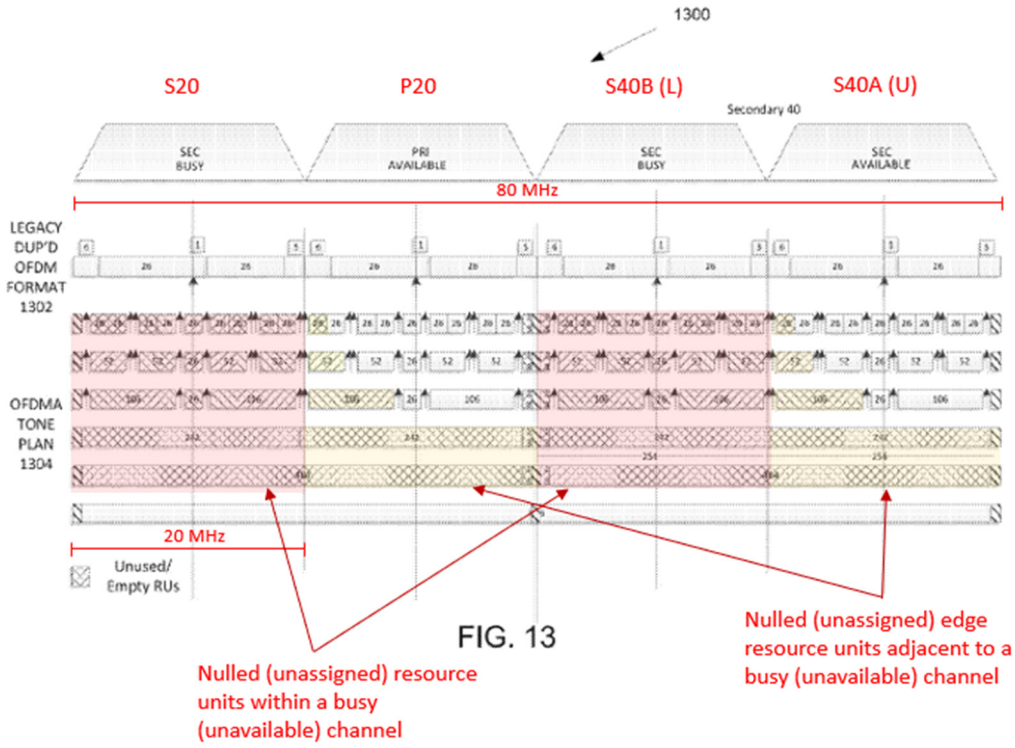
207. Josiam teaches that the resource units in the resource unit arrangement may indicate a specific resource unit of 26, 52, or 106 tones. SAMSUNG-1014, Table 4; SAMSUNG-1016, Fig. 8. Moreover, where the information of an unassigned resource unit is information of a nulled edge resource unit, Josiam teaches that the specific resource unit would correspond to at least a 26-tone, 52-

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corresponds to the claimed "Null STA ID." SAMSUNG-1001, 12:50-54 ("The identification information of the STA includes at least one of an association ID (AID), a partial AID, and a MAC address of the STA.").

[5] *See supra* note 1.

tone, or 106-tone resource unit. SAMSUNG-1014, [0137]-[0148] ("***A 26 tone[] RU that is the closest to the edge of the channel being nulled is the smallest RU size that needs to be nulled or left unused in the used band***."), Figs. 9-10 (illustrating nulled edge RUs of 26, 52, and 106-tone sizes); SAMSUNG-1017, 6-11.



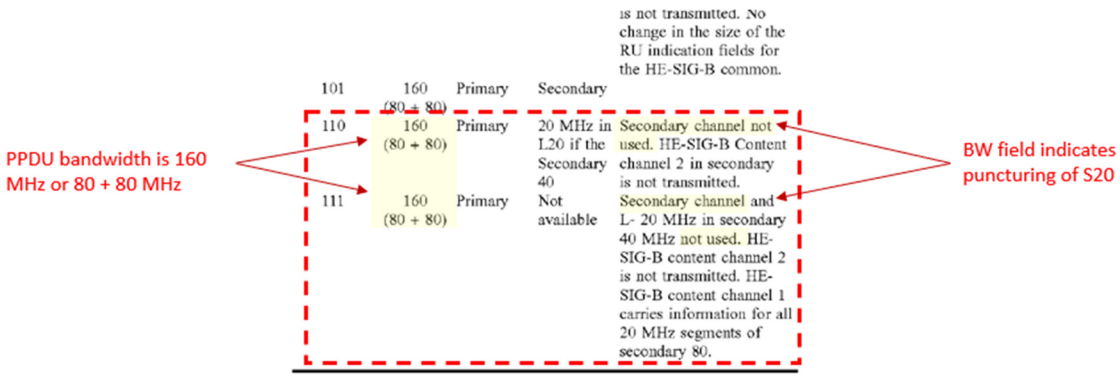
SAMSUNG-1014, Fig. 13 (annotated); SAMSUNG-1017, Fig. 11

6. Claim 14

[14] The wireless communication method of claim 8, wherein when the bandwidth field indicates puncturing of a secondary 20 MHz channel within a bandwidth of 160 MHz or 80+80 MHz or puncturing of at least one of two 20 MHz channels in a secondary 40 MHz channel within a bandwidth of 160 MHz

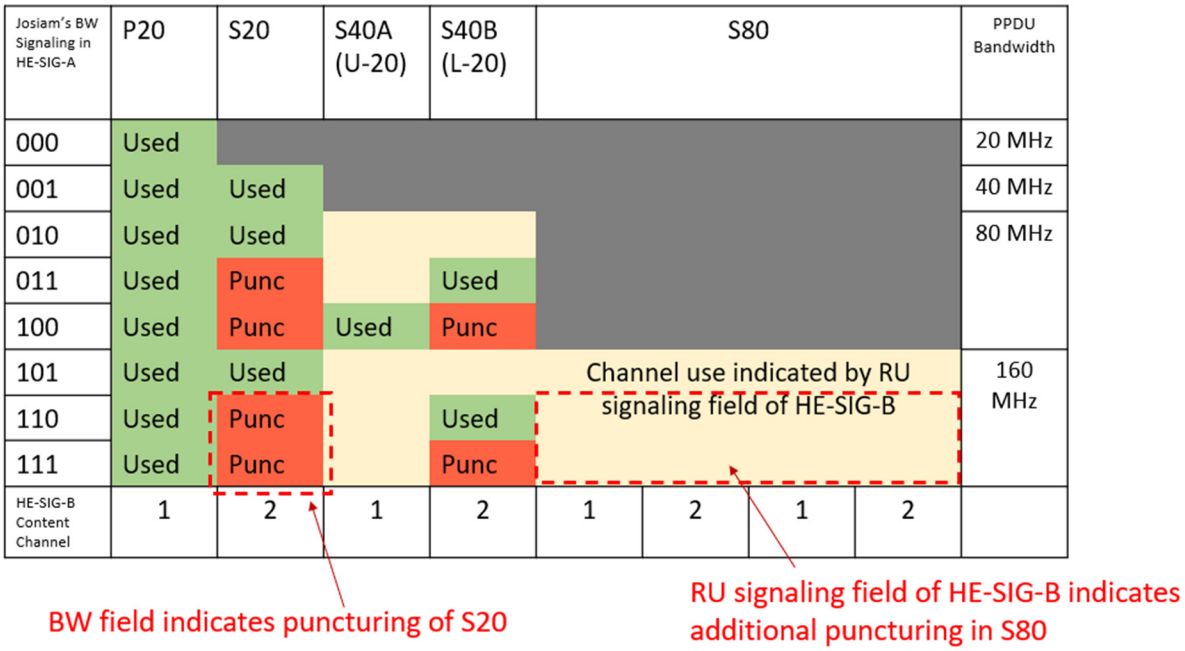
or 80+80 MHz, the resource unit allocation field indicates additional puncturing in a secondary 80 MHz channel.

208. Josiam teaches this limitation. As discussed for [8.6], Josiam teaches that the bandwidth field of HE-SIG-A indicates channel information to be punctured within the bandwidth, and the RU signaling field (i.e., resource unit allocation field) indicates additional puncturing information. SAMSUNG-1014, [0155]-[0168]; SAMSUNG-1017, 12-15; *see* § X.A.1. A POSITA would have understood that, when Josiam's bandwidth field indicates puncturing of a secondary 20MHz channel within a bandwidth of 160MHz or 80 + 80MHz (e.g., Josiam's bandwidth indication is set to "110" or "111"), Josiam's RU signaling field indicates additional puncturing in the S80 channel. SAMSUNG-1014, [0155]-[0168], Table 1; SAMSUNG-1017, 12-15.

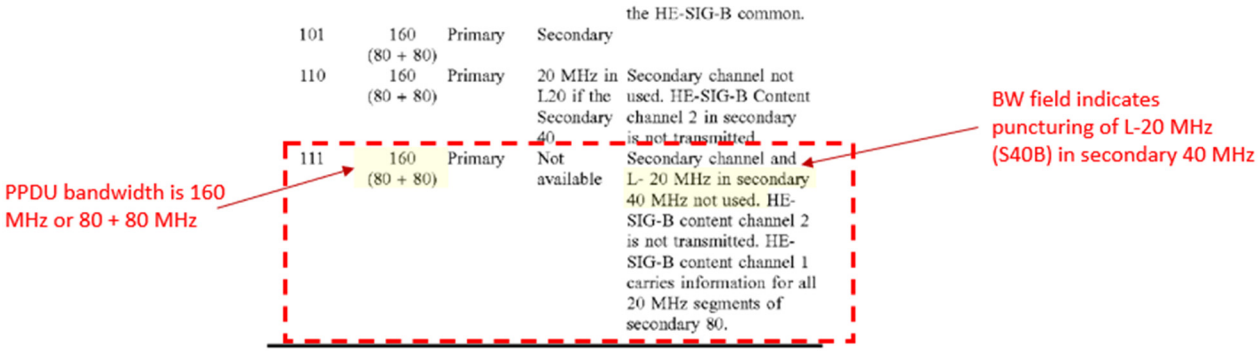


				is not transmitted. No change in the size of the RU indication fields for the HE-SIG-B common.
101	160 (80 + 80)	Primary	Secondary	
110	160 (80 + 80)	Primary	20 MHz in L20 if the Secondary 40	Secondary channel not used. HE-SIG-B Content channel 2 in secondary is not transmitted.
111	160 (80 + 80)	Primary	Not available	Secondary channel and L- 20 MHz in secondary 40 MHz not used. HE-SIG-B content channel 2 is not transmitted. HE-SIG-B content channel 1 carries information for all 20 MHz segments of secondary 80.

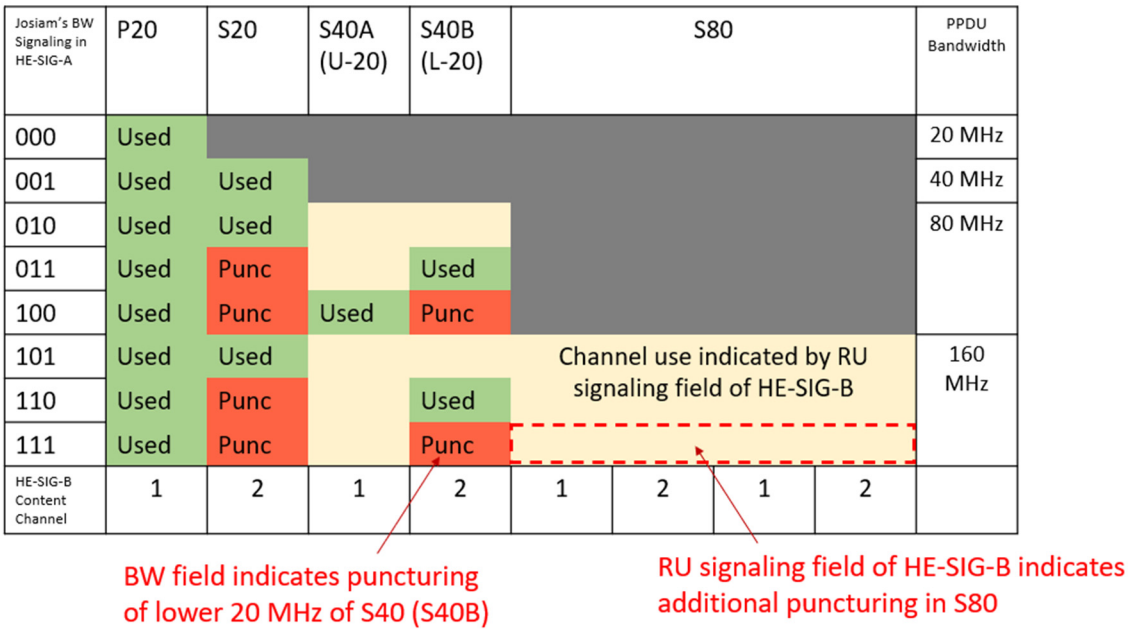
SAMSUNG-1014, Table 1 (annotated); SAMSUNG-1017, 13-14



209. Additionally or alternatively, a POSITA would have understood that, when Josiam's bandwidth field indicates puncturing of at least one of two 20MHz channels in a secondary 40MHz channel within a bandwidth of 160MHz or 80 + 80MHz (e.g., Josiam's bandwidth indication is set to "111"), Josiam's RU signaling field indicates additional puncturing in the S80 channel. SAMSUNG-1014, [0155]-[0168], Table 1; SAMSUNG-1017, 12-15.



SAMSUNG-1014, Table 1 (annotated); SAMSUNG-1017, 13-14



7. Claims 1-5 and 7

210. Claims 1-5 and 7 require "[a] wireless communications terminal, the terminal comprising: a processor; and a communication unit, wherein the processor is configured to" perform steps corresponding to the methods of claims 8-12, 14, respectively. To the extent the preamble of claim 1 is limiting, Josiam discloses "a station (STA) in a wireless local area network (WLAN)." SAMSUNG-1014, [0006]; SAMSUNG-1016, 1-6, 9-10; SAMSUNG-1017, 1-2, 7-8, 11-13. Josiam further discloses that the station includes "a radio frequency (RF) transceiver 210" and "a controller/processor 240." *Id.*, [0095]. The RF transceiver 210 (***communication unit***) is configured to receive a PPDU (***wireless packet***). SAMSUNG-1014, [0097]. The controller/processor 240 (***processor***) includes "processing circuitry configured to provide efficient wideband operations in

WLANs." SAMSUNG-1014, [0103].

211. Although Josiam's provisional applications (SAMSUNG-1015-SAMSUNG-1017) do not explicitly disclose that the stations have a processor and a communications unit, a POSITA would have understood that the stations described in Josiam's provisional applications require a processor. For example, Josiam's January 12, 2016 and April 27, 2016 provisional applications state that the stations receive and decode a wireless packet. SAMSUNG-1016, 1-6, 9-10; SAMSUNG-1017, 1-2, 7-8, 11-13. Josiam's April 27 disclosure specifically teaches that a STA "process[es] a 160MHz PPDU." SAMSUNG-1017, 13.

212. Based on these disclosures in the Josiam provisional applications, a POSITA would have understood that a station necessarily has a communication device (e.g., RF transceiver 210) to receive a wireless packet (e.g., PPDU) and a processor (e.g., controller/processor 240) to perform at least the decoding of the received wireless packet. Moreover, a POSITA would have found it obvious to include a processor and a communications device to perform the methods disclosed in Josiam's provisional applications.

213. A POSITA would have understood that, without such hardware, the station would be unable to perform the functions described in the Josiam provisional applications. For similar reasons as those described above with respect to claims 8-12 and 14, a POSITA would have understood Josiam as rendering

obvious a wireless communication terminal (e.g., a station) having a processor (e.g., controller/processor 240), a communications unit (e.g., RF transceiver 210), wherein the processor is configured to perform the steps recited in the remaining limitations of claim 1 and claims 2-4 and 7.

B. Ground 1B – Combination of Josiam and Kim renders obvious claims 1-7 and 13 by May 14, 2016

214. All of my opinions with respect to Ground 1B (§ X.B) are from the vantage point of a POSITA as of the Critical Date (May 14, 2016).

1. Claim 13

[13] The wireless communication method of claim 8, wherein when the bandwidth field indicates puncturing of one of two 20 MHz channels in a secondary 40 MHz channel within a bandwidth of 80 MHz or puncturing of at least one of two 20 MHz channels in a secondary 40 MHz channel within a bandwidth of 160 MHz or 80+80 MHz, the resource unit allocation field indicates which 20 MHz channel in the secondary 40 MHz channel is punctured.

215. As discussed in Ground 1A, Josiam teaches that the bandwidth field of HE-SIG-A indicates channel information to be punctured within the bandwidth and the RU signaling field (i.e., resource unit allocation field) indicates additional puncturing information. SAMSUNG-1014, [0155]-[0168]; SAMSUNG-1017, 12-15; § X.A.1. In the Josiam-Kim combination, a POSITA would have understood that, when the bandwidth field indicates a non-contiguous PPDU with a bandwidth of 80MHz (e.g., the bandwidth indication is set to "100"), the bandwidth field indicates puncturing of either S40A or S40B (per Kim). SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44. This is because, if neither S40A nor

S40B is transmitted, a 40MHz PPDU (e.g., bandwidth indication "001") would be indicated, and if both S40A and S40B are transmitted, a continuous 80MHz PPDU (e.g., bandwidth indication "010") would be transmitted.

