

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

NXP Semiconductors, N.V.; and NXP USA, Inc.
Petitioners

v.

Bell Northern Research, LLC
Patent Owner

Inter Partes Review No.: IPR2024-01044

**DECLARATION OF R. MICHAEL BUEHRER IN SUPPORT OF
PETITION FOR *INTER PARTES* REVIEW OF
U.S. PATENT NO. RE48,629**

I hereby declare under penalty of perjury under the laws of the United States of America that the following is true and correct, and that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I understand that willful false statements are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code.

Date: June 21, 2024



R. Michael Buehrer

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1003	U.S. Patent No. 7,990,842
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1006	I.E.E.E. 802.11-1999 Standard (“802.11”)
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1012	U.S. Patent No. 8,014,267 (“Boer”)
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1014	U.S. Patent No. 7,453,793 (“Jones”)
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1016	WWiSE Proposal: High throughput extension to the 802.11 Standard (“WWiSE Proposal”)
1017	Order No. 29, Construing Certain Claim Terms, ITC Inv. No. 337-TA-1367
1018	Order No. 42, Denying Respondents’ Motion for Summary Determination on Invalidity of Asserted Claims of U.S Patent No. RE48,629, ITC Inv. No. 337-TA-1367
1019	IPR2019-01174, filed 6/12/2019
1020	IPR2019-01345, filed 7/18/2019
1021	IPR2019-01437, filed 8/5/2019
1022	PO’s Infringement Claim Chart, ITC Inv. No. 337-TA-1367
1023	https://www.cnet.com/home/internet/group-proposes-faster-wi-fi-specification/ (Group Proposes Faster WiFi Specification (CNET))
1024	https://grouper.ieee.org/groups/802/11/Reports/highthroughput_update.html (Status of Project IEEE 802.11n)
1025	https://www.air802.com/ieee-802.11-standards-facts-amp-channels.html (IEEE 802.11 Standards Facts & Channels)
1026	Order No. 52: Initial Determination Granting Motion to Withdraw Complaint and Terminate Investigation as to NXP, ITC Inc. No. 337-TA-1367

Exhibit No.	Description
1027	Commission Determination Not to Review Initial Determination Granting Motion to Withdraw Complaint and Terminate Investigation as to NXP, ITC Inc. No. 337-TA-1367
1028	International Application No. PCT/US2004/021026 (“Boer PCT Application”)
1029	U.S. Provisional Application No. 60/634,102 (“’629 December 2004 Provisional”)
1030	U.S. Provisional Application No. 60/462,286 (“Jones Provisional”)
1031	U.S. Patent No. 7,646,703 (“Parent of ’629 Patent”)

TABLE OF CLAIMS

[1pre] A wireless communications device, comprising:							
[1a] a signal generator that generates an extended long training sequence; and							
[1b] an Inverse Fourier Transformer operatively coupled to the signal generator,							
[1c] wherein the Inverse Fourier Transformer processes the extended long training sequence from the signal generator and provides an optimal extended long training sequence with a minimal peak-to-average ratio, and							
[1d] wherein at least the optimal extended long training sequence is carried by a greater number of subcarriers than a standard wireless networking configuration for an Orthogonal Frequency Division Multiplexing scheme,							
[1e] wherein the optimal extended long training sequence is carried by exactly 56 active sub-carriers, and							
[1f] wherein the optimal extended long training sequence is represented by encodings for indexed sub-carriers -28 to +28, excluding indexed sub-carrier 0 which is set to zero, as follows:							
<i>Sub-carrier</i>	-28	-27	-26	-25	-24	-23	-22
<i>Encoding</i>	+1	+1	+1	+1	-1	-1	+1
<i>Sub-carrier</i>	-14	-13	-12	-11	-10	-9	-8
<i>Encoding</i>	+1	+1	+1	-1	-1	+1	+1
<i>Sub-carrier</i>	1	2	3	4	5	6	7
<i>Encoding</i>	+1	-1	-1	+1	+1	-1	+1
<i>Sub-carrier</i>	15	16	17	18	19	20	21
<i>Encoding</i>	+1	+1	-1	-1	+1	-1	+1
<i>Sub-carrier</i>	-21	-20	-19	-18	-17	-16	-15
<i>Encoding</i>	+1	-1	+1	-1	+1	+1	+1
<i>Sub-carrier</i>	-7	-6	-5	-4	-3	-2	-1
<i>Encoding</i>	-1	+1	-1	+1	+1	+1	+1
<i>Sub-carrier</i>	8	9	10	11	12	13	14
<i>Encoding</i>	-1	+1	-1	-1	-1	-1	-1
<i>Sub-carrier</i>	22	23	24	25	26	27	28
<i>Encoding</i>	-1	+1	+1	+1	+1	-1	-1
[4] The wireless communications device according to claim 1, wherein the optimal extended long training sequence has a minimum peak-to-average power ratio of 3.6 dB.							

