

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of: Juhyung Son, et al. Attorney Docket No. 39843-0194IP1
U.S. Patent No.: 11,470,595
Issue Date: October 11, 2022
Appl. Serial No.: 16/868,525
Filing Date: May 6, 2020
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 12, 2025

By: 

R. Michael Buehrer

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I, R. Michael Buehrer, of Blacksburg, Virginia, declare that:

I. ASSIGNMENT

1. I have been retained on behalf of Samsung Electronics Co., Ltd. (“Samsung”) to offer technical opinions related to 11,470,595 (“the ‘595 patent”) (SAMSUNG-1001). I understand that Samsung is requesting that the Patent Trial and Appeal Board (“PTAB” or “Board”) institute an *inter partes* review (“IPR”) proceeding of the ‘595 patent.

2. I have been asked to provide my independent analysis of the ‘595 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 ‘595 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 ‘595 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 Engineering 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 Virginia 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 Virginia 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 communications, 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 at 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, and *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 '595 patent at the time of the earliest possible priority date of the '595 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, as the priority date (i.e., the Critical Date).

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 '595 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. Any figures that appear within this document have been prepared with the assistance of Counsel and reflect my understanding of the '595 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. To summarize those conclusions, based upon my knowledge and experience and my review of the prior art references listed above, I believe that:

- Josiam renders obvious claims 1-12 of the '595 patent;
- Josiam combined with Seok further renders obvious claims 1-6 of the '595 patent; and
- Chen combined with Wu renders obvious claims 1-12 of the '595 patent.

25. In support of these conclusions, I provide an overview of the references in Section IX and more detailed comments regarding the obviousness of claims 1-12 (“the Challenged Claims”) of the '595 patent in Section X.

IV. LEVEL OF ORDINARY SKILL IN THE ART

26. 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, as of the Critical Date. Increased educational experience can make up for less work experience, and vice versa.

27. Further, all positions in this declaration are from the vantage point of a POSITA as of December 24, 2015.

28. 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 post-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

29. 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 and ordinary 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).

30. The '595 patent was filed on May 6, 2020, and claims priority to, among other documents, Korean Priority Application No. 10-2015-0186871 filed December 24, 2015, which I refer to as the "Critical Date" in this proceeding. Because I do not know at what date the invention as claimed was made, if ever, I have used the Critical Date of the '595 patent as the point in time for claim interpretation purposes.

B. Legal Standards

31. 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.

32. 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.

C. Anticipation

33. 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.

34. 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.

35. 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

36. 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.

37. 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.

38. 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.

39. 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."

40. 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.

41. 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.

42. 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.

43. 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.

44. 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.

45. 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.

46. 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.

47. 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

48. My analysis and conclusions set forth in this declaration are based on my educational background and experiences in the field (*see* Section 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, and I taught, participated in organizations, and worked closely with many such persons

in the field during that time frame.

49. 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 the art during the time before the Critical Date; my own knowledge and experiences gained from my work experience in the field of the '595 patent and related disciplines; and my experience in working with others involved in this field and related disciplines.

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

- SAMSUNG-1001 U.S. Patent No. 11,470,595 to Son, et al. (“the '595 Patent”)
- SAMSUNG-1002 Excerpts from the Prosecution History of the '595 Patent (“the Prosecution History”)
- 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-1005 U.S. Patent Publication No. US2016/0330300A1 (“Josiam”)
- SAMSUNG-1006 U.S. Provisional Application No. 62/216,514 (“Josiam Provisional”)
- SAMSUNG-1007 U.S. Patent Publication No. US2016/0174200A1 (“Seok”)
- SAMSUNG-1008 U.S. Patent Publication No. US2016/0330058A1 (“Chen”)
- SAMSUNG-1009 U.S. Patent Publication No. US2017/0070998A1 (“Wu”)

- SAMSUNG-1010 U.S. Provisional Application No. 62/215,054 (“Wu Provisional”)
- SAMSUNG-1011 December 7, 2015 IEEE 802.11ax Draft Specification Framework
- SAMSUNG-1012 IEEE 802.11ac-2013 Specification
- SAMSUNG-1013 Ron Porat et al., *SIG-B Encoding Structure* (Jul. 13, 2015) IEEE 802.11-15/0873
- SAMSUNG-1014 Yujin Noh et al., *Preamble Structure in 802.11ax* (May 2015) IEEE 802.11-15/0575r0
- SAMSUNG-1015 Jiayin Zhang et al., *Preamble Structure for 11ax System* (Jan. 2015) IEEE 802.11-15/0101r1
- SAMSUNG-1016 U.S. Patent Publication No. US2016/0150514A1 (“Kwon”)
- SAMSUNG-1017 Joonsuk Kim et al., *HE-SIG-B Structure* (Jul. 11, 2015) IEEE 802.11-15/0821r2
- SAMSUNG-1018 Hongyuan Zhang et al., *BW Field in HE-MU Format* (Jul. 25, 2016) IEEE 802.11-16/0898
- SAMSUNG-1019 Andreas F. Molisch, *Wireless Communications* (2nd ed. 2011)
- SAMSUNG-1020 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)

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

VII. TECHNOLOGY OVERVIEW

52. In this section I provide an overview of the relevant technology and state of the technical community before the Critical Date. 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

53. 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.

54. 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

55. 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.

56. 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.

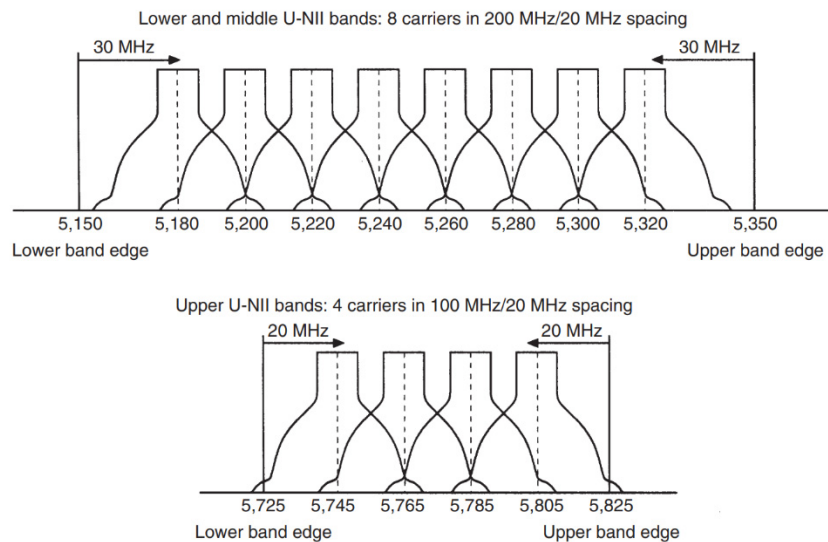


Figure 29.2 802.11a channel plan.

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SAMSUNG-1019, Fig. 29.2

57. 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 $0.8\mu\text{s}$ symbols (as shown below) that are used for coarse frequency estimation and Automatic Gain Control. The STF is followed by an $8\mu\text{s}$ 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 $\frac{1}{2}$ code and uses BPSK modulation. The relationship between the three fields can be seen more clearly in the figure below.

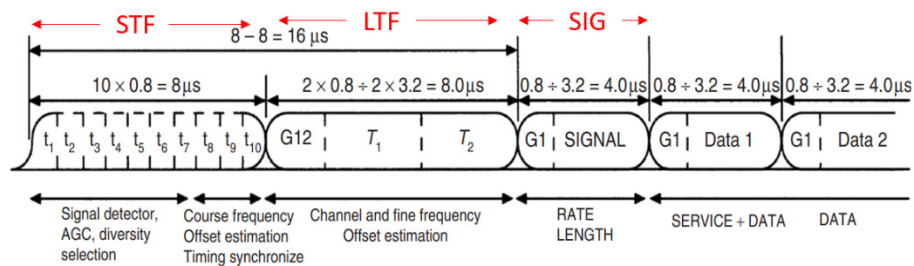


Figure 29.6 Orthogonal frequency division multiplexing training structure.

SAMSUNG-1019, Fig. 29.6

C. 802.11a/g MAC Layer

58. 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.

59. 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.

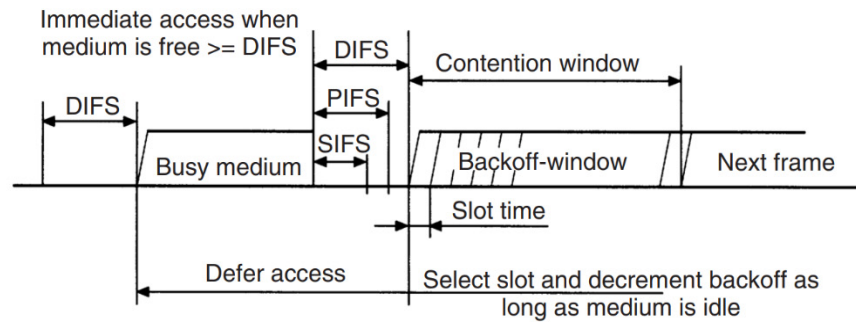


Figure 29.14 Basic access method.

SAMSUNG-1019, Fig. 29.14

60. 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.

61. As alluded to above, DCF defines different Interframe Spaces (IFS) to

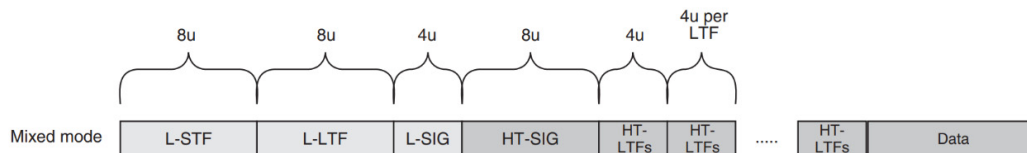
prioritize transmissions. DIFS is used before starting a new transmission. SIFS (Short Interframe Space) is used for high-priority responses like acknowledgements (ACKs). Each frame transmission is acknowledged (ACK) by the receiver. If no ACK is received, the sender retransmits after a backoff period.

D. 802.11n

62. 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.

63. 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-1019, Fig. 29.9 (excerpt)

64. 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.

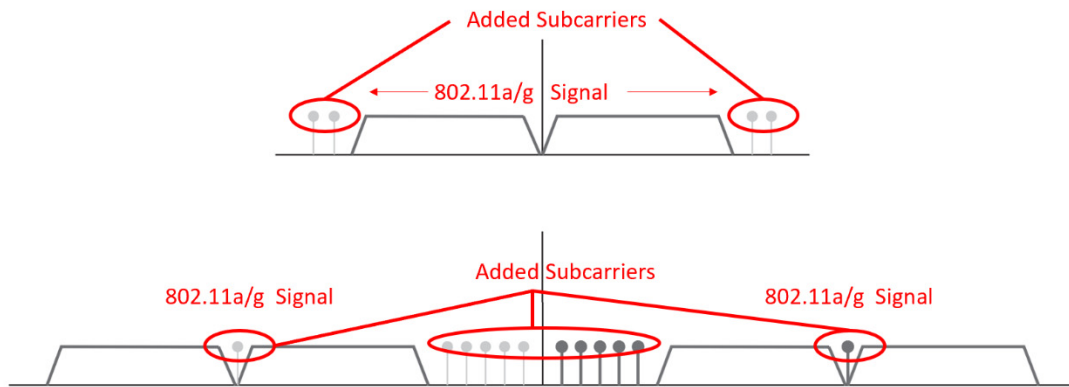


Figure 29.8 20-MHz and 40-MHz subcarriers.

SAMSUNG-1019, Fig. 29.8 (annotated)

65. 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

66. 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.

67. 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.

68. 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

69. As discussed above IEEE 802.11ac defines frequency channels for bandwidths of 20, 40, 80 and 160 MHz, as illustrated below:

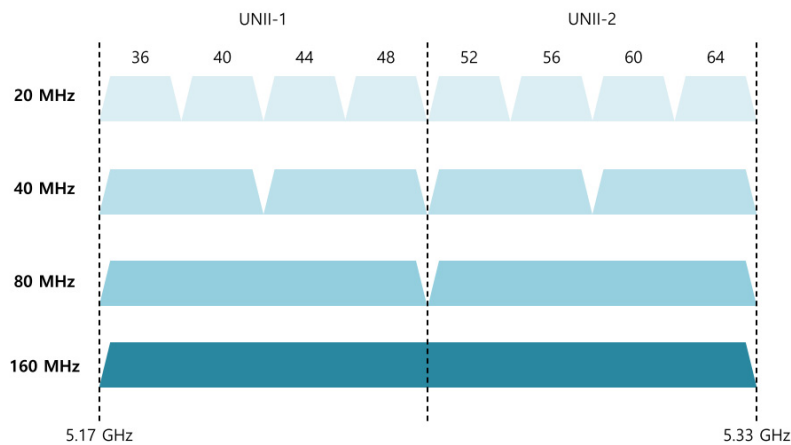


FIGURE 1. Channelization of IEEE 802.11 for various bandwidths in the 5 GHz band.

SAMSUNG-1020, Fig. 1

70. In 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.

71. 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 20 MHz channels from the left.

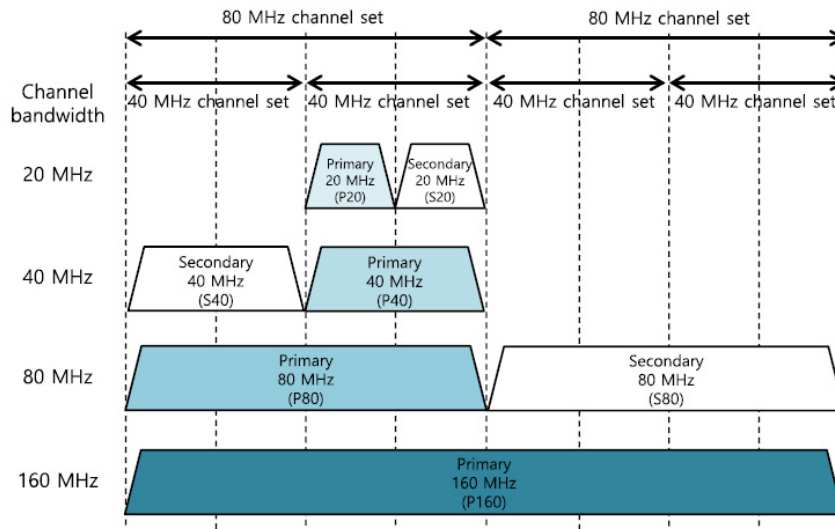


FIGURE 2. Contiguous channel bonding rule when the primary 20 MHz channel is the third (from the left) of the 20 MHz channels.

SAMSUNG-1020, Fig. 2

72. 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, 25 μ s 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.

73. 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

74. For the next version of 802.11, it was determined that higher efficiency and higher throughput would be goals. By December 2015 (i.e., the critical date of the '595 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.

75. 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

76. By the Critical 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.

77. 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

78. 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 $\frac{1}{2}$ 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.

79. When 802.11n was developed, the SIG field was maintained for backwards compatibility, but renamed the Legacy SIG (L-SIG). A 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 long. Each OFDM

symbol contained 24 signaling bits which were convolutionally encoded with a rate $\frac{1}{2}$ code. The 48 bits were used 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 transmission
- 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

80. 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.

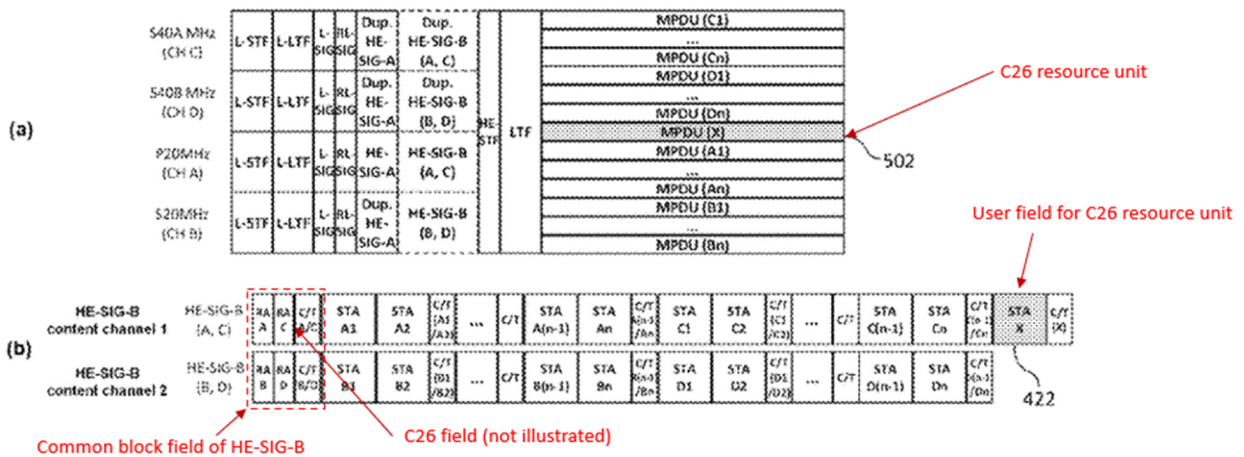
81. When 802.11ac was introduced, for backwards compatibility it also required the transmission of the L-SIG, which was not changed from the 802.11n L-SIG. Like 802.11n, 802.11ac added two separate SIG fields known as Very High Throughput SIG-A (VHT-SIG-A) and VHT-SIG-B. The former contained most of 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 '595 PATENT

A. Overview of the '595 Patent

82. The '595 patent is directed to “a method of signaling allocation information of a center 26-tone RU [resource unit] in an HE MU PPDU.” *Id.*, 45:3-60. According to the '595 patent, “[w]hen a PPDU is transmitted in a total bandwidth of 80MHz or more, a center 26-tone RU 502 as shown in Fig. 38 (a) may additionally be used. . . . [T]he common block field of the HE-SIG-B may further include a C26 field (not illustrated) indicating whether a user is allocated to the center 26-tone RU 502. The C26 field may consist of a 1-bit indicator located before or after the RA field in the common block field.” *Id.*



SAMSUNG-1001, Fig. 38 (annotated)

83. Claims 7-12 recite method claims, and claims 1-6 recite apparatus claims, which include a processor configured to perform steps corresponding to the methods described in claims 7-12, respectively. I treat claims 7-12 as exemplary of the '595 patent's claims.

B. Prosecution History of the '595 Patent

84. During prosecution, the '595 patent was twice rejected as obvious in view of Chen (U.S. Patent Pub. No. 2016/0330058 A1), Hedayat (U.S. Patent No. 10,219,271 B1), and Noh (U.S. Patent Pub. No. 2017/0041929 A1). SAMSUNG-1002, 64-79, 113-130. Applicant first responded by amending the independent claims to additionally recite "wherein the unassigned resource unit is explicitly indicated with the information of the unassigned resource unit based on the bandwidth field and the at least one subfield" and argued that neither Chen nor

Hedayat taught the newly added limitation. *Id.*, 92-102. Specifically, Applicant argued the examiner’s reliance on Chen was misplaced because Chen’s method of indicating an unassigned resource unit using a “special (e.g., blank or null) PAID¹ which is not decodable by or known to any of the scheduled [stations]” meant that Chen’s stations “implicitly recognize that the RU was unallocated or skipped if the PAID is not decodable or known.” *Id.*, 98-99. According to Applicant, this may result in a station recognizing an allocated resource as “not allocated or skipped if it is not recognized or decoded due to an error.” *Id.*, 98-66.

85. The examiner found Applicant’s arguments unpersuasive, pointing to paragraph [0090] of Chen, “which states that one alternative for RU assignment is to explicitly indicate the non-allocated RU in the HE-SIG-B field.” *Id.*, 66-67.

Specifically, the examiner found that Chen taught:

wherein the unassigned resource unit is explicitly indicated with the information of the unassigned resource unit (*non-allocated RU is explicitly indicated*; see paragraph [0090]) based on the bandwidth field and the at least one subfield (*RU pattern is determined by channel BW (i.e. BW field) in conjunction with the other fields*; see paragraphs [0098] and [0103]; *RU allocation is explicitly indicated in HE-SIG-B (i.e. subfield)*; see paragraph

¹ I note that a partial AID (PAID) is a form of station ID carried in the station-specific part of HE-SIG-B. SAMSUNG-1008, [0033], [0037], [0039], [0047], [0063].

[0090])

Id., 69 (emphasis original).

86. Applicant responded by first arguing that Chen’s disclosure in paragraph [0090] did not teach the previously added limitation because that limitation requires “both ‘the bandwidth field and the at least one subfield’ are based for explicitly indicating the unassigned resource unit.” *Id.*, 51-53. Applicant did not address whether Hedayat, alone or in combination with Chen, satisfies this limitation. *Id.*

87. Applicant also further amended the claims to recite “the information of the unassigned resource unit includes information of a C26 field indicating whether a user is allocated to a center 26-tone resource unit of 80MHz upon the bandwidth related to a transmission of the received wireless packet indicated by the bandwidth field being 80MH or more, not 20 MHz or 40MHz.” *Id.*, 48, 53-54. Applicant argued that the amended claim was allowable over Hedayat’s disclosure, which disclosed using a C26 field for 20MHz PPDU. *Id.*, 53-54 (emphasis original).

88. Following this amendment, the examiner issued a notice of allowance. *Id.*, 20-29. The examiner found that “[t]he independent claims are directed towards the idea of obtaining information about unassigned resource units, information which indicates whether the center 2Mhz chunk (a 26 tone RU) in an 80MHz or

greater block is allocated to a user, using a particular configuration of information in HE-SIG-A and HE-SIG-B fields of HEW [high efficiency wireless] communication.” *Id.*, 27. According to the examiner,

HEW communication is known in the art, and the general idea of indicating unassigned RUs using HE-SIG-A and HE-SIG-B fields is also known (see e.g. Chen (US20160330058 A1) at paragraph [0093] and Fig. 14). It is also known in the art that [for some] blocks (20MHz, 80MHz, and 80+80MHz), the center 2MHz chunk may need to be allocated separately (see Hedayat (US 10219271 B1) Col. 18 Lines 40-50), while for example the 40MHz block does not have the center RU.

Id.

89. The examiner noted that the claims were allowed because of

Applicant’s negative limitation amendment:

The independent claims have been specifically amended to require that the claimed process of indication and allocation only be performed on 80MHz or greater PPDU, and not the 20MHz PDU indicated by Hedayat. The examiner does not believe one of ordinary skill in the art would have found it obvious to modify Hedayat to exclude performing the claimed process on 20MHz PPDU, as Hedayat teaches directly away from this, and would result in an inferior system.

Id.

90. I note that the examiner maintained his citation to the same method in Chen that Applicant argued did not teach indicating information of an unassigned resource based on HE-SIG-A and HE-SIG-B. *Id.* I also note that the Applicant did not dispute the examiner’s findings with respect to Chen. *Id.*, 18-19, 27.

IX. OVERVIEW AND COMBINATIONS OF PRIOR ART REFERENCES

A. U.S. Patent Publication No. US2016/0330300A1 (“Josiam”)

91. Josiam “relates to signaling and addressing in WLAN systems.”

SAMSUNG-1005, [0002]; SAMSUNG-1006, 1-7. Specifically, Josiam discloses methods for resource unit arrangement and signaling in a high efficiency (HE) multi-user (MU) physical layer convergence protocol (PLCP) protocol data unit (PPDU). SAMSUNG-1005, [0002]-[0003]; SAMSUNG-1006, 1-9, 11. Josiam discloses “a header for a HE PPDU transmission,” which includes “HE signal A (HE-SIG-A) and HE signal B (HE-SIG-B) fields 525 and 530, respectively.” SAMSUNG-1005, [0074], [0093]-[0094], [0102], Fig. 5; SAMSUNG-1006, 1-3, 7-8, 16, Figs. 1-3.

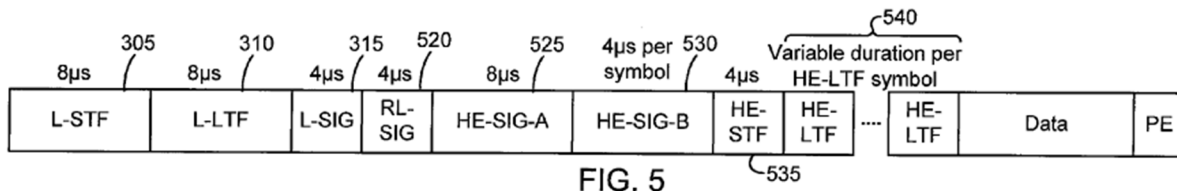


FIG. 5

SAMSUNG-1005, Fig. 5; SAMSUNG-1006, 1-3, 7-8, 16, Figs. 1-3.

92. Josiam discloses an “HE-SIG-B multiplexing scheme 2900 for 80MHz including 2 channels, each carrying independent information per a 20 MHz HE-SIG-B channel.” SAMSUNG-1005, [0165]; SAMSUNG-1006, 24-25, Fig. 29. For example, as illustrated in Figure 29 below, “an 80MHZ MU PPDU includes two channels 2915 and 2920. . . . Each HE-SIG-B channel 2915 and 2920 carries

different information and the HE-SIG-B channels 2915 and 2920 are duplicated per 40MHz, i.e., HE-SIG-B channel 1 2915 is carried in channel A & C of 80MHz while HE-SIG-B Channel 2 [] 2920 is carried in B & D of 80MHz.” *Id.*

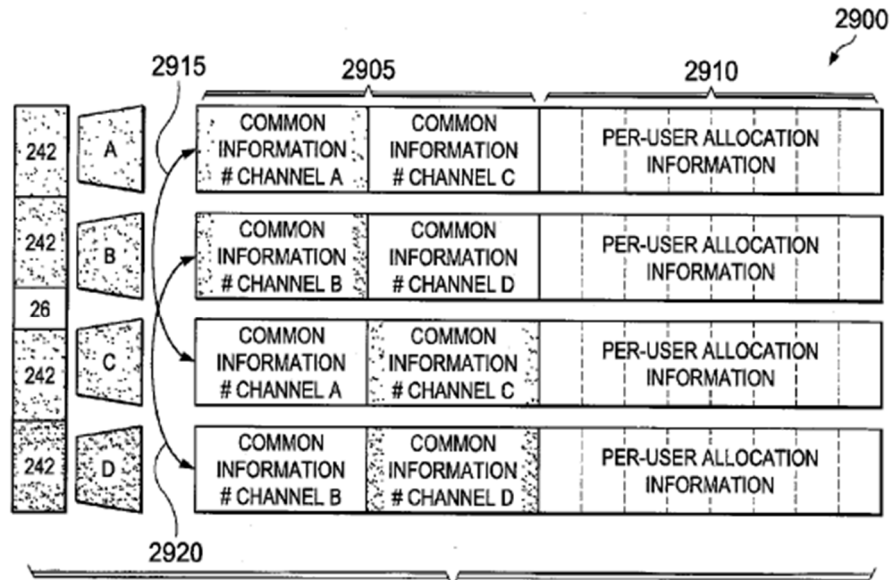


FIG. 29

SAMSUNG-1005, Fig. 29; SAMSUNG-1006, Fig. 29

93. Josiam discloses a resource unit allocation index carried in the common field² of HE-SIG-B, which “can communicate indices that indicate

² I note that a POSITA would have understood that the “common field” of HE-SIG-B was also commonly referred to as the “common part,” “common portion,” or “common block.” See, e.g., SAMSUNG-1005, Abstract, [0005]-[0006], [0111], [0114], [0115], [0153], cls. 1, 5; SAMSUNG-1006, 8-9, 10-11, 14, 23-24; SAMSUNG-1008, Abstract, [0037], [0060], [0090];

unused resources and used resources.” SAMSUNG-1005, [0154], Table 3; SAMSUNG-1006, 21-22. Josiam further discloses a method for signaling whether one or more center 26-tone resource units in an 80 or 160MHz PPDU is assigned to a user. SAMSUNG-1005, [0110], [0118], [0126], [0169], [0173], [0190]; SAMSUNG-1006, 9-11, 24-25, 29-30, Figs. 10-11. For example, Josiam explains that “[t]he common information portion 2905 of one of the HE-SIG-B channels also includes 1 bit indicating whether the center 26-tone RU is assigned to a[] user or not. . . . If the bit is set to 1, the per-user allocation information is carried at the end, after the user allocations for segments A & C are carried.” SAMSUNG-1005, [0169], Fig. 11; SAMSUNG-1006, 11, Fig. 11.

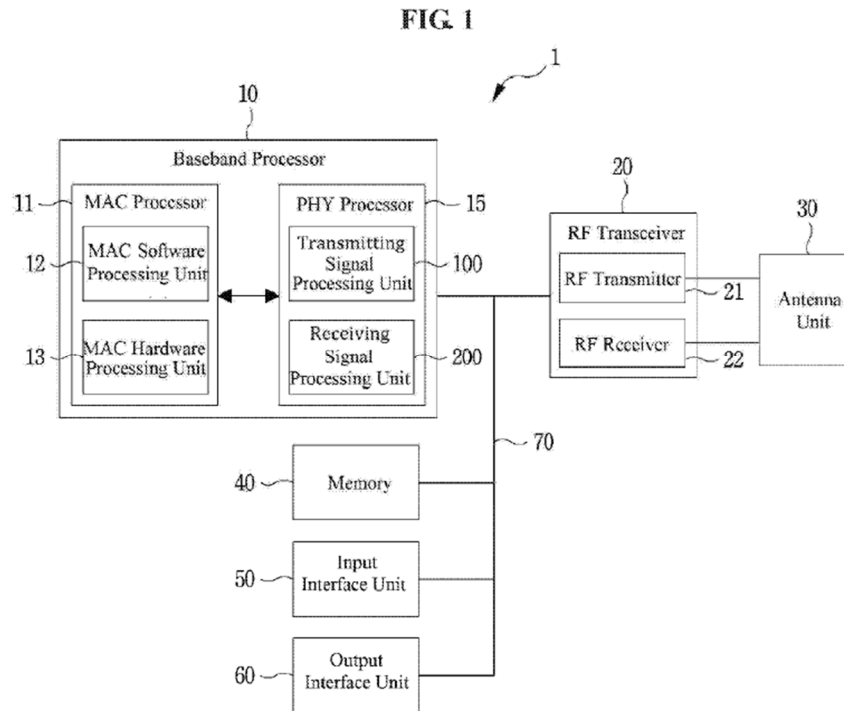
B. U.S. Patent Publication No. US2016/0174200A1 (“Seok”)

94. Seok relates to “Wireless Local Area Networks (WLANs), and more particularly, to a method and apparatus for resource allocation for multiple user transmission in a High Efficiency WLAN (HEW).” SAMSUNG-1007, [0003].

SAMSUNG-1009, Abstract, [0004]-[0005], [0036]; SAMSUNG-1010, 1-2, 4, 8-12; SAMSUNG-1011, 8-12. These terms all refer to the portion of HE-SIG-B that carries information applicable to all stations receiving the PPDU, such as the resource unit allocation of the bandwidth. SAMSUNG-1005, [0111]; SAMSUNG-1006, 11; SAMSUNG-1008, [0037]; SAMSUNG-1009, [0036]; SAMSUNG-1010, 2-4; SAMSUNG-1011, 8-12.

Seok discloses “a WLAN device 1,” which includes “a baseband processor 10.”

SAMSUNG-1007, [0046]. “The baseband processor 10 may be simply referred to as a processor and may perform baseband signal processing.” *Id.*, [0047].



SAMSUNG-1007, Fig. 1.