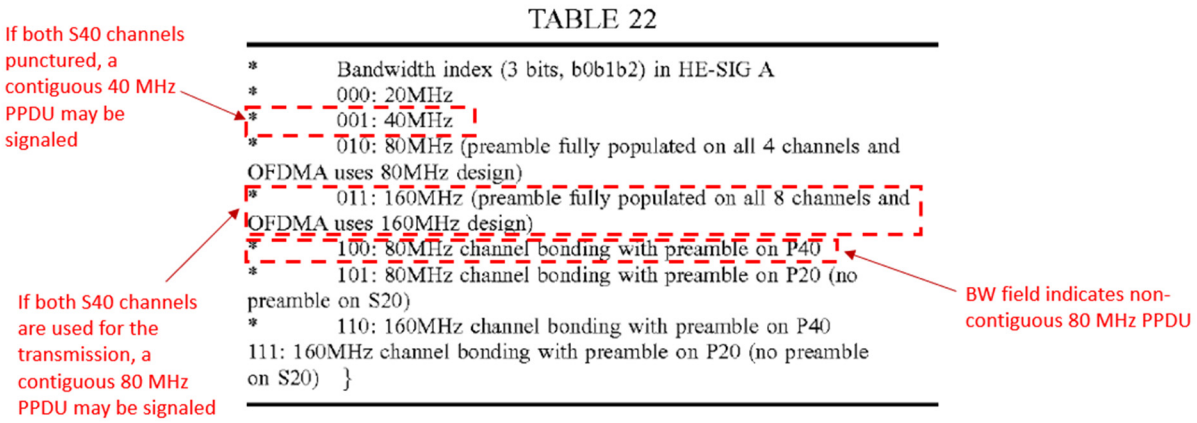
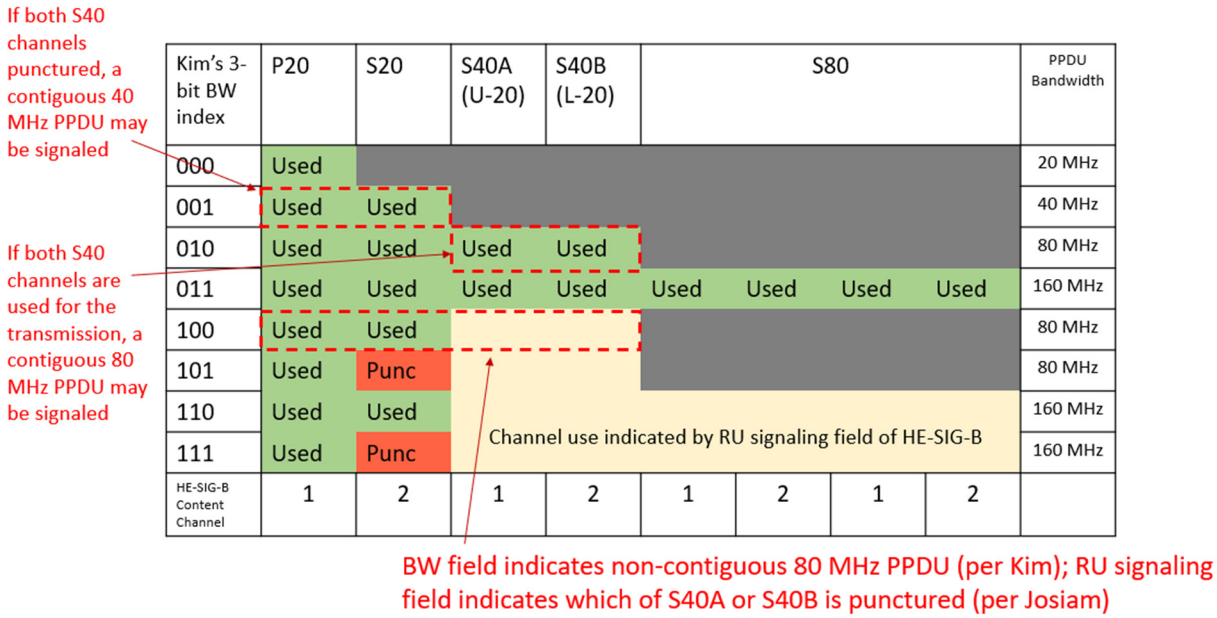


TABLE 22

* Bandwidth index (3 bits, b0b1b2) in HE-SIG A
* 000: 20MHz
* 001: 40MHz
* 010: 80MHz (preamble fully populated on all 4 channels and OFDMA uses 80MHz design)
* 011: 160MHz (preamble fully populated on all 8 channels and OFDMA uses 160MHz design)
* 100: 80MHz channel bonding with preamble on P40
* 101: 80MHz channel bonding with preamble on P20 (no preamble on S20)
* 110: 160MHz channel bonding with preamble on P40
111: 160MHz channel bonding with preamble on P20 (no preamble on S20) }

SAMSUNG-1018, Table 22 (annotated); SAMSUNG-1019, 37-38



216. In this case, the RU arrangement field would indicate which 20MHz channel in the S40 is punctured (S40A or S40B), per Josiam. SAMSUNG-1014, [0156], [0165]-[0167], Table 1; SAMSUNG-1017, 12-15. For example, in Josiam-Kim, if the bandwidth field of HE-SIG-A signals an 80MHz non-contiguous PPDU, the RU signaling field in HE-SIG-B content channel 1 may indicate a null 242-tone resource unit for the bandwidth corresponding to S40A or the RU signaling field in HE-SIG-B content channel 2 may indicate a null 242-tone resource unit for the bandwidth corresponding to S40B.

217. In this way, a POSITA would have understood Josiam-Kim as rendering obvious that, when the bandwidth field indicates puncturing of one of two 20MHz channels (e.g., S40A or S40B) in a secondary 40MHz channel within a bandwidth of 80MHz, the resource unit allocation field indicates which 20MHz channel in the secondary 40MHz channel (e.g., S40A or S40B) is punctured. During prosecution of the ’281 patent, the examiner considered claim 13 to be satisfied if one of the two indications of puncturing information was shown. SAMSUNG-1002, 65-66. Applicant did not dispute the examiner’s interpretation of claim 13. *Id.*, 43-51.

2. Claims 1-7

218. Claims 1-7 require “[a] wireless communications terminal, the terminal comprising: a processor; and a communication unit, wherein the processor

is configured to" perform steps corresponding to the methods of claims 8-14, respectively. To the extent the preamble of claim 1 is limiting, Kim discloses a "STA (station) operating in a wireless LAN (WLAN)." SAMSUNG-1018, [0008]; SAMSUNG-1018, 2-3. Kim further discloses that the station (e.g. STA 150) includes "a processor 160, a memory 170, and a transceiver 180." SAMSUNG-1018, [0161]; SAMSUNG-1019, 49. Transceiver 180 (***communication unit***) "may transmit/receive radio signals." SAMSUNG-1018, [0162]; SAMSUNG-1019, 49. Processor 160 (***processor***) may be connected to transceiver 180 to "implement a physical layer and/or a MAC layer according to the IEEE 802 system." *Id*.

219. A POSITA would have at least found it obvious for the Josiam-Kim combination to include a processor (e.g., processor 160) and a communications device (e.g., transceiver 180) to perform Josiam's methods described in Ground 1A and Josiam-Kim's methods described with respect to claims 6 and 13. A POSITA would have recognized the processor and transceiver, per Kim, as a suitable and predictable solution to implement Josiam and Josiam-Kim's methods. *Id.* Such a combination would have yielded expected results and was within the skill of a POSITA. *Id.*

220. For similar reasons to those discussed in Ground 1A and above with respect to claim 13, a POSITA would have understood Josiam-Kim as rendering obvious a wireless communication terminal (e.g., a station) having a processor

(e.g., processor 160), a communications unit (e.g., transceiver 180), wherein the processor is configured to perform the steps recited in the remaining limitations of claim 1 and claims 2-6. *See* §§ X.A, X.B.1.

C. Ground 2A – Combination of Bharadwaj and Li renders obvious claims 1-3, 7-10, and 14 by the Earliest Filing Date (December 24, 2015)

221. All of my opinions with respect to Ground 2A (§ X.C) are from the vantage point of a POSITA as of the Earliest Filing Date (December 24, 2015).

1. Claim 8

[8.pre] A wireless communication method of a wireless communication terminal, the method comprising:

222. To the extent the preamble is limiting, Bharadwaj describes "design aspects of high efficiency wireless local area networks (WLANs)," which may include "an access point (AP) that may communication with one or more (STAs) or mobile devices." SAMSUNG-1021, [0003]-[0005]; SAMSUNG-1022, [0001]-[0002].

[8.1] receiving a wireless packet;

223. Bharadwaj teaches receiving a "WLAN protocol data unit (PDU) 200 (e.g., a physical layer convergence PDU (PPDU)." SAMSUNG-1021, [0024], [0090], [0092]-[0101], Fig. 2; SAMSUNG-1022, [0017], [0028], [0042]-[0051], Fig. 2. In view of the '281 patent's discussion of a wireless packet, a POSITA would have understood that a PPDU is a wireless packet. SAMSUNG-1023,

[0015]; SAMSUNG-1046, 6:29-49; SAMSUNG-1001, 34:11-13 ("the received wireless packet may be an HE MU PPDU").

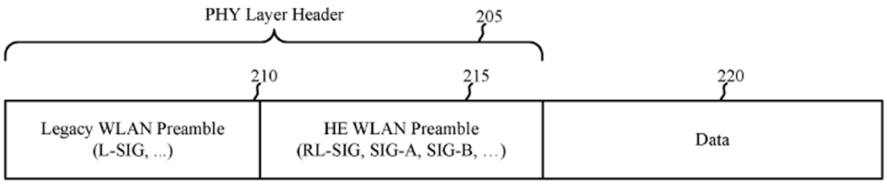


FIG. 2 200

SAMSUNG-1021, Fig. 2; SAMSUNG-1022, Fig. 2

224. Bharadwaj teaches that WLAN protocol data unit 200 includes a high efficiency WLAN preamble 215, which may include "a first high efficiency WLAN signaling field [305] such as HE-SIG-A [330]" and "a second high efficiency WLAN signaling field [310] such as HE-SIG-B [310-a]." SAMSUNG-1021, [0101]-[0104], [0117]; SAMSUNG-1022, [0051]-[0054], [0067].

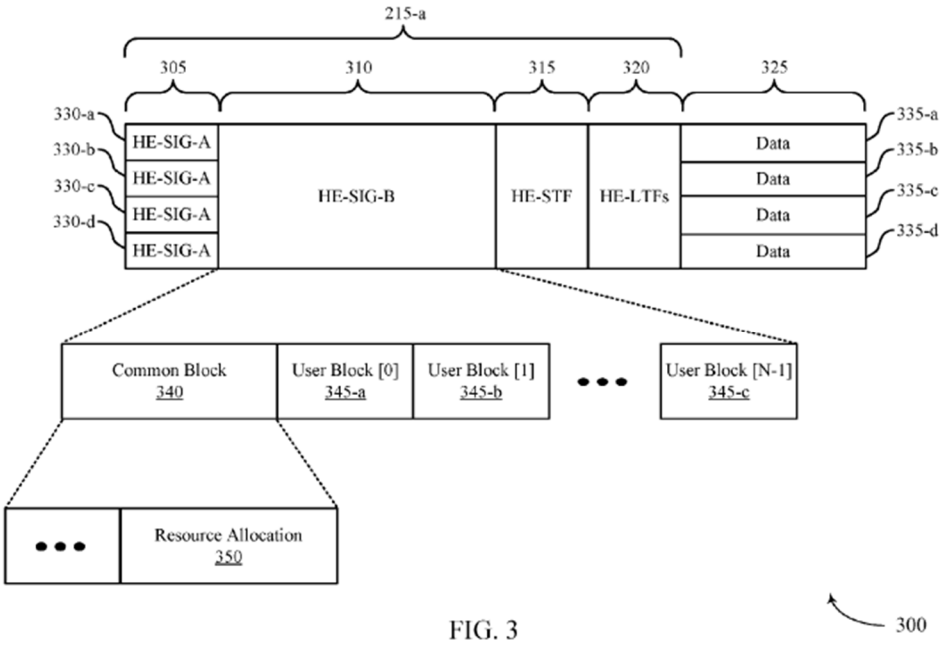


FIG. 3

SAMSUNG-1021, Fig. 3; SAMSUNG-1022, Fig. 3

[8.2] obtaining bandwidth information indicated via a bandwidth field of HE-SIG-A of the received packet;

225. Bharadwaj teaches that HE-SIG-A field 305-a includes a bandwidth field (e.g., BW field 410) that indicates "the bandwidth of [the] PPDU." SAMSUNG-1021, [0111]; SAMSUNG-1022, [0061]. Bharadwaj teaches that "BW field 410 may be used to indicate that the PPDU uses one of four different bandwidths," e.g., 20, 40, 80, or 160MHz. SAMSUNG-1021, [0111]; SAMSUNG-1022, [0061]. Li teaches "a bandwidth and subchannel indication system [that] may allocated one or more indication bits of the HE-SIG-A field to be used as an indication of the bandwidth of the transmission and/or an indication of the subchannels that are used and/or not used for the transmission. The bandwidth

indication may have the same format for all channel band sizes (e.g., 20/40/80/160MHz channel bands) since the receiving device … may not know the bandwidth before decoding the HE-SIG-A field." SAMSUNG-1023, [0031]; SAMSUNG-1024, [0028], 9.

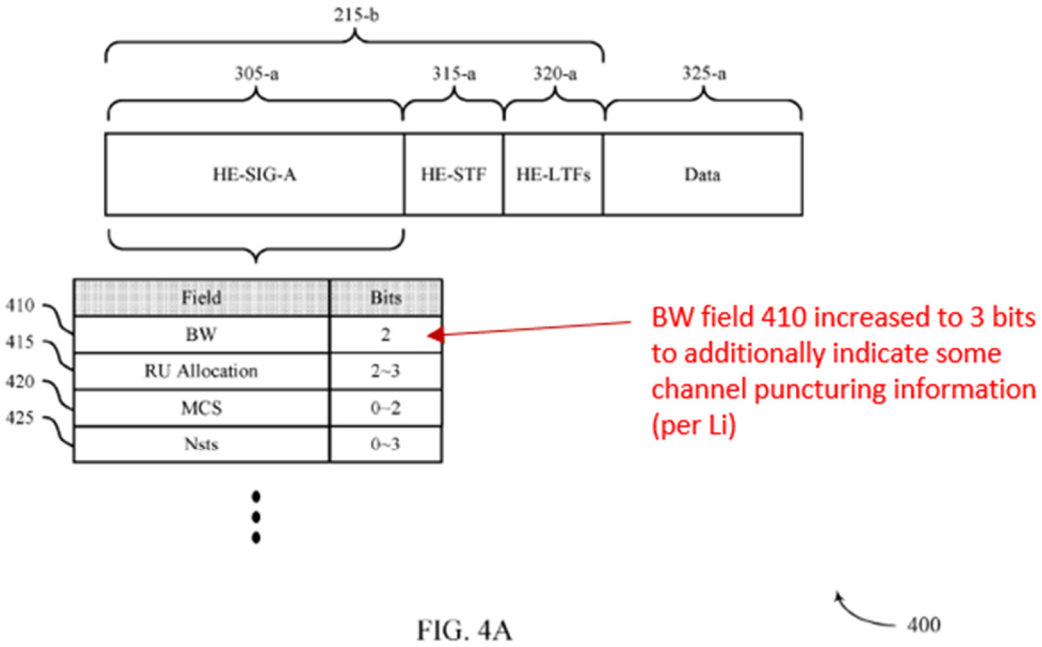


FIG. 4A

SAMSUNG-1021, Fig. 4A (annotated); SAMSUNG-1022, Fig. 4A

226. As discussed in § IX.F, the Bharadwaj-Li combination includes a bandwidth field (e.g., BW field 410) that indicates overall PPDU bandwidth information and channel puncturing information. SAMSUNG-1021, [0111]; SAMSUNG-1022, [0061]; SAMSUNG-1023, [0030]-[0032]; SAMSUNG-1024, [0025]-[0030]; *see* § IX.F.

[8.3] obtaining information of an unassigned resource unit via at least one of the bandwidth field of the HE-SIG-A and a subfield of HE-SIG-B of the received packet; and

227. For similar reasons to those discussed for [8.5], Bharadwaj-Li renders obvious obtaining information of an unassigned resource unit via at least one of the bandwidth field (e.g., BW field 410) and a subfield (e.g., resource allocation field 350 in common block field 340) of HE-SIG-B. *See* [8.5].

[8.4] decoding the received packet based on the bandwidth information and the information of the unassigned resource unit,

228. Bharadwaj-Li renders obvious decoding the received PPDU ("wireless packet") based on the PPDU bandwidth ("bandwidth information") and the information of the unassigned resource unit.

229. Bharadwaj teaches that "[t]ransmissions to/from STAs 110 and APs 105 oftentimes include control information within a header that is transmitted prior to data transmissions. ***The information provided in a header is used by a device to decode the subsequent data***. High efficiency (HE) WLAN preambles can be used to schedule multiple devices, such as STAs 110, for single-user simultaneous transmission (e.g., single-user orthogonal frequency division multiple access (SU OFDMA)) and/or MU-MIMO transmissions (e.g., multiple input/multiple-output MU-MIMO)." SAMSUNG-1021, [0097]; SAMSUNG-1022, [0047]. For example, "a HE WLAN signaling field is used to signal a resource allocation pattern to multiple receiving STAs 110." *Id.* Additionally, "***[a] device uses the scheduling***

[information] to determine which resource units associated with the frequency spectrum utilized by data field 220 have been allocated to the device for forthcoming communications." SAMSUNG-1021, [0101]; SAMSUNG-1022, [0051].

230. A POSITA would have understood that the PPDU bandwidth is among the information used to decode a received PPDU. For example, the PPDU bandwidth informs a receiving station to which channels it should tune its receiver to receive the PPDU (i.e., "the frequency spectrum utilized by data field 220"). SAMSUNG-1021, [0101]; SAMSUNG-1022, [0051]; SAMSUNG-1023, [0027]; SAMSUNG-1024, [0025]; SAMSUNG-1031, 3-5; SAMSUNG-1034, 9; SAMSUNG-1040, 9. As another example, a POSITA would have understood that the PPDU bandwidth indicates the length of the common field of HE-SIG-B, which a station decodes to obtain scheduling information of the resource units within the PPDU bandwidth. SAMSUNG-1021, [0101], [0117], [0141]; SAMSUNG-1022, [0051], [0067], [0081]; SAMSUNG-1023, [0034] ("[T]he common part only varies with the total bandwidth not total used bandwidth."). Additionally, a POSITA would have understood that the PPDU bandwidth informs a receiving station to which channels it should tune its receiver to receive the PPDU. SAMSUNG-1023, [0027]; SAMSUNG-1024, [0025]; SAMSUNG-1031, 3-5; SAMSUNG-1034, 9; SAMSUNG-1040, 9; *see* § X.A.1 (discussing how a

receiver acquires secondary channels using the bandwidth information in HE-SIG-A of the primary 20MHz channel).