[8] The wireless communications device according to claim 1, wherein a binary phase shift key encoding is used for each sub-carrier above the +26 indexed sub-carrier and below the -26 indexed sub-carrier.
[9] The wireless communications device according to claim 1, wherein the Inverse Fourier Transformer comprises an Inverse Fast Fourier Transformer or an Inverse Discrete Fourier Transformer.
[10] The wireless communications device according to claim 1, wherein the wireless communications device comprises one or more of the following: a personal digital assistant, a laptop computer, a personal computer, a processor, and a cellular phone.
[11] The wireless communications device according to claim 1, wherein the wireless communications device comprises a wireless mobile communications device.
[12] The wireless communications device according to claim 1, wherein the wireless communications device comprises one or more of the following: an access point and a base station.
[13] The wireless communications device according to claim 1, wherein the wireless communications device is backwards compatible with legacy wireless local area network devices.
[14] The wireless communications device according to claim 1, wherein the optimal extended long training sequence is longer than a long training sequence used by a legacy wireless local area network device in accordance with a legacy wireless networking protocol standard.
[15] The wireless communications device according to claim 14, wherein the legacy wireless local area network device uses the optimal extended long training sequence to estimate a carrier frequency offset even though the optimal extended long training sequence is longer than the long training sequence that is specified by the legacy wireless networking protocol standard.
[16] The wireless communications device according to claim 15, wherein the long training sequence that is specified by the legacy wireless networking protocol standard is maintained in the extended long training sequence or the optimal extended long training sequence
[17] The wireless communications device according to claim 1, wherein the wireless communications device decreases power back-off.
[18] The wireless communications device according to claim 1, wherein the wireless communications device registers with one or more of the following: an access point and a base station.
[19] The wireless communications device according to claim 1, wherein the extended long training sequence or the optimal extended long training sequence

is encoded using binary phase shift key encoding on each of the 56 active subcarriers.

[20] The wireless communications device according to claim 1, comprising: a symbol mapper operatively coupled to the signal generator, wherein the symbol mapper receives coded bits and generates symbols for each of 64 subcarriers of an Orthogonal Frequency Division Multiplexing sequence.

[21] The wireless communications device according to claim 14, wherein the legacy wireless networking protocol standard for the Orthogonal Frequency Division Multiplexing scheme corresponds to exactly 52 active subcarriers.

[22] The wireless communications device according to claim 21, wherein, for a long training sequence of the legacy wireless networking protocol standard, the indexed sub-carrier 0 is set to zero and encodings for the indexed sub-carriers -26 to +26 excluding the indexed sub-carrier 0 are:

<i>Sub-carrier</i>	-26	-25	-24	-23	-22	-21	-20
<i>Encoding</i>	+1	+1	-1	-1	+1	+1	-1
<i>Sub-carrier</i>	-13	-12	-11	-10	-9	-8	-7
<i>Encoding</i>	+1	+1	-1	-1	+1	+1	-1
<i>Sub-carrier</i>	1	2	3	4	5	6	7
<i>Encoding</i>	+1	-1	-1	+1	+1	-1	+1
<i>Sub-carrier</i>	14	15	16	17	18	19	20
<i>Encoding</i>	-1	+1	+1	-1	-1	+1	-1
<i>Sub-carrier</i>	-19	-18	-17	-16	-15	-14	
<i>Encoding</i>	+1	-1	+1	+1	+1	+1	
<i>Sub-carrier</i>	-6	-5	-4	-3	-2	-1	
<i>Encoding</i>	+1	-1	+1	+1	+1	+1	
<i>Sub-carrier</i>	8	9	10	11	12	13	
<i>Encoding</i>	-1	+1	-1	-1	-1	-1	
<i>Sub-carrier</i>	21	22	23	24	25	26	
<i>Encoding</i>	+1	-1	+1	+1	+1	+1	

[23pre] The wireless communications device according to claim 22, wherein:

[23a] the Inverse Fourier Transformer comprises an Inverse Fast Fourier Transformer or an Inverse Discrete Fourier Transformer;

[23b] the wireless communications device comprises one or more of the following: a personal digital assistant, a laptop computer, a personal computer, a cellular phone, an access point, a processor, and a base station;

[23c] the wireless communications device is backwards compatible with the legacy wireless local area network device;
[23d] the legacy wireless local area network device uses the optimal extended long training sequence to estimate a carrier frequency offset even though the optimal extended long training sequence is longer than the long training sequence that is specified by the legacy wireless networking protocol standard;
[23e] the wireless communications device decreases power back-off;
[23f] the extended long training sequence or the optimal extended long training sequence is encoded using binary phase shift key encoding on each of the 56 active subcarriers; and
[23g] the wireless communications device further comprises a symbol mapper operatively coupled to the signal generator, wherein the symbol mapper receives coded bits and generates symbols for each of 64 subcarriers of an Orthogonal Frequency Division Multiplexing sequence.
[27] The wireless communications device according to claim 1, wherein an output of the Inverse Fourier Transformer is operatively coupled to a time-domain windower.

I. INTRODUCTION

I, R. Michael Buehrer, declare as follows:

1. My name is R. Michael Buehrer. I have been asked by Petitioners NXP Semiconductors, N.V.; and NXP USA, Inc. to provide my expert opinions in support of the above-identified petition for *inter partes* review of U.S. Patent No. RE48,629 (“’629 patent,” EX1001), challenging the validity of claims 1, 4, 8-23 and 27 (the “Challenged Claims”).

2. I currently hold the opinions set forth in this declaration.

3. In summary, it is my opinion that the references cited below render obvious the Challenged Claims. My detailed opinions on the claims are set forth below.

4. I am being compensated for my time at the rate of \$550 per hour. This compensation is not contingent upon my performance, the outcome of this matter, or any issues involved in or related to this matter.