C. Combination of Josiam and Seok

95. In my opinion, it would have been obvious to a POSITA to combine Josiam’s methods with the hardware implementation details describe in Seok. For example, a POSITA would have been motivated to combine the teachings of Josiam with Seok to realize implementation details and to achieve an operable station that would be capable of carrying out the techniques described in Josiam

through, for example, the inclusion of processing circuitry and radio circuitry for receiving and processing transmissions that include HE MU PPDU.

96. I further believe that a POSITA would have understood the combination of Josiam and Seok merely involve combining prior art elements according to known methods to yield predictable results. Indeed, Seok discloses communication devices, stations and APs in an IEEE 802.11ax Wi-Fi network (e.g., HE-WLAN). SAMSUNG-1007, [0044]-[0045]. Seok specifically discusses implementation of HE MU PPDU preamble designs with HE-SIG-A and HE-SIG-B fields. SAMSUNG-1007, [0097]-[0118].

97. In my opinion, a POSITA would have found the combination predictable and foreseeable, at least because:

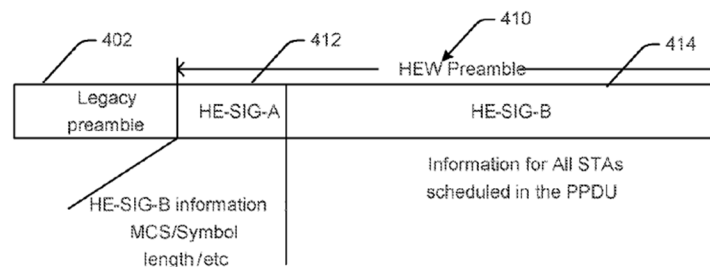
- (1) Seok discloses communications between a station and an AP within a HE-WLAN environment, consistent with IEEE 802.11; and
- (2) the combination merely involves incorporating known hardware and software elements expressly disclosed by Seok to implement the HE MU PPDU described by Josiam. SAMSUNG-1007, [0044]-[0045]; [0097]-[0118].

98. A POSITA would have also found the combination obvious and predictable because elements of the combined system would each perform similar functions they had been known to perform prior to the combination. For example,

the station in the Josiam-Seok combination would perform the same functions contemplated by Josiam but would include specific circuitry like that disclosed in Seok to carry out those functions. Thus, a POSITA would have had a reasonable expectation of success implementing the combination.

D. U.S. Patent Publication No. US2016/0330058A1 (“Chen”)

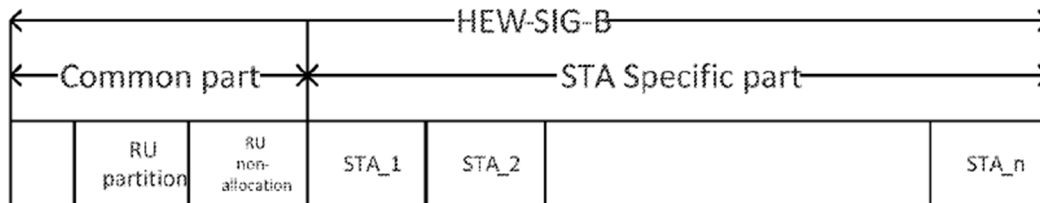
99. Chen relates to “resource unit (RU) allocation in high efficiency (HE) Wi-Fi preambles,” particularly in IEEE 802.11ax or High-Efficiency WLAN. SAMSUNG-1008, [0002]-[0003]. Chen discloses “identifying an RU for transmitting and receiving data based at least in part on a received PPDU.” SAMSUNG-1008, [0101]-[0104]. Chen’s PPDU includes HE-SIG-A and HE-SIG-B fields. *Id.*, [0035], [0076], [0101]-[0104], Fig. 4.



SAMSUNG-1008, Fig. 4

100. Chen further discloses methods for identifying an unassigned resource unit. SAMSUNG-1008, [0090]-[0093], Figs. 12-14. For example, Chen describes a

method for “[e]xplicit indication of [a] non-allocated RU in the common part³ of HE-SIG-B.” SAMSUNG-1008, [0093], Fig. 14. Specifically, Chen discloses that, “[a]fter the RU allocation information (e.g., the allocation pattern in the common part of HE-SIG-B), there may be RU non-allocation information. This non-allocation information may indicate the non-allocated RUs.” SAMSUNG-1008, [0093].



SAMSUNG-1008, Fig. 14

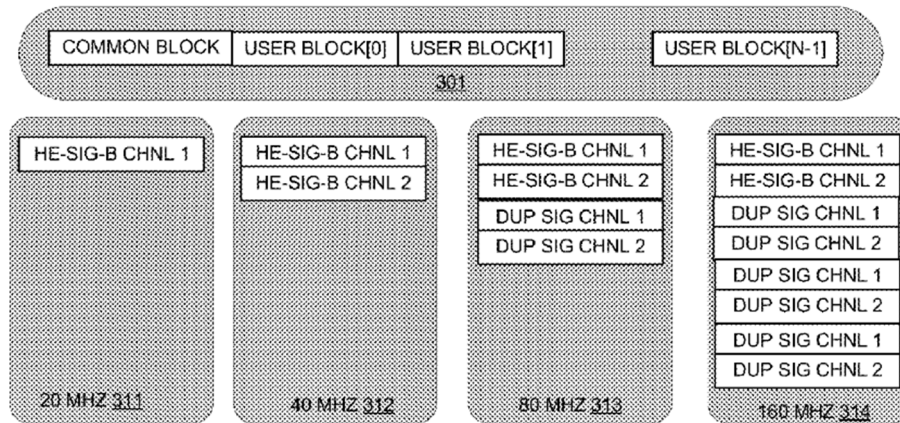
E. U.S. Patent Publication No. US2017/0070998A1 (“Wu”)

101. Wu relates to resource allocation indication in 802.11ax wireless networking. SAMSUNG-1009, [0003]-[0004]; SAMSUNG-1010, 2. Wu discloses methods for “HE-SIG-B . . . common field formats and indications.” SAMSUNG-1009, [0005]; SAMSUNG-1010, 1-2. Wu describes an HE-SIG-B duplication scheme, in which SIG-B information for each 20MHz segment of an HE PPDU is included in one of two HE-SIG-B content channels and replicated across each

³ See *supra* note 1.

20MHz segment in an alternating fashion as depicted below in Figure 3.

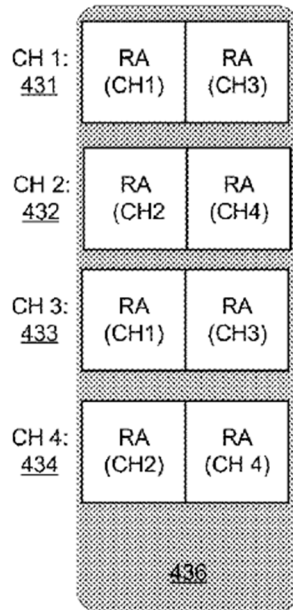
SAMSUNG-1009, [0036], Fig. 3; SAMSUNG-1010, 4.



SAMSUNG-1009, Fig. 3; SAMSUNG-1010, 4

102. Each of Wu's HE-SIG-B content channels includes "a common block [and] multiple user blocks." SAMSUNG-1009, [0036], Fig. 3; SAMSUNG-1010, 4. Wu explains that the common block may carry resource unit allocation information in the form of "RU indexes in the HE-SIG-B" which "are used for a look-up table (LUT) to obtain the resource allocation information." SAMSUNG-1009, [0036]; SAMSUNG-1010, 5-6. Specifically, "a fixed format common field in the HE-SIG-B is defined for each operation bandwidth." SAMSUNG-1009, [0036]; SAMSUNG-1010, 10. For example, when the operation bandwidth is 80MHz "there are two RA LUTs on each of the HE-SIG-B common field," which indicate resource allocation for each of the four 20MHz channels of the 80MHz transmission. SAMSUNG-1009, [0039]; SAMSUNG-1010, 12. In one

embodiment illustrated below, HE-SIG-B content channel 1 carries resource unit allocation for channels 1 and 3, and content channel 2 carries resource unit allocation for channels 2 and 4. SAMSUNG-1009, [0039], Fig. 4C; SAMSUNG-1010, 12.



SAMSUNG-1009, Fig. 4C; SAMSUNG-1010, 12

103. Wu discloses a method for signaling one or more “middle 26-tone RU for 80MHz and 160MHz” by including “a one-bit indication in the HE-SIG-B common [field].” SAMSUNG-1009, [0043]-[0044], [0046], Figs. 5-6; SAMSUNG-1010, 27.

F. Combination of Chen and Wu

104. In my opinion, a POSITA would have found it obvious to combine a method of signaling a non-allocated resource unit, per Chen, with a method of

carrying HE-SIG-B information in two content channels, per Wu. In the combination, the HE-SIG-B information (e.g., resource unit allocation, non-allocation, and station assignment information) would be partitioned into segments corresponding to each 20MHz channel used. SAMSUNG-1008, [0084]-[0087] (“Each allocation pattern may be one partitioning of the whole band (e.g., 80MHz or a subchannel 20MHz)”); SAMSUNG-1009, [0035]-[0042], [0072]; SAMSUNG-1010, 3-4, 10, 12. The information would be carried in an HE-SIG-B content channel corresponding to the 20MHz channel. SAMSUNG-1009, [0036], Fig. 3; SAMSUNG-1010, 4.

105. For example, an 80MHz PPDU would be transmitted over four 20MHz channels, each of which carries either an HE-SIG-B content channel 1 or an HE-SIG-B content channel 2. SAMSUNG-1009, [0036], [0039], Figs. 3, 4C; SAMSUNG-1010, 4, 12. Each HE-SIG-B content channel would carry resource unit allocation information for the tones in 242-tone segments that correspond to the 20MHz channels that carry the content channel. *Id.*; SAMSUNG-1009, [0042]; SAMSUNG-1010, 12. This indication would cover 968 (242 tones x 4 channels) of the 996 available tones in an 80MHz PPDU. SAMSUNG-1009, [0035], Fig. 2; SAMSUNG-1010, 3, 5, 12, 27. Thus, an additional indication bit would be included in each HE-SIG-B content channel to indicate the use of a C26 resource unit located in the middle of the 80MHz PPDU, per Wu. SAMSUNG-1009,

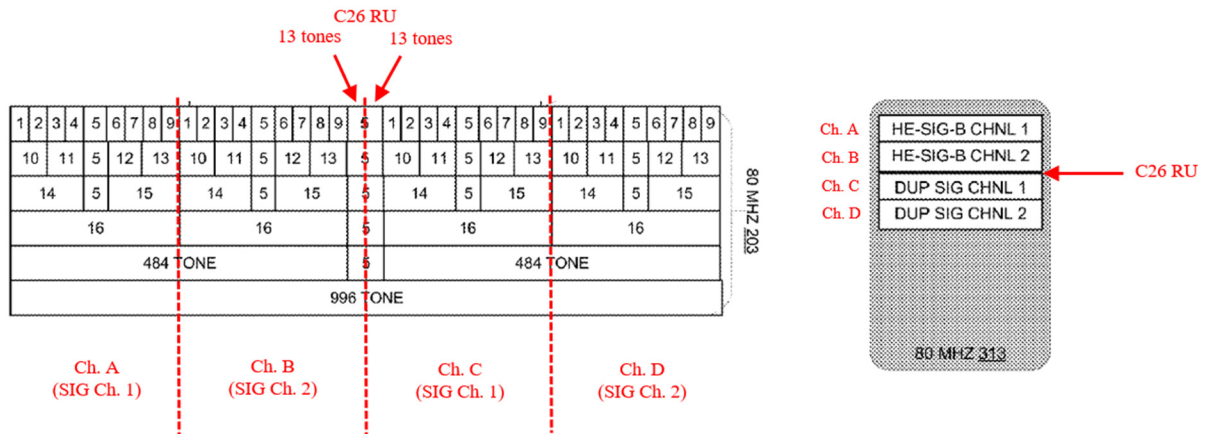
method of carrying HE-SIG-B information in two content channels, per Wu, for several reasons. First, splitting resource allocation information between two content channels would reduce signaling overhead as compared to signaling all resource allocation information for all channels in a single HE-SIG-B field. SAMSUNG-1013, 8-10.

107. More specifically, a POSITA would have been motivated to use a content channel scheme (like the one described in Wu) because it strikes a balance between channel use efficiency and complexity. SAMSUNG-1012, 9-10; SAMSUNG-1013, 5-9. Putting all of the signaling into a single 20 MHz channel would have eased complexity (since only a single channel would need to be decoded for the signaling information) but would have increased the duration of the HE-SIG-B (which is overhead), thus reducing the efficiency of the transmission. *Id.* However, dividing the HE-SIG-B across all channels, while minimizing HE-SIG-B duration, would have increased complexity considerably, since in the worst case, the receiver would need to decode the HE-SIG-B on all eight 20 MHz channels of a 160 MHz PPDU. *Id.* In my opinion, using two content channels is an obvious balance between these two extremes.

108. Moreover, by the Critical Date, the relevant standards organization, TGax, had adopted the SIG-B replication structure described in Wu into the draft 802.11ax Specification Framework. SAMSUNG-1011, 8-12, Figs. 4-5, 6-7. But

methods for indicating the non-allocation of a resource unit had not yet been decided.

109. Chen teaches methods for indicating the non-allocation of a resource unit by including non-allocation information in the common field of HE-SIG-B. *See* § IX.D. However, as a POSITA would have understood that Chen’s method does not contemplate the HE-SIG-B content channel structure described in Wu and adopted into the draft standard. Specifically, a POSITA would have understood that, because a center or middle 26-tone RU falls between two 20MHz channels carried in two different HE-SIG-B content channels, it does not clearly fall within the common field of a particular content channel. SAMSUNG-1009, [0035]-[0036], [0041]-[0043], Figs. 2-4; SAMSUNG-1010, 3-6, 27-28 (“The middle 26 tone RU for 80 MHz [bandwidth] can not be signaled in the existing [resource unit allocation tables].”); *see* § X.A.1 (discussing resource unit arrangement in 80 MHz and larger PPDUs). Indeed, the draft specification recognized this issue, noting that “[s]ignaling for the center 26 unit in 80MHz is TBD.” SAMSUNG-1011, 9.



SAMSUNG-1009, Figs. 2-3 (annotated); SAMSUNG-1010, 3-4

110. A POSITA would have understood that a separate method for indicating the C26 resource unit, e.g., as described in Wu, would have been one such solution for indicating allocation of a C26 resource unit. Thus, Wu's method of indicating a C26 resource unit reflects a known solution to a known problem. But Wu does not explicitly disclose a method for indicating the non-allocation of a resource unit apart from the C26 resource unit. As a result, a POSITA would have found it obvious to combine the method for indicating the non-allocation of resource units within each 242-tone portion of the PPDU corresponding to a 20MHz channel, per Chen, with the method for indicating the special case of a C26 resource unit in 80MHz or larger PPDU, per Wu. SAMSUNG-1008, [0089]-[0093], Figs. 12-14; SAMSUNG-1009, [0007], [0041]-[0047], Figs. 4-6; SAMSUNG-1010, 3-6, 10-13, 27-28.

111. Moreover, combining Chen and Wu's teachings would have been well

within the skill of a POSITA prior to the earliest effective filing date. Indeed, the combination would have amounted to nothing more than the application of a known technique of splitting HE-SIG-B information into two content channels to a known method of indicating resource unit allocation and non-allocation information to yield predictable results. *Id.*; SAMSUNG-1008, [0090]-[0093], Figs. 12-14; SAMSUNG-1009, [0036], Fig. 3; SAMSUNG-1010, 4. Given that Chen teaches that allocation information may be indicated on a per 20MHz basis, and that the edge case of the allocation of a C26 resource unit may be accounted for through the methods described in Wu, a POSITA would have naturally expected success when applying Wu's techniques to Chen's methods. SAMSUNG-1008, [0084]-[0087]; SAMSUNG-1009, [0007], [0043]-[0047]; SAMSUNG-1010, 27. Moreover, a POSITA would have found the Chen-Wu combination predictable given that the standards body had adopted the two-content-channel approach for signaling HE-SIG-B and noted that indication of C26 resource units was to be determined. SAMSUNG-1011, 8-12.

X. MANNER IN WHICH THE PRIOR ART REFERENCES RENDER THE '595 CLAIMS UNPATENTABLE

A. Ground 1A – Josiam Renders Obvious Claims 1-12

1. Claim 7

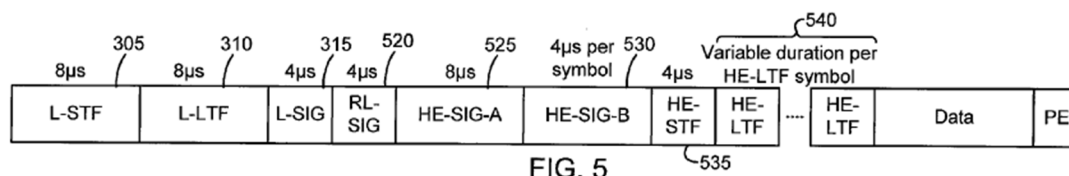
[7.pre] A wireless communication method of a wireless communication terminal, the method comprising:

112. To the extent the preamble is limiting, Josiam discloses “methods for

efficient signaling and addressing in WLAN systems.” SAMSUNG-1005, [0004];
 see SAMSUNG-1006, 7-8. Josiam’s methods describe at least one station (i.e., a
 wireless communication terminal). *Id.*

[7.1] receiving a wireless packet including an high efficiency (HE)-signal (SIG)-A and HE-SIG-B;

113. In my opinion, Josiam renders obvious receiving a high efficiency
 (HE) PPDU including HE-SIG-A and HE-SIG-B fields. SAMSUNG-1005, [0074],
 [0093]-[0094], [0102], Fig. 5; SAMSUNG-1006, 1-8, 16, Figs. 1-5. In my opinion,
 a POSITA would have understood that a PPDU is a wireless packet. SAMSUNG-
 1005, [0003] (“The data packet transmitted is called a HE physical layer
 convergence procedure (PLCP) protocol data unit (PPDU).”); SAMSUNG-1006, 1.



SAMSUNG-1005, Fig. 5; SAMSUNG-1006, 1-8, 16, Figs. 1-5

[7.2] obtaining bandwidth information indicated via a bandwidth field included in the HE-SIG-A;

114. In my opinion, Josiam renders obvious obtaining bandwidth
 information indicated via a bandwidth field included in the HE-SIG-A.
 SAMSUNG-1005, [0094], [0105], [0123], [0132]; SAMSUNG-1006, 8-9, 13, 16.
 For example, Josiam discloses that “[t]he size of the RU position index carried in

the block of user allocation information varies according to the bandwidth information signaled in the HE-SIG-A.” SAMSUNG-1005, [0132], SAMSUNG-1006, 16. In my opinion, a POSITA would have understood that the bandwidth information signaled in HE-SIG-A would be carried in a field within the HE-SIG-A. SAMSUNG-1007, [0125], [0193]; SAMSUNG-1006, Fig. 2; SAMSUNG-1012, 259-260, Table 22-12; SAMSUNG-1015, 13.

115. Moreover, a POSITA would have understood Josiam’s disclosure as building upon VHT-SIG fields of 802.11ac (Wi-Fi 5). SAMSUNG-1005, [0102]; SAMSUNG-1006, 1-2; SAMSUNG-1007, [0124]. A POSITA would have understood that the previous generation VHT-SIG-A field includes a bandwidth field, which indicates the bandwidth of the PPDU (e.g., 20, 40, 80, or 160MHz), and would have found it obvious to carry this field over into HE-SIG-A. SAMSUNG-1007, [0125], [0193]; *see also* SAMSUNG-1006, Fig. 2; SAMSUNG-1012, 259-260, Table 22-12; SAMSUNG-1015, 13 (“[The] 11ax PPDU should also contain HE-SIG-A to carry some similar fields as in HT-SIG/VHT-SIG-A of 11n/ac, e.g., BW, GI.”).

116. Finally, including a bandwidth field in HE-SIG-A was within the general knowledge of a POSITA by the Critical Date. SAMSUNG-1011, 4-8; SAMSUNG-1015, 13; SAMSUNG-1016, [0078]-[0079]. For example, the December 6, 2015 802.11ax Draft Specification Framework includes a bandwidth

field in HE-SIG-A, and a POSITA would have found it obvious that this field was included in the PPDU described in Josiam, which is directed to 802.11 communications. SAMSUNG-1011, 4-8; SAMSUNG-1005, [0003]; SAMSUNG-1006, 1, 7.

[7.3] obtaining information of an unassigned resource unit via at least one subfield included in the HE-SIG-B,

117. Josiam renders obvious obtaining resource unit allocation information via at least a common field (i.e., at least one subfield) included in HE-SIG-B. SAMSUNG-1005, [0104], [0111], [0154], [0159], [0167]-[0171]; SAMSUNG-1006, 8, 11, 21-20, 24. This resource unit allocation information may include information of an unassigned resource unit. *Id.* The unassigned resource unit may fall within a 242-tone segment corresponding to a 20MHz channel or may be one or more 26-tone resource units (“C26 resource units⁴”) that do not fall within any 242-tone segment corresponding to a 20MHz channel. *Id.* A POSITA would have understood the common field as a subfield of HE-SIG-B. *Id.*; SAMSUNG-1005, [0105]-[0106], [0156]-[0157]; SAMSUNG-1006, 11, 23; SAMSUNG-1011, 8-9.

⁴ I use the term “C26 resource unit” in my declaration to refer to one or more 26-tone resource units in an 80 or 160MHz tone plan that does not fall within any 242-tone segment corresponding to a 20MHz channel.

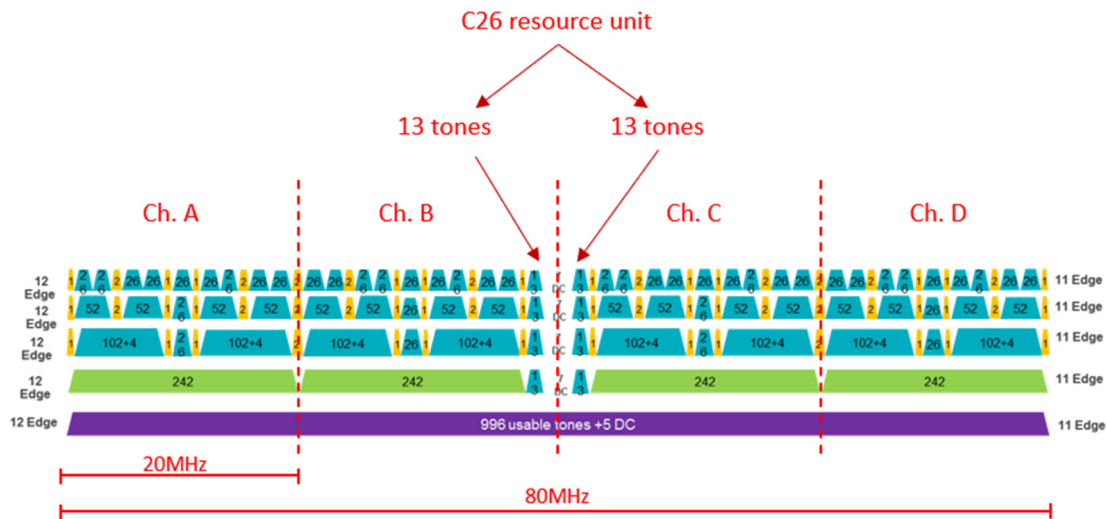
118. For example, Josiam teaches obtaining information of an unassigned resource unit through a resource unit allocation index included in the common portion of HE-SIG-B. SAMSUNG-1005, [0154], Table 3; SAMSUNG-1006, 21-22. Specifically, Josiam states that “the RU allocation index can communicate indices that indicate unused resources [i.e., information of an unassigned resource unit] and used resources. The total number of per-STA information fields that follow changes depending on the number of used resources indicated by the index. No per-STA information fields are sent for resources indicated to be unused in the resource allocation index.” SAMSUNG-1005, [0154], Table 3; SAMSUNG-1006, 21-22. As one example, Josiam explains that a 26-tone resource unit within a 242-tone segment “may not be used or allocated to any STA-ID to improve padding efficiency.” *Id.* Thus, a POSITA would have understood Josiam as obtaining information of an unassigned resource unit (e.g., an unused resource unit within a 242-tone segment) via at least one subfield (e.g., the common field) of HE-SIG-B.

TABLE 3

RU indexes for improved padding efficiency									
	#1	#2	#3	#4	#5	#6	#7	#8	#9 Num User
176		106			X			106	64
240	52		52		X	52		52	1

SAMSUNG-1005, Table 3; SAMSUNG-1006, 21-22

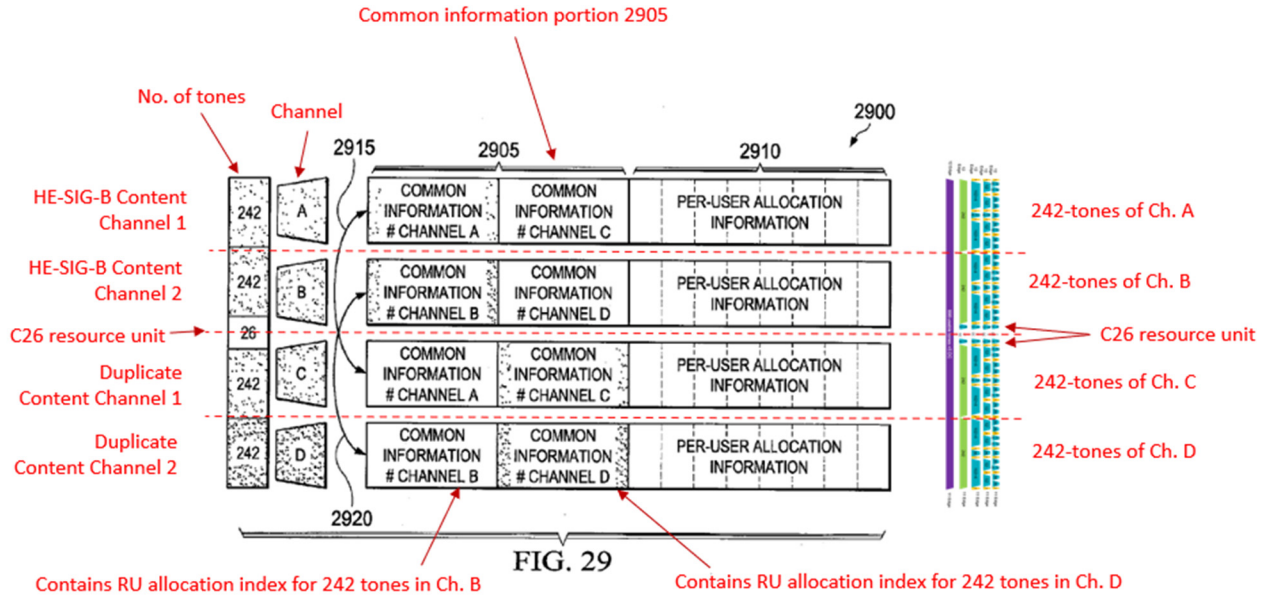
119. As another example, Josiam teaches an additional method for obtaining information as to whether one or more C26 resource units are assigned to a user. SAMSUNG-1005, [0118], [0165]-[0169], [0190]; SAMSUNG-1006, 11-12, 24, 29-30. This is because the tone plans for 80 and 160MHz bandwidths are not aligned with 20MHz segments. SAMSUNG-1005, [0188]; SAMSUNG-1006, 24, 29. For example, an 80MHz bandwidth consists of 996 usable tones, 968 of which may be broken into four 242-tone segments corresponding to four 20MHz channels. That leaves one 26-tone resource unit in the center of the 80MHz bandwidth, in which 13 tones are transmitted in one 20MHz channel and 13 tones are transmitted in an adjacent 20MHz channel.



SAMSUNG-1011, Fig. 13⁵ (annotated)

120. Josiam carries HE-SIG-B information via two HE-SIG-B channels, one of which carries resource unit allocation information for channels A & C and one of which carries resource unit allocation information for channels B & D. SAMSUNG-1005, [0158]-[0159], [0164]-[0170], [0187]-[0190], Figs. 27, 29, 37; SAMSUNG-1006, 23-25, 29-30, Figs. 27, 29, 37. Because the C26 resource unit falls between two 20MHz channels corresponding to two different HE-SIG-B content channels, a POSITA would have understood that allocation information for the entire C26 resource unit does not fall within the resource unit allocation for the 242-tones corresponding to either 20MHz channel. SAMSUNG-1005, [0118], [0165]-[0169], [0190]; SAMSUNG-1006, 11-12, 24, 29-30. Indeed, the draft specification framework recognized this issue, noting that “[s]ignaling for the center 26 unit in 80MHz is TBD.” SAMSUNG-1011, 9.

⁵ This figure is also reproduced on multiple lines in SAMSUNG-1005, Fig. 16 and identically in SAMSUNG-1006, Fig. 16. I use the IEEE figure here for readability purposes.



SAMSUNG-1005, Fig. 29; SAMSUNG-1006, Fig. 29 illustrated with SAMSUNG-1011, Fig. 13⁶ (annotated)

121. To handle this situation, Josiam discloses including an indication bit in the common field of HE-SIG-B that indicates whether “the central 26 tone RU is assigned to a[] user or not.” SAMSUNG-1005, [0169]; SAMSUNG-1006, 24. “If the bit is set to 1, the per-user allocation information is carried at the end, after the user segments for A & C are carried.” SAMSUNG-1005, [0169]; SAMSUNG-1006, 24. A POSITA would have understood that, if the bit is set to zero, this indicates that the C26 resource unit is not assigned to any user (i.e., an unassigned

⁶ See *supra* note 4.

resource unit). *Id.* Thus, a POSITA would have understood Josiam as obtaining information of an unassigned resource unit (e.g., an unassigned C26 resource unit) via at least one subfield (e.g., the common field) of HE-SIG-B.