231. A POSITA would have further understood that a received PPDU is decoded based on the information of an unassigned resource unit. *see* [8.5]. For example, Bharadwaj teaches that a station decodes a received PPDU based on its resource unit assignment (i.e., "which resource units associated with the frequency spectrum utilized by data field 220 have been allocated to the device for forthcoming communications"). SAMSUNG-1021, [0101], [0104]; SAMSUNG-1022, [0051], [0054]; *see also* SAMSUNG-1025, [0101]-[0103], Fig. 17; SAMSUNG-1031, 4-5.

232. Bharadwaj teaches that a station determines its resource unit assignment by comparing the position of a user-field that addressed to the station to the resource unit arrangement indicated by the resource allocation field:

> The second WLAN signaling field 310 includes a common block field 340 that signals information to a group of devices, such as high efficiency STAs within range of an AP, and user blocks 345-a to 345-c that signal information specific to specific high efficiency STAs. ***The common block includes a resource allocation field 350 that signals to the high efficiency device how the data field 325 is partitioned amongst devices*** (e.g., partitions the data field into resource units), which of the resource units are associated with SU-OFDMA and which are associated with MU-MIMO. Furthermore, ***the order of the user blocks 345 provides a link between the device associated with the user block 345 and the resource unit that has been allocated to the device***. As an example, the resource allocation field 350 partitions the data field into nine regions (e.g., 20 MHz data

> region is partitioned into nine sub-regions that each span 26 tones). The STA addressed in the first user block corresponds to the first 26 tones, the second STA addressed in the second user block corresponds to the next 26 tones, etc.

SAMSUNG-1021, [0104]; SAMSUNG-1022, [0054].

233. In PPDUs larger than 40MHz (as indicated by the bandwidth field of HE-SIG-A), user fields are split between the HE-SIG-B content channels. SAMSUNG-1021, [0117]; SAMSUNG-1022, [0067]. Bharadwaj teaches that when a resource unit is unassigned (as discussed below for [8.6]), no user fields are transmitted for the unassigned resource unit. SAMSUNG-1021, [0141]-[0142] ("SIG-B duplicated structure may be maintained, while the dedicated content for punctured channels are not transmitted."); SAMSUNG-1022, [0081]-[0082]; *see* SAMSUNG-1014, [0294]-[0296]; SAMSUNG-1016, 11; SAMSUNG-1028, 13. In this case, a receiving station would adjust the alignment between its position in the user-specific field and the resource unit arrangement information based on the information of an unassigned resource unit when decoding a received PPDU. SAMSUNG-1021, [0104]; SAMSUNG-1022, [0054]; *see* SAMSUNG-1025, [0089]-[0093], Figs. 12-14; SAMSUNG-1014, [0294]-[0296]; SAMSUNG-1016, 11.

[8.5] wherein the information of the unassigned resource unit is indicated via a combination of the bandwidth field of the HE-SIG-A and a resource unit allocation field of the HE-SIG-B, and

234. Bharadwaj-Li renders obvious that information of an unassigned

resource unit is indicated via a combination of the bandwidth field of the HE-SIG-A (e.g., BW field 410) and a resource unit allocation field of the HE-SIG-B (e.g., resource allocation field 350 in common block field 340). SAMSUNG-1021, [0130]-[0132], [0138]-[0142]; SAMSUNG-1022, [0076]-[0082]; SAMSUNG-1023, [0030]-[0032]; SAMSUNG-1024, [0025]-[0030].

235. Specifically, a POSITA would have understood that information of an unassigned resource unit is indicated via the channel puncturing information discussed below for [8.6]. *Id.*; *see* [8.6]; § IX.F. Bharadwaj does not define the term "puncturing," but a POSITA would have understood the term as meaning that a certain channel within the PPDU bandwidth is not used, and thus the group of tones (i.e., resource unit) corresponding to the punctured channel is nulled, i.e., not transmitted nor assigned to any user. SAMSUNG-1021, [0130]-[0132], [0138]-[0142]; SAMSUNG-1022, [0076]-[0082]; SAMSUNG-1032, 11-15; SAMSUNG-1036, 13-15; SAMSUNG-1045, 11-17; SAMSUNG-1031, 4-5; SAMSUNG-1030, 15; SAMSUNG-1014, [0139], [0154]; SAMSUNG-1015, 8-9; SAMSUNG-1023, [0026], [0034]-[0035], [0051], [0057], [0071]; SAMSUNG-1024, [0011], [0024], [0031]-[0032], [0054].

236. A POSITA would have understood or otherwise found it obvious that nulling is indicated in units of resource units to maintain the structure of the overall OFDMA tone plan in the PPDU and the HE-SIG-B field and ensure that each

station has a contiguous resource unit allocation. SAMSUNG-1021, [0145]; SAMSUNG-1022, [0081]-[0082] (teaching that when an "RU allocation bit sequence" indicates a punctured channel, the common field, user field, and duplication structure of HE-SIG-B remain unchanged); *see* SAMSUNG-1015, 8 ("Resource units of OFDMA that full [sic] under the channel segment left unused are nulled. The nulling is always in units of resource units and not smaller."); SAMSUNG-1032, 12-15. Thus, a POSITA would have understood that when a punctured channel is indicated in the Bharadwaj-Li combination, this indicates to a receiving station that a 242-tone resource unit (which spans an entire 20MHz segment) corresponding to the punctured channel is not assigned to any user. SAMSUNG-1021, [0108]-[0109], Figs. 4B-C; SAMSUNG-1022, [0058]-[0059], Figs. 4B-C; SAMSUNG-1014, [0167]; SAMSUNG-1017, 15.

237. Bharadwaj-Li also renders obvious that the information of an unassigned resource unit corresponding to a punctured channel is indicated via a combination of the bandwidth field of HE-SIG-A and the resource allocation field in the HE-SIG-B common field. For example, Bharadwaj-Li renders obvious that a receiving station determines the number and arrangement of the resource unit allocation fields based on the total PPDU bandwidth, and the resource unit allocation field indicates a null 242-tone resource unit corresponding to a nulled channel within the PPDU bandwidth. SAMSUNG-1021, [0101], [0141];

SAMSUNG-1022, [0051], [0081]; SAMSUNG-1023, [0034], [0042]-[0043]; SAMSUNG-1024, [0036]-[0039]; SAMSUNG-1027, 8-11.

238. As another example, Bharadwaj-Li renders obvious that the bandwidth field of HE-SIG-A indicates the number, location, and length (number of resource unit allocation fields) of the HE-SIG-B content channels, which may contain a resource unit allocation field that indicates a null 242-tone resource unit corresponding to a nulled channel within the PPDU bandwidth indicated by HE-SIG-A. SAMSUNG-1021, [0111], [0130]-[0132], [0138]-[0142]; SAMSUNG-1022, [0061]; [0076]-[0081]; SAMSUNG-1023, [0030]-[0032]; SAMSUNG-1024, [0025]-[0030]; § IX.F; *see* [8.6]. I note that this mapping appears consistent with Wilus's infringement allegations. SAMSUNG-1004, 19-20.

[8.6] wherein the bandwidth field of the HE-SIG-A indicates channel information to be punctured within the bandwidth, and the resource unit allocation field indicates additional puncturing information for the unassigned resource unit within the bandwidth.

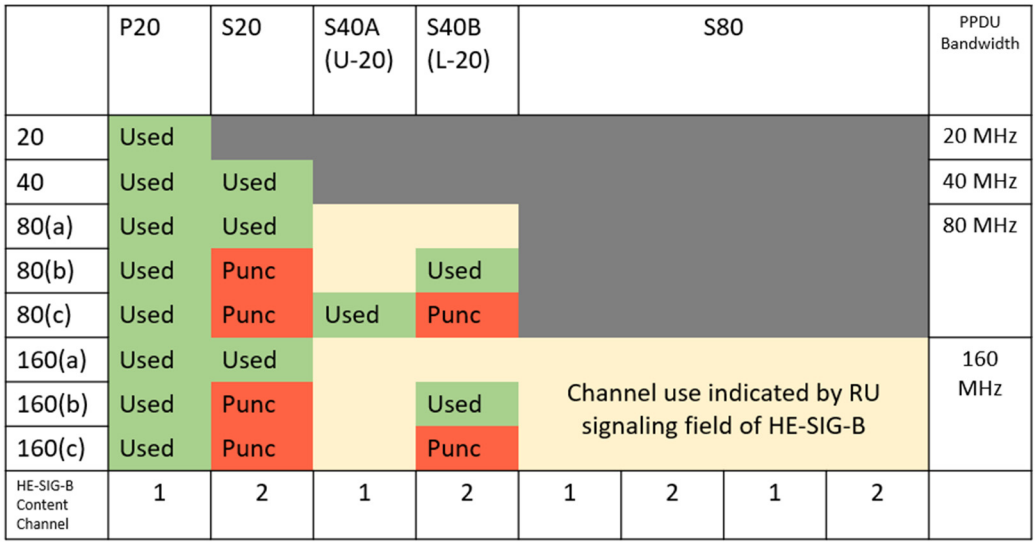
239. Bharadwaj discloses a method of indicating puncturing of 20MHz subchannels using the HE-SIG-A and HE-SIG-B fields. SAMSUNG-1021, [0130]-[0132], [0138]-[0142]; SAMSUNG-1022, [0076]-[0082]; *see* § IX.D. Specifically, Bharadwaj teaches that HE-SIG-A may indicate that certain channels (e.g., S20 or S40B) in the primary 80MHz bandwidth responsible for carrying HE-SIG-B content channel 2 are punctured. SAMSUNG-1021, [0131]-[0132], [0138]; SAMSUNG-1022, [0076]-[0078]. Based on this indication, a station may

determine if and where an HE-SIG-B content channel 2 may be found. *Id*. Bharadwaj teaches that additional puncturing information for other 20MHz channels may be indicated through "a special or dedicated RU allocation bit sequence." SAMSUNG-1021, [0139]-[0142]; SAMSUNG-1022, [0079]-[0082]. Specifically, "the indication may be made by adding an additional entry in an RU allocation table." *Id*. A POSITA would have understood that the RU allocation bit sequence would be indicated in a resource unit allocation field (e.g., resource allocation field 350), which indicates resource unit allocation information using a bit sequence corresponding to indices in a resource unit allocation table (e.g., lookup table 600). *Id.*; SAMSUNG-1021, [0124], Fig. 6; SAMSUNG-1022, [0070], Fig. 6; SAMSUNSG-1027, 8-11; SAMSUNG-1028, 13; SAMSUNG-1023, [0044]; SAMSUNG-1024, [0038].

240. In Bharadwaj-Li, the bandwidth field of HE-SIG-A (e.g., BW field 410) contains an index value (per Li) corresponding to both PPDU bandwidth and whether the S20 and/or S40B channels are transmitted (per Bharadwaj). *See* § IX.F; SAMSUNG-1021, [0111], [0130]-[0132], [0138]-[0142]; SAMSUNG-1022, [0061]; [0076]-[0081]; SAMSUNG-1023, [0030]-[0032]; SAMSUNG-1024, [0025]-[0030]. A POSITA would have understood this information as channel information to be punctured within the bandwidth. Per Bharadwaj, puncturing information for other channels may be indicated using the resource unit allocation

field (e.g., resource allocation field 350). SAMSUNG-1021, [0141]-[0142]; SAMSUNG-1022, [0081]-[0082].

241. As one example, when the bandwidth field of HE-SIG-A indicates a total bandwidth of 80MHz and the HE-SIG-B content channel 2 is transmitted in S40B, this indicates that the S20 channel is punctured. SAMSUNG-1021, [0138]; SAMSUNG-1022, [0078]. Otherwise, a POSITA would have understood that HE-SIG-B content channel 2 would be read from the S20. SAMSUNG-1021, [0131]; SAMSUNG-1022, [0076]. Here, a POSITA would have understood that the bandwidth field of HE-SIG-B indicates information of a channel to be punctured (e.g., S20).



242. Continuing with this example, the resource unit allocation field may indicate whether, e.g., the S40A is punctured by indicating a special RU allocation bit sequence in the resource unit allocation field corresponding to S40A.

SAMSUNG-1021, [0139]-[0142]; SAMSUNG-1022, [0079]-[0082]. Thus, a POSITA would have understood that the resource unit allocation field indicates additional puncturing information (e.g., special RU allocation bit sequence indicating S40A is punctured) for the unassigned resource unit within the PPDU bandwidth (e.g., null 242-tone resource unit corresponding to punctured channel).

243. Thus, a POSITA would have understood the combined teachings of Bharadwaj and Li as rendering obvious this limitation.

2. Claim 9

[9] The wireless communication method of claim 8, wherein the resource unit allocation field indicates a specific resource unit not assigned to a user through a predetermined index.

244. As discussed for [8.6], Bharadwaj-Li renders obvious that the resource unit allocation field of HE-SIG-B "may be used to indicate that a 20 MHz channel is punctured" through "a special or dedicated RU allocation bit sequence." SAMSUNG-1021, [0139]-[0142]; SAMSUNG-1022, [0079]-[0082]. Specifically, "the indication may be made by adding an additional entry in an RU allocation table." *Id*. A POSITA would have understood that this "special or dedicated RU allocation bit sequence" in the RU allocation table (e.g., lookup table 600) indicates that a 242-tone resource unit corresponding to the 20MHz channel is nulled, and thus not assigned to a user. *See* [8.5].

245. Alternatively, it would have been obvious for a POSITA to include

one or more special entries in the RU allocation table to indicate that a specific size resource unit is punctured. Bharadwaj teaches that the lookup table may indicate RU allocations that span multiple 20MHz channels (e.g., a 484-tone or 996-tone resource unit). SAMSUNG-1021, [0104], [0124], Fig. 6; SAMSUNG-1022, [0054], [0070], Fig. 6. It would have been obvious to a POSITA to include special or dedicated RU allocation entries which indicate a specific resource unit of 242-tones or larger is nulled, thus indicating that multiple 20MHz channels are punctured.

246. In this way, a single RU allocation entry may indicate that more than one 20MHz channel is punctured. I believe a POSITA would have found this particularly useful in a 160MHz PPDU when both S20 and S40B are punctured, and HE-SIG-B content channel 1 carries HE-SIG-B information for all 8 channels. SAMSUNG-1021, [0132]; SAMSUNG-1022, [0077]. For example, if the last two channels of S80 are busy, the resource unit allocation field may use one 484-tone null resource unit allocation to indicate both channels are punctured instead of using two separate 242-tone null resource unit allocations. Thus, by specifying that a resource unit larger than 242-tones is punctured, a POSITA would have understood that multiple corresponding 20MHz channels may be indicated as punctured using fewer bits in the HE-SIG-B common field. SAMSUNG-1021, [0104], [0124], [0141], Fig. 6; SAMSUNG-1022, [0054], [0070], [0081], Fig. 6.

3. Claim 10

[10] The wireless communication method of claim 9, wherein the specific resource unit not assigned to a user is at least one of a 242-tone resource unit, a 484-tone resource unit, and a 996-tone resource unit.

247. As discussed for [9], a POSITA would have understood Bharadwaj as teaching that the specific resource unit is a 242-tone resource unit, or alternatively, that it would have been obvious that the specific resource unit is a 242, 484, or 996-tone resource unit. SAMSUNG-1021, [0104], [0124], [0141], Fig. 6; SAMSUNG-1022, [0054], [0070], [0081], Fig. 6; *see* § X.C.3.

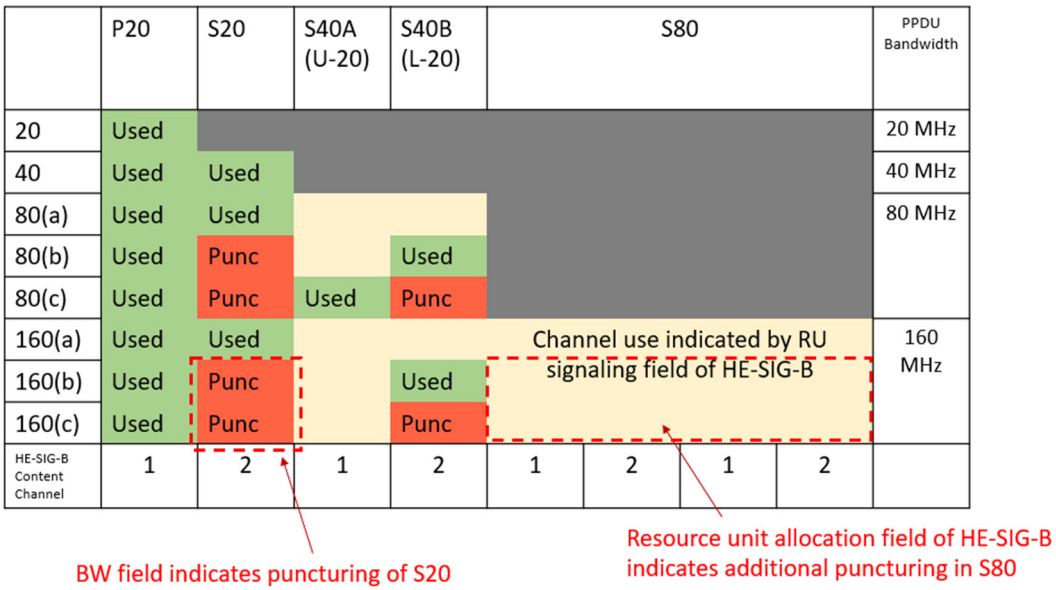
4. Claim 14

[14] The wireless communication method of claim 8, wherein when the bandwidth field indicates puncturing of a secondary 20 MHz channel within a bandwidth of 160 MHz or 80+80 MHz or puncturing of at least one of two 20 MHz channels in a secondary 40 MHz channel within a bandwidth of 160 MHz or 80+80 MHz, the resource unit allocation field indicates additional puncturing in a secondary 80 MHz channel.