II. BACKGROUND AND QUALIFICATIONS

5. I did my undergraduate studies at the University of Toledo where I graduated with a bachelor’s degree in electrical engineering in 1991.

6. After receiving my bachelor’s degree, I remained at the University of Toledo where I graduated with a master’s degree in electrical engineering in 1993.

I then went on to Virginia Polytechnic Institute and State University (AKA Virginia Tech) and received my Ph.D. in electrical engineering in 1996.

7. After receiving my Ph.D., in 1996 I joined Bell Laboratories (“Bell Labs”), the research division of Lucent Technologies where I worked five years as a Member of Technical Staff and then later as a Distinguished Member of Technical Staff.

8. At Bell Labs, my work focused on developing advanced technologies for cellular telecommunications, including for 3G cellular standards.

9. While at Bell Labs, I developed and implemented algorithms for intelligent antenna systems that increased the voice capacity (i.e., number of simultaneous phone calls) and data capacity of cellular systems. These algorithms were included in Lucent Technologies’ 3G CDMA cellular base station.

10. I also developed techniques known as transmit diversity techniques that increased reliability (i.e., reduced the probability of a dropped call) of cellular systems. These transmit diversity techniques were standardized in the 3GPP2 cellular standard known as cdma2000.

11. During this same time at Bell Labs, I supported the standardization of my ideas by writing contributions to the working groups developing the standards and attending standards meetings. In particular, I participated in the 3GPP2

standardization process. During that time, I worked with colleagues to include my ideas on the use of transmit diversity in CDMA systems in the 3GPP2 standard.

12. While at Bell Labs, I received the Best Paper Award for *Bell Labs Technical Journal* in 1999. I also received the Bell Labs President's Silver Award for outstanding research contributions.

13. After Bell Labs, I joined Virginia Tech in 2001 as an Assistant Professor of Electrical and Computer Engineering. In 2006, I became an Associate Professor of Electrical and Computer Engineering. And I've been a full professor of Electrical and Computer Engineering since 2012.

14. For the past 20+ years at VA Tech, I've taught and conducted research in the area of wireless communications. I've taught classes on wireless communications and signal processing at the undergraduate and graduate levels.

15. I also teach graduate level courses for advanced technologies underlying the latest wireless systems. I also teach graduate courses on advanced topics such as Information Theory, Machine Learning Applied to Communication Systems, Spread Spectrum Communications and CDMA. Furthermore, I have taught short courses covering topics such as WiFi, spread spectrum, cellular technologies, position location and position location using ultra-wideband signals.

16. In addition to teaching, I've also conducted extensive research while at Virginia Tech. For example, I completed work on Ultra-Wideband signal propagation, receiver design, and signal processing across a number of funded research projects. I also developed a UWB-based ranging system as part of an automated cargo container transfer system for the United States Navy.

17. I also developed geolocation systems in a number of projects including developing a prototype system for localizing first responders, developing localization techniques for 5G and 6G cellular networks, localization sub-systems for in-home smart health systems, algorithms for enhancing cellular-based localization, localization in the presence of interference and harsh propagation, and another UWB-based positioning system.

18. From 2014 until 2022, I also served as the director of *Wireless @ Virginia Tech*, a comprehensive research group focusing on wireless communications, which consists of 14 faculty members and approximately 85 graduate students. My specific research focuses on advanced wireless communications and geolocation techniques.

19. I've also received grants in connection with my research. For example, my research work has been funded by national agencies including the National Science Foundation (NSF), the Defense Advanced Research Projects

Agency (DARPA), the Office of Naval Research (ONR), the Army Research Lab, the Air Force Research Lab as well as many industrial sponsors.

20. I am a Fellow of the IEEE (so named “for contributions to wideband signal processing in communications and geolocation”).

21. I have also received numerous awards including six best paper awards (two this year). Additionally, in 2023 I received the prestigious MILCOM Lifetime Award for Technical Achievement. This award recognizes individuals who have made important technical contributions to military communications over the course of their careers.

22. Last year I was a co-recipient of both the Vanu Bose Award for the best paper and the Fred Ellersick Award for the best paper, both at the 2023 Military Communications Conference. I was also a co-recipient of the Vanu Bose Award for the best paper at the 2021 Military Communications Conference.

23. I have also written extensively on the subject of wireless communications. I authored and co-authored over 300 publications in my area of expertise, which have been published in the leading journals in my field including *IEEE Transactions on Communications*, *IEEE Transactions on Wireless Communications*, *IEEE Transactions on Information Theory*, *Proceedings of the IEEE*, and *IEEE Transactions on Signal Processing*, and at all of the major conferences in my field. This research work has been cited over 12,000 times.

24. I also hold 18 patents in the field of wireless communications.

25. My qualifications, publications, professional experience and expertise are set forth more fully in my curriculum vitae, attached as **Appendix A**.

III. DOCUMENTS AND OTHER MATERIALS RELIED UPON

26. In forming the opinions set forth in this declaration, I have reviewed the documents listed above in the Index of Exhibits.

27. Additionally, I have utilized my own experience and expertise, including regarding the knowledge and capabilities of a person of ordinary skill in the relevant art in the timeframe of the claimed priority date of the '629 patent (*i.e.*, July 27, 2004).