[7.4] wherein the bandwidth field is related to bandwidth over which the received wireless packet is transmitted, and

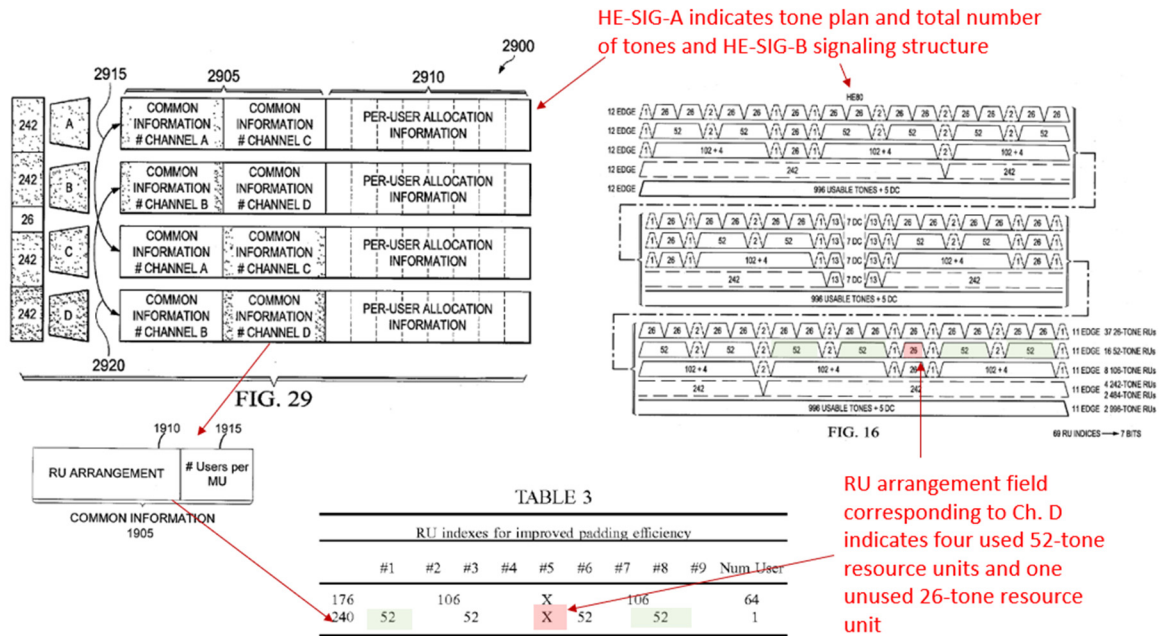
122. As I discussed above for [7.2], a POSITA would have understood Josiam as teaching a bandwidth field that indicates the bandwidth of the PPDU. SAMSUNG-1005, [0094], [0105], [0123], [0132]; SAMSUNG-1006, 8-9, 13, 16; *see* [7.2]. A POSITA would have understood the bandwidth of the PPDU (*a wireless packet*) as related to the bandwidth over which the wireless packet is transmitted. *Id.*

[7.5] wherein the bandwidth field of HE-SIG-A is used to obtain the information of the unassigned resource unit; and

123. Josiam renders obvious wherein the bandwidth field of HE-SIG-A is used to obtain the information of the unassigned resource unit (e.g., an unused resource unit within a 242-tone segment or an unused C26 resource unit). As I discussed for [7.2], the bandwidth field of HE-SIG-A indicates the bandwidth of the PPDU. The number of HE-SIG-B content channels and the length of the common field in each content channel varies based on the bandwidth. SAMSUNG-1005, [0156]-[0192]; SAMSUNG-1006, 22-30; *see* [7.2].

124. As one example, information of an unassigned resource unit in an 80

MHz PPDU may be obtained via and indicated by the bandwidth field of HE-SIG-A and the RU allocation index of HE-SIG-B. SAMSUNG-1005, [0130]-[0138], [0164]-[0175], Figs. 11, 14-16, 29; SAMSUNG-1006, 11-12, 15-17, 24-29. The bandwidth field first indicates the total bandwidth of the PPDU, thus indicating, among other things, the total number of possible tones (here, 996 tones for 80 MHz) and HE-SIG-B signaling structure (here, two HE-SIG-B content channels containing resource unit allocation information for two segments of 242-tones corresponding to alternating 20 MHz channels). SAMSUNG-1005, [0130]-[0134], [0164]-[0175], Figs. 14-16, 29; SAMSUNG-1006, 15-17, 24-29. The RU allocation index for one or more of the four 242-tone segments may include a value (e.g., 240) indicating that a 26-tone resource unit within the 242-tones corresponding to a particular 20 MHz segment is not assigned to a user. SAMSUNG-1005, [0135]-[0140], [0150]-[0155], Table 3, Figs. 17, 23, 29. By these two fields, a station may determine that a particular resource unit within the overall 80 MHz bandwidth (i.e., 996-tones) is unassigned. SAMSUNG-1005, [0135]-[0138] (“Given the fixed location of the RUs in the OFDMA tone plan, the enumeration of possible RU arrangements over a specific bandwidth is specified and signaled.”), Fig. 17; SAMSUNG-1006, 16-17.



SAMSUNG-1005, Fig. 29 illustrated with SAMSUNG-1005, Table 3, Figs. 16, 19;
SAMSUNG-1006, 22, Figs. 16, 19, 29 (annotated)

125. As another example, Josiam teaches that the number of indication bits in the common part of HE-SIG-B—which indicate information as to whether one or more C26 resource units is unassigned—is determined based on the bandwidth as indicated by the bandwidth field of HE-SIG-A. For example, Josiam teaches that, in an 80MHz PPDU, “[t]he common portion 2905 of one of the HE-SIG-B channels also includes 1 bit indicating whether the central 26 tone RU is assigned to a[] user or not.” SAMSUNG-1005, [0165]-[0169]; SAMSUNG-1006, 24. In a 160MHz PPDU, “[t]wo 26 tone RUs are signaled using 1 bit separately[,] . . . one in HE-SIG-B channel-1 3715 and the other in HE-SIG-B channel-2 3720.”

SAMSUNG-1005, [0190]; SAMSUNG-1006, 29-30. No indication bit for a C26 resource unit is included in 20 or 40MHz PPDU. *Compare* SAMSUNG-1005, [0156]-[0163]; SAMSUNG-1006, 22-24, *with* SAMSUNG-1005, [0164]-[0192]; SAMSUNG-1006, 24-30.

126. Because the bandwidth as indicated by the bandwidth field of HE-SIG-A triggers the number of indication bits for one or more C26 resource units in the common part of HE-SIG-B, a POSITA would have understood Josiam's bandwidth field as being used to obtain the information of the allocation of the C26 RU—i.e., information of an unassigned resource unit. *See* [7.8].

127. Thus, a POSITA would have understood that the bandwidth field of HE-SIG-A is used to obtain the information of the unassigned resource unit (e.g., an unused resource unit within a 242-tone segment or an unused C26 resource unit).

[7.6] decoding a data of the received wireless packet based on the total bandwidth information and the information of the unassigned resource unit,

128. Josiam explains that “[t]he header to both SU and MU PPDU includes information necessary to decode the PDU.” SAMSUNG-1005, [0003]; SAMSUNG-1006, 1. As I explained above for [7.2], a bandwidth field in Josiam's HE-SIG-A is used to determine the PDU bandwidth. *See* [7.2]. A POSITA would have understood that a receiving station uses the PDU bandwidth information to determine how many 20 MHz channels are used, possible resource unit

arrangements (i.e., tone plans), number of HE-SIG-B channels, and number of C26 resource units. SAMSUNG-1005, [0095]-[0101], [0104], [0136]-[0138], [0156]-[0192]; SAMSUNG-1006, 7-12, 15-17, 23-30; SAMSUNG-1017, 9; SAMSUNG-1011, 7-11, 17-20, 23-25. Thus, a POSITA would have understood that the data of the received wireless packet is decoded based on the bandwidth of the PPDU as indicated by the bandwidth field of HE-SIG-A.

129. A POSITA would have also understood that the information of the unassigned resource unit is used to decode data of the received wireless packet. Josiam teaches that “[t]he STAs decode each HE-SIG-B in each 20MHz segment to identify which section carries information for them.” SAMSUNG-1005, [0115]; SAMSUNG-1006, 11. For example, Josiam explains that a station “uses the common information portion 2605 and the position of the STA’s per-user allocation to unambiguously identify the RU including the STA’s data.” SAMSUNG-1005, [0157], Fig. 26; SAMSUNG-1006, 22-23. A POSITA would have understood that information of an unassigned resource unit (e.g., an unused resource unit within a 242-tone segment or an unused C26 resource unit) is used to determine that (a) the unassigned resource unit does not need to be decoded as part of the decoding processing and (b) the position of a station’s per-user allocation. For example, if the indication bit is 0, a station will know not to expect a user field for the C26 resource unit. SAMSUNG-1005, [0154] (“No per-STA information

fields are sent for resources indicated to be unused in the resource allocation index.”), SAMSUNG-1006, 21-22; SAMSUNG-1006, 21-22; SAMSUNG-1005, [0169] (“If the bit is set to 1, the per-user allocation information [for the center 26-tone resource unit] is carried at the end, after the user allocations for segments A & C are carried.”); SAMSUNG-1006, 24.

130. Additionally, one or more resource units not being allocated to a user may change the length of the user-specific field of HE-SIG-B. Josiam explains that, “if the [indication] bit [for a C26 resource unit] is set to 1, the per-user allocation information [i.e., a user field] is carried at the end, after the user allocations for segments A & C are carried [i.e., carried in the user specific field].” SAMSUNG-1005, [169]; SAMSUNG-1006, 24. A POSITA would have understood that, if an indication bit for a C26 resource unit is set to 0, a per-user allocation information would not be carried in the user-specific field. A receiving station uses the number of resource units to determine the length (specifically the number of user fields) of the user-specific field of HE-SIG-B, and thus properly decode HE-SIG-B to obtain the station’s assigned resource unit and decode data therein. SAMSUNG-1005, [0142], [0149], [0170]; SAMSUNG-1006, 18-19, 24; SAMSUNG-1008, [0089]-[0093]. From this disclosure, a POSITA would have further understood that Josiam renders obvious that the information of an unassigned resource unit is used to decode data of the received PPDU.

[7.7] wherein the unassigned resource unit is explicitly indicated with the information of the unassigned resource unit based on the bandwidth field and the at least one subfield, and

131. Josiam renders obvious that the bandwidth field of HE-SIG-A and the common field of HE-SIG-B provide information specifically indicating that a particular resource unit is unassigned (e.g., through an RU allocation index or indication bits for a C26 resource unit). By contrast, a POSITA would have understood that, in some circumstances, the non-assignment of a resource unit may be implicitly derived based on other information.

132. For example, the '595 patent states that “whether the center 26-tone RU [] is assigned may be implicitly identified” based on the nulling of nearby channels. SAMSUNG-1001, 47:22-51; *see also* SAMSUNG-1005, [0193]-[0198] (“If the STA 111 determines that the non-contiguous channel bonding field is set to indicate null channels, the STA 111 then interprets the RU arrangement in the common information portion to have null RUs that are adjacent to the nulled channels and determines the number of per-STA fields based on the channel bonding field and the RU arrangement.”); SAMSUNG-1006, 31-33.

133. A POSITA would have understood Josiam’s methods as rendering obvious that an unassigned resource unit is explicitly indicated with the information of the unassigned resource unit based on the bandwidth of the PPDU (as indicated by the bandwidth field of HE-SIG-A) and the common field (i.e., at

least one subfield) of HE-SIG-B. I note that this satisfies the interpretation of “explicitly indicated with the information of the unassigned resource unit based on the bandwidth field of HE-SIG-A and a subfield of HE-SIG-B” that Wilus has advanced for purposes of infringement. SAMSUNG-1004, 28.

134. For example, a POSITA would have understood Josiam as rendering obvious that an unassigned resource unit is explicitly identified with the information of the unassigned resource unit when the resource unit allocation index (carried in the common field of HE-SIG-B) is set to a value that indicates an unassigned resource unit in a 242-tone portion of a PPDU. SAMSUNG-1005, [0154] (“[T]he RU allocation index can communicate indices that indicate unused resources and used resources.”), [0169] (“The common information portion 2905 of one of the HE-SIG-B channels also includes 1 bit indicating whether the central 26 tone RU is assigned to a[] user or not.”); SAMSUNG-1006, 11, 21-22; *see* [7.3], [7.5]. As I explained above for [7.5], the location of the unassigned resource unit within the overall PPDU is determined based on the bandwidth indicated by the bandwidth field of HE-SIG-A. *See* [7.5].

135. As another example, a POSITA would have understood Josiam as rendering obvious that an unassigned resource unit (e.g., a C26 resource unit) is explicitly identified with the information of the unassigned resource unit based on Josiam’s bandwidth field indicating a PPDU of 80MHz or greater and one or more

of Josiam's indication bits (carried in the common field of HE-SIG-B) indicating that one or more corresponding C26 resource units is not assigned to a user.

SAMSUNG-1005, [0110], [0118], [0126], [0169], [0173], [0190], Figs. 10-11;

SAMSUNG-1006, 9-11, 24-25, 29-30, Figs. 10-11. As I discussed above for [7.5],

Josiam teaches that the number of C26 resource units varies based on the PPDU bandwidth: zero C26 resource units for 20 and 40 MHz PPDUs, one C26 resource unit for 80 MHz PPDUs, and two C26 resource units for 160 (or 80+80 MHz) PPDUs; *Id.*; *see* [7.5], [7.8].

136. Thus, a POSITA would have further understood that an unassigned resource unit (e.g., a C26 resource unit) is explicitly indicated based on the bandwidth of the PPDU (indicated by the bandwidth field of HE-SIG-A) and the one or more C26 indication bits in the common field (i.e., at least one subfield) of HE-SIG-B.

137. As a result, a POSITA would have understood that Josiam renders obvious that an unassigned resource unit is explicitly indicated with the information of the unassigned resource unit based on the bandwidth field of HE-SIG-A and the common field of HE-SIG-B.

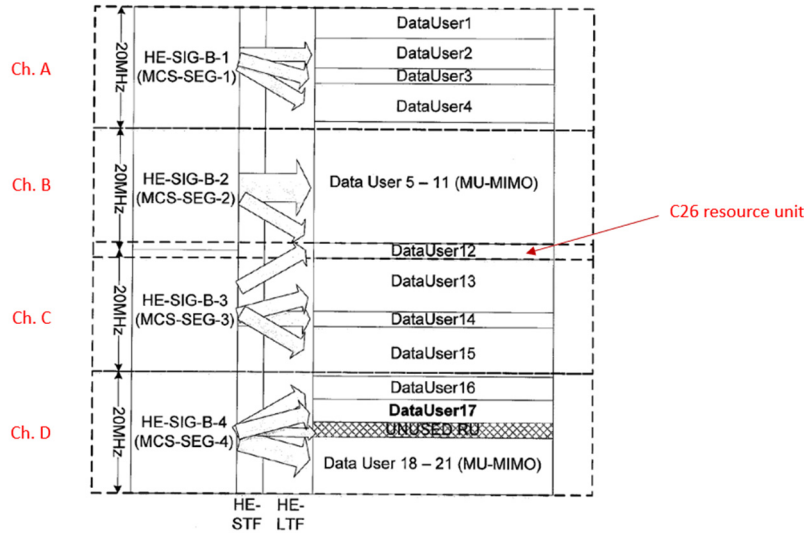
[7.8] wherein the information of the unassigned resource unit includes information of a C26 field indicating whether a user is allocated to a center 26-tone resource unit of 80 MHz upon the bandwidth related to a transmission of

the received wireless packet indicated by the bandwidth field being 80 MHz or more, not 20 MHz or 40 MHz.

138. Josiam renders obvious that the resource unit allocation information includes information of a C26 field indicating whether a user is allocated to a C26 resource unit of 80MHz by way of indication bits included in the common field of HE-SIG-B. SAMSUNG-1005, [0110], [0118], [0126], [0169], [0173], [0190], Figs. 10-11; SAMSUNG-1006, 9-11, 24-25, 29-30, Figs. 10-11. For example, Josiam explains that

In an embodiment of the present disclosure, the resource allocation for the 26 tone RU split around the DC tones of an 80 MHz MU PPDU may be indicated by an extra bit in either of the 20 MHz segments or duplicated in both 20 MHz segments surrounding the DC tones. The presence of the extra bit is triggered by the bandwidth signaling when set to 80 MHz. The extra bit comes immediately preceding the 5 bit RU arrangement indication for the 20 MHz segment. The STAID and user specific portion also follow the same order of indication as the RU arrangement indication.

SAMSUNG-1005, [0118]; SAMSUNG-1006, 11-12.



SAMSUNG-1005, Fig. 11; SAMSUNG-1006, Fig. 11 (annotated)

139. Josiam additionally teaches that, in an 80MHz PPDU, “[t]he common portion 2905 of one of the HE-SIG-B channels also includes 1 bit indicating whether the central 26 tone RU is assigned to a[] user or not.” SAMSUNG-1005, [0165]-[0169]; SAMSUNG-1006, 24. In a 160MHz PPDU, “[t]wo 26 tone RUs are signaled using 1 bit separately[,] . . . one in HE-SIG-B channel-1 3715 and the other in HE-SIG-B channel-2 3720.” SAMSUNG-1005, [0190]; SAMSUNG-1006, 29-30.

140. No indication bit for a C26 resource unit is included in 20 or 40MHz PPDUs. *Compare* SAMSUNG-1005, [0156]-[0163]; SAMSUNG-1006, 22-24, *with* SAMSUNG-1005, [0164]-[0192]; SAMSUNG-1006, 24-30. A POSITA would have understood that the extra indication bit used for signaling the use of a C26 resource unit is not required for 20 or 40MHz PPDUs because the tone plans

for those transmission bandwidths do not include a 26-tone resource unit that falls between channels. SAMSUNG-1005, [0130]-[0134], Figs. 14-16; SAMSUNG-1006, 5-8.

141. More specifically, 20 MHz, 40 MHz and 80 MHz PPDU's are built using one, two or four 20 MHz channels respectively. SAMSUNG-1005, [0095]-[0101], Figs. 6-8; SAMSUNG-1006, 5-7. The finest granularity supported for a single 20 MHz is a set of nine 26-tone resource units. SAMSUNG-1005, [0130]-[0136], Fig. 14; SAMSUNG-1006, 8-9. A 40 MHz channel can support up to 18 26-tone resource units, including nine from each 20MHz channel comprising the 40 MHz channel. SAMSUNG-1005, [0095]-[0101], Figs. 6-8; SAMSUNG-1006, 5-7. An 80 MHz channel supports up to 37 26-tone RU's. *Id.*

142. Since resource allocation is sent in 20 MHz increments (i.e., on a per channel basis), all RU's are signaled in a single field for a 20 MHz PPDU. SAMSUNG-1005, [0136]; SAMSUNG-1006, 16. Further, since there are at most 18 RU's in a 40 MHz PPDU, nine are signaled for the first 20 MHz and the other nine are signaled for the second 20 MHz. SAMSUNG-1005, [0158]-[0159]; SAMSUNG-1006, 23. However, for an 80 MHz PPDU, there are at most 37 RU's across four 20 MHz channels. SAMSUNG-1005, [0095]-[0101], Figs. 6-8. 16; SAMSUNG-1006, 5-7. The first and last channels each have at most nine 26-tone RU's. *Id.* The middle two 20 MHz channels, on the other hand, each are comprised

of nine 26-tone RU's plus one half of the final (center) 26-tone RU. *Id.* Thus, the center 26-tone RU is not fully allocated to any 20 MHz channel.

143. To make the RU allocation for each 20 MHz channel the same, the final 26-tone RU is treated separately using a single bit. SAMSUNG-1005, [0110], [0118], [0126], [0169], [0173], [0190]; SAMSUNG-1006, 9-11, 24-25, 29-30, Figs. 10-11. 160 MHz PPDU's are comprised of two 80 MHz channels with the same subcarrier plan as the 80 MHz channels. SAMSUNG-1005, [0187]; SAMSUNG-1006, 30. Josiam explains that "[t]he 160 MHz tone plan is built as two concatenated 80MHz tone plans," i.e., a first and second 80MHz bandwidth. SAMSUNG-1005, [0187]; SAMSUNG-1006, 30. Thus, a 160 MHz channel should have two indicator bits for the reasons discussed above. As a result, signaling the non-allocation of resource units in 20 and 40 MHz can be handled by the RU allocation index alone, but 80 MHz and 160 MHz benefit from the use of an additional indicator bit.

144. A POSITA would have understood Josiam's indication bit as corresponding to the claimed "C26 field." This aligns with the '595 patent's disclosure, which states that the "C26 field may consist of a 1-bit indicator before or after the [resource allocation] field in the common block field." SAMSUNG-1001, 22:29-51, Fig. 15.

2. *Claim 8*

[8.pre] The wireless communication method of claim 7,

[8.1] wherein the HE-SIG-B field consists of HE-SIG-B content channel 1 and HE-SIG-B content channel 2 in units of 20 MHz respectively, and

145. Josiam renders obvious that the HE-SIG-B field consists of HE-SIG-B content channel 1 and HE-SIG-B content channel 2 in units of 20MHz respectively. SAMSUNG-1005, [0158]-[0159], [0164]-[0170], [0187]-[0190], Figs. 27, 29, 37; SAMSUNG-1006, 23-25, 29-30, Figs. 27, 29, 37. For example, Josiam's Figure 29, reproduced below, "illustrates an example of HE-SIG-B multiplexing scheme 2900 for 80MHz including 2 channels, each carrying independent information per a 20MHz HE-SIG-B channel." SAMSUNG-1005, [0164], Fig. 29; SAMSUNG-1006, 24-25, Fig. 29. Josiam explains that "each HE-SIG-B channel 2915 and 2920 carries different information and the HE-SIG-B channels 2915 and 2920 are duplicated per 40MHz, i.e., HE-SIG-B Channel 1 2915 is carried in channel A & C of 80MHz while HE-SIG-B Channel [] 2920 is carried in B & D of 80MHz." SAMSUNG-1005, [0165]; SAMSUNG-1006, 24-25, Fig. 29.

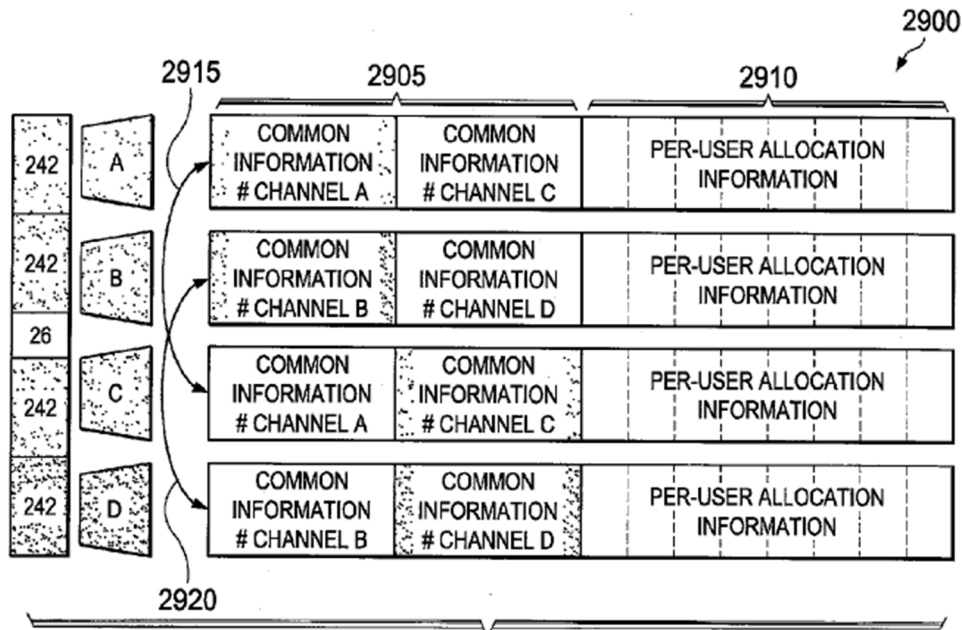


FIG. 29

SAMSUNG-1005, Fig. 29; SAMSUNG-1006, Fig. 29

[8.2] wherein the C26 field is carried in both the HE-SIG-B content channel 1 and the HE-SIG-B content channel 2.

146. Josiam renders obvious that the C26 field (e.g., Josiam's indication bit) is carried in both the HE-SIG-B content channel 1 and the HE-SIG-B content channel 2. SAMSUNG-1005, [0118], [0169], [0190]; SAMSUNG-1006, 11-12, 24, 30.

147. For example, Josiam teaches that a C26 field may be carried in both HE-SIG-B content channels: “[t]wo 26 tone RUs are signaled using 1 bit separately. By convention one in HE-SIG-B channel-1 [] and the other in HE-SIG-B channel-2.” SAMSUNG-1005, [0190]; SAMSUNG-1006, 29-30; *see* §§ X.A.5-

6.

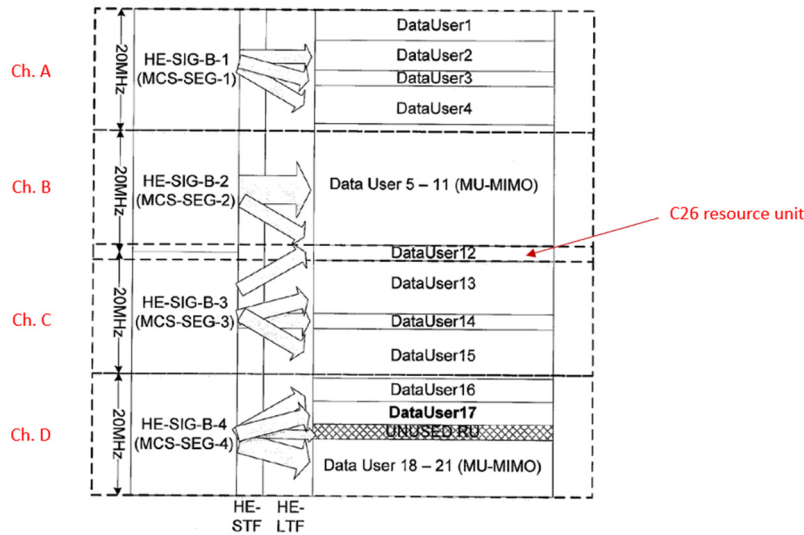
148. In my opinion, claim 11 does not require the same C26 field to be carried both HE-SIG-B content channels. Indeed, claims 11-12, which depend on claim 8 and require two separate C26 fields in each HE-SIG-B content channel. *See* §§ X.A.5-6. But even if the claim requires the same C26 field to be carried in both HE-SIG-B content channels, Josiam renders obvious including the same C26 field in both HE-SIG-B content channels for the reasons I explain below for [9]. *See* § X.A.3.

3. *Claim 9*

[9] The wireless communication method of claim 8, wherein when the received wireless packet is transmitted in a total bandwidth of 80 MHz, both of a C26 field carried in the HE-SIG-B content channel 1 and a C26 field carried in the HE-SIG-B content channel 2 indicate whether a user is allocated to a center 26-tone resource unit in the total bandwidth of 80 MHz.

149. Josiam describes an 80MHz PPDU in which “[t]he common information portion [] of one of the HE-SIG-B channels also includes 1 bit indicating whether the central 26 tone RU is assigned to a[] user or not.” SAMSUNG-1005, [0169]; SAMSUNG-1006, 24. While this embodiment does not explicitly disclose including a C26 field in both content channels, an earlier embodiment explains that “the resource allocation for the 26 tone RU split around the DC tones of an 80MHz MU PPDU may be indicated by an extra bit in either of the 20MHz segments or duplicated in both.” SAMSUNG-1005, [0118];

SAMSUNG-1006, 11-12.



SAMSUNG-1005, Fig. 11; SAMSUNG-1006, Fig. 11 (annotated)

150. In light of Josiam's teaching, a POSITA would have found it obvious to duplicate the indication bit in both HE-SIG-B content channels in an 80MHz PPDU. SAMSUNG-1005, [0118]; SAMSUNG-1006, 11-12. For example, a POSITA would have been motivated to duplicate the indication bit in both HE-SIG-B content channels to balance the signaling load between the two channels and reduce the need for padding in the other HE-SIG-B content channel.

SAMSUNG-1005, [0159], [0179], [0181]; SAMSUNG-1006, 10, 23, 27.

Specifically, a POSITA would have understood that the HE-SIG-B content channels should be equal in length to ensure symbol alignment. *Id.* A POSITA would have understood that duplicating the indication bit for the C26 resource unit in both HE-SIG-B content channels may reduce the need for a padding bit to be

added to the other HE-SIG-B content channel to balance the length between the two channels. *Id.*

151. Moreover, a POSITA would have understood that because the two HE-SIG-B content channels should be equal in length, duplicating the indication bit for a C26 resource unit in both HE-SIG-B content channels would have been an obvious design choice. SAMSUNG-1005, [0159], [0179], [0181]; SAMSUNG-1006, 10, 23, 27. Duplicating the indication bit would have been a predictable solution in light of Josiam's teachings that the indication bit for the C26 resource unit in an 80 MHz PPDU may be duplicated in both 20 MHz channels carrying the C26 resource unit and that indication bits may be placed in both HE-SIG-B content channels for 160 MHz PPDU's. SAMSUNG-1005, [0118], [0187]; SAMSUNG-1006, 11-12, 30.

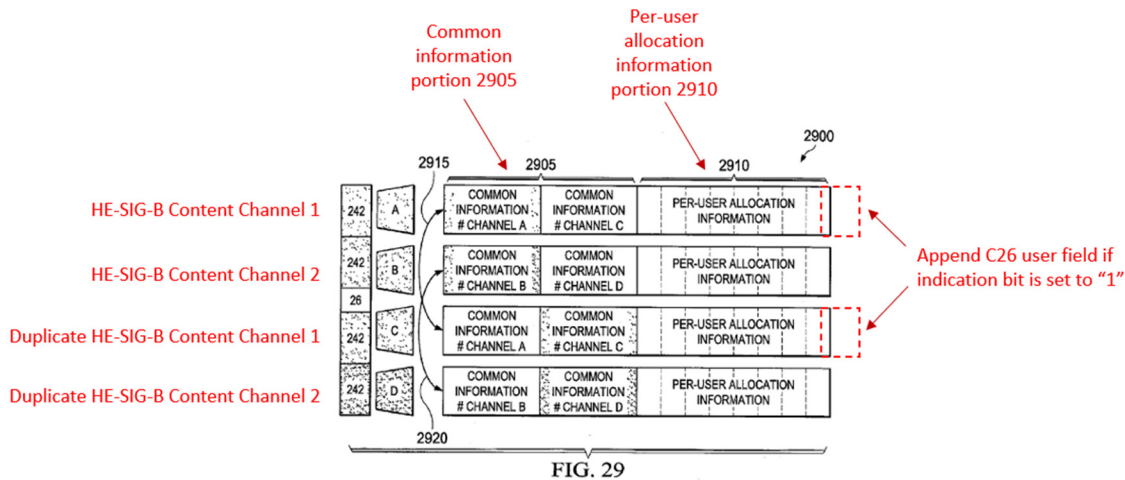
4. *Claim 10*

[10] The wireless communication method of claim 9, wherein when the C26 field indicates that a user is allocated to the center 26-tone resource unit, a user field corresponding to the center 26-tone resource unit is carried in a user specific field of the HE-SIG-B content channel 1.

152. In the 80MHz PPDU described in [9], Josiam explains that, "if the [indication] bit is set to 1 [i.e., the C26 field], the per-user allocation information [i.e., a user field] is carried at the end, after the user allocations for segments A & C are carried [i.e., carried in the user specific field]." SAMSUNG-1005, [0169]; SAMSUNG-1006, 24; § X.A.3. As illustrated below in Figure 29, the content

channel carrying segments A & C correspond to HE-SIG-B content channel 1

2915. SAMSUNG-1005, [0165], Fig. 29; SAMSUNG-1006, 26-27.



SAMSUNG-1005, Fig. 29; SAMSUNG-1006, Fig. 29 (annotated)

5. Claim 11

[11] The wireless communication method of claim 8, wherein when the received wireless packet is transmitted in a total bandwidth of 160 MHz or 80+80 MHz, the total bandwidth includes a first 80 MHz bandwidth and a second 80 MHz bandwidth, a first C26 field carried in the HE-SIG-B content channel 1 indicates whether a user is allocated to a first center 26-tone resource unit in the first 80 MHz bandwidth, and a second C26 field carried in the HE-SIG-B content channel 2 indicates whether a user is allocated to a second center 26-tone resource unit in the second 80 MHz bandwidth.