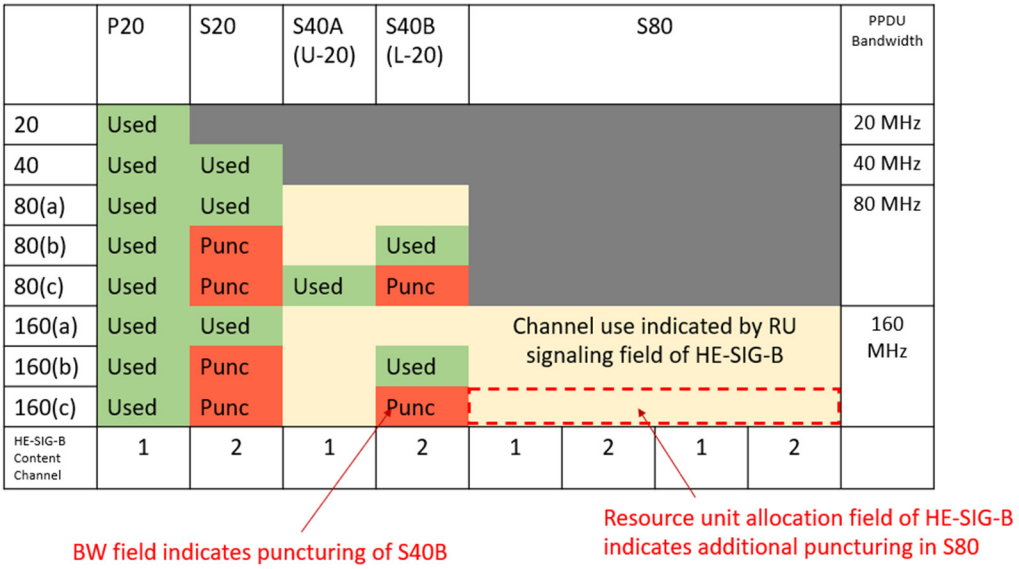
248. Bharadwaj-Li renders obvious this limitation. As discussed for [8.6], Bharadwaj-Li renders obvious that the bandwidth field of HE-SIG-A indicates channel information to be punctured within the bandwidth, and the RU signaling field indicates additional puncturing information. *See* §§ IX.F, X.C.1.

249. In the Bhardwaj-Li combination, a POSITA would have understood that, when the bandwidth field indicates puncturing of the secondary 20MHz channel within a bandwidth of 160MHz (e.g., 160(b) and (c) below), the resource unit allocation field may indicate additional puncturing in a secondary 80MHz

channel. SAMSUNG-1021, [0131]-[0132], [0138]; SAMSUNG-1022, [0076]-[0078]; *see* § X.C.1.



250. Additionally or alternatively, a POSITA would have understood that, when the bandwidth field indicates puncturing of at least one of two 20MHz channels (e.g., 160(c) below) in a secondary 40MHz channel within a bandwidth of 160MHz, the resource unit allocation field indicates additional puncturing in the S80 channel. SAMSUNG-1021, [0131]-[0132], [0138]; SAMSUNG-1022, [0076]-[0078]; *see* §§ IX.F, X.C.1.



5. Claims 1-3 and 7

251. Claims 1-3 and 7 require "[a] wireless communications terminal, the terminal comprising: a processor; and a communication unit, wherein the processor is configured to" perform steps corresponding to the methods of claims 8-10 and 14, respectively. To the extent the preamble of claim 1 is limiting, Bharadwaj discloses "a wireless device 1390, which may be an example of a STA 110 or an AP 105." SAMSUNG-1021, [0181], Fig. 13A; SAMSUNG-1022, [0084], Fig 9A. Bharadwaj further discloses that wireless device 1390 includes a processor 1305, "which may process information received through the transceiver(s) 1320." Id.

252. For similar reasons to those discussed above with respect to claims 8-10 and 14, a POSITA would have found obvious that the Bharadwaj-Li combination includes a wireless communications terminal (e.g., wireless device 1390) having a processor (e.g., processor 1305), a communications unit (e.g.,

transceiver 1320), per Bharadwaj, wherein the processor is configured to perform the steps recited in the remaining limitations of claim 1 and claims 3 and 7. *See* §§ X.C.1-4.

D. Ground 2B – Combination of Bharadwaj, Li, and Chen render obvious claims 1-5, 7-12, and 14 by December 24, 2015

253. All of my opinions with respect to Ground 2B (§ X.D) are from the vantage point of a POSITA as of the Earliest Filing Date (December 24, 2015).

1. Claim 8

254. Bharadwaj-Li-Chen renders obvious claim 8 for the reasons discussed above in Ground 2A. *See* § X.C.1. Bharadwaj-Li-Chen further renders obvious claim 8 based on Chen's teachings.

[8.3] obtaining information of an unassigned resource unit via at least one of the bandwidth field of the HE-SIG-A and a subfield of HE-SIG-B of the received packet

255. In the Bharadwaj-Li-Chen combination, a POSITA would have understood that information of an unassigned resource unit may additionally be obtained via a subfield (e.g., a user field of HE-SIG-B), per Chen. SAMSUNG-1025, [0090]-[0093], Figs. 12-14; *see* § IX.H.

[8.4] decoding the received packet based on the bandwidth information and the information of the unassigned resource unit

256. For similar reasons to those explained in Ground 2A, a POSITA would have also understood that the information of an unassigned resource unit obtained using a null station ID (per Chen) is used to decode the PPDU. *See* §

X.C.1. A POSITA would have understood that the receiving device uses the information of an unassigned resource unit obtained using a null station ID (per Chen) to decode the PPDU based on "which resource units associated with the frequency spectrum utilized by data field 220 have been allocated to the device for forthcoming communications." SAMSUNG-1021, [0101]; SAMSUNG-1022, [0051]. For example, a POSITA would have understood that the null STA ID indicates that an unassigned resource unit should be skipped by receiving stations. SAMSUNG-1025, [0090]-[0092], Figs. 12-13; *see* § IX.H.

[8.5] wherein the information of the unassigned resource unit is indicated via a combination of the bandwidth field of the HE-SIG-A and a resource unit allocation field of the HE-SIG-B

257. A POSITA would have further understood that the information of the unassigned resource obtained by a null station ID in the user field is also indicated via a combination of the bandwidth field of the HE-SIG-A and a resource unit allocation field of the HE-SIG-B (e.g., the resource unit allocation field of the HE-SIG-B common field). SAMSUNG-1021, [0101]-[0104], [0117], Figs. 3, 5; SAMSUNG-1022, [0051]-[0054], [0067], Fig. 3, 5; SAMSUNG-1025, [0090]-[0093], Figs. 12-14; *see* § IX.H.

258. For example, information of an unassigned resource unit indicated according using a null station ID (per Chen) is also indicated via a combination of:

(1) the bandwidth field of HE-SIG-A, which indicates (a) the number and arrangement of the resource unit allocation fields based on the total

PPDU bandwidth, and (b) the number and location of the HE-SIG-B content channels (*see* [8.5] in § X.C.1), and

(2) the resource unit allocation field (e.g., resource allocation field 350) of the HE-SIG-B common field (e.g., common block field 340), which indicates the number, size, and position of one or more resource units within a particular 20MHz region of the bandwidth indicated by the bandwidth field of HE-SIG-A (SAMSUNG-1021, [0101]-[0104], [0117], Figs. 3, 5; SAMSUNG-1022, [0051]-[0054], [0067], Figs. 3, 5; SAMSUNG-1025, [0090]-[0093], Figs. 12-14).

259. Specifically, the resource unit allocation field (e.g., resource allocation field 350) partitions segments of the PPDU bandwidth into resource units, one or more of which may be indicated as an unassigned resource unit using a null STA ID in the user block (e.g., user block 345) corresponding to an unassigned resource unit. SAMSUNG-1021, [0101]-[0104], [0117], Figs. 3, 5; SAMSUNG-1022, [0051]-[0054], [0067], Fig. 3, 5; SAMSUNG-1025, [0090]-[0093], Figs. 12-14; *see* § IX.H.

[8.6] wherein the bandwidth field of the HE-SIG-A indicates channel information to be punctured within the bandwidth, and the resource unit allocation field indicates additional puncturing information for the unassigned resource unit within the bandwidth.

260. Bharadwaj-Li-Chen renders obvious this limitation for the reasons discussed in Ground 2A. See § X.C.1. As I discussed for [8.6] in Ground 2A, the resource unit allocation field of HE-SIG-B may indicate puncturing information. *See* § X.C.1. Here, a POSITA would have understood that the additional puncturing information is for the unassigned resource unit within the bandwidth (e.g., nulled edge resource unit) because Bharadwaj-Li-Chen renders obvious

indicating a nulled edge resource unit adjacent to a punctured channel indicated by the resource unit allocation field. *See* § IX.H; SAMSUNG-1014, [0139], [0143], [0147], Figs. 11-13; SAMSUNG-1015, 8-11.

261. For these reasons, a POSITA would have understood Bharadwaj-Li-Chen as additionally rendering obvious the limitations of claim 8.

2. Claim 11

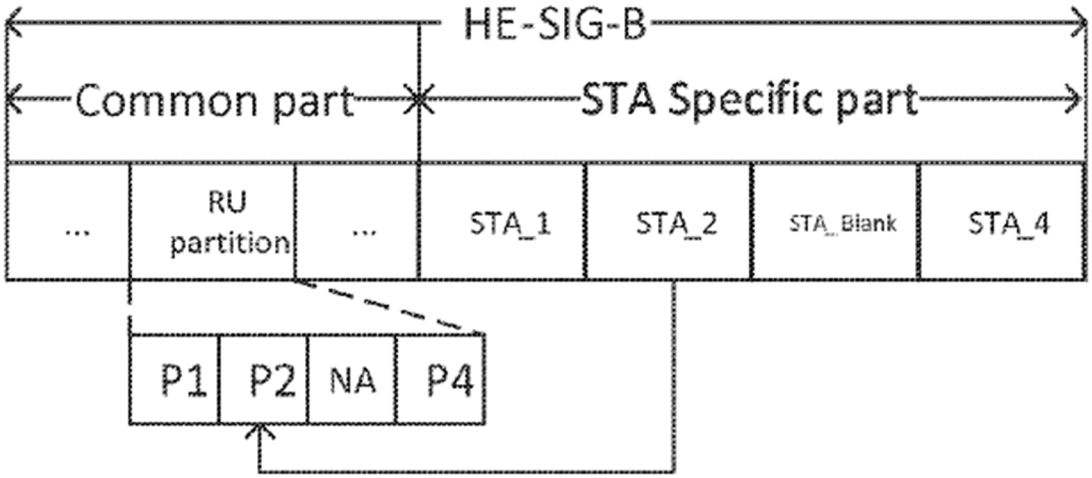
[11] The wireless communication method of claim 8, wherein the information of the unassigned resource unit is obtained through resource unit arrangement information indicated by the resource unit allocation field of the HE-SIG-B and a Null STA ID contained in a user field corresponding to a specific resource unit in the resource unit arrangement.

262. Bharadwaj-Li-Chen renders obvious this limitation. Bharadwaj teaches that HE-SIG-B includes "a common block field 340 that signals information to a group of devices, such as high efficiency STAs within range of an AP, and user blocks 345-a to 345-c that signal information specific to specific high efficiency STAs. The common block includes a resource allocation field 350 that signals to the high efficiency device how the data field 325 is partitioned amongst devices (e.g., partitions the data field into resource units)." SAMSUNG-1021, [0104]; SAMSUNG-1022, [0054]. Bharadwaj explains that the "the order of the user blocks 345 provides a link between the device associated with the user block 345 and the resource unit that has been allocated to the device. As an example, the resource allocation field 350 partitions the data field into nine regions (e.g.,

20MHz data region is partitioned into nine sub-regions that each span 26 tones). The STA addressed in the first user block corresponds to the first 26 tones, the second STA addressed in the second user block corresponds to the next 26 tones, etc." *Id*.

263. Chen teaches a method of indicating an unassigned resource unit using the user fields of HE-SIG-B. SAMSUNG-1025, [0090]-[0093], Fig. 13. Specifically, Chen teaches that "[i]f one RU is not allocated or is skipped, AP 110 may assign a special (e.g., blank or null) PAID[6] which is not decodable by or known to any of the scheduled STA. As a result, all of the STAs 140 will skip that RU. FIG. 13 depicts a datagram illustrating an example HE-SIG-B 1300 portion indicating a sequence of RU allocation information with an unallocated RU." SAMSUNG-1025, [0092].

[6] *See supra* note 4.



SAMSUNG-1025, Fig. 13

264. In the Bharadwaj-Li-Chen combination, it would have been obvious to use Chen's method of indicating an unassigned resource unit using a null station ID in the Bharadwaj-Li combination. *See* § IX.H. In Bharadwaj-Li-Chen, a POSITA would have found it obvious that information of an unassigned resource unit is obtained through resource unit arrangement information (e.g., resource unit partitioning information) indicated by the resource unit allocation field (e.g., resource allocation field 350) of the HE-SIG-B and a Null STA ID (e.g., null PAID[7] per Chen) contained in a user field (e.g., user block 345) corresponding to a specific resource unit in the resource unit arrangement (e.g., a particular resource unit corresponding to the user block 345 based on the user block's position in the

[7] *See supra* note 4.

user-specific portion of HE-SIG-B). SAMSUNG-1021, [0101]-[0104], [0117], Figs. 3, 5; SAMSUNG-1022, [0051]-[0054], [0067], Fig. 3, 5; SAMSUNG-1025, [0090]-[0093], Figs. 12-14; *see* § IX.H.

3. Claim 12

[12] The wireless communication method of claim [11][8], wherein the specific resource unit is at least one of a 26-tone resource unit, a 52-tone resource unit, and a 106-tone resource unit.

265. Bharadwaj-Li-Chen renders obvious that the specific resource unit (e.g., a particular resource unit corresponding to the user block 345 based on the user block's position in the user-specific portion of HE-SIG-B) is at least one of a 26-tone resource unit, a 52-tone resource unit, and a 106-tone resource unit. SAMSUNG-1021, [0104]; SAMSUNG-1022, [0054]; *see* § X.D.1. For example, Bharadwaj teaches that resource allocation field 350 may partition the data field into nine 26-tone resource units and a corresponding user field to one of those resource units may indicate that the specific 26-tone resource unit is not assigned to a user using a null STA ID, per Chen. SAMSUNG-1025, [0090]-[0093], Figs. 12-14; *see* § X.D.1.

4. Claims 1-5, 7, 9-10, and 14

266. Bharadwaj-Li-Chen renders obvious claims 1-3, 7, 9-10, and 14 for

[8] *See supra* note 1.

the reasons discussed above in Ground 2A. *See* § X.C. Bharadwaj-Li-Chen further renders obvious these claims and claims 4 and 5 based on Chen's teachings. *See* §§ IX.G, X.D.1-3.

E. Ground 2C – Combination of Bharadwaj, Li, and Kim renders obvious claims 6 and 13 by May 14, 2016

267. All of my opinions with respect to Ground 2C (§ X.E) are from the vantage point of a POSITA as of the Critical Date (May 14, 2016).

1. Claims 6 and 13

[13] The wireless communication method of claim 8, wherein when the bandwidth field indicates puncturing of one of two 20 MHz channels in a secondary 40 MHz channel within a bandwidth of 80 MHz or puncturing of at least one of two 20 MHz channels in a secondary 40 MHz channel within a bandwidth of 160 MHz or 80+80 MHz, the resource unit allocation field indicates which 20 MHz channel in the secondary 40 MHz channel is punctured.

268. In the Bharadwaj-Li-Kim combination, a POSITA would have understood that when the bandwidth field indicates a non-contiguous PPDU with a bandwidth of 80MHz (e.g., the bandwidth indication is set to "100"), the bandwidth field indicates puncturing of either S40A or S40B (per Kim). SAMSUNG-1018, [0144]-[0145], Table 22; SAMSUNG-1019, 43-44. This is because, if neither S40A nor S40B is transmitted, a 40MHz PPDU (e.g., bandwidth indication "001") would be indicated, and if both S40A and S40B are transmitted, a continuous 80MHz PPDU (e.g., bandwidth indication "010") would be transmitted.