IV. STATUTORY GROUNDS FOR CHALLENGE

28. In this declaration, I offer opinions on the following grounds that are the basis for this IPR proceeding:

Ground(s)	Claims	Basis	Reference(s)
1	1, 4, 8-23, 27	§103	Jones, 802.11a, 802.11-1999, Zelst and Boer
2	1, 4, 8-23, 27	§103	Jones, 802.11a, 802.11-1999 and Boer

V. RELEVANT PATENT LAW AND LEGAL STANDARDS

A. Obviousness

29. I am informed and understand that a patent claim is invalid under 35 U.S.C. § 103 if the differences between the invention and the prior art are such that

the subject matter as a whole would have been obvious at the time of the invention to a person having ordinary skill in the art to which the subject matter pertains.

Obviousness, as has been explained to me, is based on (i) the scope and content of the prior art, (ii) the differences between the prior art and the claim, (iii) the level of ordinary skill in the art, and (iv) any secondary indicia of non-obviousness (*e.g.*, “secondary considerations” such as commercial success in the market place of the claimed invention), to the extent that they exist.

30. I further understand that obviousness may be demonstrated by showing that it would have been obvious to combine the teachings of more than one item of prior art. In determining whether a piece of prior art could have been combined with other prior art or with other information within the knowledge of a person having ordinary skill in the art, the following are examples of approaches and rationales that may be considered:

- Combining prior art elements according to known methods to yield predictable results;
- Simple substitution of one known element for another to obtain predictable results;
- Use of a known technique to improve similar devices (methods, or products) in the same way;

- Applying a known technique to a known device (method or product) ready for improvement to yield predictable results;
- Applying a technique or approach that would have been obvious to try (choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success);
- Known work in one field of endeavor may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations would have been predictable to a person having ordinary skill in the art; and
- Some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention.

31. I further understand that an invention may be obvious if one of ordinary skill in the art, facing a wide range of needs created by developments in the field, would have seen an obvious benefit to the solutions tried by the applicant. When there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, it may be obvious to a person of ordinary skill to try the known options. If a technique has been used to

improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique would have been obvious.

32. I further understand that a person of ordinary skill in the art is a hypothetical person who is presumed to be aware of all of the relevant art at the time of the invention. The person of ordinary skill may be able to fit together the teachings of multiple patents and/or printed publications employing ordinary creativity and the common sense that familiar items may have uses in another context or beyond their primary purposes.

33. I also understand that when considering the obviousness of a patent claim, one should consider whether a teaching, suggestion, or motivation to combine the references exists so as to avoid impermissibly applying hindsight when combining or modifying the prior art. I understand this test should not be applied rigidly, but that the test can be important to avoid such hindsight.

34. I also understand that one of ordinary skill in the art must have a reasonable expectation of success in combining or modifying prior art references.

35. I also understand that all elements of a claim must be considered in an obviousness analysis.

B. Dynamic Drinkware

36. I understand that based on a court decision known as the Dynamic Drinkware case, a published patent or patent application qualifies as prior art under pre-AIA 102(e) as of its provisional filing date if at least one claim in the published patent or patent application finds written description support in the disclosure of its provisional application. In addition, as a second step in the analysis, the subject matter relied on from the published patent or patent application must be present in and supported by its provisional.

C. Standard of Proof

37. I understand that the standard to prove unpatentability in an *inter partes* review proceeding is by a preponderance of the evidence, which means more likely than not.

VI. THE '629 PATENT

A. Background

38. The '629 patent is generally directed toward wireless orthogonal frequency division multiplexing (OFDM) communications. "OFDM works by spreading a single data stream over a band of subcarriers, each of which is transmitted in parallel." EX1001, 2:22-24.

39. In one embodiment, the '629 patent purports to improve on the prior art 52-subcarrier long training sequence used in 802.11a (and 802.11g) by adding 4 (for a total of 56) or 11 (for a total of 63) subcarriers. EX1001, FIG. 4, 5:30-35.

40. Figure 4 (56-subcarrier embodiment) is annotated below with the prior art 52 subcarriers (-26 to 26) highlighted in blue, the four new subcarriers (-28, -27, 27, 28 with the values +1, +1, -1, -1, respectively) highlighted in yellow and the indexed subcarrier zero highlighted in red.

+1	+1	1	1	-1	-1	1	1	-1	1	-1	1	1	1	
-28	-27	-26	-25	-24	-23	-22	-21	-20	-19	-18	-17	-16	-15	
Sub-carrier index														

1	1	1	-1	-1	1	1	-1	1	-1	1	1	1	1	0
-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0
Sub-carrier index														

+1	-1	-1	1	1	-1	1	-1	1	-1	-1	-1	-1	-1	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Sub-carrier index														

1	1	-1	-1	1	-1	1	-1	1	1	1	1	1	-1	-1
15	16	17	18	19	20	21	22	23	24	25	26	27	28	
Sub-carrier index														

LONG TRAINING SEQUENCE FOR 56 ACTIVE
FIGURE 4

EX1001, FIG. 4.

41. Figure 5 (63-subcarrier embodiment) is annotated below in the same way, showing the 11 new subcarriers (-32 to -27 and 27 to 31) highlighted in yellow, the legacy subcarriers highlighted in blue and the indexed subcarrier zero highlighted in red.