153. Josiam describes “an example channel structure and duplication scheme 3700 for multiplexing control information in HE-SIG-B for 160MHz.” SAMSUNG-1005, [0187]; SAMSUNG-1006, 30. Josiam explains that “[t]he 160 MHz tone plan is built as two concatenated 80MHz tone plans,” i.e., a first and second 80MHz bandwidth. SAMSUNG-1005, [0188]; SAMSUNG-1006, 30. In

scheme 3700, “[t]wo 26 tone RUs are signaled using 1 bit separately. By convention, one in HE-SIG-B channel-1 3715 and the other in HE-SIG-B channel-2 3720.” SAMSUNG-1005, [0187]; SAMSUNG-1006, 30. A POSITA would have understood Josiam’s indication bits in content channel 1 and content channel 2 as indicating whether a user is allocated to C26 resource units in the first and second 80MHz bandwidths, respectively. *Id.*

154. In my opinion, a POSITA would have understood Josiam’s disclosure as rendering obvious using the above-described methods for 80+80MHz bandwidths. Specifically, a POSITA would have understood that an “80+80 MHz” PPDU refers to a 160 MHz PPDU that is transmitted using two non-contiguous⁷ 80 + 80 MHz channels. SAMSUNG-1012, 31, 247, 260, 262-263, 268-269, 300-302. Indeed, using non-contiguous 80 + 80 MHz bandwidths was included in the previous generation of 802.11ac (Wi-Fi 5). *Id.*

⁷ I note that “non-contiguous” in this sense refers to true non-contiguous channel bonding using carrier aggregation. This is distinct from non-contiguous channel bonding via resource unit nulling discussed elsewhere in the ’595 patent’s specification, which was later renamed to “channel puncturing.” SAMSUNG-1018, 12.

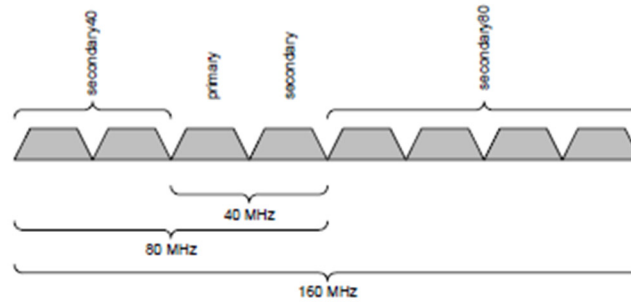


Figure 7-1—The channel-list parameter element for 40 MHz, 80 MHz, and 160 MHz channel width

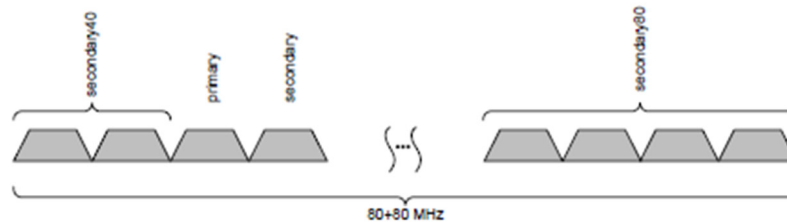


Figure 7-2—The channel-list parameter element for 80+80 MHz channel width

SAMSUNG-1012, Fig. 7

155. A POSITA would have understood that Josiam's methods for 160MHz PPDU's may be used for both contiguous 160MHz bandwidths and non-contiguous 80 + 80 MHz bandwidths because these bandwidths are treated similarly for the purposes of resource unit allocation. SAMSUNG-1011, 20, 24-25, 28 ("The indicated 20 MHz channel(s) can be either Primary20, Primary40, Primary80 or 160/80+80 MHz."); SAMSUNG-1005, [0188] ("The 160MHz tone plan is built as two concatenated 80MHz tone plans that are not aligned with 20MHz segments.").

6. *Claim 12*

[12] The wireless communication method of claim 11, wherein when the first C26 field indicates that a user is allocated to the first center 26-tone resource unit, a user field corresponding to the first center 26-tone resource unit is carried in a user specific field of the HE-SIG-B content channel 1, and wherein when the second C26 field indicates that a user is allocated to the second center 26-tone resource unit, a user field corresponding to the second center 26-tone resource unit is carried in a user specific field of the HE-SIG-B content channel 2.

156. As I discussed above for [11], Josiam teaches that “[t]wo 26 tone RUs are signaled using 1 bit separately. . . . [T]he common portion 3705 in each of the HE-SIG-B channels 3715 and 3720 also includes 1 bit indicated if the central 26 tone RU is assigned to a[] user or not.” SAMSUNG-1005, [190]; SAMSUNG-1006, 30; *see* § X.A.5. Josiam further teaches that “[i]f the [indication] bit is set to 1, the per-user allocation information [i.e., user fields] is carried at the end, after the user allocations for the other segments are carried [i.e., carried in the user-specific fields].” *Id.* A POSITA would have understood this disclosure as teaching that, when the indication bit in an HE-SIG-B channel is set to 1, a user-specific field for the C26 resource unit corresponding to that content channel is included in the HE-SIG-B user-specific field. *Id.*

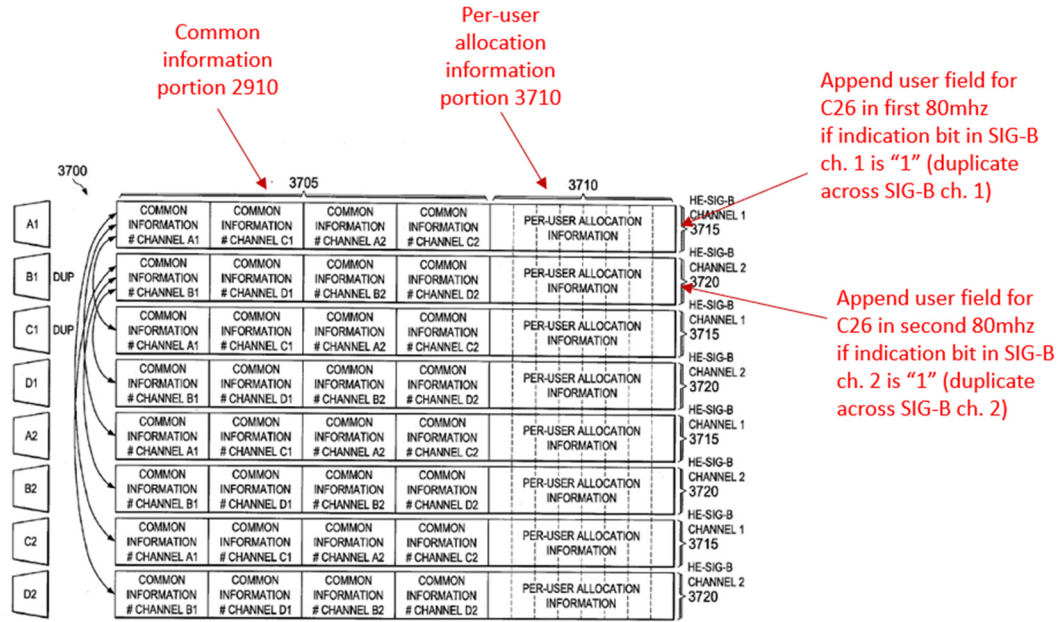


FIG. 37

SAMSUNG-1005, Fig. 37; SAMSUNG-1006, Fig. 37 (annotated)

7. Claims 1-6

157. Claims 1-6 recite “[a] wireless communication terminal, the terminal comprising a processor, wherein the processor is configured to” perform the methods of claims 7-12, respectively. To the extent the preamble is limiting, Josiam discloses “a STA [(station), i.e., a wireless communication terminal] for identifying scheduling information in a WLAN.” SAMSUNG-1005, [0005]; SAMSUNG-1006, 7-8. Josiam discloses that the STA includes a “controller/processor 240 . . . capable of executing . . . operations for using or implementing efficient signaling and addressing in a WLAN system.” SAMSUNG-1005, [0077]. Although Josiam’s provisional does not explicitly

disclose that the stations have a processor, a POSITA would have understood that the stations described in Josiam's provisional application require a processor. For example, Josiam's provisional states that the stations receive and decode a wireless packet. SAMSUNG-1006, 8, 10-11, 15, 31. Josiam's provisional application also discloses "[p]rocessing at the STA to interpret RU arrangement when non-contiguous channel bonding is used." SAMSUNG-1006, 33. Based on these disclosures in the Josiam provisional, a POSITA would have understood that a station necessarily has a processor to perform at least the decoding of a received wireless packet.

158. Additionally, a POSITA would have found it obvious to use a processor to perform Josiam's methods. Using a processor to perform methods associated with the decoding of a received wireless packet was well known in the art and within the general knowledge of a POSITA. *See, e.g.*, SAMSUNG-1007, [0046]-[0047]; SAMSUNG-1008, [0068]-[0075] ("The processor[] may be configured to receive a PPDU and identify the preamble therefrom. . . . The processor[] may be further configured to identify a first part of the HEW preamble (e.g., HE-SIG-A) to decode a second part of the preamble (e.g., HE-SIG-B).").

159. For similar reasons to those described above with respect to claims 7-12, a POSITA would have understood Josiam as rendering obvious a processor (e.g., controller/processor 240), wherein the processor is configured to perform the

steps recited in the remaining limitations of claim 1 and claims 2-6. *See* § X.A.1-6.

B. Ground 1B – Combination of Josiam and Seok Renders Obvious Claims 1-6

160. Claims 1-6 recite “[a] wireless communication terminal, the terminal comprising: a processor, wherein the processor is configured to” perform the methods of claims 7-12, respectively.

161. To the extent the preamble is limiting, Seok describes a wireless communication terminal (e.g., WLAN device 1). SAMSUNG-1007, [0044]-[0053]. Seok discloses that the terminal comprises “a baseband processor 10,” which “may be simply referred to as a processor and may perform baseband signal processing.” SAMSUNG-1007, [0044]-[0045].

162. In the Josiam-Seok combination, a POSITA would have found it obvious to use a processor (e.g., a baseband processor per Seok) to implement Josiam’s methods. SAMSUNG-1007, [0044]-[0045]; § IX.C. Thus, for similar reasons to those discussed above in Ground 1A, I believe that Josiam-Seok further renders obvious the remaining limitations of claim 1 and 2-6. *See* § X.A.

C. Ground 2 – Combination of Chen and Wu Renders Obvious Claims 1-12

1. Claim 7

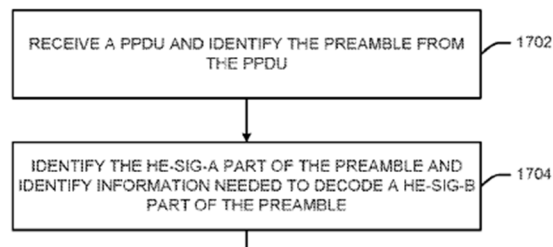
[7.pre] A wireless communication method of a wireless communication terminal, the method comprising:

163. To the extent the preamble is limiting, Chen describes “systems and

methods for Wi-Fi, and more particularly to resource unit (RU) allocation in high efficiency (HE) Wi-Fi preambles.” SAMSUNG-1008, [0002]. Chen’s methods involve a wireless communication terminal (e.g., wireless access point). SAMSUNG-1008, [0033].

[7.1] receiving a wireless packet including an high efficiency (HE)-signal (SIG)-A and HE-SIG-B;

164. Chen teaches receiving an HE PPDU (i.e., a wireless packet) including HE-SIG-A and HE-SIG-B fields. SAMSUNG-1008, [0101]-[0104], Fig. 17, [0077], Fig. 5. A POSITA would have understood that a PPDU is a wireless packet. SAMSUNG-1005, [0003] (“The data packet transmitted is called a HE physical layer convergence procedure (PLCP) protocol data unit (PPDU).”); SAMSUNG-1006, 1.

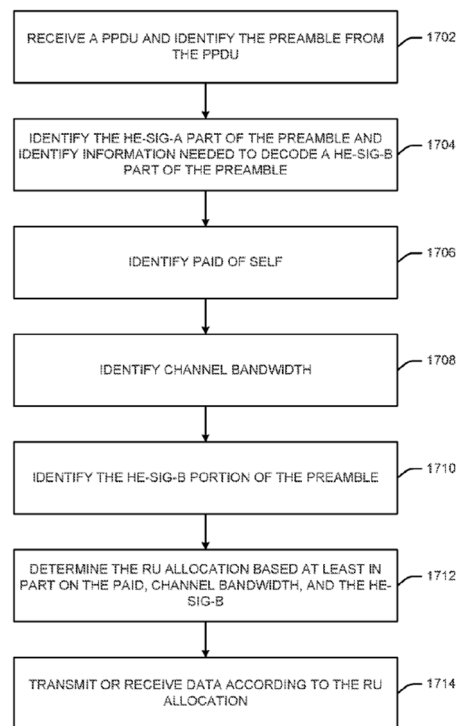


SAMSUNG-1008, Fig. 17 (excerpt)

[7.2] obtaining bandwidth information indicated via a bandwidth field included in the HE-SIG-A;

165. The Chen-Wu combination renders obvious this limitation. Chen explains that bandwidth information “may be communicated to [a station] by [an

access point], such as on the PPDU transmitted by the [access point] and received by the [station].” SAMSUNG-1008, [0102]. In the method described in Chen’s Figure 17, the channel bandwidth is identified at block 1708, which is after the HE-SIG-A is identified (block 1704) and before the HE-SIG-B is identified (block 1710). SAMSUNG-1008, [0101]-[0103], Fig. 17.



SAMSUNG-1008, Fig. 17

166. Chen further teaches that the “HE-SIG-A may carry an indication of the total channel bandwidth available in MU-MIMO mode (e.g., 20MHz channel, 40 MHz channel, or 80MHz channel).” SAMSUNG-1008, [0061]. A POSITA would have understood that the indication of the total channel bandwidth in the

HE-SIG-A would be carried in a field. SAMSUNG-1007, [0125], [0193]; SAMSUNG-1006, Fig. 2; SAMSUNG-1012, 259-260, Table 22-12; SAMSUNG-1015, 13. I note that the Applicant did not dispute the Examiner's finding that Chen teaches obtaining bandwidth information indicated via a bandwidth field included in the HE-SIG-A. *See* SAMSUNG-1002, 68, 120 (citing SAMSUNG-1008, [0061]).

167. Moreover, a POSITA would have understood that the previous generation VHT-SIG-A field includes a bandwidth field, which indicates the bandwidth of the PPDU (e.g., 20, 40, 80, or 160MHz), and would have found it obvious to carry this field over into HE-SIG-A. SAMSUNG-1007, [0125], [0193]; *see also* SAMSUNG-1006, Fig. 2; SAMSUNG-1012, 259-260, Table 22-12; SAMSUNG-1015, 13 (“[The] 11ax PPDU should also contain HE-SIG-A to carry some similar fields as in HT-SIG/VHT-SIG-A of 11n/ac, e.g., BW, GI.”).

168. Finally, including a bandwidth field in HE-SIG-A was within the general knowledge of a POSITA by the Critical Date. SAMSUNG-1011, 4-8; SAMSUNG-1015, 13; SAMSUNG-1016, [0078]-[0079]. For example, the December 6, 2015 802.11ax Draft Specification Framework includes a bandwidth field in HE-SIG-A, and a POSITA would have found it obvious that this field was included in the PPDU of the Chen-Wu combination, which is directed to 802.11 communications. SAMSUNG-1011, 4-8; SAMSUNG-1008, [0003].

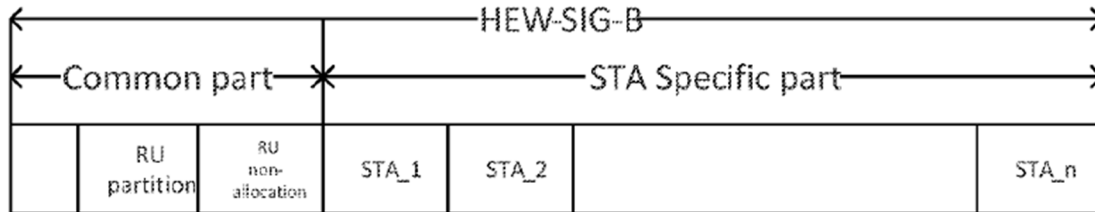
[7.3] obtaining information of an unassigned resource unit via at least one subfield included in the HE-SIG-B,

169. Chen-Wu renders obvious obtaining information of an unassigned resource unit via at least a common field in the HE-SIG-B. A POSITA would have understood the common field⁸ as a subfield of HE-SIG-B. SAMSUNG-1005, [0105]-[0106], [0156]-[0157]; SAMSUNG-1006, 11, 23; SAMSUNG-1011, 8-9; SAMSUNG-1009, [0072], Fig. 14; SAMSUNG-1010, 4.

170. For example, Chen teaches including information of non-allocated resource units in the common field of HE-SIG-B. SAMSUNG-1008, [0090]-[0093], Fig. 14. Chen describes a method of “explicitly indicating [a] non-allocated RU in the common part of the HE-SIG-B.” SAMSUNG-1008, [0090]. Chen’s Figure 14, reproduced below, “depicts a datagram illustrating an example HE-SIG-B portion 1400 indicating a sequence of RU allocation information with an unallocated RU.” SAMSUNG-1008, [0093]. Chen explains that, “after the RU allocation information (e.g., the allocation pattern in the common part of HE-SIG-B), there may be RU non-allocation information. This non-allocation information may indicate the non-allocated RUs. The non-allocation may be realized by a bit map. If there are M RU partitions in the current PPDU, M bits may be used to

⁸ See *supra* note 2.

indicate which RU is non-allocated.” *Id.*



SAMSUNG-1008, Fig. 14

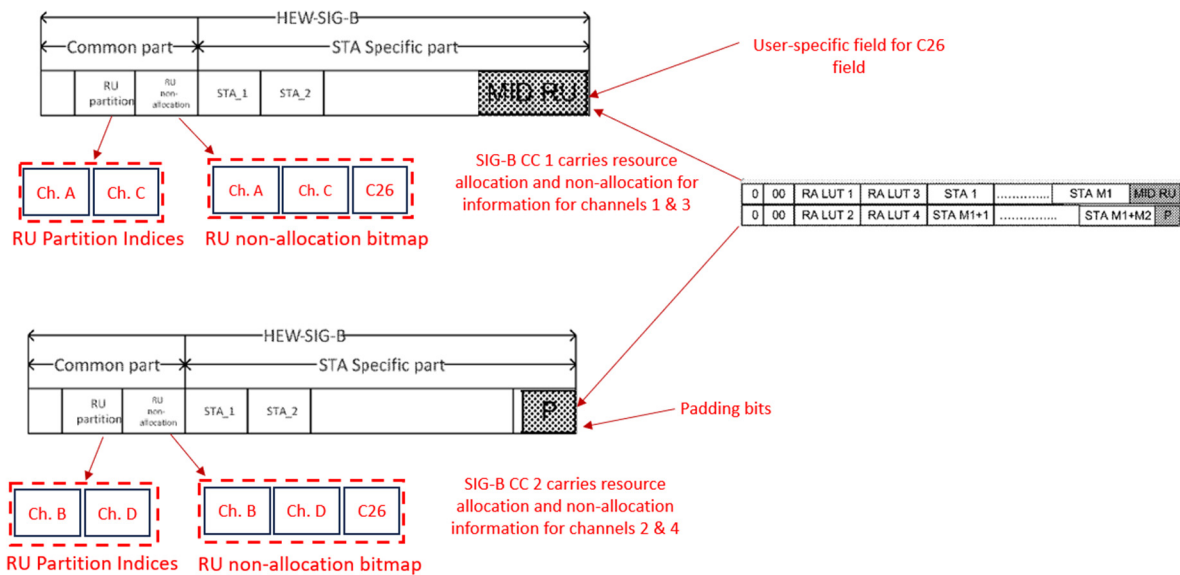
171. From this disclosure, a POSITA would have understood Chen-Wu as teaching that information of an unassigned resource unit is obtained via at least the RU non-allocation information in the common field of HE-SIG-B. I note that the Applicant did not dispute the Examiner’s finding that the “unassigned RUs can be not allocated by using RU allocation field.” SAMSUNG-1002, 68, 120 (citing SAMSUNG-1008, [0093], Fig. 14).

172. Chen-Wu further renders obvious obtaining information of an unassigned resource unit via at least one subfield of HE-SIG-B based on Wu’s teachings. Wu teaches that “the middle 26-tone RU for 80MHz and 160MHz can be signaled by . . . a one bit indication in the HE-SIG-B common [field].” SAMSUNG-1009, [0043]; SAMSUNG-1010, 27. For example, Wu explains that, in an 80MHz PPDU, “one-bit in the common field of HE-SIG-B is used to indicate whether the middle 26-tone RU is used. If the bit is set, it indicates the RU is used.” SAMSUNG-1009, [0044], Fig. 5; SAMSUNG-1010, 27. A POSITA would

have understood that a bit has two possible values (i.e., zero or one), and that if the bit is not set (e.g., the bit is zero), the bit indicates that the C26 resource unit is not used (i.e., unassigned).

173. In the Chen-Wu combination, it would have been obvious to a POSITA to combine RU non-allocation information, per Chen, with an indication bit for indicating whether a user is assigned to a C26 resource unit, per Wu. As I discussed above in § IX.F, a POSITA would have understood that, because a C26 resource unit falls between two 20MHz channels, an additional signaling bit would be required to indicate resource unit allocation information for a C26 resource unit. SAMSUNG-1009, [0035]-[0036], [0041]-[0043], Figs. 2-4; SAMSUNG-1010, 3-6, 27-28; *see* § IX.F; *see also* § X.A.1 (discussing resource unit arrangement in 80 MHz and larger PPDUUs).

174. As one example, it would have been obvious to a POSITA to append indication bits (per Wu) to one or more of the RU non-allocation bitmaps according to the bandwidth of the PPDU as indicated by the bandwidth field (per Chen). SAMSUNG-1008, [0089]-[0093], Figs. 12-14; SAMSUNG-1009, [0007], [0041]-[0047], Figs. 4-6; SAMSUNG-1010, 3-6, 10-13, 27-28; *see* § IX.F.



SAMSUNG-1008, Fig. 14 modified with SAMSUNG-1009, Figs. 4, 5;

SAMSUNG-1010, 4, 12, 27 (annotated)

175. Based on the combined teachings of Chen and Wu, a POSITA would have understood Chen-Wu as further rendering obvious that information of an unassigned resource unit (e.g., information indicating whether a C26 resource unit is allocated to a user) is obtained via at least the RU non-allocation information (e.g., a non-allocation bitmap, per Chen, including an indication bit for a C26 resource unit, per Wu) in the common field of HE-SIG-B.

[7.4] wherein the bandwidth field is related to bandwidth over which the received wireless packet is transmitted, and

176. As I discussed above for [7.2], the Chen-Wu combination renders obvious a bandwidth field in HE-SIG-A. *See* [7.2]. For example, Chen teaches that the “HE-SIG-A may carry an indication of the *total channel bandwidth*.”

SAMSUNG-1008, [0061]. A POSITA would have understood the term “total channel bandwidth” to refer to the bandwidth over which the PPDU (i.e., received wireless packet) is transmitted. I note that the Applicant did not dispute the Examiner’s finding that Chen teaches this limitation. *See* SAMSUNG-1002, 68, 120 (citing SAMSUNG-1008, [0061]).

177. Additionally, as discussed for [7.2], including a bandwidth field in HE-SIG-A to indicate the bandwidth of the PPDU was well known in the art, and it would have been obvious to a POSITA to include the known bandwidth field in HE-SIG-A. *See* [7.2]; SAMSUNG-1007, [0125], [0193]; SAMSUNG-1012, 259-260, Table 22-12; SAMSUNG-1015, 13.

[7.5] wherein the bandwidth field of HE-SIG-A is used to obtain the information of the unassigned resource unit; and

178. Chen-Wu renders obvious using the bandwidth field of HE-SIG-A to obtain the information of the unassigned resource unit. As one example, a POSITA would have understood the Chen-Wu combination as rendering obvious that RU non-allocation information in HE-SIG-B indicates the location of a non-allocated RU within a 20MHz channel, while the bandwidth field of HE-SIG-A indicates where in the overall bandwidth the non-allocated RU is located by defining the number of 20MHz channels and the arrangement and length of the HE-SIG-B content channels. SAMSUNG-1008, [0101], [0098]; SAMSUNG-1009, [0036]; SAMSUNG-1010, 10.

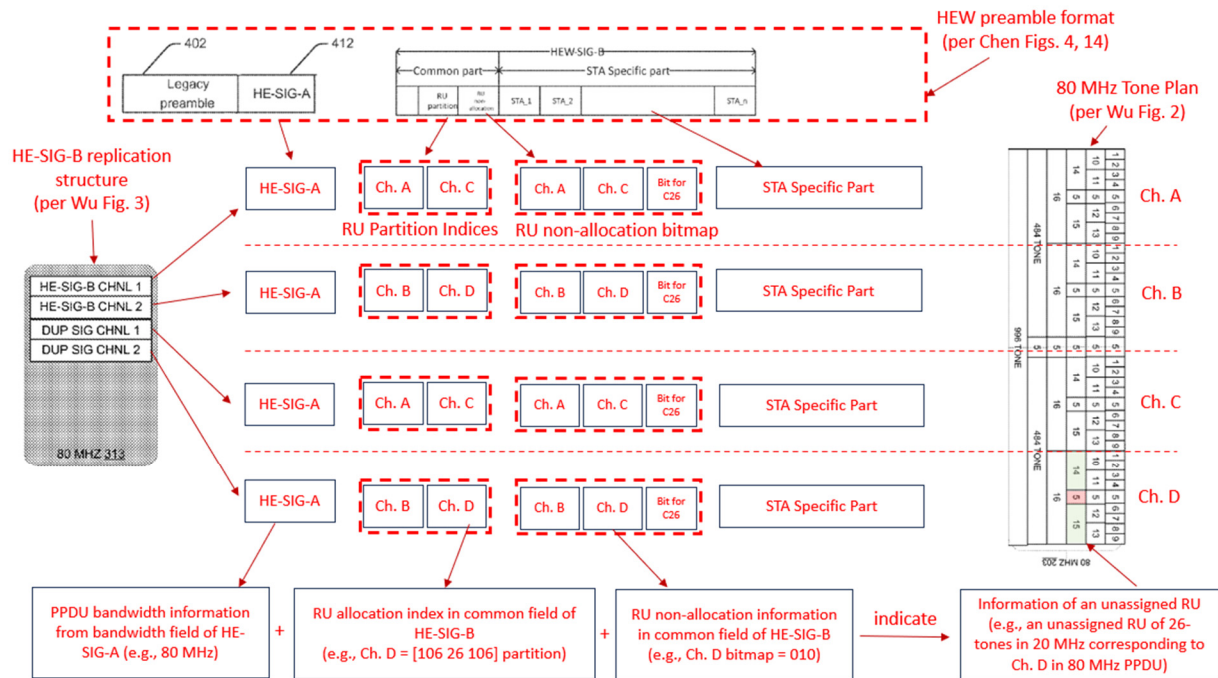
179. Chen teaches that “RU allocation may be determined based at least in part on the PAID, channel bandwidth, and the HE-SIG-B.” SAMSUNG-1008, [0101], [0098]. I note that the Applicant did not dispute the Examiner’s finding that Chen teaches this limitation. *See* SAMSUNG-1002, 68, 102 (citing SAMSUNG-1008, [0093], [0098], [0103], Fig. 14).

180. Moreover, Wu teaches “a fixed format common field in the HE-SIG-B is defined for each operation bandwidth. Therefore, the length and format of the common field are predefined [based on the bandwidth]. In this approach, there is no [additional]⁹ indication needed in the HE-SIG-A.” SAMSUNG-1009, [0036]; SAMSUNG-1010, 10. As I explained above for [7.2] and [7.4], a POSITA would have understood Chen’s HE-SIG-A as including a bandwidth field that indicates the operation bandwidth of the PPDU. *See* [7.2], [7.4].

181. For example, if the bandwidth field of HE-SIG-A indicates a PPDU bandwidth of 80 MHz, and the resource unit allocation field of the common field of HE-SIG-B indicates that the 20 MHz corresponding to the fourth channel is partitioned into 106, 26, and 106-tone resource units, the resource unit non-

⁹ Wu discloses other embodiments for “flexible signaling of resource allocation” using “additional indication in the HE-SIG-A.” SAMSUNG-1009, [0048]; SAMSUNG-1010, 14.

allocation information may indicate that the 26-tone resource unit is not assigned to any user through, e.g., a bitmap per Chen. SAMSUNG-1008, [0075], [0089]-[0093], Figs. 4, 12-14; SAMSUNG-1009, [0035]-[0043], Figs. 2-4; SAMSUNG-1010, 2-6, 10-14.



SAMSUNG-1008, Figs. 4, 14 illustrated with SAMSUNG-1009, Figs. 2, 3;

SAMSUNG-1010, 3-4 (annotated)

182. Thus, a POSITA would have understood the combined teachings of Chen and Wu as rendering obvious that the bandwidth field of HE-SIG-A is used to obtain the information of an unassigned resource unit.

183. The Chen-Wu combination additionally renders obvious the use of the bandwidth field to obtain information of an unassigned resource unit when the

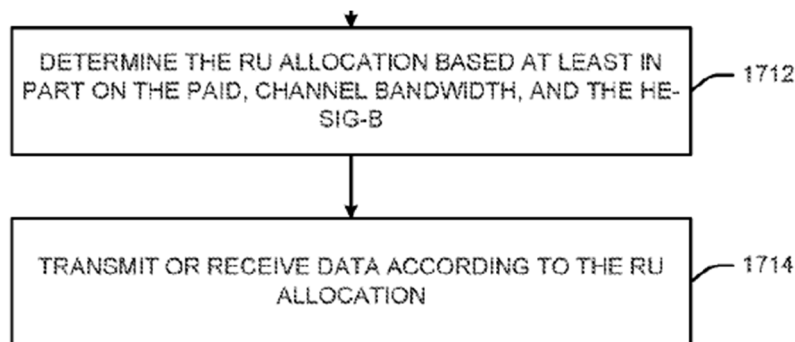
unassigned resource unit is a C26 resource unit. Wu teaches that “the middle 26-tone RU for 80MHz and 160MHz can be signaled by . . . a one bit indication in the HE-SIG-B common field.” SAMSUNG-1009, [0043]; SAMSUNG-1010, 27. Wu explains that when the bandwidth is 80MHz, one bit is included in the common field to indicate the presence of the C26 resource unit. SAMSUNG-1009, [0044], Fig. 5; SAMSUNG-1010, 27. When the bandwidth is 160MHz, one bit is included in the common field of each HE-SIG-B content channel to indicate the presence of a C26 resource unit in each 80MHz portion of a 160MHz PPDU. SAMSUNG-1009, [0046], Fig. 6; SAMSUNG-1010, 27. No indication bit for a C26 resource unit is included in 20 or 40MHz PPDUs. *See* SAMSUNG-1009, [0007], [0035], [0043]; SAMSUNG-1010, 3, 27, 40.

184. A POSITA would have understood that in the Chen-Wu combination, the bandwidth field is used to determine how many C26 resource units to expect and the location of the C26 resource units within the overall bandwidth. SAMSUNG-1009, [0043]-[0047]; SAMSUNG-1010, 27-28. For example, when the bandwidth field indicates a bandwidth of less than 80MHz, no C26 resource units are present. *Id.* When the bandwidth field indicates 80MHz, one C26 resource unit is present and the bit in HE-SIG-B indicates whether they are unassigned. *Id.* Similarly, when the bandwidth field indicates 160MHz, two C26 resource units are present, and two bits in the HE-SIG-B indicates whether either or both are

unassigned. *Id.* In this sense, a POSITA would have understood the Chen-Wu combination as rendering obvious that the bandwidth field of HE-SIG-A is used to obtain information of an unassigned resource unit (e.g., an unassigned C26 resource unit).