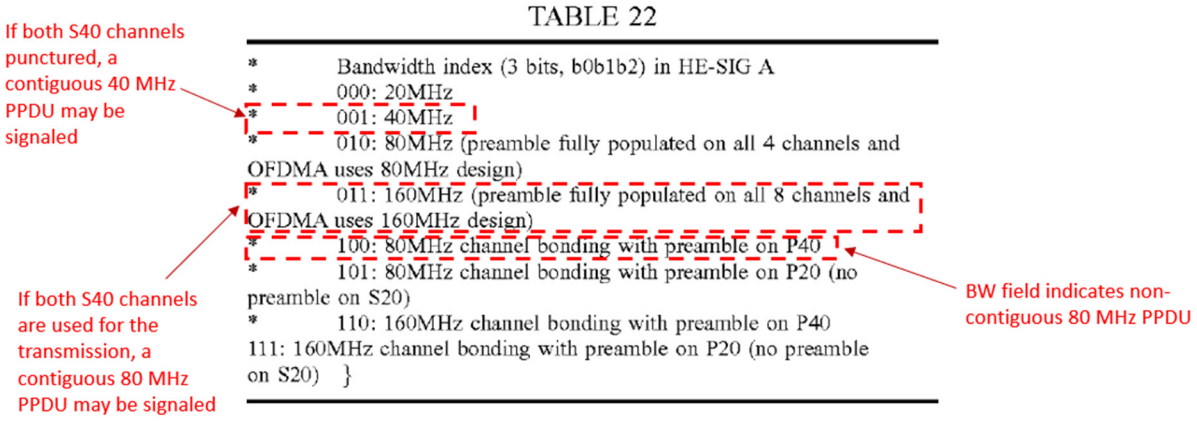
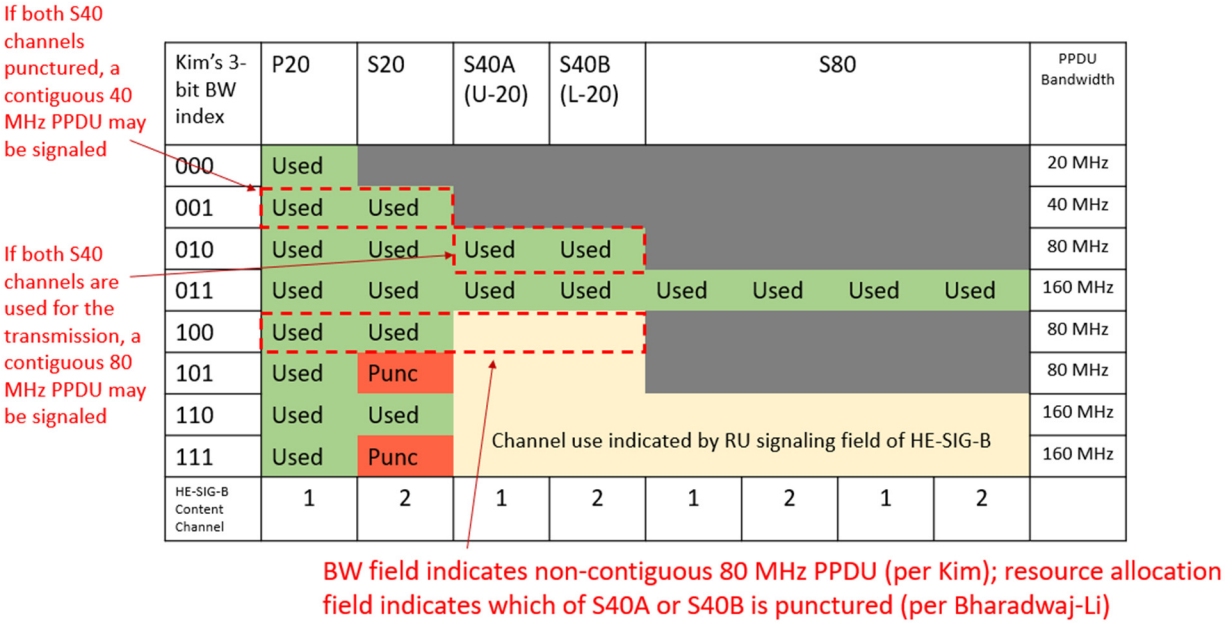


TABLE 22

* Bandwidth index (3 bits, b0b1b2) in HE-SIG A
* 000: 20MHz
* 001: 40MHz
* 010: 80MHz (preamble fully populated on all 4 channels and OFDMA uses 80MHz design)
* 011: 160MHz (preamble fully populated on all 8 channels and OFDMA uses 160MHz design)
* 100: 80MHz channel bonding with preamble on P40
* 101: 80MHz channel bonding with preamble on P20 (no preamble on S20)
* 110: 160MHz channel bonding with preamble on P40
111: 160MHz channel bonding with preamble on P20 (no preamble on S20) }

SAMSUNG-1018, Table 22 (annotated); SAMSUNG-1019, 43-44



269. In this case, the resource unit allocation field would indicate which 20MHz channel in the S40 is punctured (S40A or S40B), per Bharadwaj-Li. SAMSUNG-1021, [0141]-[0142]; SAMSUNG-1022, [0081]-[0082].

270. For example, if S40A is punctured, the resource unit allocation field

in HE-SIG-B content channel 1 would include a special RU allocation bit sequence indicating that S40A is punctured. SAMSUNG-1021, [0141]-[0142]; SAMSUNG-1022, [0081]-[0082]. Similarly, if S40B is punctured, the resource unit allocation field in HE-SIG-B content channel 2 would include a special RU allocation bit sequence indicating that S40B is punctured. *Id.*

271. During prosecution of the ’281 patent, the examiner considered claim 13 to be satisfied if one of the two indications of puncturing information was shown. SAMSUNG-1002, 65-66. Applicant did not dispute the examiner’s interpretation of claim 13. *Id.*, 43-51.

272. Bharadwaj-Li-Kim renders obvious claim 6 for similar reasons.

F. Ground 2D – Combination of Bharadwaj, Li, Chen, and Kim renders obvious claims 6 and 13 by May 14, 2016

273. All of my opinions with respect to Ground 2D (§ X.F) are from the vantage point of a POSITA as of the Critical Date (May 14, 2016).

1. Claims 6 and 13

274. Bharadwaj-Li-Kim-Chen renders obvious claims 6 and 13 for the reasons discussed for Bharadwaj-Li-Kim in Ground 2C. *See* § X.E. For similar reasons to those discussed in Ground 2B, Bharadwaj-Li-Kim-Chen combination further renders obvious claims 6 and 13 based on Chen’s teachings. *See* § X.F.

XI. CONCLUSION

275. For all the reasons I have noted in the foregoing paragraphs, claims 1-

14 of the ’281 patent are obvious in view of the references discussed above.

276. I currently hold the opinions set expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

APPENDIX A

R. Michael Buehrer, FIEEE

Virginia Polytechnic Institute and State University
The Bradley Department of Electrical and Computer Engineering
432 Durham Hall; Mail Stop 0350
Blacksburg, Virginia 24061
Telephone: 540.231.1898; Fax: 540.231.2968
buehrer@vt.edu

Education

June 1996	Virginia Polytechnic Institute and State University, The Bradley Department of Electrical and Computer Engineering, Bradley Fellowship, Ph.D.
August 1993	The University of Toledo, Department of Electrical Engineering and Computer Science, M.S.
June 1991	The University of Toledo, Department of Electrical Engineering and Computer Science, B.S.

Employment

Aug. 2012 - Present	Professor, Virginia Polytechnic Institute and State University, Bradley Department of Electrical and Computer Engineering, Director of *Wireless @ Virginia Tech*
Aug. 2006 – Aug. 2012	Associate Professor, Virginia Polytechnic Institute and State University, Bradley Department of Electrical and Computer Engineering, Mobile and Portable Radio Research Group.
Aug. 2009 – Dec. 2009	Visiting Researcher at the Laboratory for Telecommunication Sciences (LTS) a federal research lab which focuses on telecommunication challenges for national defense.
Aug. 2001 – Aug. 2006	Assistant Professor, Virginia Polytechnic Institute and State University, Bradley Department of Electrical and Computer Engineering, Mobile and Portable Radio Research Group.
Aug. 2001 – Present	Independent Consultant, self-employed.
Aug. 1996 – Aug. 2001	Member Technical Staff, Bell Laboratories, Lucent Technologies, promoted to Distinguished Member of Technical Staff in September 2000.
Sep. 1993 – Jun. 1996	Graduate Research Assistant, Virginia Polytechnic Institute and State University, Bradley Department of Electrical and Computer Engineering, Mobile and Portable Radio Research Group.
May 1994 – Aug. 1994	Senior Engineer, Stanford Telecommunications, Advanced Programs.
Sep. 1991 – Aug. 1993	Graduate Research Assistant, The University of Toledo, Department of Electrical Engineering and Computer Science, Communications Research Group.

Honors and Recognitions

- Fellow of the IEEE (So named "for contributions to wideband signal processing in communications and geolocation")
- 2023 MILCOM Lifetime Award for Technical Achievement
  - For Outstanding, Sustained Technical Contributions to Military Communications
- NSC Vanu Bose Best Paper Award *IEEE Military Communications Conference (MILCOM)* 2023.
- 2023 Fred W. Ellersick Award for the Best Paper in the Unclassified Technical Program, *IEEE Military Communications Conference (MILCOM)*, 2023
- NSC Vanu Bose Best Paper Award *IEEE Military Communications Conference (MILCOM)* 2021.
- Dean's Award for Teaching Excellence - April 2014.
- 2010 Fred W. Ellersick Award for the Best Paper in the Unclassified Technical Program, *IEEE Military Communications Conference (MILCOM)* 2010.
- SDR Forum Best Paper Award, 2007.
- Outstanding Paper Award, SDR Forum, 2008.
- Dean's Award for Outstanding New Assistant Professor, College of Engineering, 2003.
- Dean's List for Teaching Effectiveness (teaching evaluation greater than 3.6) 16 out of 18 semesters list was published.
- Nominated for Certificate of Teaching Excellence (CTE), College of Engineering, Spring 2004 and Spring 2005.
  - Served as a member of the College of Engineering CTE committee from 2006 through 2021.
- Bell Labs President's Silver Award for outstanding research contributions.
- 1999 Best Paper Award for *Bell Labs Technical Journal.*

Patents

- S. D. Gordon, R.M. Vaghefi, and R.M. Buehrer, "Estimating the Location of a Wireless Terminal Based on Cooperative Measurements," *US Patent No. 10,527,708* , January 7, 2020.
- S. D. Gordon, R.M. Vaghefi, and R.M. Buehrer, "Estimating the Location of a Wireless Terminal Based on Radio-Frequency Pattern Matching and Cooperative Measurements," *US Patent No. 9,989,620 B1*, June 5, 2018.
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- R. D. Benning, R. M. Buehrer, P. A. Polakos, and R. A. Soni, "Split Shift Phase Sweep Transmit Diversity, " *US Patent No. 6,980,778 B2*, December 27, 2005.
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- R.M. Buehrer, S.-C. Liu, S.P. Nicoloso, and D. Uptegrove, "Method of channel estimation and compensation based thereon," *U.S. Patent No. 6,542,560*, April 1, 2003.
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- R.D. Benning, R.M. Buehrer, and R.A. Soni, "Apparatus and method of enhancing transmit diversity," U.*S. Patent No. 6,594,226*, July 15, 2003.
- R.M. Buehrer, S.-C. Liu, S.P. Nicoloso, and D. Uptegrove, "Iterative channel estimation and compensation based thereon," *U.S. Patent No. 6,614,857*, September 2, 2003.
- R.M. Buehrer and R.A. Soni, "Methods And Apparatus For Downlink Diversity In CDMA Using Walsh Codes", *U.S. Patent No. 6,515,978*, February 4, 2003.
- R.M. Buehrer, S. Gollamudi, and S.P. Nicoloso, "Multistage interference cancellation for CDMA applications using M-ary orthogonal modulation," *US Patent No. 6,363,103*, March 26, 2002.
- S.A. Allpress, R.M. Buehrer, and R.A. Soni, "Receiver Architecture Employing Space Time Spreading and Orthogonal Transmit Diversity Techniques," *US Patent No. 6,317,410 B1*, November 13, 2001.
- S.A. Allpress, R.M. Buehrer, Quinn Li, Ramesh Nallepilli, and R.A. Soni, "Transmitter Architecture Employing Space Time Spreading and Orthogonal Transmit Diversity Techniques," *US Patent No. 6,392,988*, May 21, 2001.
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Teaching

Undergraduate Courses

- Engineering Exploration (ECE 1024)
- Electric Circuits (ECE 2004)
- Signals and Systems (ECE 2704, ECE 2714)
- Introduction to Communications (ECE 3614)
- Digital Communications (ECE 4634)
- Analog and Digital Communication Laboratory (ECE 4664)– *developed this course with $70k grant from the State of Virginia.*

Graduate Courses

- Spread Spectrum Communications (ECE 5660)– *developed this course for the ECE department. It is has been a permanent offering since 2003.*
- Advanced Digital Communications (ECE 5654)
- Multi-Channel Communications (Course covers the fundamentals of OFDM and MIMO techniques the underlying technologies for 4G cellular communications) – *Developed this course for the ECE dept. It is has been a permanent offering since 2008.*
- Information Theory (ECE 5634)
- Machine Learning for Communication Systems (ECE 5984)

Teaching Evaluations (Fall 2001 through Spring 2011)

- Average student evaluation – 3.8/4.0 (17 courses, 450 students)
- Dean's List (student evaluation $>$ 3.6) in 16 of 18 semesters of teaching

Teaching Evaluations (Fall 2011 through Spring 2023)

- Average student evaluation – 5.5/6.0 (25 courses, $>$ 700 students)

Short Courses Given

- Position Location
- Position Location using Ultra-Wideband Signals
- Radio Resource Management in CDMA Systems
- WiFi – An introduction to WLANs
- OFDM – Multicarrier transmission for high data rate systems; Application to 4G (LTE) cellular and Wi-Fi
- Ultra Wideband Communications
- Multi-Input Multi-Output (MIMO) Communication Systems; Application to 4G (LTE/LTE-Advanced) cellular and Wi-Fi

Advising

Current

- Don-Roberts Emenonye, " Machine Learning Approaches to Remote Rehabilitation," Ph.D. candidate, expected graduation December 2023.
- Sam Shebert, "Automatically Classifying Modern Communication Waveforms," Ph.D. candidate, expected graduation May 2024.
- Megan Moore, "Geolocation via LEO Networks," Ph.D. candidate, expected graduation May 2025.

- Haozhou Hu, “Geolocation via Landmarks,” Ph.D. candidate, expected graduation May 2025.
- Gaurav Duggal, “Combined Radar and Communications Signals for Geolocation,” Ph.D. candidate, expected graduation May 2025.
- Harish Dureppagari, “Emergency Localization using UAVs and Collaborative Localization,” Ph.D. candidate, expected graduation May 2026.
- Kumar Sai Bondada, “Synchronization for Distributed MIMO,” Ph.D. candidate, expected graduation May 2026.
- Xinrui Li, “Interference Mitigation in Radio Astronomy,” Ph.D. candidate, expected graduation May 2026.
- Tom Anders, “Resource Allocation in Multi-static and Mono-static Radar Networks,” M.S. candidate, expected graduation December 2024.
- Olivia Leonard, “Resource Allocation in Cognitive Radar Networks,” M.S. candidate, expected graduation December 2025.
- Joe Esser, “Mode Control in Cognitive Radar Networks,” M.S. candidate, expected graduation May 2026.

Former

1. William H. Howard, “Distributed Learning for Cognitive Radar Networks,” Ph.D. Novemer 2023.
2. Charlie Thornton, “ On the Value of Online Learning for Cognitive Radar Waveform Selection,” Ph.D., May 2023.
3. Jianyuan Yu, “Wireless Sensing and Fusion using Deep Neural Networks,” Ph.D., August 2022.
4. Yue Xu, “ Deep Recurrent Q Networks for Dynamic Spectrum Access in Dynamic Heterogeneous Environments with Partial Observations,” Ph.D. , August 2022.
5. Chris O’Lone, “Statistical Analysis of Geolocation Fundamentals Using Stochastic Geometry,” Ph.D. December 2020.
6. Jeff Poston, “ILoViT: Indoor Localization via Vibration Tracking,” Ph.D. March 2018.
7. Mahi Abdelbar, “Applications of Sensor Fusion in Classification, Localization and Mapping,” Ph.D. February 2018.
8. Mico Woolward, “SUPPLEMENTING LOCALIZATION ALGORITHMS FOR INDOOR FOOTSTEPS,” Ph.D., July 2017.
9. Daniel Jakubisin, “Advances in Iterative Probabilistic Processing for Communication Receivers,” Ph.D., April, 2016, *currently employed by The Hume Center*.
10. Jeannette Nounagnon “Using Kullback-Leibler Divergence to Analyze the Performance of Collaborative Positioning,”, Ph.D., April, 2016, *currently employed by ComSat*.
11. SaiDhiraj Amuru, “Intelligent Approaches for Communication Denial,” Ph.D., September, 2015, *currently employed by Samsung*.
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14. Jeong-heon Lee, "Physical Layer Security for Wireless Position Location in the Presence of Location Spoofing," Ph.D., March 2011, *currently employed by Samsung*.

15. Haris I. Volos, "Cognitive Radio Engine Design For Link Adaptation," Ph.D., September 2010, *currently employed by the University of Arizona.*

16. Tao Jia, "Collaborative Position Location for Wireless Networks in Harsh Environments," Ph.D., March 2010, *currently employed by Qualcomm, Inc.*

17. Heba Shaban, "A Novel Highly Accurate Wireless Wearable Human Locomotion," Ph.D., April 2010, *currently employed by Arab Academy of Science and Technology.*

18. Haesoo Kim, "Cooperative Communications," Ph.D., August 2008, *currently employed by LG Electronics.*

19. Rekha Menon, - "Interference Avoidance based Underlay Techniques for Dynamic Spectrum Sharing," Ph.D., April 2007, *currently employed by Tyco Electronics*.

20. Swaroop Ventkatesh, "The Design and Modeling of Ultra-Wideband Position-Location Networks," Ph.D., February 2007, *currently employed by Marvel Semiconductor*.

21. Jihad Ibrahim, "Algorithms and Architectures for UWB Receiver Design," Ph.D. January 2007, *currently employed by MathWorks*.

22. Chris Anderson, "A Software Defined Ultra Wideband Transceiver Testbed for Communications, Ranging, or Imaging," Ph.D., September 2006, *currently an Associate Professor at the US Naval Academy.*

23. Samir Al-Ghadhban - " Multi-layered Space Frequency Time Codes," Ph.D. October, 2005, *currently an associate professor at King Fahd University*.

24. Jing Jiang – "Increasing the Capacity of Wireless Data Systems - A Cross Layer Perspective," Ph.D., July 2004, *currently employed by Texas Instruments*.

25. Jiann-An Tsai – "Overloaded Array Processing Using Interference Cancellation," Ph.D., May 2002. *Currently employed by Samsung.*

26. Zachary Schutz, "Use of Reinforcement Learning for Interference Avoidance or Efficient Jamming in Wireless Communications," M.S., May 2024.

27. Sebastian Rodriguez, "Value of Machine Learning and Cognition on Target Tracking," M.S., June 2022.

28. C. Tanner Fredieu, "Spectrum Awareness: Deep Learning and Isolation Forest Approaches for Open-set Identification of Signals," M.S. May 2022.