-1	-1	+1	+1	+1	+1	1	1	-1	-1	1	1	-1	1	-1	1	1	1
-32	-31	-30	-29	-28	-27	-26	-25	-24	-23	-22	-21	-20	-19	-18	-17	-16	-15

Sub-carrier index

1	1	1	-1	-1	1	1	-1	1	-1	1	1	1	1	1	0
-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	0

Sub-carrier index

+1	-1	-1	1	1	-1	1	-1	1	-1	-1	-1	-1	-1	-1
1	2	3	4	5	6	7	8	9	10	11	12	13	14	

Sub-carrier index

1	1	-1	-1	1	-1	1	-1	1	1	1	1	-1	-1	-1	+1	-1
15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

Sub-carrier index

LONG TRAINING SEQUENCE FOR 63 ACTIVE
FIGURE 5

EX1001, FIG. 5.

42. One should note that the 52, 56, and 63 value sequences discussed above are 53, 57, and 64 value sequences if the “0” subcarrier is counted. The “0” subcarrier is not counted because it is set to zero and does not carry any data because of complications with converting between RF and baseband.

B. Overview of Related File Histories

1. The '104 Provisional – EX1002

43. The earliest claim of priority in the '629 patent is to 60/591,104, filed 7/27/2004 (“the '104 Provisional”). EX1001, Cover. No claim of the '629 patent is entitled to the filing date of the '104 Provisional, at least for the reason that it does not disclose limitations [1a]-[1c]. Nonetheless, I have been asked to perform my analysis in light of the asserted 7/27/2004 priority date.

2. The '842 Patent – EX1003

44. The '629 patent is a reissue of U.S. Patent No. 7,990,842 (“the '842 patent”). EX1001, Cover. The independent claim of the '842 patent was not explicitly limited to 56 subcarriers or a specific encoding. EX1003, Claim 1.

3. IPRs on the '842 Patent

45. IPR2019-01174, -01345, and -01437 were filed between June and August 2019 and challenged certain claims of the '842 patent. *See* EX1019-EX1021. These IPRs were dismissed prior to institution.

4. U.S. Patent Reissue Application No. 16/686,468

46. On 11/18/2019, PO filed Reissue Application No. 16/686,468, which eventually issued as the '629 patent. EX1001, Cover. Through a preliminary amendment dated 11/18/2019 (EX1004, 414) and a second amendment dated 4/22/2021 (EX1004, 66), PO amended the claims to explicitly claim the 56-subcarrier embodiment with the encodings in Figure 4. On 5/17/2021, the examiner allowed the claims. EX1004, 27-35.

VII. CLAIM CONSTRUCTION

47. I applied a construction to all claim terms according to their plain and ordinary meaning to a POSITA at the time of the '629 patent. The claim term listed below was specifically addressed by the Administrative Law Judge (“ALJ”) in the related ITC investigation.

1. “an optimal extended long training sequence with a minimal peak-to-average power” (claim 1)

48. I understand the ALJ found “the recited encoding scheme [in the table of claim 1] provides clear boundaries for the claimed invention” and that “the patentee’s use of the word optimal cannot reasonably be read to implicitly claim a different, unrecited encoding sequence.” EX1017, 39. I also understand the ALJ concluded this phrase “does not need to be construed because it is adequately defined by the claim itself.” EX1017, 40.

49. Similarly, I understand the ALJ also construed the term “optimal” in the claims of the original ’842 patent to “encompass” the explicitly recited sequence. EX1018, 8. The ALJ found that there was no basis for construing “optimal” to require anything else. EX1018, 7-8. In other words, the ALJ effectively ruled that this limitation simply means the specific training sequence explicitly stated later in the claim.

VIII. OVERVIEW OF PRIOR ART

A. 802.11-1999-EX1006

50. The 802.11-1999 standard was published by IEEE in 1999 (“802.11,” EX1006). EX1006, Cover; EX1007.

B. 802.11a-EX1008

51. The 802.11a standard was published in 1999 by the Institute of Electrical and Electronics Engineers (“802.11a,” EX1008). EX1008, Cover; EX1009.

52. The 802.11a standard is a “Supplement to IEEE Std. 802.11-1999,” stating “Changes and additions to IEEE Std. 802.11-1999 are provided to support the new high-rate physical layer (PHY) for operation in the 5GHz band.” EX1008, Cover; *see also* EX1001, 1:59-63. Thus, they are meant to be treated as a single document.

53. Alternatively, it would have been obvious to combine the teachings of 802.11a with 802.11-1999 based on the express teaching of 802.11a that it is a supplement to 802.11-1999. A POSITA would have had a reasonable expectation of success in making the combination because 802.11a was designed so that a POSITA could perform that very combination and the industry did, in fact, successfully make that combination. EX1001, 1:59-2:45 (admitting the extension is prior art).

54. 802.11a is incorporated by reference by Boer (EX1012, 1:33-36) and Jones. EX1014, 5:34-37.

C. 802.11n and Applicant Admitted Prior Art (AAPA)

55. The '629 patent admits in its Background section that “802.11n, a new extension of 802.11, is being developed to address, among other things, higher throughput and compatibility issues.” EX1001, 1:67-2:2. The '104 Provisional specifically acknowledges that “56 active subcarriers” was “under consideration for 802.11n.”