[7.6] decoding a data of the received wireless packet based on the total bandwidth information and the information of the unassigned resource unit,

185. Chen-Wu renders obvious this limitation. For example, Chen teaches “an example method 1700 for identifying an RU for transmitting or receiving data based at least in part on a received PPDU.” SAMSUNG-1008, [0101]. Chen explains that data is received according to an RU allocation, which is determined “based at least in part on the PAID, channel bandwidth, and the HE-SIG-B.” SAMSUNG-1008, [0101]-[0103], Fig. 17.



SAMSUNG-1008, Fig. 17 (excerpt)

186. A POSITA would have understood that the bandwidth field of HE-SIG-A informs a receiving station on which channels to receive the PPDU. SAMSUNG-1017, 9; SAMSUNG-1011, 7-11, 17-20, 23-25. Moreover, the

possible resource unit arrangements, number of HE-SIG-B channels, and number of C26 resource units varies based on the bandwidth of the PPDU. SAMSUNG-1008, [0034]-[0037], [0072], [0083]-[0088]; SAMSUNG-1009, [0034]-[0039], [0041]-[0047]; SAMSUNG-1010, 2-6, 10-13, 27-28, 40; SAMSUNG-1013, 8-10; SAMSUNG-1011, 7-11, 17-20, 23-25. Thus, a POSITA would have understood Chen-Wu as rendering obvious decoding a packet based on the PPDU bandwidth as indicated by the bandwidth field of HE-SIG-A.

187. In the Chen-Wu combination, a POSITA would have also found it obvious that the information of the unassigned resource unit is used to decode data of the received wireless packet. Chen explains that “after the STA 140 knows the RU allocation pattern and non-allocated RUs, the STA 140 may remove the non-allocated RUs from the allocation pattern and use its STA position in the STA list in the STA specific part to derive the RU assignment for itself.” SAMSUNG-1008, [0093].

188. For example, as discussed for [7.5], information from the bandwidth field of HE-SIG-A (e.g., a total PPDU bandwidth of 80 MHz) and the common field of HE-SIG-B indicate information of an unassigned resource unit (e.g., information of an unassigned 26-tone resource unit in the bandwidth corresponding to a fourth 20 MHz channel in a bandwidth of 80 MHz). *See* [7.5]. In such a case, a station considers the information of the unassigned resource unit when determining

which of the resource units in the partition corresponds to its station assignment.

SAMSUNG-1008, [0090]-[0093], Figs. 12-14. For example, if the resource unit allocation field indicates that a 20 MHz segment of bandwidth is partitioned into resource units of [106 26 106] tones, if a receiving station's PAID is located in the position that would otherwise correspond to the unassigned 26-tone resource unit, the station would understand that it is assigned to a second 106-tone resource unit and not the 26-tone resource unit per the RU non-allocation information.

SAMSUNG-1008, [0090]-[0093].

189. Additionally, a POSITA would have understood that one or more resource units not being allocated to a user may change the length of the user-specific field of HE-SIG-B. For example, as discussed below for [10], if indication bits indicate that a C26 resource unit is used (per Wu), the per-user allocation information is carried at the end, after the user allocations for segments A & C are carried. SAMSUNG-1009, cl. 10, [0044]-[0045]; SAMSUNG-1010, 27-28; *see* § X.C.4. A POSITA would have understood that the indication bits indicate that a C26 resource unit is not used, a per-user allocation would not be carried in the user-specific field. A receiving station uses the number of resource units to determine the length (specifically the number of user fields) of the user-specific field of HE-SIG-B, and thus properly decode HE-SIG-B to obtain the station's assigned resource unit and decode data therein. SAMSUNG-1008, [0076], [0089]-

[0093], [0101]-[0103], Fig. 17. Thus, a POSITA would have further understood that Chen-Wu renders obvious that the information of an unassigned resource unit is used to decode data of the received PPDU.

[7.7] wherein the unassigned resource unit is explicitly indicated with the information of the unassigned resource unit based on the bandwidth field and the at least one subfield, and

190. Chen-Wu renders obvious wherein the unassigned resource unit is explicitly indicated with the information of the unassigned resource unit based on the bandwidth field and the at least one subfield (e.g., common field of HE-SIG-B).

191. Specifically, a POSITA would have understood Chen-Wu as rendering obvious that the bandwidth field of HE-SIG-A and the common field of HE-SIG-B provide information specifically indicating that a particular resource unit is unassigned (e.g., RU non-allocation information per Chen and/or an additional indication bit for one or more C26 resource units per Wu). SAMSUNG-1008, [0089]-[0093]; SAMSUNG-1009, [0007], [0035], [0043]-[0047]; SAMSUNG-1010, 3, 27, 40. By contrast, a POSITA would have understood that, in some circumstances, the non-assignment of a resource unit may be implicitly derived based on other information.

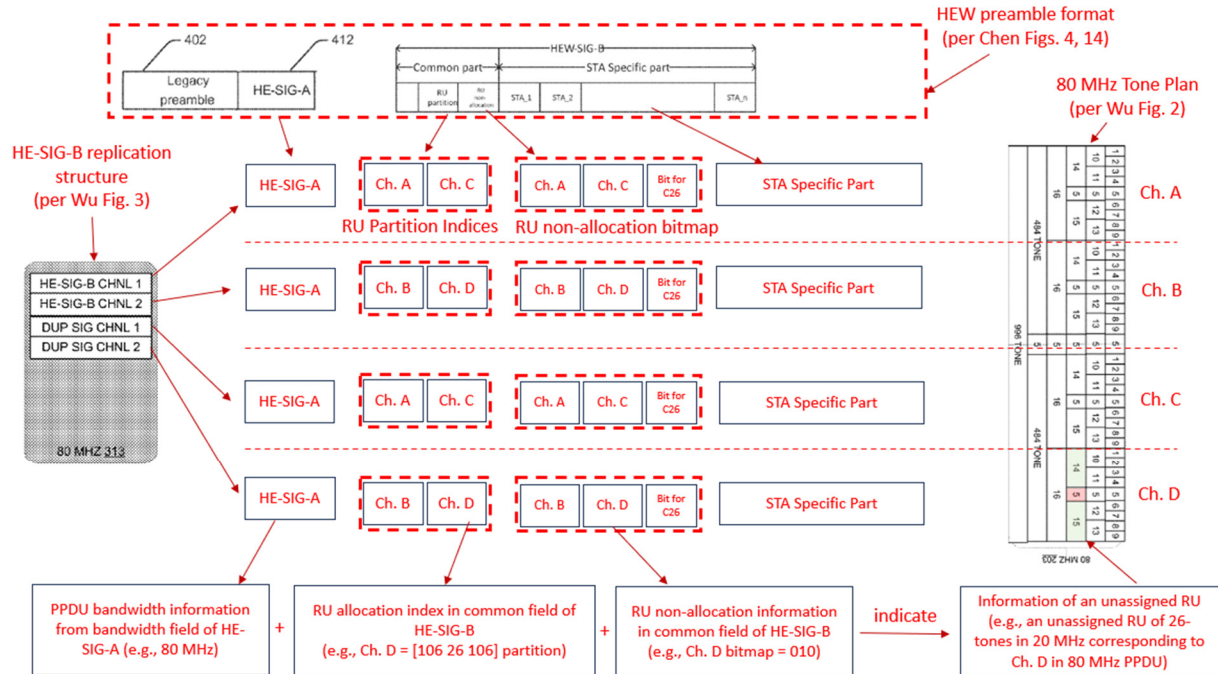
192. For example, the '595 patent explains that “whether the center 26-tone RU [] is assigned may be implicitly identified” based on nulling of resource units

in surrounding channels. SAMSUNG-1001, 47:22-51; *see also* SAMSUNG-1005, [0193]-[0198] (“If the STA 111 determines that the non-contiguous channel bonding field is set to indicate null channels, the STA 111 then interprets the RU arrangement in the common information portion to have null RUs that are adjacent to the nulled channels and determines the number of per-STA fields based on the channel bonding field and the RU arrangement.”); SAMSUNG-1006, 31-33.

193. A POSITA would have understood Chen-Wu’s methods as rendering obvious that an unassigned resource unit is explicitly indicated with the information of the unassigned resource unit based on the bandwidth of the PPDU (as indicated by the bandwidth field of HE-SIG-A) and the common field (i.e., at least one subfield) of HE-SIG-B. I note that satisfies the interpretation of “explicitly indicated with the information of the unassigned resource unit based on the bandwidth field of HE-SIG-A and a subfield of HE-SIG-B” that Wilus has advanced for purposes of infringement. SAMSUNG-1004, 28.

194. For example, a POSITA would have understood information of non-allocated resource units as explicitly indicating a non-allocated (i.e., unassigned) resource unit. SAMSUNG-1008, [0093] (“*Explicit indication of the non-allocated RU in the common part of HE-SIG-B may be understood with reference to FIG. 14.*”). This indication is carried in the common field of HE-SIG-B (i.e., the at least one subfield) and, as explained for [7.5], the location of the unassigned resource

unit within the overall PPDU is determined based on the bandwidth indicated by the bandwidth field of HE-SIG-A. *See* [7.5].



SAMSUNG-1008, Figs. 4, 14 illustrated with SAMSUNG-1009, Figs. 2, 3;

SAMSUNG-1010, 3-4 (annotated)

195. As another example, a POSITA would have understood information of the use of the C26 resource unit (per Wu) as explicitly indicating whether a C26 resource unit is unassigned. Wu teaches that this indication is carried in the common field of HE-SIG-B (i.e., the at least one subfield) and varies based on the bandwidth of the PPDU. SAMSUNG-1009, [0007], [0035], [0043]-[0047]; SAMSUNG-1010, 3, 27, 40. For example, no indication is carried in 20 and 40MHz PPDUs, an indication of a single 26-tone resource unit is carried in both

HE-SIG-B content channels in an 80MHz PPDU, and an indication of one of two 26-tone resource units are carried in each HE-SIG-B content channel in a 160MHz PPDU. *Id.* As explained above, in the Chen-Wu combination, it would have been obvious to a POSITA to include an indication bit (per Wu) in an RU non-allocation bitmap (per Chen), and a POSITA would have understood that in the Chen-Wu combination, the bandwidth field is used to determine how many C26 resource units to expect. *See* § IX.F.

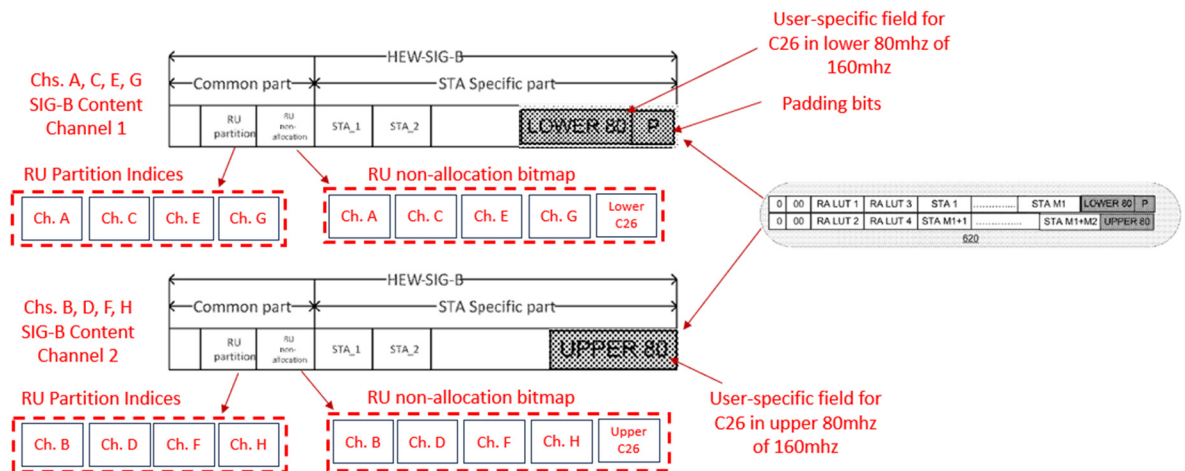
196. Thus, Chen-Wu renders obvious that an unassigned resource unit is explicitly indicated with the information of the unassigned resource unit based on the bandwidth field of HE-SIG-A and the common field of HE-SIG-B.

[7.8] wherein the information of the unassigned resource unit includes information of a C26 field indicating whether a user is allocated to a center 26-tone resource unit of 80 MHz upon the bandwidth related to a transmission of the received wireless packet indicated by the bandwidth field being 80 MH or more, not 20 MHz or 40 MHz.

197. Chen-Wu renders obvious this limitation. Wu teaches “the middle 26-tone RU for 80MHz and 160 MHz can be signaled by . . . [a] one-bit indication in the HE-SIG-B common [field].” SAMSUNG-1009, [0043], SAMSUNG-1010, 27. For example, Wu explains that, in an 80MHz PPDU, “one-bit in the common field of HE-SIG-B is used to indicate whether the middle 26-tone RU is used. If the bit is set, it indicates the RU is used.” SAMSUNG-1009, [0044], Fig. 5; SAMSUNG-1010, 27. A POSITA would have understood that a bit has two possible values

(i.e., zero or one), and that if the bit is not set (e.g., the bit is zero), the bit indicates that the C26 resource unit is not used (i.e., unassigned). A POSITA would have understood the indication bit as corresponding to the claimed “C26 field.” This aligns with the ’595 patent’s disclosure, which states that the “C26 field may consist of a 1-bit indicator before or after the [resource allocation] field in the common block field.” SAMSUNG-1001, 22:29-51, Fig. 15. A POSITA would have understood the common field as a subfield of HE-SIG-B. *Id.*; SAMSUNG-1009, [0036]; SAMSUNG-1010, 4; SAMSUNG-1011, 8-9.

198. In the Chen-Wu combination, it would have been obvious to a POSITA to include an indication bit (per Wu) in the RU non-allocation bitmap (per Chen). *See* § IX.F. For example, it would have been obvious to include an indication bit as the last bit in RU allocation bitmaps (per Chen) because the bitmaps are similarly indication bits for indicating an unassigned resource unit. *See* SAMSUNG-1008, [0093] (“The non-allocation [of resource units] may be realized by bit map.”). It would have been obvious to a POSITA to split the RU non-allocation information between HE-SIG-B content channels according to the content channel partition scheme discussed in Wu and well known to a POSITA. SAMSUNG-1009, [0035]-[0042], [0072]; SAMSUNG-1010, 3-4, 10, 12; SAMSUNG-1011, 8-12, Figs. 4-5, 6-7; SAMSUNG-1012, 8-10; *see* § IX.F.



SAMSUNG-1008, Fig. 14 modified with SAMSUNG-1009, Figs. 4, 5;

SAMSUNG-1010, 4, 12, 27 (annotated)

199. Wu teaches that an indication bit is only included when the bandwidth is 80MHz or more, not 20MHz or 40MHz. SAMSUNG-1009, [0043]-[0044], [0046]-[0047]; SAMSUNG-1010, 27. Moreover, in the Chen-Wu system, a POSITA would have understood that the extra indication bit used for signaling the use of a C26 resource unit is not required for 20 or 40MHz PPDU's because the tone plans for those transmission bandwidths do not include a 26-tone resource unit that falls between channels. SAMSUNG-1009, [0035], Fig. 2; SAMSUNG-1010, 3, 27; *see* § X.A.1. Thus, signaling the non-allocation of all resource units in 20 and 40MHz can be handled by the RU non-allocation information, per Chen. SAMSUNG-1008, [0090]-[0093]; *see* [7.3].

200. For these reasons, a POSITA would have understood Chen-Wu as

rendering obvious wherein the information of the unassigned resource unit (e.g., information indicated by Chen-Wu's RU non-allocation information) includes information of a C26 field (e.g., an indication bit per Wu) indicating whether a user is allocated to a C26 resource unit of 80 MHz upon the bandwidth related to a transmission of the received wireless packet indicated by the bandwidth field being 80 MHz or more, not 20 MHz or 40 MHz.

2. *Claim 8*

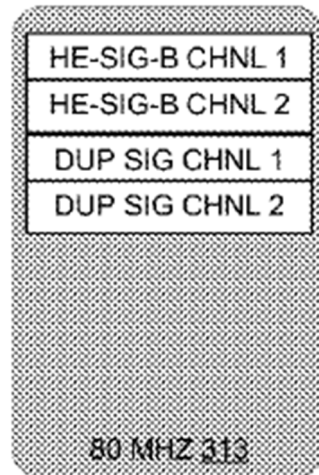
[8.pre] The wireless communication method of claim 7,

[8.1] wherein the HE-SIG-B field consists of HE-SIG-B content channel 1 and HE-SIG-B content channel 2 in units of 20 MHz respectively, and

201. Chen-Wu uses two HE-SIG-B content channels, which carry information for alternating 20MHz segments. *See* § IX.F. Specifically, Wu teaches

Different bandwidth configuration results in different number of HE-SIG-B channels. 20-MHz resource blocks 311 use one HE-SIG-B channel-1. 40-MHz resource block 312 uses two HE-SIG-B channels, HE-SIG-B Channel-1 and HE-SIG-B Channel-2. 80-MHz resource block 313 uses four HE-SIG-B channels, HE-SIG-B Channel-1, HE-SIG-B Channel-2 and one set of duplicated Channel-1 and Channel-2. 160-MHz resource block 313 uses eight HE-SIG-B channels, HE-SIG-B Channel-1, HE-SIG-B Channel-2 and three sets of duplicated Channel-1 and Channel-2.

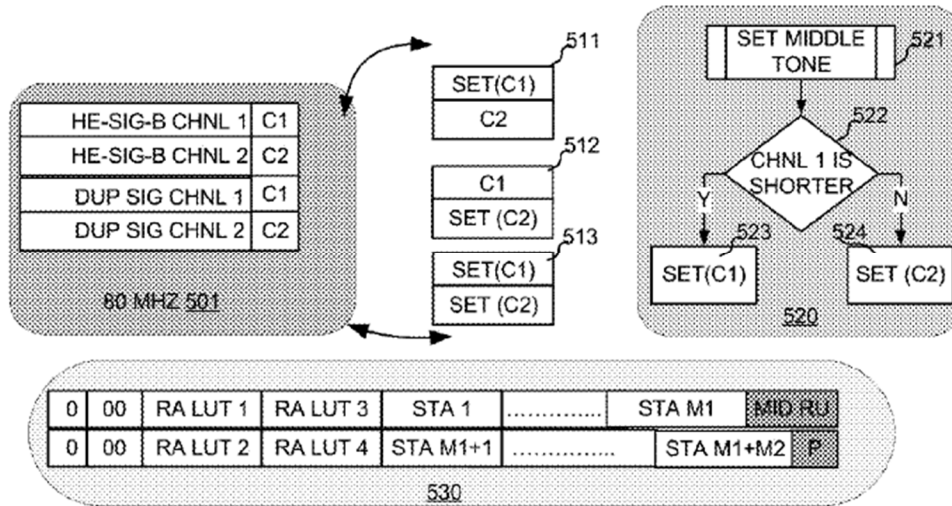
SAMSUNG-1009, [0036], Fig. 3; SAMSUNG-1010, 4.



SAMSUNG-1009, Fig. 3; SAMSUNG-1010, 4.

[8.2] wherein the C26 field is carried in both the HE-SIG-B content channel 1 and the HE-SIG-B content channel 2.

202. Chen-Wu renders obvious that the C26 field is carried in both HE-SIG-B content channels. Wu teaches “[i]n a third embodiment [of an 80MHz transmission] as shown in 513, duplicated bits are set in both [HE-SIG-B] ch-1 and [HE-SIG-B] ch-2.” SAMSUNG-1009, [0044], Fig. 5, cl. 8-9; SAMSUNG-1010, 27.

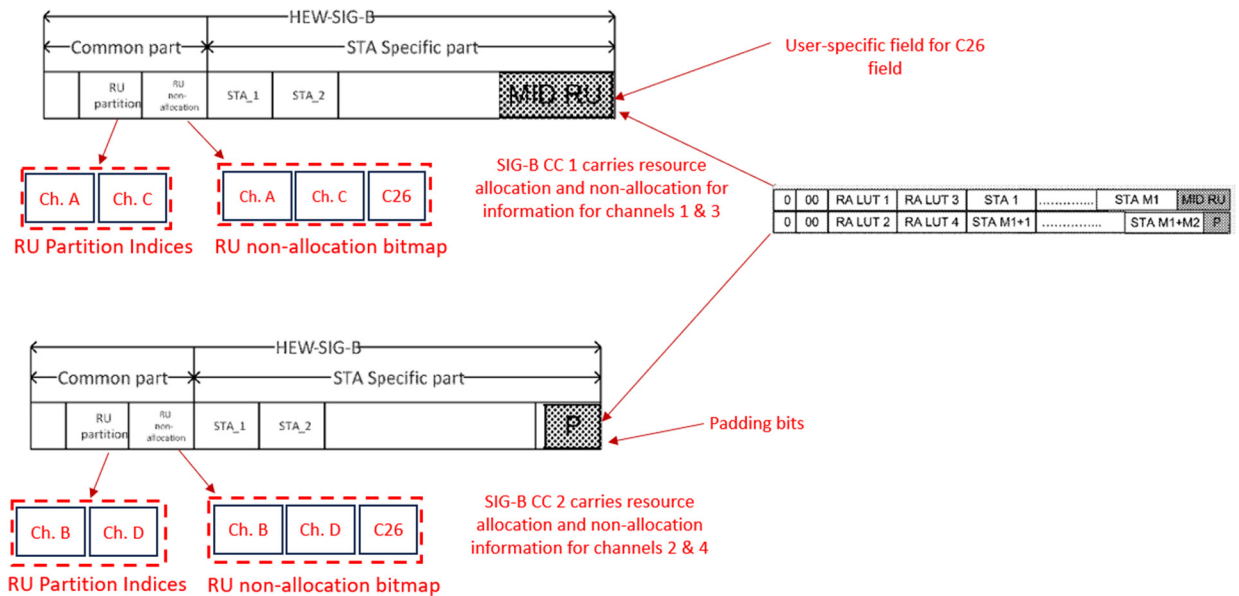


SAMSUNG-1009, Fig. 5; SAMSUNG-1010, 4, 27

203. Wu further describes a 160MHz transmission in which “one-bit in ch-1 of the HE-SIG-B common field is defined to be the middle 26-tone indicator for the middle 26-tone RU of the lower 80MHz. One-bit in ch-2 of the HE-SIG-B common field is defined to be the middle 26-tone indicator for the middle 26-tone RU of the upper 80MHz.” SAMSUNG-1009, [0046], Fig. 6, cl. 12-13; SAMSUNG-1010, 27.

204. As discussed above for [7.8], it would have been obvious to include indication bits (per Wu) in an RU non-allocation information bitmap (per Chen). *See* § X.C.1. For example, in an 80MHz PPDU, a POSITA would have found it obvious to append an indication bit at the end of the RU non-allocation bitmap in both channels, as taught by Wu. SAMSUNG-1009, [0044], Fig. 5; SAMSUNG-1010, 27; *see* § X.C.1; *see also* § X.C.5 (explaining that a 160 MHz PPDU would

also have an indication bit in HE-SIG-B content channel).



SAMSUNG-1008, Fig. 14 modified with SAMSUNG-1009, Figs. 4, 5;

SAMSUNG-1010, 4, 12, 27 (annotated)

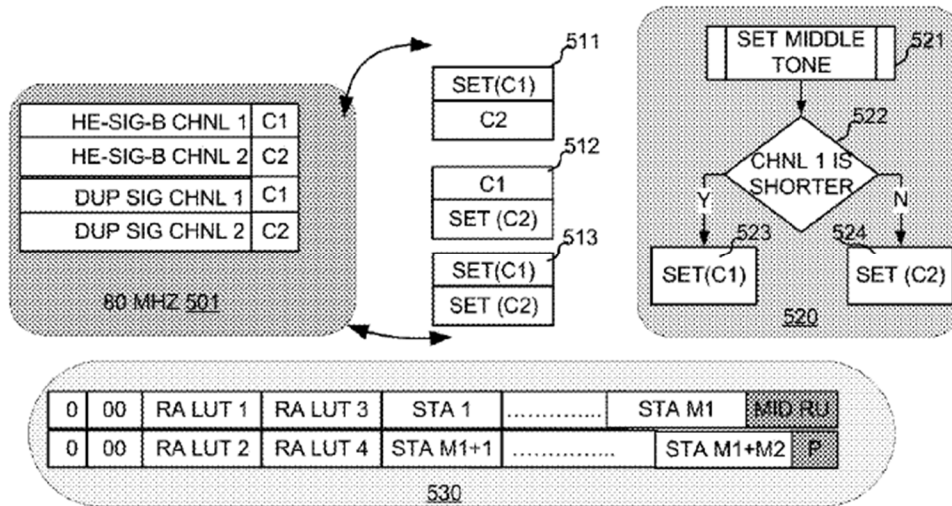
3. Claim 9

[9] The wireless communication method of claim 8, wherein when the received wireless packet is transmitted in a total bandwidth of 80 MHz, both of a C26 field carried in the HE-SIG-B content channel 1 and a C26 field carried in the HE-SIG-B content channel 2 indicate whether a user is allocated to a center 26-tone resource unit in the total bandwidth of 80 MHz.

205. In the Chen-Wu combination, when the received wireless packet is transmitted in a total bandwidth of 80MHz, both a C26 field carried in the HE-SIG-B content channel 1 and a C26 field carried in the HE-SIG-B content channel 2 indicate whether a user is allocated to a C26 resource unit in the total bandwidth

of 80MHz. Wu teaches “[i]n a third embodiment [of an 80MHz transmission] as shown in 513, duplicated bits are set in both [SIG-B] ch-1 and [SIG-B] ch-2.”

SAMSUNG-1009, [0044], Fig. 5, cl. 8-9; SAMSUNG-1010, 27.



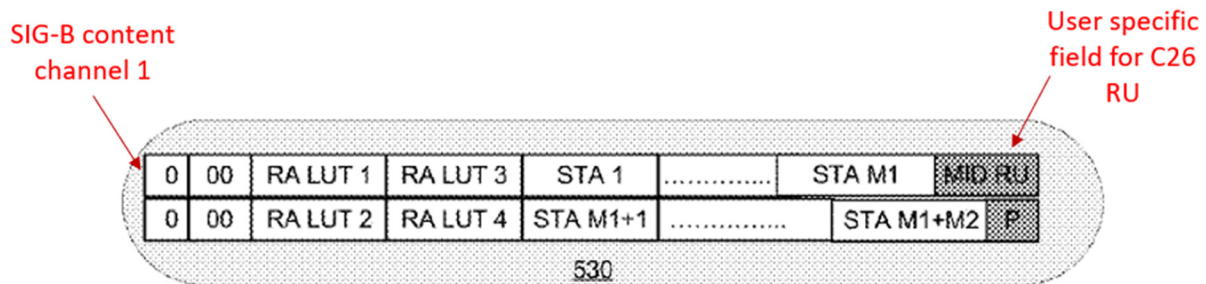
SAMSUNG-1009, Fig. 5; SAMSUNG-1010, 4, 27

4. Claim 10

[10] The wireless communication method of claim 9, wherein when the C26 field indicates that a user is allocated to the center 26-tone resource unit, a user field corresponding to the center 26-tone resource unit is carried in a user specific field of the HE-SIG-B content channel 1.

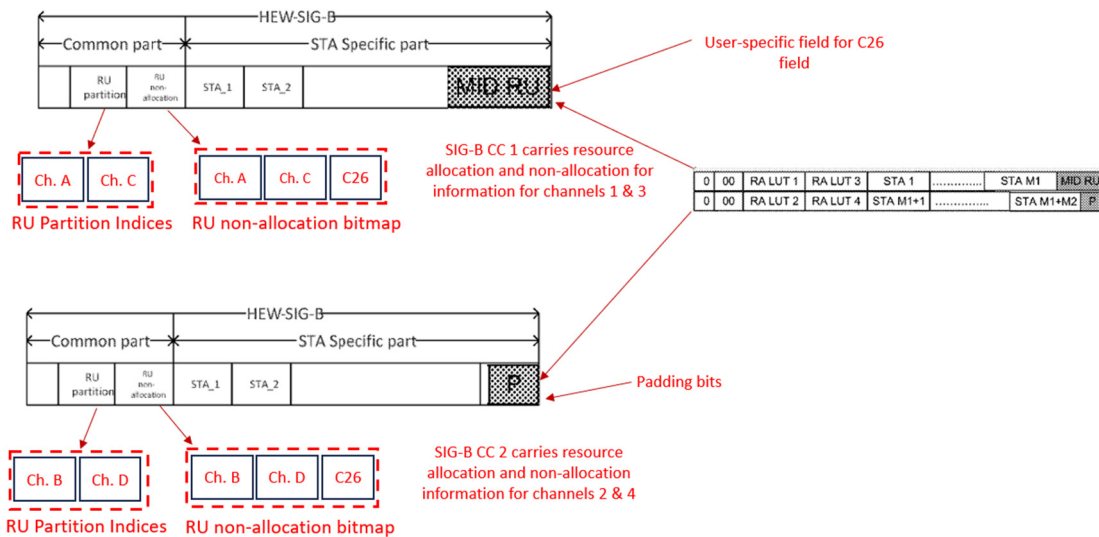
206. Chen-Wu renders obvious that when the C26 field indicates that a user is allocated to the C26 resource unit, a user field corresponding to the C26 resource unit carried in a user specific field of the HE-SIG-B content channel 1. Wu teaches “wherein the operation bandwidth is 80 MHz and the middle RU indicator is set to 1, the user specific field for the middle 26 tone RU of 80 Mhz channel is placed on a fixed HE-SIG-B channel.” SAMSUNG-1009, cl. 10, [0044]-

[0045]; SAMSUNG-1010, 27-28. Wu's Figure 5 depicts the user-specific field for the C26 tone resource unit as being carried in a user specific field of the HE-SIG-B content channel 1. SAMSUNG-1009, [0044]-[0045], Fig. 5; SAMSUNG-1010, 27; *see also* SAMSUNG-1010, 27 ("The user specific field for the STA assigned to the middle RU shall be placed in a predefined position. For 80MHz, it can be placed at the end of HE-SIG-B channel 1 or 2 or both.").



SAMSUNG-1009, Fig. 5; SAMSUNG-1010, 27 (annotated)

207. In the Chen-Wu combination, a POSITA would have found it obvious to include a user field for the C26 resource unit in a user specific field of the HE-SIG-B content channel 1 when the indication bits in the common field indicate a user is allocated to the C26 resource unit, per Wu. *See* § IX.F.



SAMSUNG-1008, Fig. 14 modified with SAMSUNG-1009, Figs. 4, 5;

SAMSUNG-1010, 4, 12, 27 (annotated)

5. Claim 11

[11] The wireless communication method of claim 8, wherein when the received wireless packet is transmitted in a total bandwidth of 160 MHz or 80+80 MHz, the total bandwidth includes a first 80 MHz bandwidth and a second 80 MHz bandwidth, a first C26 field carried in the HE-SIG-B content channel 1 indicates whether a user is allocated to a first center 26-tone resource unit in the first 80 MHz bandwidth, and a second C26 field carried in the HE-SIG-B content channel 2 indicates whether a user is allocated to a second center 26-tone resource unit in the second 80 MHz bandwidth.