29. Dhwan Wanjara, "A Python Software Library to Improve the Accessibility of the Apple Watch as a Research Tool," M.S. May 2022.

30. Daniel Tait, " Electromagnetic Vector-Sensor Direction-of-Arrival Estimation in the Presence of Interference," M.S. August 2020.

31. Don-Roberts Emenonye, " Application of Machine Learning to Multi-Antenna Transmission and Machine Type Resource Allocation," M.S. July 2020.

32. Charlie Thornton, " Learning Schemes for Adaptive Spectrum Sharing Radar," M.S. May 2020.

33. Mark Kozy, "Creation of a Cognitive Radar with Machine Learning: Simulation and Implementation," M.S., May 2019.

34. Bryse Flowers, "Adversarial RFML: Evading Deep Learning Enabled Signal Classification," M.S., June 2019.

35. Parker White, "Constrained Clustering for Frequency Hopping Spread Spectrum Signal Separation," M.S., August 2019.

36. Ersin Selvi, " Cognitive Radar Applied To Target Tracking Using Markov Decision Processes," M.S. December 2017, *currently employed by Raytheon*.

37. Ali Gaber Mohamed, "Navigating via Discrete Astronomical Radio Sources: Geolocation Using Fringe Rates," M.S. April 2017, *currently employed by Alexandria University*.

38. Eric Sollenberger, "Iterative Leakage-Based Precoding for Multiuser-MIMO Systems," M.S., May, 2016, *currently employed by Qualcomm, Inc.*.

39. Kevin McDermott, "On the Improvement of Positioning in LTE with Collaboration and Pressure Sensors," M.S., May, 2015, *currently employed by Northrup Grumman*

40. Tori Jewell, "Use of GIS in Radio Frequency and Positioning Applications,", M.S. June 2014.

41. Jacob Overfield, "The Impact of MIMO on Signal Localization," MS, May 2013, *currently employed by n-ask, inc.*

42. Zachary Biskaduros, "Collaborative GPS," MS, June 2013, *currently employed by n-ask, inc.*

43. Hunter DeJarnette, "Measuring Noise in the VHF Band and Its Effect On Low SNR Signal Detection," MS Thesis, September 26, 2012, *currently employed by Johns Hopkins Applied Physics Lab.*

44. Benton Thompson, "Characterization and Improvement of the Collaborative and Non-Collaborative Position Location Problems," MS, August 2011, *currently employed by G3, Inc*.

45. Corey Cooke, "Attenuation Field Estimation using Radio Tomography," MS, August 2011, *currently a Ph.D. student at Georgia Tech.*

46. Harpreet Dhillon, "The Optimal Sum-Rate of Multi-Band MIMO Interference Channel," MS, July 2010, *currently an Assistant Professor at Virginia Tech.*

47. Justin Kelly, "The Value of Collaboration in Dynamic Spectrum Access," MS, July 2009, *currently employed by the Department of Energy*.

48. Matthew Roney, "Dual-Channel Direction Finding in Multipath Channels," M.S. candidate, *currently employed by DRS Signal Solutions*.

49. Jesse Reed, "Approaches to Multiple-source Localization and Signal Classification," MS, May, 2009, *currently employed by Arinc, Inc.*

50. Chang Li, "Non-contact Estimation of Respiration and Heartbeat Rate using Ultra Wideband," MS, August 20, 2008, *currently employed by Qualcomm, Inc.*

51. Arjun Bhupathi Raju, "Characterization of Uplink Transmit Power and Talk-Time in WCDMA Networks", MS, July 15, 2008, *currently employed by Qualcomm, Inc.*

52. Rajaraman Parameswaran – "Effects of user and spatial diversity on high data rate wireless systems," M.S., August 2005, *currently employed by Qualcomm Inc*.

53. Nathan Harter, "Single Channel Direction Finding in Multipath Channels," M.S., April 2007, *currently employed by IO-Max*.

54. John Keaveny – "The Implementation of Single-Channel Direction Finding," M.S., February 2005. *Currently employed by Boeing.*

55. Brian Donlan, "Ultra-wideband Narrowband Interference Cancellation and

    Channel Modeling for Communications," M.S., January 2005, *currently employed by IOMAX USA*.

56. Vivek Baradwaj, "Ultra-Wideband for Communications: Spatial Characteristics and Interference Suppression," M.S., April 2005. *Currently employed by Qualcomm, Inc.*

57. Liu Yang, "On the Applicability of the Tap-delay Line Model to UWB Channel Modeling," M.S., August 2004, *currently employed by Microsoft.*

58. Dan Hibbard, "The Impact of Bandwidth on Indoor Communication System Performance," M.S., May 2004. *Currently employed by Raytheon.*

59. Nishant Kumar – "MAC and Physical Layer Design for Ultra-Wideband Communications," M.S., May 2004. *Currently employed by Staccato Communicaitons.*

60. Samir Ginde – "A Game-theoretic Analysis of Link Adaptation in Cellular Radio Networks," M.S., May 2003. *Currently employed by Qualcomm, Inc.*

61. Rahul Mahajan – "Cross Layer Optimization: System Design and Simulation Methodologies," M.S., December, 2003. *Currently employed by Qualcomm, Inc.*

62. Aaron Orndorf, "Transceiver Design for Ultra Wideband Communications," M.S., completed May 2004.

63. David McKinstry – "Channel Models and Receivers for Ultra Wideband Communications," M.S., May 2003. *Currently employed by Johns Hopkins Applied Physics Lab.*

64. Venkatasubramanian Ramasamy – "MC-CDMA/OFDM and Adaptive Antennas," M.S., June 2002. *Currently employed by Apple.*

65. Ray Chan – "Link Adaptation for Public Safety Wireless Information Networks," M.S., June 2003. *Currently employed by Northrup Grummond Corp.*

66. Payal Jain – "Software Radio Implementation of Adjustable High Data Rate Receivers," M.S., November 2002. *Currently employed by Digital Receiver Technology, Germantown, MD.*

Funded Research

1. Title: "Spectrum Situational Awareness via Cognitive Radar Networks,"
   Sponsor: Army Research Lab (via Baylor University),
   Funding: $575,318
   Period of Performance: , May, 2024 - May, 2025
   Percent: 35%.

2. Title: "Mobile Distributed MIMO: Learning Meets Spreading in Networking,"
   Sponsor: Advanced Technology International,
   Funding: $8,741,427
   Period of Performance: , September, 2023 - July, 2026
   Percent: 10%.

3. Title: "Fundamentals of Geotagging Images and Videos Using Non-Unique Landmarks,"
   Sponsor: Commonwealth Cybersecurity Initiative,
   Funding: $37,500
   Period of Performance: , July 1, 2024 - July 1, 2025
   Percent: 50%.

4. Title: "Design and Control of Multi-modal Sensors and Sensor Networks,"
   Sponsor: Army Research Lab,
   Funding: $200,000 ($910,962 max)
   Period of Performance: , September 1, 2023 - August 31, 2024
   Percent: 100%.

5. Title: “Multi-Target Detection and Tracking with Multi-Mode Radar Networks,”
   Sponsor: Lockheed Martin,
   Funding: $300,000,
   Period of Performance: August 1, 2023 - July 31, 2025
   Percent: 50

6. Title: “Development of Machine Learning Methodologies for Radar Signal Classification,”
   Sponsor: Alion,
   Fudning: $118,000,
   Period of Performance: January 26, 2023 – December 31, 2024
   Percent: 100

7. Title: “Prototyping 5G-enabled Indoor Geolocation System for Fire Fighters using UAVs,”
   Sponsor: National Institutes of Standards and Technology (through George Mason University),
   Fudning: $849,994,
   Period of Performance: June 1, 2022 – May 31, 2025
   Percent: 34

8. Title:“ SWIFT: Electronically-Reconfigurable Surfaces for Improved Coexistence Between Radio Astronomy and Satellite Communications Systems,”
   Sponsor: National Science Foundation,
   Funding: $748,463,
   Period of Performance: September 1, 2021 - August 31, 2024.
   Percent: 50%.

9. Title:“ Collaborative Research: CNS Core: Medium: Localization in Millimeter Wave Cellular Networks: Fundamentals, Algorithms, and Measurement-inspired Simulator,”
   Sponsor: National Science Foundation,
   Funding: $635,000,
   Period of Performance October 2021 – September 2025.
   Percent: 50%.

10. Title:“ SWIFT: SMALL: Interference Canceling for Improved Coexistence for Passive and Active Radio Systems,”
    Sponsor: National Science Foundation,
    Funding: $499,999,
    Period of Performance January 2021– January 2024.
    Percent: 50%.

11. Title: “SCH:INT: Collaborative Research: Semi-Automated Rehabilitation in the Home,”
    Sponsor: National Science Foundation,
    Funding: $1.1M
    Period of Performance: August 2020 – July 2024,
    Percent: 10%

12. Title: “Vector Sensor Processing in the Presence of Multipath”
    Sponsor: Applied Signals Intelligence
    Funding: $170,000
    Period of Performance: April 2020 - April 2021.
    Percent: 90%

13. Title: “Machine Learning Approaches to Optimize Army Radar, Communication and EW Systems”
    Sponsor: Army Research Lab
    Funding: $975,000
    Period of Performance: May 11, 2020 - May 10, 2024.
    Percent: 100%

14. Title: “Vector Sensor Processing in the Presence of Interference”
    Sponsor: Applied Signals Intelligence
    Funding: $232,193
    Period of Performance: December 20, 2018 - April 30, 2019.
    Percent: 60%

15. Title: “Digital Beamforming and Interference Mitigation for MIMO Systems ”
    Sponsor: GIRD Systems
    Funding: $1,575,398
    Period of Performance: October 17, 2018 - October 16, 2021.
    Percent: 50%

16. Title: “Cognitive Radar for C-SCoRE: Enhancing Radar Functionality though Interference Analysis and Avoidance,”
    Sponsor: Georgia Tech Research Institute (AFRL)
    Funding: $285,000
    Period of Performance: December 15, 2018 – May 30, 2022
    Percent: 100%

17. Title: “Collaborative Learning for Harmonious Coexistence of Heterogeneous Wireless Networks”
    Sponsor: Defense Advanced Research Projects Agency
    Funding: $1,999,994
    Period of Performance: January 1, 2017 - December 30, 2019.
    Percent: 25%

18. Title: “MU-MIMO Channel Characterization”
    Sponsor: GIRD Systems
    Funding: $117,712
    Period of Performance: April 1, 2017 - March 31, 2019.
    Percent: 100%

19. Title: “Cognitive Radio Approaches to Optimize Army Radar Systems”
    Sponsor: Army Research Lab
    Funding: $250,000
    Period of Performance: January 1, 2018 - December 30, 2020.
    Percent: 100%

20. Title: “Cognitive Radio Approaches to Optimize Army Radar and Communication Systems”
    Sponsor: Army Research Lab
    Funding: $190,282
    Period of Performance: January 1, 2017 - December 30, 2017.
    Percent: 50%

21. Title: “Hyper-wideband Communications”
    Sponsor: Defense Advanced Research Projects Agency
    Funding: $182,451
    Period of Performance: May 1, 2015 - April 30, 2016.
    Percent: 50%

22. Title: “IUSE: Gamification of Wireless Communication Testbeds for Authentic STEM Learning”
    Sponsor: National Science Foundation
    Funding: $626,665
    Period of Performance: Sept. 1, 2014 - Aug. 31, 2017.
    Percent: 20%

23. Title: “Advanced Cognitive Radio Design using SDRs”
    Sponsor: Lockheed Martin Advanced Technologies

Funding: $494,600
Period of Performance: April 1, 2014 – Sept. 30, 2015
Percent: 100%

24. Title: "SDR Technology Development Support"
Sponsor: DoD
Funding: $375,000
Period of Performance: 5/1/14 – 4/30/14
P.I.: J.H. Reed
Percent: 30%

25. Title: "Improving Cellular Positioning through Collaboration"
Sponsor: Polaris Wireless
Funding: $82,813
Period of Performance: 11/01/2013 - 10/31/2014
Percent: 100%

26. Title: "Advanced Wireless Systems and Technologies"
Sponsor: DoD
Funding: $3,883,320
Period of Performance: 07/01/2012 - 06/30/2014
P.I. R.W. McGwier
Percent: 10%

27. Title: "Cognitive Radio Development"
Sponsor: Lockheed Martin – Advanced Technologies Lab
Funding: $325,000
Period of Performance: 7/1/2012 – 12/31/2013
P.I. R.M. Buehrer
Percent: 50%

28. Title: "Next Generation Secure, Scalable Communication Network for the Smart Grid"
Sponsor: Oak Ridge National Labs
Funding: $626,671
Period of Performance: 1/1/2011-10/31/2012
PI – R.M. Buehrer
Co-PI: J.H. Reed
Percent: 50%

29. Title: "Software Defined Radio Waveform and Device Development And Component Deployment Using Ossie"
Sponsor – DoD (Maryland Procurement Office)
PI – RM Buehrer
Period of Performance: Aug. 1, 2010 – July 31, 2013
Funding: $299,227
Percent: 100%

30. Title: "SDR Technology Development Support"
Sponsor – DoD (Maryland Procurement Office)
PI – R.M. Buehrer and J.H. Reed
Funding: $638,653
Period of Performance: 9/30/2010 – 4/30/2014
Percent: 75%

31. Title: "Signal Processing Research"
Sponsor: Aerospace Corp.
PI: T.C. Clancy
Co-PI: R.M. Buehrer

Period of Performance: 1/1/2011 – 10/31/2011
Funding: $130k
Percent: 50%

32. Title: "IHCS: Proactive Cross-Layer Adversary Localization for Hostile or Harsh Wireless Environments"
Sponsor: National Sceince Foundation
Funding: $494,788
Period of Performance: 5/1/08 – 4/30/11
PI: Y. Yang
Co-PI's: R.M. Buehrer and J.M. Park
Percent: 33%

33. Title: "A Fundamental Analysis of Spectrum Sharing"
Sponsor: Qualcomm, Inc.
Funding: $120,000
Period of Performance: 5/1/08 – 4/30/10
PI: Buehrer
Co-PI's: Y. Yang
Percent: 85%

34. Title: "Reasoning and Learning in Adaptive Wireless Networks"
Sponsor: BBN/DARPA
Funding: $605,000
Period of Performance: 10/1/07 – 3/31/10
PI: L. DaSilva
Co-PI's: R.M. Buehrer, C. Bostian, A. MacKenzie, and J.H. Reed
Percent: 25%

35. Title: DRS Graduate Fellowship
Sponsor: DRS Signal Solutions
Funding: $76,000
Period of Performance: 9/01/07 – 8/30/09
PI: R.M. Buehrer
Percent: 100%

36. Title: U-PoLo Nets – Position Location in Harsh Environments
Sponsor: National Science Foundation
Funding: $175k
Period of Performance: 8/1/05 – 7/30/08
PI: R.M. Buehrer
Percent: 100%

37. Title: NeTS ProWiN: An Open Systems Approach for Rapid Prototyping Waveforms for Software Defined Radio
Sponsor: National Science Foundation
Funding: $1M
Period of Performance: 8/1/05 – 7/30/09
PI: J.H. Reed (lead), R.M. Buehrer, and W.H. Tranter
Percent: 33%

38. Title: Node and Network Benefits of Improved RF Characteristics in CDMA Cellular Networks
Sponsor: ParkerVision
Funding: $131,474
Period of Performance: 11/1/07 – 10/31/08
PI: R. M. Buehrer
Percent: 100%

39. Title: UWB Propagation in Office Environments
    Sponsor: Freescale Semiconductor
    Funding: $35,000
    Period of Performance: 5/1/05 – 4/30/06
    PI: R. M. Buehrer
    Percent: 100%

40. Title: Networking Issues for Peer-to-Peer VoIP Link for Radio Interoperability, Fire Management and Security
    Sponsor: Catalyst Communications
    Funding: $67,500
    Period of Performance: 1/1/05 – 5/15/05
    PI: S.M. Midkiff (lead) and R.M. Buehrer
    Percent: 33%

41. Title: AWINN: Advanced Wireless Networking for the Navy
    Sponsor: ONR
    Funding: $3M
    Period of Performance: 12/20/04 – 6/19/06
    PI: Warren Stutzman
    Co-PI's: J.H. Reed, Scott Midkiff, R. M. Buehrer, W.H. Tranter, Peter Athanas, Tom Hou, Binoy Ravindran, Rick Habayeb
    Percent: 10%

42. Title: Ultra Wideband Communications Systems
    Sponsor: ASPIRES
    Funding: $118,360
    Period of Peformance: 7/1/03 – 6/30/04
    PI: R. M. Buehrer
    Percent: 100%

43. Title: UWB Communications
    Sponsor: Motorola
    Period of Performance: 12/15/03 – 12/14/04
    Funding: $35,000
    PI: Buehrer
    Percentage: 100%

44. Title: Simulation of Ultra Wideband Communications
    Sponsor: ITRI
    Funding: $10,000
    Period of Performance: 9/1/03 – 12/31/03
    PI: R.M. Buehrer
    Percent: 100%

45. Title: Receiver Design for Ultra Wideband Communications
    Sponsor: ITRI
    Funding: $15,000
    Period of Performance: 9/1/03 – 12/31/03
    PI: R.M. Buehrer
    Percent: 100%

46. Title: Indoor Propagation
    Sponsor: Qualcomm, Inc.
    Funding: $14,000
    Period of Performance: 12/1/03 – 5/15/04
    PI: R.M. Buehrer
    Percent: 100%

47. Title: Single Channel Direction Finding
    Sponsor: DRS Technologies
    Funding: $91,000
    Period of Performance: 10/18/02 – 10/17/05
    PI: R. M. Buehrer
    Percent: 100%

48. Title: Flexible High Data Rate Transmission for Wireless Data Applications
    Sponsor: BAE Systems
    Funding: $29,000
    Period of Performance: 10/18/01 – 10/17/02
    PI: R. M. Buehrer
    Percent: 100%

49. Title: UWB Propagation Measurements, Modeling, and Communication System Enhancements
    Sponsor: Defense Advanced Research Projects Agency
    Funding: $688,620
    Period of Performance: 5/13/02-5/12/03
    PI: R.M. Buehrer
    Co-PI: A.S. Safaai-Jazi, W. Davis, D. Sweeney
    Percentage: 35%

50. Title: Modeling and Simulation for the FCS Development Environment
    Sponsor: Boeing
    Funding: $127,022
    Period of Performance: 5/1/02 - 4/1/03
    PI: W. H. Tranter
    Co-PI: R. M. Buehrer, A. Annamalai
    Percentage: 33%

51. Title: The Benefits of Multiple Antennas at the Handset for Cellular CDMA
    Sponsor: e-Tenna Corporation
    Funding: $15,000
    Period of Performance: 5/15/02 – 8/14/02
    PI: R. M. Buehrer
    Percent: 100%

52. Title: MPRG Affiliates Program
    Sponsor: Analog Devices, ARO, Cingular, DRS Technologies, General Motors, General Dynamics, Huawei Technologies, Hughes, Lucent Technologies, Motorola, Qualcomm, Raytheon, Samsung, SW Bell, Texas Instruments, et. al.
    Funding: $2M
    Period of Performance: 8/25/01 – 5/15/11
    PI: J.H. Reed
    Co-PI's: R.M. Buehrer, W.H. Tranter, S.W. Ellingson, others
    Percent: 20%

Book Publications

1. S. Zekavat and R.M. Buehrer, editors, Position Location - Theory, Practice and Advances, Second Ed., Wiley-IEEE, 2019.