Design Goal (2)

- **Two different numbers of active subcarriers are under consideration for 802.11n:**
 - 56 active subcarriers
 - 63 active subcarriers (“extended long training” or ELTS)
- **802.11a/g uses 52 active subcarriers**
 - (indices -26 to +26, with the 0-index subcarrier, which is at the carrier frequency, set to 0).
- **Let's say that we want to use the same subcarrier values for positions -26..+26.**
 - Now, we can perform a search to find the 56- and 63-active-subcarrier sequences that have minimum PAPR.
 - We use the same +1 or -1 BPSK encoding for each new subcarrier.



BROADCOM CONFIDENTIAL AND PROPRIETARY

3

EX1002, 3 (highlighting added).

56. In July 2003, IEEE created the 802.11n Task Group and called for proposals by August 2004. EX1024. The World Wide Spectrum Efficiency (WWiSE) Consortium submitted an 802.11n proposal in August 2004. EX1016. WWiSE was led by Airgo Networks (at that time, the employer of one or more of the named inventors of Boer, Zelst and Jones) and included Broadcom (employer

of the named inventors). EX1023. The WWiSE Proposal included the claimed extended long training sequence. EX1016, 37.

57. The claimed extended long training sequence apparently originated with the inventors/authors of Boer, Zelst and Jones as those references predate the '629 patent's earliest priority dates. These references and the WWiSE Proposal also demonstrate contemporaneous development by others who were also working on improvement to 802.11a.

D. Zelst-EX1010

58. U.S. Patent No. 7,599,332 to Zelst, et al. ("Zelst") was filed 5/27/2005, issued 10/6/2009, and claims priority to, and incorporates by reference, U.S. Provisional Patent Application No. 60/575,608 ("Zelst Provisional," EX1011), filed 5/27/2004. EX1010, 1:20-27.

59. I understand that Zelst is prior art at least as of the Zelst Provisional filing date of 5/27/2004 under *Dynamic Drinkware, LLC v. National Graphics, Inc.*, 800 F.3d 1375, 1381-82 (Fed. Cir. 2015).

60. As demonstrated below, under step one of the *Dynamic Drinkware*, at least claim 1 of Zelst is fully supported and enabled by the Zelst Provisional as shown below.

Zelst (EX1010)	Zelst Provisional (EX1011)
1. A method for transmitting a training sequence, the method comprising:	<i>See, e.g.</i> , Zelst Provisional, 3:

Zelst (EX1010)	Zelst Provisional (EX1011)
	“In accordance with one embodiment of the present invention, each of a number of preambles is adapted to be used in packets sent over a wireless network, such as an 802.11a compliant wireless network. Packets containing preambles of the present invention may be received by legacy receivers that are not configured to receive and interpret these preambles. The preambles may be used to distinguish between two transmit antennas (TX), and 3 or 4 TXs, by using a double long-training sequence compared to 11a in the latter case. To detect that 3 or 4 TX antennas are used, the presence of another (8 us) long-training sequence is detected. In some embodiments, the number of TX antennas in the SIGNAL field is also signaled to verify the number of antenna detection. The preambles are described in the following pages.”
transmitting from at least first and second transmit antennas of a wireless communications system at least first and second preambles configured respectively for transmission from said at least first and second transmit antennas, each of the at least first and second preambles further comprising:	See, e.g., Zelst Provisional, 3: “In accordance with one embodiment of the present invention, each of a number of preambles is adapted to be used in packets sent over a wireless network, such as an 802.11a compliant wireless network. Packets containing preambles of the present invention may be received by legacy receivers that are not configured to receive and interpret these preambles. The preambles may be used to distinguish between two transmit antennas (TX), and 3 or 4 TXs, by using a double long-training sequence compared to 11a in the latter case. To detect that 3 or 4 TX antennas are used, the presence of another (8 us) long-training sequence is detected. In some embodiments, the number of TX antennas in the SIGNAL field is also signaled to verify the

Zelst (EX1010)	Zelst Provisional (EX1011)
	number of antenna detection. The preambles are described in the following pages.”
a short training field sequence field;	See, e.g., Zelst Provisional, 3-4: “The preambles may be used to distinguish between two transmit antennas (TX), and 3 or 4 TXs, by using a double long-training sequence compared to 11a in the latter case.” See, e.g., Zelst Provisional, 5: 3 TX case 4 TX case
a guard interval field;	See, e.g., Zelst Provisional, 4:

Zelst (EX1010)	Zelst Provisional (EX1011)																																																
	See, e.g., Zelst Provisional, 5: 3 TX case <table><tr><td>Short Sym 0ns cs</td><td>GI2</td><td>ELT 0ns cs</td><td>SIG N 0ns cs</td></tr><tr><td>Short Sym 200ns cs</td><td>GI2 cs1</td><td>ELT 1050ns</td><td>SIG N 1050ns cs</td></tr><tr><td>Short Sym 400ns cs</td><td>GI2 cs2</td><td>ELT 2100ns</td><td>SIG N 2100ns cs</td></tr><tr><td>8us</td><td>1.6us</td><td>6.4us</td><td>4us</td></tr></table> 4 TX case <table><tr><td>Short Sym 0ns cs</td><td>GI2</td><td>ELT 0ns cs</td><td>SIG N 0ns cs</td></tr><tr><td>Short Sym 200ns cs</td><td>GI2 cs1</td><td>ELT 800ns</td><td>SIG N 800ns cs</td></tr><tr><td>Short Sym 400ns cs</td><td>GI2 cs2</td><td>ELT 1600ns</td><td>SIG N 1600ns cs</td></tr><tr><td>Short Sym 600ns cs</td><td>GI2 cs3</td><td>ELT 2400ns</td><td>SIG N 2400ns cs</td></tr><tr><td>8us</td><td>1.6us</td><td>6.4us</td><td>4us</td></tr></table>	Short Sym 0ns cs	GI2	ELT 0ns cs	SIG N 0ns cs	Short Sym 200ns cs	GI2 cs1	ELT 1050ns	SIG N 1050ns cs	Short Sym 400ns cs	GI2 cs2	ELT 2100ns	SIG N 2100ns cs	8us	1.6us	6.4us	4us	Short Sym 0ns cs	GI2	ELT 0ns cs	SIG N 0ns cs	Short Sym 200ns cs	GI2 cs1	ELT 800ns	SIG N 800ns cs	Short Sym 400ns cs	GI2 cs2	ELT 1600ns	SIG N 1600ns cs	Short Sym 600ns cs	GI2 cs3	ELT 2400ns	SIG N 2400ns cs	8us	1.6us	6.4us	4us												
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a long training sequence field; and	See, e.g., Zelst Provisional, 4: <table><tr><td>Short Sym 0ns cs</td><td>GI2</td><td>ELT 0ns cs</td><td>SIG N 0ns cs</td></tr><tr><td>Short Sym 400ns cs</td><td>GI2 cs1</td><td>ELT 1600ns cs</td><td>SIG N 1600ns cs</td></tr><tr><td>8us</td><td>1.6us</td><td>6.4us</td><td>4us</td></tr></table> See, e.g., Zelst Provisional, 5: 3 TX case <table><tr><td>Short Sym 0ns cs</td><td>GI2</td><td>ELT 0ns cs</td><td>SIG N 0ns cs</td></tr><tr><td>Short Sym 200ns cs</td><td>GI2 cs1</td><td>ELT 1050ns</td><td>SIG N 1050ns cs</td></tr><tr><td>Short Sym 400ns cs</td><td>GI2 cs2</td><td>ELT 2100ns</td><td>SIG N 2100ns cs</td></tr><tr><td>8us</td><td>1.6us</td><td>6.4us</td><td>4us</td></tr></table> 4 TX case <table><tr><td>Short Sym 0ns cs</td><td>GI2</td><td>ELT 0ns cs</td><td>SIG N 0ns cs</td></tr><tr><td>Short Sym 200ns cs</td><td>GI2 cs1</td><td>ELT 800ns</td><td>SIG N 800ns cs</td></tr><tr><td>Short Sym 400ns cs</td><td>GI2 cs2</td><td>ELT 1600ns</td><td>SIG N 1600ns cs</td></tr><tr><td>Short Sym 600ns cs</td><td>GI2 cs3</td><td>ELT 2400ns</td><td>SIG N 2400ns cs</td></tr><tr><td>8us</td><td>1.6us</td><td>6.4us</td><td>4us</td></tr></table> See, e.g., Zelst Provisional, 6:	Short Sym 0ns cs	GI2	ELT 0ns cs	SIG N 0ns cs	Short Sym 400ns cs	GI2 cs1	ELT 1600ns cs	SIG N 1600ns cs	8us	1.6us	6.4us	4us	Short Sym 0ns cs	GI2	ELT 0ns cs	SIG N 0ns cs	Short Sym 200ns cs	GI2 cs1	ELT 1050ns	SIG N 1050ns cs	Short Sym 400ns cs	GI2 cs2	ELT 2100ns	SIG N 2100ns cs	8us	1.6us	6.4us	4us	Short Sym 0ns cs	GI2	ELT 0ns cs	SIG N 0ns cs	Short Sym 200ns cs	GI2 cs1	ELT 800ns	SIG N 800ns cs	Short Sym 400ns cs	GI2 cs2	ELT 1600ns	SIG N 1600ns cs	Short Sym 600ns cs	GI2 cs3	ELT 2400ns	SIG N 2400ns cs	8us	1.6us	6.4us	4us
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Zelst (EX1010)	Zelst Provisional (EX1011)												
wherein the long training sequence field of the second preamble has a cyclic shift;	See, e.g., Zelst Provisional, 4: Efficient Green-field Preamble based on Cyclic Shift (Option 1) “Green-field” preamble for 2 TX case (20 and 40 MHz) - Minimal overhead in long training (LT) sequence - On TX2: a cyclic shift (cs) in Extended Long Training (ELT) of 1.6 μs - SIG N field uses same cyclic shift as long training sequence - Use Extended Long Training to prevent interpolation issues <table><tr><td>Short Sym 0ns cs</td><td>GI2</td><td>ELT 0ns cs</td><td>SIG N 0ns cs</td></tr><tr><td>Short Sym 400ns cs</td><td>GI2 cs1</td><td>ELT 1600ns cs</td><td>SIG N 1600ns cs</td></tr><tr><td>8us</td><td>1.6us</td><td>6.4us</td><td>4us</td></tr></table>	Short Sym 0ns cs	GI2	ELT 0ns cs	SIG N 0ns cs	Short Sym 400ns cs	GI2 cs1	ELT 1600ns cs	SIG N 1600ns cs	8us	1.6us	6.4us	4us
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Short Sym 400ns cs	GI2 cs1	ELT 1600ns cs	SIG N 1600ns cs										
8us	1.6us	6.4us	4us										
and wherein the signal field of the second preamble has a cyclic shift with respect to the signal of the first preamble.	See, e.g., Zelst Provisional, 4: Efficient Green-field Preamble based on Cyclic Shift (Option 1) “Green-field” preamble for 2 TX case (20 and 40 MHz) - Minimal overhead in long training (LT) sequence - On TX2: a cyclic shift (cs) in Extended Long Training (ELT) of 1.6 μs - SIG N field uses same cyclic shift as long training sequence - Use Extended Long Training to prevent interpolation issues <table><tr><td>Short Sym 0ns cs</td><td>GI2</td><td>ELT 0ns cs</td><td>SIG N 0ns cs</td></tr><tr><td>Short Sym 400ns cs</td><td>GI2 cs1</td><td>ELT 1600ns cs</td><td>SIG N 1600ns cs</td></tr><tr><td>8us</td><td>1.6us</td><td>6.4us</td><td>4us</td></tr></table>	Short Sym 0ns cs	GI2	ELT 0ns cs	SIG N 0ns cs	Short Sym 400ns cs	GI2 cs1	ELT 1600ns cs	SIG N 1600ns cs	8us	1.6us	6.4us	4us
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8us	1.6us	6.4us	4us										