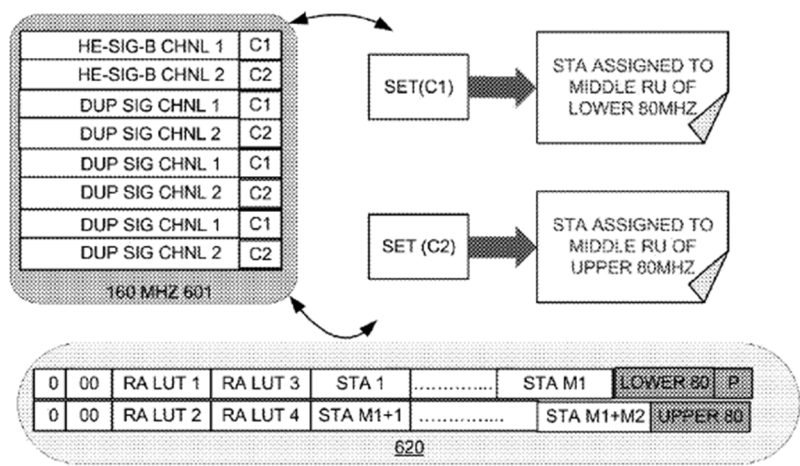
208. Chen-Wu renders obvious that in 160 (or 80 + 80) MHz PPDUs, a first C26 field in HE-SIG-B channel 1 indicates whether a user is allocated to a C26 resource unit in a first 80MHz bandwidth and a second C26 field in HE-SIG-B channel 2 indicates whether a user is allocated to a C26 resource unit in a second 80MHz bandwidth.

209. Wu discloses:

One 160 MHz HE-SIG-B channel 601 includes a HE-SIG-B Ch-1, a HE-SIG-B Ch-2, and three sets of a HE-SIG-B Duplicated Ch-1, and a HE-SIG-B Duplicated Ch-2. A one-bit in the common field of HE-SIG-B is used to indicate whether the middle 26-tone RU is used. If the bit is set, it indicates the RU is used. In one embodiment, one-bit in ch-1 of the HE-SIG-B common field is defined to be the middle 26-tone indicator [i.e., first C26 field] for the middle 26-tone RU [i.e., first center 26-tone RU] of the lower 80 MHz [i.e., first 80MHz bandwidth]. One-bit in ch-2 of the HE-SIG-B common field is defined to be the middle 26-tone indicator [i.e., second C26 field] for the middle 26-tone RU [i.e., second center 26-tone RU] of the upper 80 MHz [i.e., second 80MHz bandwidth].

SAMSUNG-1009, [0046], Fig. 6; SAMSUNG-1010, 4, 13, 27; *see also*

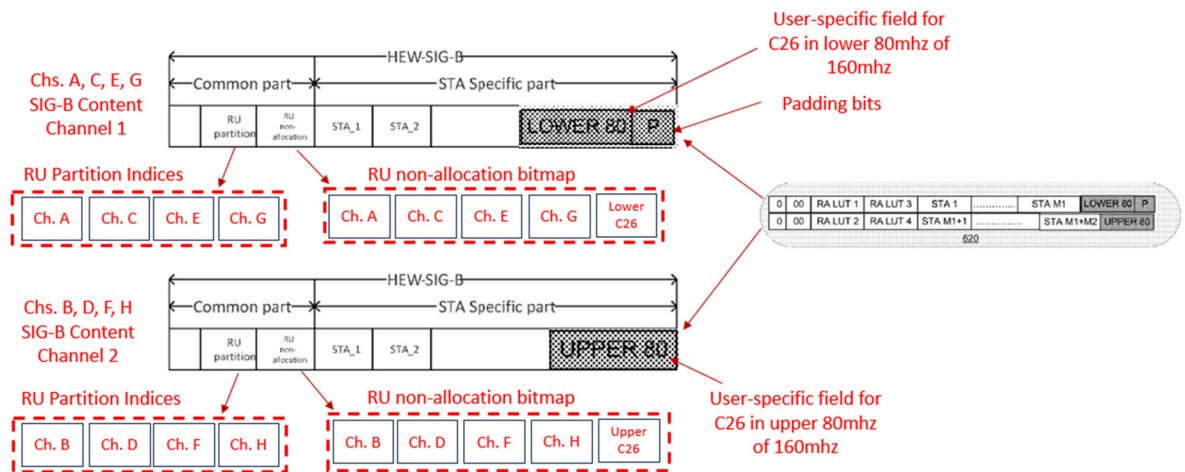
SAMSUNG-1009, cl. 12-13.



SAMSUNG-1009, Fig. 6; SAMSUNG-1010, 4, 13, 27.

210. In the Chen-Wu combination, a POSITA would have found it obvious to include a first indication bit in the resource unit non-allocation bitmap in HE-SIG-B content channel 1 and to include a second indication bit in the resource unit

non-allocation bitmap in HE-SIG-B content channel 2, per Wu.



SAMSUNG-1008, Fig. 14 modified with SAMSUNG-1009, Figs. 4, 6;

SAMSUNG-1010, 4, 12, 27 (annotated)

211. Chen-Wu also renders obvious using the above-described methods for 80+80MHz bandwidths for similar reasons to those described above in Ground 1A.

See § X.A.5.

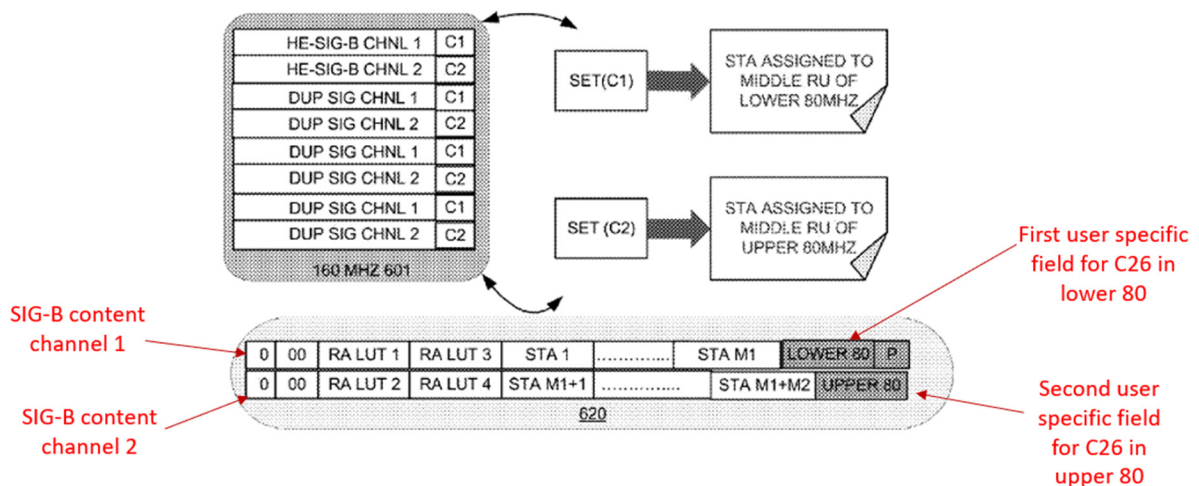
6. Claim 12

[12] The wireless communication method of claim 11, wherein when the first C26 field indicates that a user is allocated to the first center 26-tone resource unit, a user field corresponding to the first center 26-tone resource unit is carried in a user specific field of the HE-SIG-B content channel 1, and wherein when the second C26 field indicates that a user is allocated to the second center 26-tone resource unit, a user field corresponding to the second center 26-tone resource unit is carried in a user specific field of the HE-SIG-B content channel 2.

212. As I discussed above for [11], Chen-Wu renders obvious a first and second C26 field indicating that a user is allocated to first and second C26 resource

units, respectively. *See* § X.C.5. Chen-Wu further renders obvious carrying user fields for the first and second C26 resource units in HE-SIG-B content channels 1 and 2, respectively, when a user is allocated to the corresponding C26 resource unit.

213. Wu teaches placing “two user specific fields for middle RU of lower and upper 80 MHz when operation bandwidth is 160MHz.” SAMSUNG-1009, [0046]-[0047], Fig. 6, cl. 12-13 (“*[T]he user specific field for middle 26 tone RU of lower 80 Mhz is placed at the end of HE-SIG-B channel 1 and the user specific field of middle 26 tone RU of upper 80 MHz is placed at the end of HE-SIG-B channel 2.*”); SAMSUNG-1010, 27-28.



SAMSUNG-1009, Fig. 6; SAMSUNG-1010, 27-28 (annotated)

214. A POSITA would have understood Wu as teaching that the first and

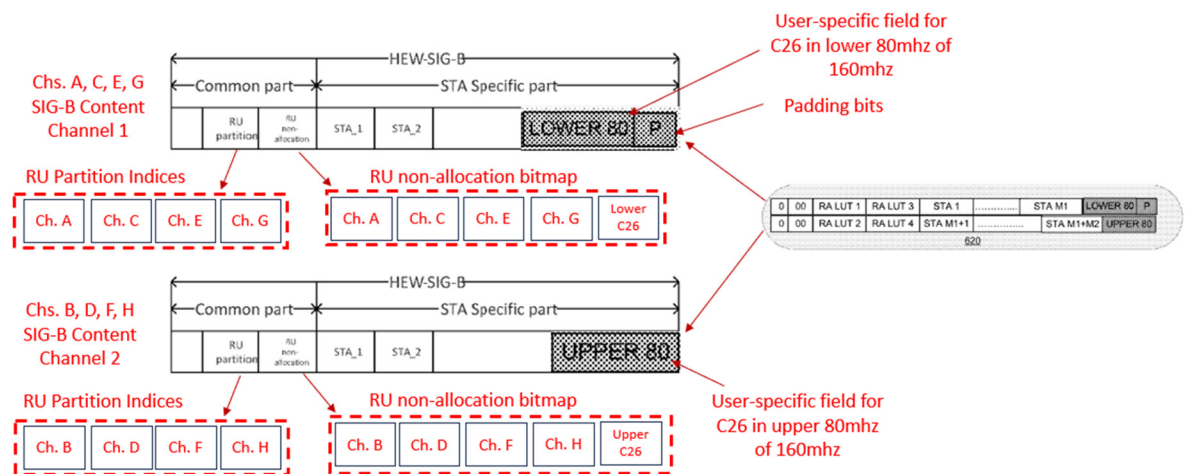
second user specific fields are carried in HE-SIG-B content channels 1 and 2, respectively, when a corresponding indication bit for the first or second C26 resource units is set. SAMSUNG-1009, cl. 13, [0034], [0072], Figs. 6, 14; SAMSUNG-1010, 27-28. This aligns with Wu's disclosure for an 80 MHz PPDU described above for [10], which includes a user field when the indication bit is set. SAMSUNG-1009, cl. 10, [0044]-[0045]; SAMSUNG-1010, 27-28; *see* § X.C.4.

215. Further, a POSITA would have understood that the purpose of the indication bit is to inform a receiving station whether a C26 resource unit is assigned to a user, and thus whether a user field is included for that C26 resource unit. SAMSUNG-1009, [0046] (“*If the bit is set, it indicates the RU is used.*”). This contrasts with the other method described in Wu where a user field for the C26 resource units is always included in the HE-SIG-B content channels, and if a particular C26 resource unit is not assigned to a user, it is set to a null station ID. *See* SAMSUNG-1009, [0045]. *Compare* SAMSUNG-1010, 27 (“One indication method is [a] 1 bit indication in the common field.”), *with id.*, 28 (“Method 2: Always define . . . two user specific fields for the middle RU of lower and upper 80 MHz when operation BW is 160 MHz. . . . No need for the 1 bit indication in the common field.”).

216. Moreover, a POSITA would have understood that if the C26 resource unit *is assigned*, a station receives its assignment to the C26 resource unit through

the user field in the user-specific part of HE-SIG-B. SAMSUNG-1008, [0037], [0039], [0071], [0091]; SAMSUNG-1009, [0038]; SAMSUNG-1010, 11.

217. In the Chen-Wu combination, a POSITA would have found it obvious to include user fields for first and second C26 resource units in HE-SIG-B content channels 1 and 2, respectively, when a user is allocated to the corresponding C26 resource unit.



SAMSUNG-1008, Fig. 14 modified with SAMSUNG-1009, Figs. 4, 6;

SAMSUNG-1010, 4, 12, 27 (annotated)

7. Claims 1-6

218. Claims 1-6 recite “[a] wireless communication terminal, the terminal comprising a processor, wherein the processor is configured to” perform the methods of claims 7-12, respectively. To the extent the preamble is limiting, Chen describes “a Wi-Fi access point (AP) [that] may be configured to identify a number

of user devices or stations (STA) with which it is to facilitate wireless communications.” SAMSUNG-1008, [0033]. Chen teaches that the stations may include “one or more processor(s) 300.” SAMSUNG-1008, [0068]. For similar reasons to those discussed above with respect to claims 7-12, a POSITA would have understood Chen-Wu as rendering obvious a processor (e.g., processor 300) configured to perform the remaining limitations of claim 1 and claims 2-6. *See* §§ X.C.1-6.

XI. CONCLUSION

219. For all the reasons I have noted in the foregoing paragraphs, claims 1-12 of the ’595 patent are obvious in view of the references discussed above.

220. 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

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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 <i>Wireless @ Virginia Tech</i>
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.
- 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. 9,596,571 B1*, March 14, 2017.
- R.M. Buehrer, R.A. Soni, and J.A. Tsai, “Methods and Apparatus for Downlink Diversity in CDMA Using Walsh Codes,” *U.S. Patent No. 7,400,614 B2*, July 15, 2008.
- R. D. Benning, R. M. Buehrer, Mark H Kramlm, and P. A. Polakos, “Space-Time Spreading and Phase Sweep Transmit Diversity”, *US Patent No. 7,042,955 B2*, May 9, 2006.
- R.D. Benning, R.M. Buehrer, and R.A. Soni, “Biased Phase Sweep Transmit Diversity”, *US Patent No. 7,035,599 B2*, April 25, 2006.

- 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.
- R.D. Benning, R.M. Buehrer, and R.A. Soni, “ Symmetric Sweep Phase Sweep Transmit Diversity”, *US Patent No. 6,920,314*, July 19, 2005.
- R.M. Buehrer, S.P. Nicoloso, R.A. Soni, and D. Uptegrove, “Cellular Communications System And Related Methods”, *US Patent No. 6,801,791*, October 5, 2004.
- 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.
- R.M. Buehrer and S.-C. Liu, “Code division multiple access system and method of operation with improved signal acquisition and processing,” *U.S. Patent No. 6,549,565*, April 15, 2003.
- 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.
- R.M. Buehrer, M.D. Hahm, S.C. Liu, and S.P. Nicoloso, “Base Station System Including Parallel Interference Cancellation Processor,” *US Patent No. 6,157,847*, December 5, 2000.

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. November 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*.
12. Javier Schloemann, “Fundamental Analyses of Collaborative and Noncollaborative Positioning,” Ph.D., August, 2015, *currently employed by Northrup-Grumman*.
13. Reza Vaghefi, “Cooperative Positioning in Wireless Sensor Networks Using Semidefinite Programming,” Ph.D., December 2014, *currently employed by Blue Danube Labs*.

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,
Funding: \$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),
Funding: \$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 Avoid-
ance,”
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 Science 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 Performance: 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. Kvac, 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 Benedetto, 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.
22. L.J. Wong, W. H. Clark IV, B. Flowers, R. M. Buehrer, A. J. Michaels, and W. C. Headley, "An RFML Ecosystem: Considerations for the Application of Deep Learning to Spectrum Situational Awareness," *IEEE Open Journal of the Communications Society*, vol. 2, pp. 2243-2264, 2021, doi: 10.1109/OJCOMS.2021.3112939.
23. C.E. O'Lone, H.S. Dhillon, and R.M. Buehrer, "Characterizing the First-Arriving Multipath Component in 5G Millimeter Wave Networks: TOA, AOA, and Non-Line-of-Sight Bias", *IEEE Transactions on Wireless Communications*, vol. 21, no. 3, pp. 1602 - 1620, March 2022, Digital Object Identifier: 10.1109/TWC.2021.3105641.
24. A. F. Martone, J. A. Kovarskiy, C. E. Thornton, B. H. Kirk, J. W. Owen, B. Ravenscroft, A. Egbert, A. Goad, R. M. Buehrer, R. M. Narayanan, S. Blunt, C. Baylis, and K. D. Sherbondy, "Closing the Loop on Cognitive Radar for Spectrum Sharing", *IEEE Aerospace and Electronic Systems Magazine*, vol. 36, no. 9, pp. 44-55, September 2021, Digital Object Identifier: 10.1109/MAES.2021.3072698.
25. S. R. Zekavat, R. M. Buehrer, G. D. Durgin, L. Lovisolo, Z. Wang, S.T. Goh, and A. Ghasem, "An Overview of Position Location: Past, Present, Future," *International Journal of Wireless Information Networks*, vol. 28, pp. 45-76, March 2021, Digital Object Identifier: 10.1007/s10776-021-00504-z.
26. C.E. Thornton, M. Kozy, A. F. Martone, K. Sherbondy, and R.M. Buehrer, "Deep Reinforcement Learning Control for Radar Detection and Tracking in Congested Spectral Environments," *IEEE Transactions on Cognitive Communications and Networking*, Vol. 6, No. 4, pp. 1335-1349, December 2020, Digital Object Identifier: 10.1109/TCCN.2020.3019605.
27. E. Selvi, R.M. Buehrer, A. Martone, and K. Sherbondy, "Reinforcement Learning For Adaptable Bandwidth Tracking Radars," *IEEE Transactions on Aerospace and Electronic Systems*, Vol. 56, No. 5, pp. 3904-3921, October 2020. Digital Object Identifier: 10.1109/TAES.2020.2987443.
28. Y. Xu, J. Yu, and R.M. Buehrer, "The Application of Deep Reinforcement Learning to Distributed Spectrum Access in Dynamic Heterogeneous Environments with Partial Observations," *IEEE Transactions on Wireless Communications*, vol. 19, no. 7, pp. 4494-4506, July 2020.
29. R. Shahanaghi, R.M. Buehrer, and Y. Yang, "Stochastic Link Modeling of Static Wireless Sensor Networks Over the Ocean Surface," *IEEE Transactions on Wireless Communications*, vol. 19, no. 6, pp. 4154-4169, June 2020.
30. C.E. O'Lone, H. Dhillon, and R.M. Buehrer, "Single-Anchor Localizability in 5G Millimeter Wave Networks," *IEEE Wireless Communications Letters*, vol. 9, no. 1, pp. 65-69, January 2020.
31. B. Flowers, W.C.Headley, and R.M. Buehrer, "Evaluating Adversarial Evasion Attacks in the Context of Wireless Communications," *IEEE Transactions on Information Forensics and Security*, vol. 15, no. 1, pp. 1102-1113, January 2020.
32. S. Aditya, H. Dhillon, A.F. Molisch, R.M. Buehrer and H.M. Behairy, "Characterizing the Impact of SNR Heterogeneity on Time-of-Arrival-Based Localization Outage Probability," *IEEE Transactions on Wireless Communications*, vol. 18, no. 1, pp. 637-649, Jan. 2019.
33. C.E. O'Lone, H.S. Dhillon, and R.M. Buehrer, "A Statistical Characterization of Localization Performance in Wireless Networks," *IEEE Transactions on Wireless Communications*, vol. 17, no. 9, pp. 5841-5856, Sept. 2018.

34. R.M. Buehrer, H. Wymeersch, and R. Vaghefi, "Collaborative Sensor Network Localization: Algorithms and Practical Issues," *Proceedings of the IEEE*, vol. 106, no. 6, pp. 1089-1114, June 2018.
35. M. Z. Win, R. M. Buehrer, G. Chrisikos, A. Conti, and H. Vincent Poor, "Foundations and Trends in Localization Technologies – Part 1", *Proceedings of the IEEE*, vol. 106, no. 6, pp. 1019 – 1021, June 2018.
36. M. Z. Win, R. M. Buehrer, G. Chrisikos, A. Conti, and H. Vincent Poor, "Foundations and Trends in Localization Technologies – Part 2", *Proceedings of the IEEE*, vol. 106, no. 7, pp. 1132 - 1135, July 2018.
37. J.D. Poston, R.M. Buehrer and P.A. Tarazaga, "A Framework for Occupancy Tracking in a Building via Structural Dynamics Sensing of Footstep Vibrations," *Frontiers in Built Environment: Structural Sensing*, 06 November 2017.
38. J. Poston, P. Tarazaga, and R.M. Buehrer, "Indoor Footstep Localization from Structural Dynamics Instrumentation," *Mechanical Systems and Signal Processing*, vol. 88, pp. 224-239, May, 2017.
39. S. Amuru, H. Dhillon, and R.M. Buehrer, "On Jamming Against Wireless Networks," *IEEE Transactions on Wireless Communications*, vol. 16, no. 1, pp. 412-428, January 2017.
40. D.J. Jakubisin and R.M. Buehrer, "Approximate Joint MAP Detection of Co-Channel Signals in Non-Gaussian Noise," *IEEE Transactions on Communications*, vol. 64, no. 10, pp. 4224-4237, October 2016.
41. R.M. Vaghefi and R.M. Buehrer, "Cooperative Source Node Tracking in Non-line-of-sight Environments," *IEEE Transactions on Mobile Computing*, vol. 16, no. 5, pp. 1287-1299, May 2017.
42. S. Garlapati, P.T. Kuruganti, R.M. Buehrer, and J.H. Reed, "SMAC : A Soft MAC to Reduce Control Overhead and Latency in CDMA based AMI Networks," *ACM/IEEE Transactions on Networking*, vol. 24, no. 5, 2648 - 2662, October, 2016.
43. S. Amuru, C. Tekin, M. van der Scharr, and R.M. Buehrer, "Jamming Bandits - A Novel Learning Method for Optimal Jamming," *IEEE Transactions on Wireless Communications*, vol. 15, no. 4, pp. 2792-2808, April 2016.
44. J. Schloemann, H. Dhillon, and R.M. Buehrer, "A Tractable Metric for Evaluating Base Station Geometries in Cellular Network Localization," *IEEE Wireless Communication Letters*, vol. 5, no. 2, pp. 140-143, February 2016.
45. J. Schloemann, H. Dhillon, and R.M. Buehrer, "A Tractable Analysis of the Improvement in Unique Localizability Through Collaboration," *IEEE Transactions on Wireless Communications*, vol. 15, no. 6, pp. 3934-3948, June 2016.
46. J. Schloemann, H. Dhillon, and R.M. Buehrer, "Towards a Tractable Analysis of Localization Fundamentals in Cellular Networks," *IEEE Transactions on Wireless Communications*, vol. 14, no. 3, pp. 1768-1782, March 2016.
47. J. Schloemann and R.M. Buehrer, "On the Value of Collaboration In Location Estimation," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 5, pp. 3585-3596, May 2016.
48. M. Lichtman, S. Amuru, J. H. Reed, and R.M. Buehrer, "A Communications Jamming Taxonomy," *IEEE Security & Privacy*, vol 14, no. 1, pp. 47-54, January 2016.
49. S. Amuru, M. van der Scharr, and R.M. Buehrer, "Blind Network Interdiction Strategies-A Learning Approach," *IEEE Transactions on Cognitive Communications and Networking*, vol. 1, no. 4, pp. 435-449, December 2015.
50. D.J. Jakubisin and R.M. Buehrer, "Performance, Complexity, and Receiver Design for Code-Aided Frame Synchronization in Multipath Channels," *IEEE Transactions on Communications*, vol. 63, no. 9, pp. 3363-3376, September, 2015.
51. S. Amuru and R.M. Buehrer, "Optimal Jamming against Digital Modulation," *IEEE Transactions on Information Forensics and Security*, vol. 10, no. 10, pp. 2212-2224, October 2015.

52. R.M. Vaghefi and R.M. Buehrer, "Cooperative Localization in NLOS Environments Using Semidefinite Programming," *IEEE Communications Letters*, vol. 19, no. 8, pp. 1382 – 1385, August, 2015.
53. R.M. Vaghefi and R.M. Buehrer, "Cooperative Joint Synchronization and Localization in Wireless Sensor Networks," *IEEE Transactions on Signal Processing*, vol. 63, no. 14, pp. 3615 – 3627, July 15, 2015.
54. R. M. Buehrer, C. R. Anderson, R. K. Martin, N. Patwari, and M. G. Rabbat, "Introduction to the Special Issue on Non-Cooperative Localization Networks", *IEEE Journal on Selected Topics in Signal Processing*, vol. 8, no. 1, pp. 2-4, January 2014.
55. S. Amuru, R. Tandon, R.M. Buehrer, and T.C. Clancy, "Retroactive Anti-Jamming for MISO Broadcast Channels," *IEEE Transactions on Information Theory*, vol. 60, no. 6, pp. 3593-3619, June 2014.
56. C.R. Anderson, H.I. Volos, and R. M. Buehrer, "Characterization of Low Antenna Ultra Wideband Propagation in a Forest Environment," *IEEE Transactions on Vehicular Technologies*, vol. 62, no. 7, pp. 2878-2895, July 2013.
57. R. M. Vaghefi, M.R. Gholami, R.M. Buehrer, and E.G. Strom, "Cooperative Received Signal Strength-Based Sensor Localization with Unknown Transmit Powers", *IEEE Transactions on Signal Processing*, vol.61, no.6, pp.1389-1403, 2013.
58. M. Baidas, R.M. Buehrer, and A.B. MacKenzie, "Network-Coded Bi-Directional Relaying for Amplify-and-Forward Cooperative Networks: A Comparative Study," *IEEE Transactions on Wireless Communications*, vol. 12, no. 7, pp. 3238 – 3252, July 2013.
59. H. I. Volos and R.M. Buehrer, "Cognitive Radio Engine Training," *IEEE Transactions on Wireless Communications*, vol. 11, no. 11, pp. 3878-3889, November, 2012.
60. C.R. Anderson, D. Hibbard, and R. M. Buehrer, "The Impact of Bandwidth on the Performance of DSSS Signals in Indoor Office Environments," *IEEE Transactions on Wireless Communications*, vol. 10, no. 9, pp. 2792-2799.
61. H.S. Dhillon, J.-O. Jeong, D. Datla, M. Benonis, R.M. Buehrer, and J.H. Reed, "A Sub-Space Method to Detect Multiple Wireless Microphone Signals in TV Band White Space," *accepted for publication in Analog Integrated Circuits and Signal Processing*, July, 2011.
62. J.H. Lee and R.M. Buehrer, "Characterization and Detection of Location Spoofing Attacks," *Journal of Communications and Networks*, vol. 14, no. 4, pp. 396-409, August, 2012.
63. J.H. Lee, A. Bhupathi Raju, and R.M. Buehrer, "Characterization of WCDMA Uplink Transmit Power for Mobile Usage Patterns," *IET Proceedings on Microwaves, Antennas and Propagation*, vol. 5, no. 5, pp. 535 – 544, May 2011.
64. T. Jia and R.M. Buehrer, "A Set-Theoretic Approach to Collaborative Position Location for Wireless Networks," *IEEE Transactions on Mobile Computing*, vol. 10, no. 9, pp. 1264-1275, September, 2011.
65. H. I. Volos and R.M. Buehrer, "Cognitive Engine Design for Link Adaptation: An Application to Multi-Antenna Systems," *IEEE Transactions on Wireless Communications*, vol. 9, no. 9, pp. 2902 – 2913, September 2010.
66. H. Shaban, M. A. El-Nasr, and R.M. Buehrer, "Towards a Highly Accurate Ambulatory System for Clinical Gait," *IEEE Transactions on Information Technology in Biomedicine*, vol. 14, no. 2, pp. 284 – 291, March 2010.
67. T. Jia and R.M. Buehrer, "On the Optimal Performance of Collaborative Position Location," *IEEE Transactions on Wireless Communications*, vol. 9, no. 1, pp. 374-383, January 2010.
68. S. Venkatesh, D.R. McKinstry, J.Ibrahim, and R.M. Buehrer "A Spatio-Temporal Channel Model for Ultra-Wideband Indoor NLOS Communications," *IEEE Transactions on Communications*, vol. 57, no. 12, pp. 3552-3555, December 2009.

69. R. Menon, A.B. MacKenzie, R.M. Buehrer and J.H. Reed, "Interference Avoidance in Networks with Distributed Receivers," *IEEE Transactions on Communications*, vol. 57, no. 10, pp. 3078-3091, October 2009.
70. C. R. Anderson, S. Venkatesh, J.Ibrahim and R.M. Buehrer, "Analysis and Implementation of a Time-Interleaved ADC Array for a Software-Defined UWB Receiver," *IEEE Transactions on Vehicular Technology*, vol. 58, no. 8, pp. 4046-4063, October 2009.
71. R. Menon, A.B. MacKenzie, J. Hicks, R.M. Buehrer, and J.H. Reed, "A Game-Theoretic Framework for Interference Avoidance," *IEEE Transactions on Communications*, vol. 57, no. 4, pp. 1087-1098, April 2009.
72. A.B. MacKenzie, J.H. Reed, P. Athanas, C.W. Bostian, R.M. Buehrer, L.A. DaSilva, S.W. Ellingson, Y. T. Hou, M. Hsiao, J.-M. Park, C. Patterson, S. Raman, and C.R.C. M. da Silva, "Cognitive Radio and Networking Research at Virginia Tech," *Proceedings of the IEEE*, vol. 97, no. 4, pp. 660-688, April 2009.
73. M. Muhamad and R.M. Buehrer, "The Effects of Ordering Criteria in Linear Successive Interference Cancellation in CDMA Systems," *IEEE Transactions on Wireless Communications*, vol. 7, no. 11, pp. 4128-4132, November 2008.
74. R. Menon, R.M. Buehrer, and J.H. Reed, "On the Impact of Dynamic Spectrum Sharing Techniques on Legacy Radio Systems," *IEEE Transactions on Wireless Communications*, vol. 7, no. 11, pp. 4198-4207, November 2008.
75. **Invited Paper** - N. Kumar and R. M. Buehrer, "The Ultra Wideband WiMedia Standard," *IEEE Signal Processing Magazine*, vol. 25, no. 5, pp. 115-119, September 2008.
76. S. Ginde, A. MacKenzie, R.M. Buehrer, and R. Komali, "A Game-Theoretic Analysis of Link Adaptation in Cellular Radio Networks," *IEEE Transactions on Vehicular Technology*, vol. 57, no. 5, pp. 3108 - 3120, September 2008.
77. H. Kim and R.M. Buehrer, "A Technique to Exploit Cooperation for Packet Retransmission in Wireless Ad Hoc Networks," *IEEE/KICS Journal of Communications and Networks (JCN), special issue on Cooperative Communications*, vol. 10, no. 2, pp. 148-155, June 2008.
78. S. Venkatesh and R.M. Buehrer, "NLOS Mitigation Using Linear Programming in Ultrawideband Location-Aware Networks," *IEEE Transactions on Vehicular Technology*, vol.56, no. 5, pp. 3182-3198, September 2007.
79. J.Ibrahim and R.M. Buehrer, "NBI Mitigation for UWB Systems Using Multiple Antenna Selection Diversity," *IEEE Transactions on Vehicular Technology*, vol. 56, no. 4, pp. 2363-2374, July 2007.
80. S. Venkatesh and R.M. Buehrer, Non-line-of-sight identification in ultra-wideband systems based on received signal statistics, *IET Microwaves, Antennas and Propagation*, vol. 1, no. 6, pp. 1120-1130, Nov. 2007.
81. **Invited Paper** - S. Venkatesh and R.M. Buehrer, "Multiple-access insights from bounds on sensor localization," *Pervasive and Mobile Computing* (2007), doi:10.1016/j.pmcj.2007.09.003.
82. B.M. Donlan, D.R. McKinstry, and R.M. Buehrer, "The UWB Indoor Channel: Large and Small Scale Modeling," *IEEE Transactions on Wireless Communications*, vol. 5, no. 10, pp. 2863- 2873, October 2006.
83. J. Jiang, R.M. Buehrer, and W.H. Tranter, "Greedy Scheduling Performance for a Zero-Forcing Dirty-Paper Coded System," *IEEE Transactions on Communication*, vol. 54, no. 5, pp. 789-792, May 2006.
84. R. Menon, J. Ibrahim, and R.M. Buehrer, "UWB Signal Detection Based on Sequence Optimization for Dense Multipath Channels," *IEEE Communications Letters*, vol. 10, no. 4, pp. 228-230, April 2006.
85. J.Ibrahim and R.M. Buehrer, "Two-Stage Acquisition for UWB in Dense Multipath," *IEEE Journal on Selected Areas in Communications*, vol. 24, no. 4, pp. 801-807, April 2006.
86. V. Bharadwaj and R.M. Buehrer, "An interference suppression scheme for UWB signals using multiple receive antennas," *IEEE Communications Letters*, vol. 9, no. 6, pp. 529-531, June 2005.