2. S. Zekavat and R.M. Buehrer, editors, Position Location - Theory, Practice and Advances, Wiley-IEEE, 2011.

3. J.H. Lee and R.M. Buehrer, "Security Issues in Position Location," Chapter 3 in Position Location - Theory, Practice and Advances, Wiley-IEEE, 2011.

4. R. M. Buehrer and S. Venkatesh, "Fundamentals of Time-of-Arrival-based Position Location," Chapter 6 in Position Location - Theory, Practice and Advances, Wiley-IEEE, 2011.

5. J.H. Lee and R.M. Buehrer, "Fundamentals of Received Signal Strength Based Position Location," Chapter 11 in Position Location - Theory, Practice and Advances, Wiley-IEEE, 2011.

6. T. Jia and R.M. Buehrer, "Collaborative Position Location," Chapter 23 in Position Location - Theory, Practice and Advances, Wiley-IEEE, 2011.

7. R.M. Buehrer, An Introduction to Code Division Multiple Access (CDMA), Morgan-Claypool Publishers, 2007.

8. R.A. Soni and R.M. Buehrer, "Multiple Antenna Techniques in 3G Wireless Systems," Chapter 25 in Space-Time Wireless Systems: From Array Processing to MIMO Communications, H. Bolecskei, D. Gesbert, C. Papadias, and A.J. vander Veen, editors, Cambridge University Press, 2005.

9. R.M. Buehrer, "Channel Modeling," Chapter 3 in An Introduction to Ultra Wideband Communication Systems, Jeff Reed, editor, pp. 73-158, Prentice-Hall, 2005.

10. A.F. Molisch, J. Kunisch, R. Qiu, D. Cassioli, M. Buehrer, M. Pendergrass, I.Z. Kvacs, G.F. Pedersen, P.C.F. Eggers, S. Roy and I. Ramachandran, "UWB Propagation Channels," Chapter 2 in UWB Communication Systems – A Comprehensive Overview, M.-G. Di Bendetto, T. Kaiser, A.F. Molisch, I. Oppermann, C. Politano, and D. Porcino, editors, pp.21-142, Hindawi Publishing Company, 2006.

11. M. Dohler, J. Liu, S. Venkatesh, R.M. Buehrer and B. Allen, "Large- and Medium-Scale Propagation Modelling," Chapter 14 in Ultra-wideband Antennas and Propagation for Communications, Radar and Imaging, B. Allen, et. al., editors, pp. 283-308, John Wiley and Sons, 2006.

12. S. Venkatesh, R.M. Buehrer, J. Liu, and M. Dohler, "Small-Scale Ultra-wideband Propagation Modelling," Chapter 15 in Ultra-wideband Antennas and Propagation for Communications, Radar and Imaging, B. Allen, et. al., editors, pp. 309-330, John Wiley and Sons, 2006.

13. R. Muhamed, R.M. Buehrer, A. Doradla, and T.S. Rappaport, "Mobile and Portable Radio Communications," Chapter 139 in The Engineering Handbook, Second Ed., R.C. Dorf, Editor, pp. 139-1 - 139-19, CRC Press, 2004.

14. T.S. Rappaport, R. Muhamed, M. Buehrer, and A. Doradla, "Mobile and Cellular Radio Systems," The Engineering Handbook, R. C. Dorf Editor, CRC Press, 1996.

15. R.M. Buehrer and B.D. Woerner, "Spread Spectrum for Wireless Communications," Wireless Personal Communications: Research Developments, B.D. Woerner, T.S. Rappaport, and J.H. Reed editors, Kluwer Academic Press, 1995.

16. H. Shaban, M. A. El-Nasr, and R. M. Buehrer, "A Full-Body Wireless Wearable UWB-Based Human Motion Capture and Gait Analysis System," Chapter 20 in E-Healthcare Systems and Wireless Communications: Current and Future Challenges, pp. 434-459, Prof. Mohamed K. Watfa, Editor.

Journal Publications

1. A.F. Martone, R.M. Buehrer, and D.M. McNamara, "Emerging Trends in Radar: Metacognitive Radar Networks for the Next Generation of Intelligent Sensing," *accepted for publication in IEEE Aerospace and Electronic Systems Magazine,* January 2025.

2. G. Duggal, R. M. Buehrer, H. S. Dhillon, and J. H. Reed"Diffraction-Aided Wireless Positioning," *accepted for publication in IEEE Transactions on Wireless Communications,* January 2025.

3. X. Li, R.M. Buehrer, and S.W. Ellingson, "Parametric Methods for Coherent Time-Domain Canceling of Radio Frequency Interference," accepted for publication in *Publications of the Astronomical Society of the Pacific*, December 2024.

4. W. Howard, A. F. Martone, and R.M. Buehrer, "Timely Target Tracking: Distributed Updating in Cognitive Radar Networks," *IEEE Transactions on Radar Systems*, vol. 2, pp. 318-332, DOI: 10.1109/TRS.2024.3373535, February 2024.

5. J. Budhu, S. Ellingson, S. Hum, and R.M. Buehrer, "Design of Rim-Located Reconfigurable Reflectarrays for Interference Mitigation in Reflector Antennas," *IEEE Transactions on Antennas and Propagation*," vol. 72, no. 4, pp. 3736-3741, April 2024. DOI:10.1109/TAP.2024.3352250.

6. J. Yu, W. Howard, Y. Xu, and R.M. Buehrer, "Model Order Estimation in the Presence of multipath Interference using Residual Convolutional Neural Networks," *IEEE Transactions on Wireless Communications*," vol. 23, no. 7, pp. 7349-7361, July 2024, DOI: 10.1109/TWC.2023.3339803.

7. D.-R. Emenonye, H. S. Dhillon, and R.M. Buehrer, "On the Limits of Single Anchor Localization: Near-Field vs. Far-Field," *IEEE Wireless Communications Letters,* vol. 13, no. 2, pp. 540-544, Feb. 2024, DOI: 10.1109/LWC.2023.3335611.

8. C.E. Thornton and R.M. Buehrer, "On the Value of Online Learning for Radar Waveform Selection," *IEEE Transactions on Radar Systems*, vol. 1, pp. 505-519, DOI: 10.1109/TRS.2023.3313624.

9. W.H. Howard and R.M. Buehrer, "Hybrid Cognition for Target Tracking in Cognitive Radar Networks," *IEEE Transactions on Radar Systems*, vol. 1, pp. 118-131, DOI: 10.1109/TRS.2023.3282846.

10. C. E. Thornton, R. M. Buehrer, and A. F. Martone, "Online Bayesian Meta-Learning for Cognitive Tracking Radar," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 59, No. 5, pp. 6485-6500, Oct. 2023, doi: 10.1109/TAES.2023.3275552.

11. D.-R. Emenonye, H. S. Dhillon and R. Michael Buehrer, "RIS-Aided Localization under Position and Orientation Offsets in the Near and Far Field," *IEEE Transactions on Wireless Communications*,vol. 22, no. 12, pp. 9327-9345, doi: 10.1109/TWC.2023.3270029.

12. D. -R. Emenonye, H. S. Dhillon and R. M. Buehrer, "Fundamentals of RIS-Aided Localization in the Far-Field," *IEEE Transactions on Wireless Communications*, vol. 23, no. 4, pp. 3408-3424, April 2024. doi: 10.1109/TWC.2023.3307818.

13. D. -R. Emenonye, A. Sarker, A. T. Asbeck, H. S. Dhillon and R. M. Buehrer, "RIS-Aided Kinematic Analysis for Remote Rehabilitation," *IEEE Sensors Journal*, vol. 23, No. 19, 2023, doi: 10.1109/JSEN.2023.3308920.

14. S.W. Ellingson and R.M. Buehrer,"Coherent Time-Domain Canceling of Interference for Radio Astronomy," *Publications of the Astronomical Society of the Pacific*, 134, no. 1041 (2022): 114505, doi:10.1088/1538-3873/ac9b92

15. W.W. Howard, A.F. Martone, and R.M. Buehrer, "Distributed Online Learning for Coexistence in Cognitive Radar Networks," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 59, no. 2, pp. 1202-1261, April 2023, doi: 10.1109/TAES.2022.3198038.

16. J. Yu, P. Wang, T. Koike-Akino, Y. Wang, P. V. Orlik and R. M. Buehrer, "Multi-Band Wi-Fi Sensing with Matched Feature Granularity," *IEEE Internet of Things Journal*, vol. 9, no. 23, pp. 23810-23825, 2022, doi: 10.1109/JIOT.2022.3190826

17. M. O. Moore, R. M. Buehrer and W. C. Headley, "Decoupling RNN Training and Testing Observation Intervals for Spectrum Sensing Applications," *Sensors* 2022, 22(13), *Special Issue on Radio Frequency Machine Learning (RFML) Applications* 4706; doi: 10.3390/s22134706.

18. C.E. Thornton, R.M. Buehrer, H.S. Dhillon, and A.F. Martone, "Universal Learning Waveform Selection Strategies for Adaptive Target Tracking," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 58, no. 6, pp. 5798-5814, Dec. 2022. doi: 10.1109/TAES.2022.3181554

19. A. Sarker, D.R. Emenonye, A. Kelliher, T. Rikakis, R. M. Buehrer, A. Asbeck, "Capturing Upper Body Kinematics and Localization with Low-cost Sensors for Rehabilitation Applications,' Sensors 2022 , 22 , 2300. https://doi.org/10.3390/s22062300.

20. D.R. Emenonye, C. Dietrich, and R.M. Buehrer, "Differential Modulation in Massive MIMO With Low-Resolution ADCs," *IEEE Transactions on Wireless Communications,* vol. 21, No. 6, pp. 4482-4496, June 2022, DOI: 10.1109/TWC.2021.3130499

21. C. E. Thornton, R. M. Buehrer, and A. F. Martone, "Constrained Contextual Bandit Learning for Adaptive Radar Waveform Selection," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 58, no. 2, pp. 1133-1148, April 2022, Digital Object Identifier: 10.1109/TAES.2021.3109110.

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Conference Publications/Presentations

1. H. Hu, H.S. Dhillon, and R.M. Buehrer, "A New Statistical Method for Indoor Localization Using Unlabeled Crowdsourced Data," *accepted for presentation at the 2025 IEEE International Conference on Communications (ICC): Wireless Communications Symposium,* May 2025, Montreal, Canada.

2. S. Dhungel, G. Duggal, D. Ron, N. Tripathi, R. M. Buehrer, J. H. Reed, and V. K. Shah, "Experimental Validation of a 3GPP compliant 5G-based Positioning System," *18th ACM Workshop on Wireless Network Testbeds, Experimental Evaluation & Characterization (WINTECH'24)*, Washington, D.C., November 18, 2024.

3. X. Li, R.M. Buehrer and S.W. Ellingson, "An Improved Weight Selection Algorithm for Interference Mitigation in Paraboloidal Reflector Antennas With Reconfigurable Rim Scattering," accepted for presentation at the *2024 IEEE Military Communications Conference (MILCOM'24), Workshop on Spectrum: Pioneering the Future of Spectrum Sharing*, Washington, D.C., Oct. 28-Nov. 1, 2024.

4. W. J Hussain, G. Duggal, H.S. Dhillon and R. M. Buehrer, "The Role of Age in Adversarial Localization Scenarios," accepted for presentation at the *2024 IEEE Military Communications Conference (MILCOM'24)*, Washington, D.C., Oct. 28-Nov. 1, 2024.

5. Z. Schutz, D.J. Jakubisin, C.E. Thornton, and R.M. Buehrer, "Linear Jamming Bandits: Learning to Jam 5G-Based Coded Communications Systems," accepted for presentation at the *2024 IEEE Military Communications Conference (MILCOM'24)*, Washington, D.C., Oct. 28-Nov. 1, 2024.

6. D.-R. Emenonye, H.S. Dhillon, and R.M. Buehrer, "Joint 9-D Receiver Localization and Ephemeris Correction With LEO and 5G Base Stations," accepted for presentation at the *2024 IEEE Military Communications Conference (MILCOM'24)*, Washington, D.C., Oct. 28-Nov. 1, 2024.

7. D.-R. Emenonye, H.S. Dhillon, and R.M. Buehrer, "Is 9-D Localization Possible With Unsynchronized LEO Satellites?," accepted for presentation at the *2024 IEEE Military Communications Conference (MILCOM'24)*, Washington, D.C., Oct. 28-Nov. 1, 2024.

8. K. S. Bondada, D. J. Jakubisin, K. Said, R. M. Buehrer, and L. Liu "Wireless Mobile Distributed-MIMO for 6G," accepted for presentation at the 100^{th} *IEEE Vehicular Technology Conference*, Washington, D.C., Oct. 7-10, 2024.

9. D.-R. Emenonye, H.D. Dhillon, and R.M. Buehrer, "Minimal Configurations to Achieve 3D Positioning with Unsynchronized LEO Satellites," accepted for presentation at 100^{th} *IEEE Vehicular Technology Conference (VTC)*, Washington, D.C., October 7-10, 2024.

10. D.-R. Emenonye, H.D. Dhillon, and R.M. Buehrer, "Can Unsynchronized LEOs Provide 3D Orientation for a Ground Receiver?" accepted for presentation at 100^{th} *IEEE Vehicular Technology Conference (VTC)*, Washington, D.C., October 7-10, 2024.

11. R. Michael Buehrer, "Wireless Positioning: A History, the State of the Art and Current Research," **Key Note Presentation** at *2024 IEEE International Communication Conference (ICC 2024), 3rd Workshop on Synergies of Communication, Localization, and Sensing towards 6G,* Denver, CO, June 9-13, 2024.

12. M. Moore, C.W. Headley, and R.M. Buehrer, "Time-Diverse Doppler-Only PNT: Initial Solution," accepted for presentation at *The ION GNSS+ 2024 Conference*, September 16-20, 2024, Baltimore, Maryland.

13. G. Duggal, H. S. Dhillon and R.M. Buehrer, "3D Positioning using a New Diffraction Path Model," *2024 IEEE International Communication Conference (ICC 2024), 3rd Workshop on Synergies of Communication, Localization, and Sensing towards 6G,* Denver, CO, June 9-13, 2024.

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19. M.O. Moore, R. M. Buehrer, and W. C. Headley, "Time-Diverse Doppler-only LEO PNT," *2023 Military Communications Conference (MILCOM'23)*, Oct. 30 - Nov. 3, 2023, Boston, MA. Winner of **NSC Vanu Bose Best Paper Award**, and **Fred W. Ellersick Award for the Best Paper in the Unclassified Technical Program**.

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142. C. Anderson, H. I. Volos, C. Headley, F. Muller, and R. M. Buehrer, "Low-Antenna Ultra Wideband Spatial Correlation Analysis in a Forest Environment," *IEEE Vehicular Technology Conference – Spring*, pp. 1-5, Barcelona, Spain, April 26-29, 2009.

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144. J.-H. Lee, A. Bhupathi raju, and R. M. Buehrer, "An Analysis of Uplink Transmit Power in WCDMA Networks," *10th IEEE Wireless and Microwave Technology Conference (WAMICON2008)*, Clearwater, FL, April 20-21, 2009.

145. C.I. Phelps and R.M. Buehrer, "A Simplified Technique for Adaptive MIMO, Modulation, and Coding," *2009 IEEE Radio and Wireless Symposium (RWS2009),* pp. 566-569, San Diego, CA, January 18-22, 2009.

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159. R. Menon, A.B. MacKenzie, R.M. Buehrer, and J.H. Reed, "A Game-Theoretic Framework for Interference Avoidance in Ad hoc Networks," *2006 IEEE Global Telecommunications Conference (GLOBECOM '06)*, pp. 1–6, San Francisco, CA, Nov. 2006.

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214. J.-A. Tsai and R.M. Buehrer, "Frequency Reuse Reduction for IS-136 Using a Four Element Adaptive Array," *8th Virginia Tech Symposium on Wireless Personal Communications*, Blacksburg, VA, pp. 11-22, June 10-12, 1998.

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224. A. Park, R.M. Buehrer, and B.D. Woerner, "Throughput Performance for a FHMA System with Variable Rate Coding," *1995 IEEE Military Communications Conference*, San Diego, CA, vol. 1, pp. 320-324, November 5-8, 1995.

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National Research Council. 2009. "Toward a Universal Radio Frequency System for Special Operations Forces", Washington, D.C.: The National Academies Press.

R. M. Buehrer, W.A. Davis, A. Saffai-Jazi, and D. Sweeney, "Ultra-wideband Propagation Measurements and Modeling - Final Report," submitted to DARPA as part of the NETEX Program.

R. M. Buehrer, A. Safaai-Jazi, W. A. Davis, D. Sweeney, "Path Loss Calculations for Ultra-wideband Signals in Indoor Environments," invited contribution to the International Telecommunications Union, Document Number USWP 3K-1, October 26, 2003.

15 technical memoranda in the areas of multiuser detection, intelligent antennas, and OFDM for Bell Labs – Lucent Technologies. Titles and abstracts are proprietary information.

Professional Affiliations

- *Fellow*, Institute of Electrical and Electronics Engineers (IEEE)
- Member, IEEE Communications Society
- Member, IEEE Vehicular Technologies Society
- Member, IEEE Signal Processing Society
- Member, Eta Kappa Nu
- Member, Tau Beta Pi
- Member, Pi Mu Epsilon

Selected Professional Activities

- Organizer, "International Workshop on Signal Reuse for Spectrum Efficiency," *IEEE DySPAN 2024 Conference*.
- Area Editor, *IEEE Transactions on Wireless Communications*, 2017 - 2022.
- Guest Lead Editor, *IEEE Journal on Special Topics in Signal Processing*, special issue on non-cooperative position location networks.
- Guest Editor, *Proceedings of the IEEE*, special issue on cooperative localization.

- Associate Editor, *IEEE Wireless Communications Letters*, 2010 - 2014
- Associate Editor, *IEEE Transactions on Communications*, 2009 - 2014
- Associate Editor, *IEEE Transactions on Wireless Communications*, 2005 - 2012, 2015 - 2017
- Associate Editor, *IEEE Transactions on Vehicular Technologies*, 2005 - 2009
- Associate Editor, *IEEE Transactions on Signal Processing*, 2006-2007
- Associate Editor, *IEEE Transactions on Education*, 1997-2000
- Co-Technical Program Chair, *IEEE Vehicular Technology Conference*, Fall 2024 (100th Anniversary)
- Chair of IEEE MILCOM Technical Achievement Award Committee
- Workshop Organizer, "International Workshop on Signal Reuse for Spectrum Efficiency," *IEEE DySPAN 2024 Conference*.
- Organizer and Technical Co-Chair, 2015 IEEE Global Communications Conference Workshop on Localization and Tracking: Indoors, Outdoors and Emerging Networks (GC - LION '15), December, 2015.
- "Signal Processing for Communications" symposium co-chair for IEEE ICC 2017
- Symposium co-chair for IEEE ICC 2017 Signal Processing for Communications Symposium
- Technical Program Co-Chair, WPNC 2013.
- Technical Program Chair for UWBST2003.
- Technical Program Committee, 2008-2016 IEEE Global Communications Conference
- Technical Program Committee, 2007-2016 IEEE International Conference on Communications
- Technical Program Committee, IEEE RWS 2006
- Technical Program Committee, IEEE 2006 International Conference on Ultra Wideband
- Technical Program Committee, IEEE Vehicular Technology Conference 2006 - Fall
- Technical Program Committee, 2004 IEEE International Workshop on Ultra Wideband Systems / Ultra Wideband Systems and Technologies.
- Technical Program Committee, 2004 IEEE Radio and Wireless Conference (RAWCON), September 2004.
- Technical Program Committee, 2005 Wireless Communications and Networking Conference.
- Reviewer for *IEEE Journal on Selected Areas in Communications*, *IEEE Transactions on Communications, IEEE Transactions on Vehicular Technology, IEEE Communications Letters, IEEE Transactions on Signal Processing, ETRI Research Journal, Army Research Office, State of Tennessee*
- Session Chair, IEEE Vehicular Technology Conference – Fall 2002

Selected Consulting

- Lutron Electronics
  - Provided recommendations on the design and testing of indoor wireless networks, August - Sept. 2019.
  - Evaluated RF coexistence plan, March 2020.
  - Evaluated RF coverage and planning techniques for 2.4GHz indoor networks, September - October 2021.
- Polaris Wireless - Provided an evaluation of Z-axis estimation algorithm, Sept-Oct 2018.
- ENSCO, Inc. – Provided an evaluation of spread spectrum ranging system. March 2011.
- FCC – Delivered short courses on various topics in wireless communications including WiFi, spread spectrum, and 3G technologies. Summer 2004, Summer 2005.

Selected Expert Witness Experience

- Maxell vs. Samsung Electronics
  - Law firm: DLA Piper
  - Represented: Samsung
  - Served as expert witness. Wrote expert reports **Was deposed.**
  - Technology: Multi-radio Cell Phones
  - Dates: Sept. 2024 - present.
- Varia Holdings vs. Apple, Inc.
  - Law firm: Gibson, Crutcher and Dunn
  - Represented: Apple
  - Served as expert witness. Wrote declaration for claim construction. **Was deposed.**
  - Technology: Emulated RFID
  - Dates: May 2024 - present.
- NXP, et. al. vs. Bell Northern Research
  - Law firm: DLA Piper
  - Represented: NXP (petitioner)
  - Served as expert in Inter Partes Review proceedings. Wrote declaration supporting petitioner.
  - Technology: Training signals in WiFi
  - Dates: May 2024 - present.
- Neo Wireless, LLC v. American Honda Motor Co. Inc.
  - Law firm: Fish and Richardson
  - Served as expert in Inter Partes Review proceedings. Wrote declaration supporting petitioner. Served as an expert witness for litigation including validity and infringement analysis. **Was deposed.**
  - Technology: Cellular communication systems
  - Dates: January 2023 - present
- NXP, et. al. vs. Bell Northern Research
  - Law firm: DLA Piper
  - Represented: NXP (later other members of JDG including MediaTek, ASUSTek, Laird Connectivity)
  - Analyzed technical aspects of several patents to aid validity/invalidity analysis. ITC case. **Was deposed.**
  - Technology: Various aspect of WiFi
  - Dates: August 2023 - April 2024.
- Apple, Inc. vs. The Holding Company LLC
  - Law firm: erise IP
  - Represented: Apple (Petitioner)
  - Served as expert in Inter Partes Review proceedings. Wrote declaration supporting petitioner.
  - IPR2024-00400, IPR2024-00400, IPR2024-00399,IPR2024-00398,IPR2024-00397
  - Technology: Geolocation using wireless devices and wireless networks
  - Dates: April 2023 - present

- Cisco, Inc. vs. Netsocket
  - Law firm: Haynes and Boone
  - Represented: Cisco (Petitioner)
  - Served as expert in Inter Partes Review proceedings. Wrote declaration supporting petitioner. **Was deposed.**
  - IPR2023-00606
  - Technology: Quality of Service in wireless/wireline networks
  - Dates: Sept. 2022 - December 2023
- Intel
  - Law firm: Wilmer and Hale
  - Represented: Intel
  - Examined technical aspects of various patents to aid validity/invalidity analysis for potential IPR filings.
  - Technology: Multi-user MIMO in WiFi (802.11ac, 802.11ax)
  - Dates: September 2023 - December 2023
- Geoscope vs. Apple
  - Law firm: Gibson, Crutcher and Dunn
  - Represented: Apple
  - Analyzed technical aspects of various patents to aid validity/invalidity and infringement/non-infringement analysis with respect to ITC case. **Was deposed**
  - Technology: Geolocation in 3GPP-based cellular systems.
  - Dates: April 2023 - August 2023
- Ericsson vs. Apple
  - Law firm: Fish and Richardson
  - Represented: Apple
  - Analyzed technical aspects of various patents to aid validity/invalidity and infringement/non-infringement analysis. Included both Inter Partes Review proceedings and ITC case. **Was deposed multiple times. Testified at trial.**
  - Dates: September 2021 - December 2022
- Godo Kaisha IP Bridge vs. Nokia
  - Law firm: Alston & Bird
  - Represented: Nokia (defendant)
  - Served as expert witness for non-infringement and invalidity.
  - Case No. 2:21-CV-215-JRG
  - Technology: Sounding Reference Signal, RACH, ACK/NACK and CQI reporting in cellular networks. **Was deposed.**
  - Dates: September 2021 - November 2022
- Honeywell, Int'l., Inc., et. al. vs. Sisvel International
  - Law firm: K&L Gates
  - Represented: Honeywell (Petitioner)

  - Served as expert in Inter Partes Review proceedings. Wrote declaration supporting petitioner. **Was deposed.**
  - IPR2021-00640
  - Technology: Cell selection and reselection in Radio Resource Control
  - Dates: December 2021 - Jan. 2022

- Thales, et. al. vs. Sisvel International
  - Law firm: AddyHart
  - Represented: Thales (Petitioner)
  - Served as expert in Inter Partes Review proceedings. Wrote declarations supporting petitioner. **Was deposed.**
  - IPR2021-00639
  - Technology: Data connection management.
  - Dates: December 2021 - Jan. 2022

- ZTE, et. al. vs. Sisvel International
  - Law firm: Banner-Witcoff
  - Represented: ZTE (Petitioner)
  - Served as expert in Inter Partes Review proceedings. Wrote declarations supporting petitioner.
  - IPR2021-00639, IPR2021-00640
  - Technology: Cell selection and reselection in Radio Resource Control; Data connection management.
  - Dates: January 2021 - April 2021

- HP, Inc. vs. Ozmo
  - Law firm: DLA-Piper
  - Represented: HP
  - Served as testifying expert
  - 6:21-cv-00383-ADA
  - Technology: Wireless local area and personal ara networks (WLANs and WPANs)
  - Dates: August 2021 - October 2021

- Samsung vs. Ericsson
  - Law firm: Fish & Richardson
  - Represented: Samsung
  - Wrote declarations for IPR filings.
  - IPR2021-00615, IPR2021-00685
  - Technology: Cellular communications
  - Dates: January 2021 - April 2021

- Tesla, Inc. vs. Optis
  - Law firm: Munger, Tolles, & Olson
  - Represented: Tesla (defendant)
  - Case 2:20-cv-00310
  - Served as testifying expert witness

  - Technology: Control channels/information in cellular systems
  - Dates: November 2020 - March 2021

- Apple, Inc.
  - Law firm: Wilmer-Hale
  - Wrote declaration in support of request for ex parte reexamination
  - Reexam Control Numbuer 90/014,653
  - Technology: Control information in cellular systems
  - Dates: November 2020 - January 2021

- Phillips vs. Garmin
  - Law firm: Alston-Bird
  - Represented: Garmin (defendant)
  - Served as testifying expert witness for Federal Trade Commission proceedings
  - Technology: Local and Cellular Wireless Connections in Personal Emergency Response Systems
  - District: FTC
  - Dates: June - July 2020

- ZTE vs. Sisvel International
  - Law firm: Banner-Witcoff
  - Represented: ZTE (Petitioner)
  - Served as expert in Inter Partes Review proceedings. Wrote declarations supporting petitioner. **Was deposed.**
  - IPR2020-01070, IPR2020-01071
  - Technology: Radio Resource Control
  - Dates: March 2020 - May 2021

- Apple, Inc. vs. Optis
  - Law firm: Wilmer-Hale
  - Represented: Apple (Plaintiff)
  - Served as testifying expert witness for litigation. **Was deposed. Testified at trial.**
  - Case 2:19-cv-66 (E.D. Tex.)
  - Technology: Control information in cellular systems
  - District: Eastern District of Texas
  - Dates: July 2019 - August 2020.

- Apple, Inc. vs. Wi-LAN
  - Law firm: DLA Piper
  - Represented: Apple (Plaintiff)
  - Served as testifying expert witness for litigation. **Was deposed. Testified at trial.**
  - Technology: Resource Allocation in Wireless Systems
  - District: Southern District of California
  - Dates: January ’19 - January ’20

- TELUS Communications, Bell Mobility, and Rogers Communications vs. WiLAN, Inc.

  - Law firm: Torys, LLP.
  - Represented: TELUS Communications, Bell Mobility, and Rogers Communications
  - Served as testifying expert. Analyzed certain patents (and the prior art) and provided technical reports on sufficiency, validity and potential double-patenting.
  - Technology: Resource allocation in wireless networks
  - Dates: January 2019 - November 2019

- Samsung vs. Sharp
  - Law firm: Fish and Richardson
  - Represented: Samsung
  - Analyzed technical aspects of patent to aid validity/invalidity analysis.
  - Technology: Feedback in MIMO-OFDM systems
  - Dates: April 2019 - July 2019

- American Patents, LLC vs. HP, Inc.
  - Law firm: DLA Piper
  - Represented:HP, Inc.
  - Analyzed technical aspects of two patents to aid validity/invalidity analysis.
  - Case 18-cv-700 (E.D. Tex.)
  - Technology:MIMO/OFDM synchronization in cellular systems
  - Dates: June 2019

- Blackberry vs. Uniloc, LLC.
  - Law firm: Oblon
  - Represented: Blackberry (Petitioner)
  - Wrote declaration to the USPTO concerning the disclosure of certain features of two patents in previous references.
  - Technology: Traffic mapping between logical channels and transport channels in wireless systems
  - Dates: June 2019.

- Apple, Inc. vs. Wi-LAN
  - Law firm: DLA Piper
  - Represented: Apple (Plaintiff)
  - Served as testifying expert witness for litigation (non-infringing alternatives). **Was deposed. Testified at trial.**
  - Case 3:14-cv-2235-DMS-BLM
  - Technology: Resource Allocation in Wireless Systems
  - District: Southern District of California
  - Dates: November ’17 - July ’18

- Apple, Inc., LG Electronics Inc., Samsung Electronics Co., Ltd., and Samsung Electronics America, Inc. vs. Uniloc, LLC.
  - Law firm: Fish and Richardson
  - Represented:Apple, Inc., LG Electronics Inc., Samsung Electronics Co., Ltd., and Samsung Electronics America, Inc. (Petitioner)

  - Wrote declarations to the USPTO concerning the disclosure of certain features of two patents in previous references.
  - IPR2019-00219, IPR2019-00222
  - Technology: Traffic mapping between logical channels and transport channels in Wireless Systems; Multi-mode transceivers
  - Dates: September 2018 - November 2019.

- CCE vs. Apple, Inc.
  - Law firm: DLA Piper
  - Represented: Apple (Defendant)
  - Served as testifying expert witness for litigation (infringement analysis). **Was deposed.**
  - 2:15-cv-00576-RWS-RSP
  - Technology: Power Headroom Reporting in Cellular Systems
  - District: Eastern District of Texas
  - Dates: January 2017 - July 2017

- Nokia Technologies vs. Apple, Inc.
  - Law firm: Wilmer-Hale
  - Represented: Apple (Defendant)
  - Served as testifying expert witness for litigation (infringement analysis)
  - Technology: antennas for handheld mobile devices
  - District: Eastern District of Texas
  - Dates: January 2017 - June 2017

- Core Wireless vs. Apple, Inc.
  - Law Firm: Wilmer-Hale
  - Represented: Apple (Defendant)
  - Role: Served as testifying expert witness for litigation (infringement and validity analysis). **Was deposed. Testified at trial.**
  - Case 5:15-cv-5008
  - Technology: Control Channels and Frame Stealing in 2G (GSM) cellular networks.
  - District: The US District Court for the Northern District of California
  - Dates: May 2015 - December 2016.

- AMERICAN SYSTEMS vs. US Navy
  - Law Firm: Miles and Stockbridge
  - Represented: AMERICAN SYSTEMS (Plaintiff)
  - Role: Served as testifying expert witness for litigation (case settled prior to expert reports being filed).
  - Technology: Wireless mesh networks.
  - Dates: Nov. 2014 - June 2015.

- TruPosition,Inc. vs. LM Ericsson Telephone Company, et. al.
  - Law Firm: Constantine-Cannon LLP
  - Represented: TruePosition (Plaintiff)
  - Role: Served as testifying expert witness for litigation. Case settled prior to depositions being taken.

  - Case 2:11-cv-04574-RK
  - Technology: Cellular-based geolocation for 4G (LTE) cellular networks.
  - District: The US District Court for the Eastern District of Pennsylvania
  - Dates: March 2013 - July 2014.

- Andrew, LLC vs TruPosition, Inc.
  - Law Firm: Patterson Belknap Webb & Tyler LLP
  - Represented: Andrew, LLC (Plaintiff)
  - Role: Served as testifying expert witness for patent litigation. **Was deposed.**
  - Civil Action 09-669
  - Technology: Cellular-based (2G, 3G) geolocation.
  - District: The US District Court for the District of Delaware
  - Dates: Nov. 2009 - March 2010.

- TCL vs. Ericcson
  - Law Firm: Sheppard Mullin
  - Provided Services for: TCL (Plaintiff)
  - Role: Served as consulting expert witness for essentiality analysis.
  - Technology: digital communications in 2G, 3G, and 4G cellular systems.
  - District: The US District Court for the Central District of California
  - Dates: March 2015 - December 2015.

- Univ. of Minnesota vs. Sprint
  - Law Firm: McGuire-Woods
  - Provided Services for: Sprint (Defendant)
  - Role: Served as consulting expert for validity analysis.
  - Technology: 4G cellular networks.
  - Dates: October 2015 - January 2016.

- Eon Corp, IP Holdings, LLC vs Research In Motion Corporation, et. al.
  - Law Firm: Sidley-Austin
  - Provided Services for: Research in Motion Corporation (Defendant)
  - Served as consulting expert for patent litigation
  - Technology: Cellular technologies
  - Dates: March 2012

- InterDigital vs. Nokia
  - Law Firm: Alston-Bird LLP
  - Provided Services for: Nokia
  - Served as a consulting expert
  - Technology: Cellular CDMA and power control
  - Date: Oct. 2011 - Dec. 2011.

- SPH America, LLC vs Acer, Inc.
  - Law Firm: Spotts Fain PC
  - Provided Services for: UT Starcomm
  - Role: Served as a consulting expert for patent litigation
  - Technology: CDMA (spread spectrum) and 3G cellular technologies.
  - Dates: Jan. 2011 - March 2011

References

Available upon request.