87. M. Muhamed and R.M. Buehrer, "On the Impact of SNR Estimation Error on Adaptive Modulation," *IEEE Communications Letters*, vol. 9, no. 6, pp. 490-492, June 2005.
88. R.M. Buehrer, R.A. Soni, and R.D. Benning, "Transmit Diversity for Combined 2G and 3G Systems," *IEEE Transactions on Communications*, vol. 52, no. 10, pp. 1648-1653, October 2004.
89. R.A. Soni and R.M. Buehrer, "On the Performance of Open Loop Transmit Diversity Methods for IS-2000 Systems: A Comparative Study," *IEEE Transactions on Wireless Communications*, vol. 3, no. 5, pp. 1602-1615, September 2004.
90. J.A. Tsai, R.M. Buehrer, and B.D. Woerner, "The BER Performance of the Uniform Circular Array Versus the Uniform Linear Array in a Mobile Radio Environment," *IEEE Transactions on Wireless Communications* vol. 3, no. 3, pp. 695-700, May 2004.
91. J. Jiang, R.M. Buehrer, and W.H. Tranter, "Antenna Diversity in Multiuser Data Networks," *IEEE Transactions on Communications*, vol. 52, no. 3, pp. 490-497, March 2004.
92. R.M. Buehrer and R. Mahajan, "On the Usefulness of Outer-loop Power Control for Successive Interference Cancellation," *IEEE Transactions on Communications*, vol. 51, no. 12, pp. 2091-2102, December 2003.
93. R. Gozali, R.M. Buehrer, and B.D. Woerner, "The Impact of Multiuser Diversity on Space-Time Block Coding," *IEEE Communications Letters*, vol. 7, no. 5, pp. 213-215, May 2003.
94. R.A. Soni, R.M. Buehrer, and R.D. Benning, "An Intelligent Antenna System for CDMA2000," *IEEE Signal Processing Magazine*, vol. 19, no. 4, pp 54-67, July 2002.
95. T.S. Rappaport, A. Annamalai, R.M. Buehrer and W.H. Tranter, "Wireless Communications: Past Events and a Future Prospective," *IEEE Communications Magazine*, vol. 40, 50th Anniversary, pp. 148-161, May 2002.
96. J.A. Tsai, R.M. Buehrer, and B.D. Woerner, "Spatial Fading Correlation Function of Circular Antenna Arrays with Laplacian Energy Distribution," *IEEE Communication Letters*, vol. 6, no. 5, pp. 178-180, May 2002.
97. R.M. Buehrer, "Equal BER Performance in Linear Successive Interference Cancellation for CDMA Systems," *IEEE Transactions on Communications*, vol. 49, no. 7, pp. 1250-1258, July 2001.
98. R.M. Buehrer, N.S. Correal, and B.D. Woerner, "A Simulation Comparison of Multiuser Receivers for Cellular CDMA," *IEEE Transactions on Vehicular Technology*, vol. 49, no. 4, pp. 1065-1085, July 2000.
99. R.M. Buehrer, A.G. Kogiantis, S.-C. Liu, J.-A. Tsai, and D. Uptegrove, "Intelligent Antennas for Wireless Communications – Uplink," *Bell Labs Technical Journal*, vol. 4, no. 3, pp. 73-103, July-September 1999.
100. R.M. Buehrer, S.P. Nicoloso, and S. Gollamudi, "Linear Versus Non-linear Interference Cancellation," *IEEE/AIEE Journal on Communications Networks*, vol. 1, no. 2, pp. 118-133, June 1999.
101. R.M. Buehrer and S.P. Nicoloso, "Comments on Partial Parallel Interference Cancellation for CDMA," *IEEE Transactions on Communications*, vol. 47, no. 5, pp. 658-661, May 1999.
102. N. Correal, R.M. Buehrer, and B.D. Woerner, "A DSP Based DS-CDMA Multiuser Receiver Based on Partial Parallel Interference Cancellation," *IEEE Journal on Selected Areas in Communications*, vol. 17, no. 4, pp. 613-630, April 1999.
103. A. Park, R.M. Buehrer, and B.D. Woerner, "Throughput Performance of an FHMA System with Variable Rate Coding," *IEEE Transactions on Communications*, vol. 46, no. 4, pp. 521-532, April 1998.
104. R.M. Buehrer and B.D. Woerner, "Analysis of Adaptive Multistage Interference Cancellation for CDMA Using an Improved Gaussian Approximation," *IEEE Transactions on Communications*, vol. 44, no. 10, pp. 1308-1321, October 1996.
105. R.M. Buehrer and B.D. Woerner, "Analysis of DS-CDMA Parallel Interference Cancellation with Phase and Timing Errors," *IEEE Journal on Selected Areas in Communications*, vol. 14, no. 8, pp. 1522-1535, October 1996.

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 100th 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 100th 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 100th 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.
14. M. Moore, W.C. Headley, and R.M. Buehrer, "Approaches to Minimizing Geometric Dilution of Precision in Doppler-based Positioning Using LEO Satellites," *2024 IEEE DySPAN Workshop on "Signal Reuse for Spectrum Efficiency*, May 13, 2024, Washington, DC, USA.

15. H. Dureppagari, H.S. Dhillon, and R.M. Buehrer, "UAV-Based 5G Localization for Emergency Response Using Signals of Opportunity," *2024 IEEE DySPAN Workshop on "Signal Reuse for Spectrum Efficiency"*, May 13, 2024, Washington, DC, USA.
16. Z. Schutz, C.E. Thornton, D.J. Jakubisin, and R.M. Buehrer, "Linear Jamming Bandits: Learning to Jam OFDM-Modulated Signals," *2024 IEEE International Communications Conference (ICC'24)*, 9–13 June 2024, Denver, CO, USA.
17. J. Budhu, S. V. Hum, S. W. Ellingson, and R. M. Buehrer, "Loading Rims of Radio Telescopes with Reconfigurable Reflectarrays for Adaptive Null-Steering," *2024 USNC-URSI National Radio Science Meeting (NRSN)*, Jan. 9 - 13, 2024, Boulder, CO.
18. S. W. Ellingson, R. M. Buehrer, T. Anders, and X. Li, "New Results on Mitigation of Satellite Interference by Coherent Time-Domain Canceling," *2024 USNC-URSI National Radio Science Meeting (NRSN)*, Jan. 9 - 13, 2024, Boulder, CO.
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**.
20. H. Hu, H.S. Dhillon and R.M. Buehrer, "Landmark-based Localization using Pairwise Constraints: A Stochastic Geometry Perspective," *Proceedings of SpaSWin 2023*.
21. H. Hu, H.S. Dhillon and R.M. Buehrer, "Stochastic Geometry Analysis of Localizability in Vision-Based Geolocation Systems," *Proceedings of the 57th Asilomar Conference on Signals, Systems, and Computers*, 2023.
22. D.-R. Emenonye, H.S. Dhillon, and R.M. Buehrer, "Limitations of RIS-Aided Localization: Inspecting the Relationships between Channel Parameters," *IEEE 2023 International Conference on Communications (ICC'23) SynComm6G Workshop*, June 2023, Rome, Italy.
23. H. K. Dureppagari, D.-R. Emenonye, H. S. Dhillon, and R. M. Buehrer, "UAV-Aided Indoor Localization of Emergency Response Personnel," *IEEE/ION Position Location and Navigation Symposium*, April 24-27, 2023, Monterey, CA.
24. D.-R. Emenonye, A. Pradhan, H.S. Dhillon, and R.M. Buehrer, "OTFS Enabled RIS-Aided Localization: Fundamental Limits and Potential Drawbacks," *IEEE/ION Position Location and Navigation Symposium*, April 24-27, 2023, Monterey, CA.
25. S.V. Hum, S.W. Ellingson, and R.M. Buehrer, "Toward Electronically Reconfigurable Rims for Reflectors in Radio Astronomy," *URSI General Assembly and Scientific Symposium 2023*.
26. S.V. Hum, S.W. Ellingson, and R.M. Buehrer, "Reflectarray Concept for Interference Mitigation in Radio Astronomy," *2023 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting*, 23-28 July, 2023, Portland, OR.
27. W.H. Howard and R.M. Buehrer, "Timely Target Tracking in Cognitive Radar Networks," *2023 IEEE Radar Conference*, San Antonio, Texas, May 1-5, 2023.
28. C.E. Thornton and R.M. Buehrer, "When Is Cognitive Radar Beneficial?" *2023 IEEE Radar Conference*, San Antonio, Texas, May 1-5, 2023.
29. D.-R. Emenonye, H.S. Dhillon, and R.M. Buehrer, "Estimation of RIS Misorientation in both Near and Far Field Regimes," *IEEE 2023 IEEE International Conference on Communications (ICC'23)*, 28 May – 01 June 2023, Rome, Italy.
30. G. Duggal, R.M. Buehrer, J. Reed, and N. Tripathi, "Line-of-Sight Probability for Outdoor-to-Indoor UAV-Assisted Emergency Networks," *IEEE 2023 IEEE International Conference on Communications (ICC'23)*, 28 May – 01 June 2023, Rome, Italy.

31. R.M. Buehrer and S.W. Ellingson, "Weight Selection for Pattern Control of Paraboloidal Reflector Antennas with Reconfigurable Rim Scattering," *Proceedings of the 2023 IEEE Aerospace Conference*, March 5-9, 2023, Big Sky, Montana.
32. S.W. Ellingson and R.M. Buehrer, "Techniques for Observing through Satellite Interference," *2023 USNC-URSI National Radio Science Meeting (NRSF)*, Boulder, CO, January 10-14, 2023,
33. S. Shebert, M.G. Amin, B.H. Kirk, and R.M. Buehrer, "Multi-Signal Classification Using Deep Learning and Sparse Arrays," *2022 IEEE Military Communications Conference (MILCOM '22)*, Rockville, MD, November 2022.
34. C.E. Thornton and R.M. Buehrer, "Linear Jamming Bandits: Sample-Efficient Learning for Non-Coherent Digital Jamming," *2022 IEEE Military Communications Conference (MILCOM '22)*, Rockville, MD, November 2022.
35. W.H. Howard and R.M. Buehrer, "Decentralized Bandits With Feedback for Cognitive Radar Networks," *2022 IEEE Military Communications Conference (MILCOM '22)*, Rockville, MD, November 2022.
36. R.M. Buehrer & S.W. Ellingson, "Pattern Control for Reflector Antennas Using Electronically-Reconfigurable Rim Scattering", *2022 IEEE Ant. & Prop. Sym.*, July 2022. (DOI pending)
37. W.H. Howard , A.F. Martone, and R.M. Buehrer, "Adversarial Multi-Player Bandits for Cognitive Radar Networks", *2022 IEEE Radar Conference*, New York, NY, March 21-25, 2022.
38. C.E. Thornton, R.M. Buehrer, and A.F. Martone, "Online Meta-Learning for Scene-Diverse Waveform-Agile Radar Target Tracking," *2022 IEEE Radar Conference*, New York, NY, March 21-25, 2022.
39. B. K. Chalise, D. Wong, M. G. Amin, R. M. Buehrer, A. Martone, B. Kirk, K. Sherbondy, "Sparsity-Based Distributed DoA Estimation for Radar Networks", *2022 IEEE Radar Conference*, New York, NY, March 21-25, 2022.
40. S. R. Shebert, A. F. Martone and R. M. Buehrer, "Wireless Standard Classification Using Convolutional Neural Networks," *2021 IEEE Global Communications Conference (GLOBECOM)*, 2021, pp. 1-6, doi: 10.1109/GLOBECOM46510.2021.9685799.
41. C.T. Fredieu, R.M. Buehrer and A. F. Martone, "Open-set Classification of Common Waveforms Using A Deep Feed-forward Network and Binary Isolation Forest Models," *2022 IEEE Wireless Communications and Networking Conference (WCNC 2022)*, December 2021.
42. W.H. Howard and R.M. Buehrer, "Multi-Target Localization Using Polarization Sensitive Arrays," *2021 IEEE Military Communications Conference (MILCOM2021)*, October 2, 2021.
43. C.E. Thornton, R.M. Buehrer, and A.F. Martone, "Waveform Selection for Radar Tracking in Target Channels With Memory via Universal Learning," *2021 IEEE Military Communications Conference (MILCOM2021)*, October 2, 2021. **(Received Vanu Bose Best Paper Award)**
44. S. Shebert, A.F. Martone, and R.M. Buehrer, "Open Set Wireless Standard Classification Using Convolutional Neural Networks," *2021 IEEE Military Communications Conference (MILCOM2021)*, October 2, 2021.
45. J. Yu, Y. Xu, H. Saad, and R.M. Buehrer, "Predicting Bit Error Rate from Meta Information Using Random Forests and Partial Data Augmentation," *SoutheastCon 2021*, Feb. 2021.
46. J. Yu, W. Howard, D. Tait, and R.M. Buehrer, "Direction-of-Arrival Estimation With A Vector Sensor Using Deep Neural Networks," *2021 IEEE Spring Vehicular Technology Conference*, Spring, 2021.
47. C.E. Thornton, R.M. Buehrer and A.F. Martone, "Constrained Online Learning to Mitigate Distortion Effects in Pulse-Agile Cognitive Radar", *2021 IEEE Radar Conference*, May 10-14, 2021.
48. W.H. Howard, C.E. Thornton, R.M. Buehrer and A.F. Martone, "Multi-Player Bandits for Distributed Cognitive Radar", *the 2021 IEEE Radar Conference*, May 10-14, 2021.

49. M. Moore, W.H. Clark IV, R.M. Buehrer, and W.C. Headley, "When is Enough Enough? "Just Enough" Decision Making with Recurrent Neural Networks for Radio Frequency Machine Learning," *39th IEEE – International Performance Computing and Communications Conference (IPCCC 2020)*, November 6th - 8th 2020.
50. C.E. Thornton, R.M. Buehrer and A.F. Martone, "Efficient Online Learning for Cognitive Radar-Cellular Coexistence via Contextual Thompson Sampling," *IEEE 2020 Global Communications Conference, GlobeCom2020*, Taipei, Taiwan, 7-11 December 2020.
51. J. Yu, M. S. Alhassoun, and R.M. Buehrer, "Interference Classification Using Deep Neural Networks," *IEEE Vehicular Technology Conference – Fall*, Victoria, British Columbia, July 2020.
52. A. Martone, K. Sherbondy, J. Kovarskiy, B. Kirk, J. Owen, B. Ravenscroft, A. Egbert, A. Dockendorf, A. Goad, C.E. Thornton, S. Blunt, R.M. Buehrer, C. Baylis, and R.M. Narayanan, "Practical Aspects of Cognitive Radar", *IEEE RadarConf2020*, June 2020.
53. D. Tait, J. Yu, W. Howard, and R.M. Buehrer, "Direction of Arrival Estimation of Digital Sources With Uni-Vector-Sensor ESPRIT," *Proceedings of The 21st IEEE International Workshop on Signal Processing Advances in Wireless Communications (SPAWC 2020)*, Atlanta, GA, USA, May 26-29, 2020.
54. A. Shahanaghi, Y. Yang, and R. M. Buehrer, "Link Stability Analysis of Wireless Sensor Networks Over the Ocean Surface," *Proceedings of the 17th Annual IEEE International Conference on Sensing, Communication and Networking (IEEE SECON 2020)*, June 22-25, 2020, Como, Italy.
55. J. Yu, H. Saad, and R. M. Buehrer, "Indoor Localization from Channel State Information with Recurrent Neural Networks," *Proceedings of NAVIGATIONPORTLANDIEEE/ION Position Location and Navigation Symposium (PLANS)*, Portland, OR, April 20–23, 2020.
56. C.E. Thornton, R.M. Buehrer and A.F. Martone, "Experimental Analysis of Reinforcement Learning Techniques for Spectrum Sharing Radar", *Proceedings of 2020 IEEE International Radar Conference (RADAR2020)*, Washington D.C., April 27 - May 1, 2020.
57. A. F. Martone, K. D. Sherbondy, J. A. Kovarskiy, B. H. Kirk, C. E. Thornton, J. W. Owen, B. Ravenscroft, A. Egbert, A. Goad, A. Dockendorf, R. M. Buehrer, R. M. Narayanan, S. D. Blunt, and C. Baylis, "Metacognition for Radar Coexistence," *Proceedings of 2020 IEEE International Radar Conference (RADAR2020)*, Washington D.C., April 27 - May 1, 2020.
58. C.E. O'Lone, H.S. Dillon, and R.M. Buehrer, ""A Mathematical Justification for Exponentially Distributed NLOS Bias", *Proceedings of the IEEE Global Communications Conference (GLOBECOM 2019)*, Waikoloa, Hawaii, December 9 – 13, 2019.
59. A. Shahanaghi, Y. Yang, and R. M. Buehrer, "On the Stochastic Link Modeling of Static Wireless Sensor Networks in Ocean Environments," *IEEE Conference on Computer Communications (IEEE INFOCOM 2019)*, Paris, France, April 29 - May 2, 2019.
60. M. Kozy, J. Yu, R. M. Buehrer, A. Martone, and K. Sherbondy, "Applying Deep-Q Networks to Target Tracking to Improve Cognitive Radar," *Proceedings of 2019 IEEE Radar Conference*, Boston, MA, April 22-26, 2019.
61. B. Kirk, M. Kozy, K. Gallagher, R. Narayanan, R. Buehrer, A. Martone, K. Sherbondy, "Cognitive Software Defined Radar: Evaluation of Target Detection with RFI Avoidance", *Proceedings of 2019 IEEE Radar Conference*, Boston, MA, April 22-26, 2019. [FINALIST FOR BEST STUDENT PAPER]
62. J. A. Kovarskiy, M. Kozy, C. Thornton, A. F. Martone, R. M. Narayanan, R. M. Buehrer, and K. D. Sherbondy, "Comparing stochastic and Markov decision process approaches for predicting radio frequency interference," *Proc. SPIE Conference on Commercial and Defense Sensing*, April 14-18, 2019, doi: 10.1117/12.2519675.
63. Y. Xu, J. Yu, and R.M. Buehrer, "Dealing with Partial Observations in Dynamic Spectrum Access: Deep Recurrent Q-Networks," *IEEE 2018 Military Communications Conference (MILCOM'18)*, Los Angeles, CA, October 29 - 31, 2018.

64. Y. Xu, J. Yu, W.C. Headley, and R.M. Buehrer, "Deep Reinforcement Learning for Dynamic Spectrum Access in Wireless Networks," *IEEE 2018 Military Communications Conference (MILCOM'18)*, Los Angeles, CA, October 29 - 31, 2018.
65. S. Dhiraj and R.M. Buehrer, "On Jammer Power Allocation Against OFDM Signals in Fading Channels," *IEEE 2018 Military Communications Conference (MILCOM'18)*, Los Angeles, CA, October 29 - 31, 2018.
66. M. Abdelbar and R.M. Buehrer, "Pedestrian GraphSLAM using Smartphone-based PDR in Indoor Environments," *IEEE ICC 2018 Workshop - 6th IEEE Workshop on Advances in Network Localization and Navigation (ANLN)*, Kansas City, MO, May 24, 2018.
67. E. Selvi, A. Martone, K. Sherbondy, R.M. Buehrer, "On the Use of Markov Decision Processes in Cognitive Radar: an Application to Target Tracking," *2018 IEEE Radar Conference*, Oklahoma City, USA, April 23-27, 2018.
68. M. Abdelbar and R. M. Buehrer, "Indoor Localization Through Trajectory Tracking Using Neural Networks," *Proceedings of the 2017 IEEE Military Communications Conference (MILCOM'17)*, Oct. 23-25, 2017, Baltimore, MD.
69. C.B. Dietrich, R. Goff, N. Polys, V. Marojevic, R. M. Buehrer, X. Gomez, S. Kim, A. Gaber Mohamed Ali and J. Garcia-Sheridan, "Remote laboratory exercises and tutorials for spectrum-agile radio frequency systems)," *Proceedings of 2017 IEEE Frontiers in Education Conference (FIE)*, Oct. 18-21, 2017, Indianapolis, IN.
70. J. A. García-Sheridan, R. M. Goff, C.B Dietrich, V. Marojevic, N.F Polys, and R. M. Buehrer, "A Pretest-Posttest Quasi-Experimental Study for a Game Intervention in an Undergraduate Wireless Communications Course," *2017 ASEE Annual Conference & Exposition*, June 25 - 28, 2017, Columbus, OH.
71. V. Marojevic, R. M. Goff, C. B Dietrich, T. Yang, C. W. Hearn, N. F Polys, and R.M. Buehrer, "Wireless Communication Testbed and Tools for Authentic STEM Learning," *Innovations in Communications and Wireless Systems Education Collection, 2015 ASEE Annual Conference & Exposition*", June 14 - 17, 2015, Seattle, WA.
72. C.E. O'Lone and R.M. Buehrer, "Towards a Characterization of Localization Performance in Networks with Random Geometries," *IEEE ICC Workshop on Advances in Network Localization and Navigation (ANLN)*, May 25, 2017, Paris, France.
73. S. Amuru, M. van der Schaar, and R.M. Buehrer, "Bandit Strategies for Blindly Attacking Networks," *Proceedings of the 2017 IEEE International Conference on Communications (ICC'17)*, May 21-25, 2017, Paris, France.
74. A. A. Gaber, H. Tillman, R.M. Buehrer, and S.W. Ellingson, "Sensitivity Analysis of Localization Using Discrete Astronomical Radio Sources," *Proceedings of the 2017 IEEE Wireless Communications and Networking Conference*, March 2017, San Francisco, CA.
75. S.W. Ellingson and R.M. Buehrer, "Frequency Channel Delay Modulation for Interference-Robust Low Data Rate Communication," *Proceedings of 2016 IEEE Military Communications Conference*, November 1-3 2016, Baltimore, MD.
76. T. Bhandari, H. Dhillon, and R.M. Buehrer, "The Impact of Proximate Base Station Measurements on Localizability in Cellular Systems," *Proceedings of 2016 IEEE 17th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC)*, July 3-6, 2016 in Edinburgh, UK.
77. D.J. Jakubisin and R.M. Buehrer, "BP, MF, and EP for Joint Channel Estimation and Detection of MIMO-OFDM Signals," *Proceedings of the 2016 IEEE Global Communications Conference (GLOBECOM'16)*, December 5-7, 2016.
78. M. Abdelbar and R.M. Buehrer, "A Novel Approach for Indoor Localization Through Motion Trajectories Similarities in Smart Buildings," in *Proceedings of IEEE/ION PLANS 2016 Conference*, Savannah, Georgia, April 11-14, 2016.

79. A. A. Gaber, H. Tillman, R.M. Buehrer, and S.W. Ellingson, "Navigating via Celestial Bodies: Geolocalization Using Fringe Rates," in *Proceedings of IEEE/ION PLANS 2016 Conference*, Savannah, Georgia, April 11-14, 2016.
80. C. E. O'Lone and R.M. Buehrer, "An Analysis of the Convex Hull's Impact on Localization Performance," in *Proceedings of IEEE/ION PLANS 2016 Conference*, Savannah, Georgia, April 11-14, 2016.
81. J. Poston, R.M. Buehrer, A. G. Woolard, and P.A. Tarazaga, "Indoor Positioning from Vibration Localization in Smart Buildings," in *Proceedings of IEEE/ION PLANS 2016 Conference*, Savannah, Georgia, April 11-14, 2016.
82. R. M. Vaghefi, D. Jakubisin, and R.M. Buehrer, "MIMO-Radar-Based Indoor Passive Localization and Tracking," *Proceedings of IEEE/ION PLANS 2016 Conference*, Savannah, Georgia, April 11-14, 2016.
83. R. M. Vaghefi and R.M. Buehrer, "On the CRLB of TDOA/FDOA Estimation from MIMO Signals," in *Proceedings of IEEE/ION PLANS 2016 Conference*, Savannah, Georgia, April 11-14, 2016.
84. S. Amuru, H. Dhillon and R.M. Buehrer, "An Error Probability Analysis of Jamming Against Wireless Networks," in the *Proceedings of IEEE International Conference on Communications (ICC'16)*, June 2016.
85. N. El Gamel, J. Schloemann, F. Jondral, and R.M. Buehrer, "Improved Indoor Positioning Using the Baum-Welch Algorithm," in *Proceedings of the 2015 IEEE Global Communications Conference Workshop on Localization and Tracking: Indoors, Outdoors and Emerging Networks (GC - LION '15)*, San Diego, CA, December 6, 2015.
86. J. Schloemann, H. Dhillon, and R.M. Buehrer, "Effect of Collaboration on Localizability in Range-Based Localization Systems," in *Proceedings of the 2015 IEEE Global Communications Conference Workshop on Localization and Tracking: Indoors, Outdoors and Emerging Networks (GC - LION '15)*, San Diego, CA, December 6, 2015.
87. K. McDermott, R. M. Vaghefi, and R.M. Buehrer, "Cooperative UTDOA Positioning in LTE Cellular Systems," in *Proceedings of the 2015 IEEE Global Communications Conference Workshop on Localization and Tracking: Indoors, Outdoors and Emerging Networks (GC - LION '15)*, San Diego, CA, December 6, 2015.
88. D.J. Jakubisin and R.M. Buehrer, "Approximate Joint MAP Detection of Co-Channel Signals," in *Proceedings of the 2015 IEEE Military Communications Conference (MILCOM'15)*, Tampa, FL, October 26-28, 2015.
89. S. Amuru and R.M. Buehrer, "To Send or Not to Send - Learning MAC Contention," in *Proceedings of the 2015 IEEE Global Communications Conference (GLOBECOM '15)*, San Diego, CA, December 6-10, 2015.
90. J.D. Poston, J. Schloemann, R.M. Buehrer, V.V. N. S. Malladi, A. Woolard, P. Tarazaga, "Vibration Sensing in Smart Buildings for Indoor Positioning of Pedestrians," in *Proceedings of the 2015 Indoor Positioning and Indoor Navigation Conference*, Oct. 13-16, 2015, Banff, Alberta, Canada.
91. J. D. Poston, J. Schloemann, R. M. Buehrer, V. S. Malladi, A. G. Woolard, and P. A. Tarazaga, "Towards Indoor Localization of Pedestrians via Smart Building Vibration Sensing," in *Proceedings of the International Conference on Localization and GNSS*, June 22-24, 2015, Gothenburg, Sweden.
92. S. Yousefi, R.M. Vaghefi, X.-W. Chang, B. Champagne, and R.M. Buehrer, "Sensor Localization in NLOS Environments with Anchor Uncertainty and Unknown Clock Parameters," in *Proceedings of the 2015 ICC Workshop on Advances in Network Localization and Navigation*, June 8-12, 2015.
93. J. Schloemann, H.S. Dhillon, and R.M. Buehrer, "Localization Performance in Cellular Networks," in *Proceedings of the 2015 ICC Workshop on Advances in Network Localization and Navigation*, June 8-12, 2015.
94. S. Amuru and R.M. Buehrer "A Systematic Learning Method for Optimal Jamming", *to appear in Proceedings of the 2015 IEEE International Conference on Communications (ICC'15)*, June 8-12, 2015.

95. R.M. Vaghefi and R.M. Buehrer, "Improving Mobile Node Tracking Performance in NLOS Environments Using Cooperation", *to appear in Proceedings of the 2015 IEEE International Conference on Communications (ICC'15)*, June 8-12, 2015.
96. J. Schloemann, S. Malladi, P. Tarazaga, and R.M. Buehrer, "Vibration event localization in an instrumented building", *Proceedings of IMAC XXXIII - A Conference and Exposition on Structural Dynamics*, February 2-5 2015.
97. S. Amuru and R.M. Buehrer "Optimal Jamming Strategies in Digital Communications-Impact of Modulation", *Proceedings of the 2014 IEEE Global Communications Conference (GlobeCom'14)*, Austin, TX, December 2014.
98. R. Vaghefi and R.M. Buehrer, "A Linear Estimator for Joint Synchronization and Localization in Wireless Sensor Networks," *Proceedings of the 2014 IEEE Global Communications Conference (GlobeCom'14)*, Austin, TX, December 2014.
99. J. Schloemann and R.M. Buehrer, "On the Value of Collaboration in Multidimensional Location Estimation," *Proceedings of the 2014 IEEE Global Communications Conference (GlobeCom'14)*, Austin, TX, December 2014.
100. J. Schloemann and R.M. Buehrer, "On the Value of Collaboration in Non-Line-of-Sight Location Estimation", *Proceedings of the 2014 IEEE Military Communications Conference (MILCOM'14)*, Baltimore, MD, October, 2014.
101. S. Amuru and R.M. Buehrer, "Optimal Jamming using Delayed Learning", *Proceedings of the 2014 IEEE Military Communications Conference (MILCOM'14)*, Baltimore, MD, October, 2014.
102. R. M. Vaghefi and R.M. Buehrer, "Cooperative RF Pattern Matching Positioning for LTE," *Proceedings of the IEEE Personal, Indoor, Mobile Radio Conference (PIMRC'14)*, Washington, DC. 2014
103. D.J. Jakubisin and R.M. Buehrer, "On the Complexity-Performance Trade-off in Code-Aided Frame Synchronization," *The 15th IEEE International Workshop on Signal Processing Advances in Wireless Communications*, Toronto, Canada, 22-25 June 2014.
104. A. Amini, R. M. Vaghefi, J.M. da la Garza and R.M. Buehrer, "Improving GPS-Based Vehicle Positioning for Intelligent Transportation Systems," *Proceedings of 2014 IEEE Intelligent Vehicles Symposium*, Dearborn, Michigan, June 8 - 11, 2014.
105. R. M. Vaghefi and R.M. Buehrer, "Improving Positioning in LTE through Collaboration," *11th Workshop on Positioning, Navigation and Communications 2014 (WPNC'14)*, Dresden, Germany, March 12-13, 2014.
106. A. Amini, R. M. Vaghefi, J.M. da la Garza and R.M. Buehrer, "GPS-Free Cooperative Mobile Tracking with the Application in Vehicular Networks," *11th Workshop on Positioning, Navigation and Communications 2014 (WPNC'14)*, Dresden, Germany, March 12-13, 2014.
107. R. Vaghefi and R.M. Buehrer, "Joint TOA-Based Sensor Synchronization and Localization Using Semidefinite Programming," *Proceedings of the 2014 IEEE International Conference on Communications (ICC'14)*, Sydney, Australia, June 6-10, 2014.
108. R. Tandon, S. Amuru, R.M. Buehrer, and T.C. Clancy, "On Secure Distributed Storage Systems with Exact Repair," *Proceedings of the 2014 IEEE International Conference on Communications (ICC'14)*, Sydney, Australia, June 6-10, 2014.
109. S. Amuru, R. Tandon, R.M. Buehrer, and T.C. Clancy, "Jamming Countermeasures for Multi-User MISO Broadcast Channels - a DoF perspective," *Proceedings of the 2013 IEEE Global Communications Conference (GlobeCom'13)*, December 2013.
110. R. Vaghefi and R.M. Buehrer, "Asynchronous Time-of-Arrival-Based Source Localization," *Proceedings of the 2013 International Conference on Acoustics, Speech, and Signal Processing (ICASSP'13)*, May 26-31, 2013, Vancouver, Canada.

111. R. Vaghefi and R.M. Buehrer, "Received signal strength-based sensor localization in spatially correlated shadowing," *Proceedings of the 2013 International Conference on Acoustics, Speech, and Signal Processing (ICASSP'13)*, May 26-31, 2013, Vancouver, Canada.
112. S. Amuru, D. Jakubisin, R. M. Buehrer, and C. da Silva, "Asynchronous Signal Detection in Frequency-Selective Non-Gaussian Channels," *Proceedings of the 47th Asilomar Conference on Signals, Systems and Computers*, Pacific Grove, CA, Nov. 3-6, 2013.
113. S. Amuru, R. Tandon, R. M. Buehrer, and T.C. Clancy, "Interference Alignment for MISO Broadcast Channels under Jamming attacks," *Proceedings of the 47th Asilomar Conference on Signals, Systems and Computers*, Pacific Grove, CA, Nov. 3-6, 2013.
114. Y. Hasan and R. M. Buehrer, "Interference Analysis of Multi-hop Cellular Networks," *Proceedings of the 47th Asilomar Conference on Signals, Systems and Computers*, Pacific Grove, CA, Nov. 3-6, 2013.
115. J. Schloemann and R.M. Buehrer, "Using Fisher Information Matrix Summary Statistics to Assess the Value of Collaborative Positioning Opportunities," *Proceedings of the 2013 IEEE Military Communications Conference*, San Diego, CA, Nov. 18-20, 2013.
116. R. Vaghefi and R.M. Buehrer, "Target Tracking in NLOS Environments Using Semidefinite Programming," *Proceedings of the 2013 IEEE Military Communications Conference*, San Diego, CA, Nov. 18-20, 2013.
117. S. Amuru, R. Tandon, R.M. Buehrer, and T.C. Clancy, "MIMO Radar Waveform Design to support Spectrum Sharing," *Proceedings of the 2013 IEEE Military Communications Conference*, San Diego, CA, Nov. 18-20, 2013.
118. R. Vaghefi, J. Schloemann, and R.M. Buehrer, "NLOS Mitigation in TOA-Based Localization Using Semidefinite Programming," *Proceedings of the 10th Workshop on Positioning, Navigation, and Communication*, Dresden, Germany, March, 2013.
119. C.I. Phelps and R.M. Buehrer, "Signal Classification by Probabilistic Reasoning," *Proceedings of Radio Wireless World 2013*, January 20-23, 2013.
120. A.E. Martin, Y. Hasan, and R.M. Buehrer, "Physical Layer Security of Hybrid Spread Spectrum Systems," *Proceedings of Radio Wireless World 2013*, January 20-23, 2013.
121. J. Schloemann and R.M. Buehrer, "On the Value of Collaboration in Anchorless Robot Self-Localization," *Proceedings of the 2012 IEEE Military Communications Conference (MILCOM '12)*, Orlando, FL, Oct. 29 – Nov. 1, 2012.
122. D. Jakubisin and R.M. Buehrer, "Improved Modulation Classification using a Factor-Graph-based Iterative Receiver," *Proceedings of the 2012 IEEE Military Communications Conference (MILCOM '12)*, Orlando, FL, Oct. 29 – Nov. 1, 2012.
123. M. W. Baidas, A.B. MacKenzie, and R.M. Buehrer, 'Performance Analysis of Network-Coded Bi-Directional Relaying for Amplify-and-Forward Cooperative Wireless Networks' accepted to *IEEE IWCMC 2012*, Limassol, Cyprus, August 27-31, 2012.
124. J. Overfield, Z. Biskadourous, and R.M. Buehrer, "Geolocation of MIMO signals using the Cross Ambiguity Function and TDOA/FDOA," *Proceedings of the International Conference on Communications (ICC'12) – Signal Processing for Communications Symposium*, Ottawa, Canada, June 11-16, 2012.
125. R. Vaghefi and R.M. Buehrer, "Cooperative Sensor Localization with NLOS Mitigation Using Semidefinite Programming," *Proceedings of the 9th Workshop on Positioning, Navigation, and Communication*, Dresden, Germany, March 15-16, 2012.
126. B. Thompson and R.M. Buehrer, "Characterizing and Improving the Collaborative Position Location Problem," *Proceedings of the 9th Workshop on Positioning, Navigation, and Communication*, Dresden, Germany, March 15-16, 2012.

127. Z. Biskadurous and R.M. Buehrer, "Collaborative Localization Enhancement to the Global Positioning System," *Proceedings of the 9th Workshop on Positioning, Navigation, and Communication*, Dresden, Germany, March 15-16, 2012.
128. B. Thompson and R.M. Buehrer, "Cooperative Indoor Position Location Using Reflected Estimations," *European Wireless 2011*, pp. 644-649, Vienna, Austria, April 27-29, 2011. (**Invited Paper**).
129. J.-H. Lee and R.M. Buehrer, "Location Spoofing Attack Detection in Wireless Networks," *2010 IEEE Global Communications Conference (GLOBECOM'11)*, pp. 1-6, Miami, FL, December 6-10, 2010.
130. H. Dhillon and R.M. Buehrer, "On the Sum-Rate of Peer-to-Peer MIMO Multiuser Gaussian Interference Channels," *2010 IEEE Global Communications Conference (GLOBECOM)*, pp. 1-6, Miami, FL, December 6-10, 2010.
131. T. Jia and R.M. Buehrer, "Collaborative Position Location for Wireless Networks Using Iterative Parallel Projection Method," *2010 IEEE Global Communications Conference (GLOBECOM)*, pp. 1-6, Miami, FL, December 6-10, 2010.
132. H. Dhillon and R.M. Buehrer, "On the Maximum Sum-Rate of Cognitive MIMO Interference Channels," *2010 IEEE Military Communications Conference (MILCOM 2010)*, pp. 755-761, San Jose, CA, Oct. 31 2010-Nov. 3 2010.
133. H. Volos and R.M. Buehrer, "Robust Training of A Link Adaptation Cognitive Engine," *2010 IEEE Military Communications Conference (MILCOM 2010)*, pp. 1442 – 1447, San Jose, CA, Oct. 31 2010-Nov. 3 2010.
NOTE: Fred W. Ellersick MILCOM Award for Best Paper in the Unclassified Technical Program.
134. T. Jia and R.M. Buehrer, "Collaborative Position Location with NLOS Mitigation," *IEEE to the Personal, Indoor, and Mobile Radio Conference (PIMRC2010), Workshop on Advanced in Positioning and Location Enabled Communications (APLEC)*, pp. 267 – 271, Istanbul, Turkey, Sept. 26, 2010. (**Invited Paper**)
135. R. M. Buehrer, B. Thomson, and T. Jia, "Cooperative Indoor Position Location," *2010 International Conference on Indoor Positioning and Indoor Navigation (IPIN)*, pp. 1-10, Zurich, Switzerland, September 17-19, 2010
136. H. I. Volos and R. M. Buehrer, "On Balancing Exploration vs. Exploitation on a Cognitive Engine for Multi-Antenna Systems," *IEEE Global Communications Conference*, pp. 1-6, November 30-December 5, 2009.
137. J. H. Lee and R. M. Buehrer, "Location Estimation Using Differential RSS with Correlated Shadow Fading," *IEEE Global Communications Conference*, November 30-December 5, 2009.
138. H. Shaban, M. A. El-Nasr, and R. M. Buehrer, "Performance of Ultralow-power IR-UWB Correlator Receivers for Highly Accurate Wearable Human Locomotion Tracking and Gait Analysis Systems," *IEEE Global Communications Conference*, November 30-December 5, 2009.
139. J. Reed, C.A. da Silva, and R.M. Buehrer, "An Optimization Approach to Single-Source Localization with a Sensor Network using Direction and Range Estimates," *IEEE Global Communications Conference*, November 30-December 5, 2009.
140. H. Dhillon and R.M. Buehrer, "Cognitive MIMO Radio: Incorporating Dynamic Spectrum Access in Multiuser MIMO Network," *IEEE Global Communications Conference*, pp. 1-6, November 30-December 5, 2009.
141. H.I. Volos, R. M. Buehrer, and C. Anderson, "A practical link budget for I-UWB systems," *IEEE Vehicular Technology Conference (VTC'09) – Spring*, pp. 1-5, Barcelona, Spain, April 26-29, 2009.
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.
143. J.-H. Lee, A. Bhupathi raju, and R. M. Buehrer, "Experimental Investigation of WCDMA Uplink Transmit Power for Practical Usage Scenarios," *10th IEEE Wireless and Microwave Technology Conference (WAMI-CON2008)*, Clearwater, FL, April 20-21, 2009.

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.
146. U. Shukla, H.I. Volos, and R.M. Buehrer, "On The Effect of Antenna Height On the Characterization of The Indoor Ultra Wideband Channel," *2008 IEEE Global Communications Conference (GlobeCom'08)*, New Orleans, LA, November 29 - December 2, 2008.
147. T. Jia and R.M. Buehrer, "A New Cramer-Rao Lower Bound for TOA-based Localization," *2008 IEEE Military Communications Conference (MILCOM'08)*, San Diego, California, November 17-19, 2008.
148. H. Volos, C.I. Phelps, and R.M. Buehrer, "Physical Layer Cognitive Engine for Multi-Antenna Systems," *2008 IEEE Military Communications Conference (MILCOM'08)*, San Diego, California, November 17-19, 2008.
149. J.R. Reed, C.R.M. da Silva and R.M. Buehrer, "Multiple-Source Localization using Line-of-Bearing Measurements," *2008 IEEE Military Communications Conference (MILCOM'08)*, San Diego, California, November 17-19, 2008.
150. C. Anderson and R.M. Buehrer, "An Undergraduate Research Experience: Wireless Propagation and Position Location in a Forest Environment," *2008 ASEE Conference on Excellence in Education*, Pittsburgh, PA, June 21-25, 2008.
151. H. Volos and R.M. Buehrer, "Design and Scaled Implementation of a UWB Sensor System for Cargo Transfer," *IEEE Global Communications Conference, (GlobeCom 2007), Ad Hoc and Sensor Networking Symposium*, pp. 1081-1085, Washington, D.C., November 2007.
152. R. Menon, A.B. MacKenzie, R.M. Buehrer, and J.H. Reed, "Joint Power Control and Waveform Adaptation for Distributed Networks," *IEEE Global Communications Conference, (GlobeCom 2007), Ad Hoc and Sensor Networking Symposium*, Washington, D.C., November 2007.
153. M. Di Renzo, R.M. Buehrer, and J. Torres, "Pulse Shape Distortion and Ranging Accuracy in UWB-Based Body Area Networks for Full-Body Motion Capture and Gait Analysis," *2007 IEEE Global Telecommunications Conference (GLOBECOM'07)*, pp. 3775-3780, November 26-30, 2007.
154. H. Volos, C. Anderson, C. Headley, R.M. Buehrer, C. da Silva, and A. Nieto, "Preliminary UWB Propagation Measurements in an Underground Limestone Mine," *IEEE Global Communications Conference, (GlobeCom 2007), Ad Hoc and Sensor Networking Symposium*, pp. 3770-3774, Washington, D.C., November 2007.
155. H. I. Volos, C. I. Phelps, and R. M. Buehrer, "Initial Design of a Cognitive Engine for MIMO Systems," *SDR Forum Technical Conference*, Nov. 2007. **Best Paper Award.**
156. W.C. Headley, R.M. Buehrer, and C. da Silva, "Indoor Location Positioning of Non-Active Objects Using Ultra-Wideband Radios," *2007 IEEE Radio and Wireless Symposium*, pp. 105-108, San Diego, CA, January 2007.
157. H. Kim and R.M. Buehrer, "Power Allocation Strategies in Cooperative MIMO Networks," *IEEE Wireless Communications and Networking Conference (WCNC)*, 2006.
158. S. Venkatesh and R.M. Buehrer, "MAC Design for UWB Position-Location Networks," *IEEE Wireless Communications and Networking Conference (WCNC)*, 2006.
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.

160. S. Venkatesh, C.R. Anderson, R.M. Buehrer, and J.H. Reed, "On the use of Pilot-Assisted Matched Filtering in UWB Time-Interleaved Sampling," *2006 IEEE 2006 International Conference on Ultra-Wideband*, pp. 119–124, September 2006, Boston, MA.
161. J. Ibrahim and R.M. Buehrer, "A Modified Tracking Algorithm for UWB Pilot-Assisted Receivers," *2006 IEEE 2006 International Conference on Ultra-Wideband*, pp. 1-6, September 2006, Boston, MA.
162. N. V. Rivera, S. Venkatesh, C.Anderson, and R.M. Buehrer, "Multi-Target Estimation of Heart and Respiration Rates Using Ultra Wideband Sensors," *14th European Signal Processing Conference (EUSIPCO 2006)*, September 6-8, 2006, Florence, Italy. **(Invited Paper)**
163. N. V. Rivera, S. Venkatesh, and R.M. Buehrer, "Non-invasive Wireless Application of Ultra Wideband (UWB) for Estimation of Single and Mutliple Person Vital-Signs," *2006 Engineering in Medicine and Biology Conference*, New York, August 30-September 3, 2006.
164. J. Ibrahim and R.M. Buehrer, "A UWB Multiple Antenna System for NBI Mitigation under Rayleigh and Ricean Fading," *2006 IEEE International Conference on Communications*, pp. 3953–3959, Istanbul, Turkey, June 11-15, 2006.
165. S.Venkatesh, and R.M. Buehrer, "Power Control in UWB Position-Location Networks," *2006 IEEE International Conference on Communications*, pp. 3953–3959, Istanbul, Turkey, June 11-15, 2006.
166. S. Venkatesh and R.M. Buehrer, "Multiple-access insights from bounds on sensor localization," *International Symposium on a World of Wireless, Mobile and Multimedia Networks, (WoWMoM 2006)*, pp. 26-29, June 10, 2006.
167. R.M. Buehrer and S.Venkatesh, "On the Impact of Propagation on UWB-Based Communication and Position Location Networks," *IEE Seminar on Ultra Wideband Systems, Technologies and Applications*, London, UK, April 21, 2006. **(Invited Keynote Speech)**
168. S.Venkatesh and R.M. Buehrer, "A Linear Programming Approach to NLOS Error Mitigation in Sensor Networks," *5th International Conference on Information Processing in Sensor Networks (ISPN 2006)*, pp. 301-308, April 19-21, 2006.
169. A. Hugine, H. I. Volos, J. Gaeddert, and R. M. Buehrer, "Measurement & Characterization of the Near-Ground Indoor Ultra Wideband Channel," *Wireless Communications and Networking Conference*, pp. 1062-1067, Las Vegas, NV, April 3-6, 2006.
170. S.Venkatesh, C.R. Anderson, N.V.Rivera, and R.M. Buehrer, "On Respiration-Rate Estimation using Impulse-based Ultra-Wideband," *National Radio Science Meeting of United States National Committee of the International Union of Radio Science (URSI)*, pp. K1-1, Boulder, CO, January 4-7, 2006.
171. R. Menon, R.M. Buehrer, and J.H. Reed, "Outage Probability based Comparison of Underlay and Overlay Spectrum Sharing Techniques," *1st IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks (DySPAN 2005)*, pp. 101-109, Baltimore, MD, November 8-11, 2005.
172. N. Harter, J. Keaveny, S. Venkatesh, and R.M. Buehrer, "Analysis and Implementation of a Single Channel Direction Finding System," *IEEE Military Communications Conference (MILCOM2005)*, pp. 2530–2533, Atlantic City, NJ, October 2005.
173. J.Ibrahim, R. Menon, and R.M. Buehrer, "UWB Sequence Optimization for Enhanced Energy Capture and Interference Mitigation," *IEEE Military Communications Conference (MILCOM2005)*, pp. 2086-2092, Atlantic City, NJ, October 2005.
174. J. Ibrahim and R.M. Buehrer, "Two-Stage Acquisition for UWB in Dense Multipath," *IEEE Military Communications Conference (MILCOM2005)*, pp. 1898-1904, Atlantic City, NJ, October 2005.
175. S.Venkatesh, C.R. Anderson, N.V.Rivera and R.M. Buehrer, "Implementation and Analysis of Respiration-Rate Estimation using Impulse-based Ultra-Wideband," *IEEE Military Communications Conference (MILCOM2005)*, Atlantic City, NJ, October 2005.

176. J. Ibrahim and R.M. Buehrer, "A Data-Aided Iterative UWB Receiver with LDPC," *IEEE Vehicular Technology Conference (VTC'05), Fall*, pp. 33-37, Dallas, TX, September 25-28, 2005.
177. S. Venkatesh, N. Kumar, and R.M. Buehrer, "A Spread-Spectrum MAC Protocol for Impulse-Radio Networks," *IEEE Vehicular Technology Conference (VTC'05), Fall*, pp. 665-669, Dallas, TX, September 25-28, 2005.
178. S. Venkatesh, V. Bharadwaj, and R.M. Buehrer, "A New Spatial Model for Impulse-based Ultra-Wideband Channels," *IEEE Fall Vehicular Technology Conference*, pp. 2617-2621, September 25-28, 2005.
179. R. Menon, J.Ibrahim, and R.M. Buehrer, "UWB Signal Detection Based on Sequence Optimization," *2005 International Conference on Wireless Networks, Communications and Mobile Computing*, pp. 1231-1236, June 13-16, 2005.
180. N. Harter, J. Keaveny, S. Venkatesh, and R.M. Buehrer, "Analysis and Implementation of a Novel Single-Channel Direction-Finding Method," *Wireless Communications and Networking Conference*, pp. 2530 – 2533, New Orleans, LA, 13-17 March 2005.
181. S. Venkatesh, J. Ibrahim, and R. M. Buehrer, "A new 2-cluster model for indoor UWB channel measurements," *IEEE AP-S International Symposium and UNSC/URSI National Radio Science Meeting*, pp. 946- 949, June 2004.
182. J. Jiang, R. M. Buehrer, and W. H. Tranter, "High-speed downlink packet transmission with spatial multiplexing and scheduling," *Wireless Communications and Networking Conference, WCNC 2004*, pp. 2148 - 2152, Atlanta, GA, March 2004.
183. M. Gong, S.F. Midkiff, and R.M. Buehrer, "A Self-Organized Clustering Algorithm for UWB Ad Hoc Networks," *Wireless Communications and Networking Conference, WCNC 2004*, pp. 1806 - 1811, Atlanta, GA, March 2004.
184. Y. Ahmed, J.H. Reed, W.H. Tranter, R.M. Buehrer, "A model-based approach to demodulation of Co-channel MSK signals," *Global Telecommunications Conference*, pp. 2442 – 2446, Dec. 1-5, 2003
185. M. Gong, S.F. Midkiff, and R.M. Buehrer, "A New Piconet Formation Protocol for UWB Ad Hoc Networks," *2003 Ultra Wideband Systems and Technologies Conference*, pp. 180 – 184, Reston, VA, Nov. 16-19, 2003.
186. D.A. McKinstry and R.M. Buehrer, "LMS Analog and Digital Narrowband Rejection System for UWB Communications," *2003 Ultra Wideband Systems and Technologies Conference*, pp. 91-95, Reston, VA, Nov. 16-19, 2003.
187. R.M. Buehrer, A. Safaai-Jazi, W.A. Davis, and D. Sweeney, "Characterization of the Ultra-wideband Channel," *2003 Ultra Wideband Systems and Technologies Conference*, pp. 26-31, Reston, VA, Nov. 16-19, 2003.
188. D.R. McKinstry and R.M. Buehrer, "UWB Small Scale Channel Modeling and System Analysis," *Fall 2003 Vehicular Technology Conference*, pp. 6-10, Orlando, FL, Oct. 6-9, 2003.
189. S. Ginde, J.Neel, and R.M. Buehrer, "Game Theoretic Analysis of Joint Link Adaptation and Distributed Power Control in GPRS," *Fall 2003 Vehicular Technology Conference*, pp. 732-736, Orlando, FL, October 6-9, 2003.
190. J. Jiang, R.M. Buehrer, and W.H. Tranter, "Spatial T-H Precoding for Packet Data Systems with Scheduling," *Fall 2003 Vehicular Technology Conference*, pp. 537-541, Orlando, FL, October 6-9, 2003.
191. R.M. Buehrer, "The Impact of Channel Estimation Error on 2 X 1 Space-Time Block Codes," *IEEE Vehicular Technology Conference – Fall 2002*, Vancouver, British Columbia, Canada, pp. 1921-1925, September 24-29, 2002.
192. R.M. Buehrer, "On the Usefulness of Outer-loop Power Control with Successive Interference Cancellation," *IEEE Vehicular Technology Conference – Fall 2002*, Vancouver, British Columbia, Canada, pp. 1897-1901, September 24-29, 2002.

193. R.M. Buehrer, "The Impact of Angular Energy Distribution on Spatial Correlation," *IEEE Vehicular Technology Conference – Fall 2002*, Vancouver, British Columbia, Canada, pp. 1173-1177, September 24-29, 2002.
194. J. Tsai, R.M. Buehrer, and B.D. Woerner, "BER Analysis of Orthogonal Transmit Waveform with Space-Time Diversity for MIMO CDMA Systems," *IEEE Vehicular Technology Conference – Fall 2002*, Vancouver, British Columbia, Canada, pp. 1051-1055, September 24-29, 2002.
195. J. Tsai, R.M. Buehrer, and B.D. Woerner, "Performance of Transmit Beamforming in Rician Fading Channels: Robustness of Quantization Error and Feedback Error," *IEEE Vehicular Technology Conference – Fall 2002*, Vancouver, British Columbia, Canada, pp. 1792-1795, September 24-29, 2002.
196. R. Gozali, R.M. Buehrer, and B.D. Woerner, "On the Performance of Scheduling Over Space-time Architectures," *IEEE Vehicular Technology Conference – Fall 2002*, Vancouver, British Columbia, Canada, pp. 415-419, September 24-29, 2002.
197. R. Gozali, R.M. Buehrer, and B. D. Woerner, "The Impact of Multiuser Diversity on Space-time Block Coding," *IEEE Vehicular Technology Conference – Fall 2002*, Vancouver, British Columbia, Canada, pp. 420-424, September 24-29, 2002.
198. N.A. Kumar and R.M. Buehrer, "Application of Layered Space-Time Processing to Ultra-Wideband Communication," *45th IEEE Midwest Symposium on Circuits and Systems*, Tulsa, OK, pp. 597-600, August 4-7, 2002.
199. P. Jain and R.M. Buehrer, "Implementation of Adaptive Modulation on Sunrise Software Radios," *45th IEEE Midwest Symposium on Circuits and Systems*, Tulsa, OK, pp. 405-408, August 4-7, 2002.
200. R. Venkatasubramanian, J. Tsai, and R. M. Buehrer, "Beamforming for MC-CDMA," *45th IEEE Midwest Symposium on Circuits and Systems*, Tulsa, OK, pp. 441-444, August 4-7, 2002.
201. D.R. McKinstry and R.M. Buehrer, "Issues in the Performance and Covertness of UWB Communications Systems," *45th IEEE Midwest Symposium on Circuits and Systems*, Tulsa, OK, pp. 601-604, August 4-7, 2002.
202. J. Neel, R.M. Buehrer, J.H. Reed, and R.P. Gilles, "Game theoretic analysis of a network of cognitive radios," *45th IEEE Midwest Symposium on Circuits and Systems*, Tulsa, OK, pp. 409-412, August 4-7, 2002.
203. J.A. Tsai, R.M. Buehrer, and B.D. Woerner, "The Impact of AOA Energy Distribution on the Spatial Fading Correlation of Linear Antenna Array," *55th IEEE Vehicular Technology Conference – VTC Spring 2002*, Birmingham, AL, vol. 2, pp. 933-937, May 2002.
204. R.A. Soni, R.M. Buehrer, and R.D. Benning, "Transmit Beamforming Combined with Diversity Techniques for cdma2002 Systems," *IEEE International Conference on Acoustics, Speech, and Signal Processing – ICASSP 01*, Salt Lake City, UT, vol. 2, pp. 1029-1032, May 2001.
205. R.M. Buehrer, S. Arunachalam, and K. Wu, "Spatial Channel Model and Measurements for IMT-2000 Systems," *53rd IEEE Vehicular Technology Conference – VTC Spring 2001*, Rhodes, Greece, vol. 1, pp. 342-246, May 2001.
206. R.M. Buehrer, R.A. Soni, and Q. Li, "Transmit Diversity with More than Two Transmit Antennas," *10th Virginia Tech Symposium on Wireless Personal Communications*, Blacksburg, VA, pp. 131-143, June 2000.
207. R.M. Buehrer, "Generalized Equations for Spatial Correlation for Low to Moderate Angle Spread," *10th Virginia Tech Symposium on Wireless Personal Communications*, Blacksburg, VA, pp. 101-108, June 2000.
208. S.P. Nicoloso, M. Metke, and R.M. Buehrer, "Frame-Quality-Based vs. Eb/No-Based Forward Power Control Methods for cdma2000," *10th Virginia Tech Symposium on Wireless Personal Communications*, Blacksburg, VA, pp. 239-248, June 2000.
209. R.M. Buehrer, "On the Convergence of Multistage Interference Cancellation," *33rd IEEE Conference on Signals, Systems and Computers - Asilomar*, Pacific Grove, CA, vol. 1, pp. 634-638, October 1999.

210. R.A. Soni, R.M. Buehrer, and J. Tsai, "Open-Loop Transmit Diversity in IS-2000 Systems," *33rd IEEE Conference on Signals, Systems and Computers - Asilomar*, Pacific Grove, CA, vol. 1, pp. 654-658, October 1999.
211. J.-A. Tsai, R.M. Buehrer, and D. Uptegrove, "Performance Comparisons of Adaptive Antenna Arrays with Fixed Multibeam Systems for TDMA Systems," *49th IEEE Vehicular Technology Conference – VTC Spring 99*, Houston, TX, vol. 2, pp. 1079-1083, May 1999.
212. S. Gollamudi, S. Nagaraj, Y.-F. Huang, and R.M. Buehrer, "Optimal Multistage Interference Cancellation for CDMA Systems Using the MMSE Criterion," *32nd IEEE Conference on Signals, Systems and Computers – Asilomar*, Pacific Grove, CA, vol. 1, pp. 665-669, November 1998.
213. A. Kogiantis and R.M. Buehrer, "Adaptive Antenna Arrays on 3G CDMA Systems: Performance Characteristics," *5th Smart Antenna Workshop*, Stanford University, July 23, 1998, Palo Alto, CA.
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.
215. N.S. Correal, R.M. Buehrer, and B.D. Woerner, "Real-Time DSP Implementation of a Coherent Partial Interference Cancellation Multiuser Receiver for DS-CDMA," *IEEE International Conference on Communications - ICC*, Atlanta, GA, vol. 3, pp. 1536-1540, May 1998.
216. R.M. Buehrer and B.D. Woerner, "The Asymptotic Multiuser Efficiency of M -Stage Interference Cancellation Receivers," *8th IEEE International Symposium on Personal, Mobile, and Indoor Radio Conference*, Helsinki, Finland, vol. 2, pp. 570-574, September 1997.
217. N. Correal, R.M. Buehrer, and B.D. Woerner, "Improved CDMA Performance Through Bias Reduction for Parallel Interference Cancellation," *International Conference on Personal, Mobile, and Indoor Radio Conference*, Helsinki, Finland, vol. 2, pp. 565-569, September 1997.
218. N. Correal, R.M. Buehrer, and B.D. Woerner, "DSP Implementation of Parallel Interference Cancellation," *Symposium on Interference Rejection and Signal Separation in Wireless Communications*, George Washington University, Washington, D.C., (proceeding pages unnumbered), March 1997.
219. R.M. Buehrer, N.S. Correal, and B.D. Woerner, "A Comparison of Multiuser Receivers for Cellular CDMA," *IEEE Global Telecommunications Conference '96*, London, England, pp. 1571-1577, November 11-18, 1996.
220. J. Feil, L. Ippolito, M. Buehrer, G. Feldhake, and S. Horan, "The First Two Years of Experimental Results from the New Mexico ACTS Propagation Terminal at 20.185 and 27.505 GHz," *1996 IEEE International Symposium on Antennas and Propagation*, Baltimore, MD, vol. 3, pp. 1868-1871, July 21-26, 1996.
221. J. Feil, L. Ippolito, M. Buehrer, G. Feldhake, and S. Horan, "First Year Propagation Experiment Results from the New Mexico ACTS Receiver Terminal at 20.185 and 27.505 GHz," *16th AIAA International Communications Satellite Systems Conference*, Washington, D.C. pp. 1-11, February 1996.
222. R.M. Buehrer and B.D. Woerner, "Performance of CDMA Multistage Interference Cancellation with Phase and Timing Errors," *1995 IEEE Conference on Universal Personal Communications – UPC'95*, Tokyo, Japan, pp. 153-157, November 6-9, 1995.
223. R.M. Buehrer and B.D. Woerner, "Analysis of Adaptive Multistage Interference Cancellation for CDMA Using an Improved Gaussian Approximation," *1995 IEEE Military Communications Conference*, San Diego, CA, vol. 3, pp. 1195-1199, November 5-8, 1995.
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.
225. R.M. Buehrer and B.D. Woerner, "Spread Spectrum for Wireless Communications," *4th Virginia Tech Symposium on Wireless Personal Communications*, Blacksburg, VA, pp. 3-1 – 3-20, June 1994.

226. R.M. Buehrer, S.C. Kwatra, and J. Kim, "A Satellite/Terrestrial Hybrid System for the National Research and Education Network," *15th AIAA International Communications Satellite Systems Conference*, San Diego, CA, March 1994.
227. M. Keaton, R.M. Buehrer, S.C. Kwatra, and J. Kim, "A Wideband Communications Satellite for the National Research and Education Network," *1993 IEEE Global Communications Conference*, Houston, TX, vol. 3, 1644-1648, December 1993.
228. M. Keaton, R.M. Buehrer, S.C. Kwatra, and J. Kim, "Network Requirements for a Satellite Based National Research and Education Network," *1993 IEEE Military Communications Conference*, Boston, MA, vol. 3, pp. 993-997, November 1993.

Technical Reports

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 area 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 Number 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: Torgys, 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. Ericsson
 - 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.