61. Pursuant to step two of *Dynamic Drinkware*, citations to the disclosures in Zelst relied on herein are followed by a parallel citation to where that subject matter is disclosed in the Zelst Provisional.

E. Boer-EX1012

62. U.S. Patent No. 8,014,267 (“Boer”) was filed on 6/30/2004 as PCT/US2004/021026 (EX1029) in English, designating the U.S., and at the

USPTO as the national receiving office, Boer was assigned [10/562,619](#) and issued 9/6/2011. I understand Boer is therefore prior art under pre-AIA 35 U.S.C. § 102(e) based on its actual filing date of 6/30/2004. Boer claims priority to, and incorporates by reference, U.S. Provisional Patent Application No. 60/483,719 (“Boer Provisional,” E1013), filed 6/30/2003. EX1012, 1:10-18. Because Boer incorporates the Boer Provisional, all citations to the Boer Provisional herein are also citations to Boer itself.

63. Boer incorporates 802.11a by reference. EX1012, 1:30-36. Thus, Boer includes the entire disclosure of 802.11a, which is a supplement to 802.11-1999, as if fully reproduced therein.

F. Jones-EX1014

64. U.S. Patent No. 7,453,793 (“Jones”), filed 4/12/2004, issued 11/18/2008, and I understand is prior art under pre-AIA 35 U.S.C. § 102(e). Jones was assigned to Airgo. EX1015.

65. Jones claims priority to, and incorporates by reference, U.S. Provisional Patent Application No. 60/483,719 (“Jones Provisional,” EX1030), filed 4/10/2003. EX1014, 1:9-13.

66. Jones incorporates 802.11a by reference. EX1014, 5:33-37. Thus, Jones includes the entire disclosure of 802.11a, which is a supplement to 802.11-1999, as if fully reproduced therein.

G. Analogous Art

67. Each of the prior art references asserted herein is analogous art because each is in the field of wireless communication systems. EX1001, 1:28-34.

IX. BACKGROUND OF THE PRIOR ART

68. I provide the timeline below as it relates to training sequences, which is the subject of the prior art and challenged patent. The two relevant aspects of the ELTS are the number of subcarriers (exactly 56 is required by [1e]) and their specific encodings of +1/-1 (specified in [1f]).

69. In 1999, IEEE adopted 802.11-1999 (EX1006).

70. In 1999, IEEE adopted 802.11a (EX1008), which added OFDM in the 5Ghz band. 802.11a defined 20MHz channels containing 64 subcarriers with 0.3125 MHz spacing, but only used 52 of them to carry information. 802.11a defined a “short training sequence” (STS) on 12 subcarriers for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition and a “long training sequence” (LTS) on 52 subcarriers for fine synchronization and channel estimation.

71. On 4/10/2003, the Jones inventors filed the Jones Provisional teaching 802.11a could be improved by extending the long training sequence, and disclosed the same 56-subcarrier encoding sequence claimed in the '629 patent by disclosing the full 63-subcarrier sequence. EX1014, Fig. 2 (L2).

72. In July 2003, the IEEE created the Task Group n (TGn) to develop 802.11n with the goal of significantly increasing the throughput rate, including via multiple-input multiple-output (MIMO) and spatial multiplexing. EX1025.

73. On 6/30/2003, the Boer inventors (including Allert van Zelst) filed the Boer Provisional teaching that the 802.11a long training sequence could be extended to 56 subcarriers by adding 4 additional subcarriers. EX1013, 23-25. The Boer Provisional taught that, as of 2003, reasonable filtering enabled the use of the four extra subcarriers within the spectral mask provided by 802.11a. EX1013, 23-25. The Boer Provisional explicitly disclosed all 16 of the possible encodings for the additional 4 subcarriers. EX1013, 45-46 (including (1,1,-1,-1), the encoding claimed in the '629 patent for the 4 new subcarriers).

74. On 4/12/2004, the Jones inventors (including Vincent Jones and Richard van Nee) filed the non-provisional application that issued As Jones. EX1014, cover. Jones, like the Jones Provisional, disclosed the precise encoding sequence for 56 subcarriers claimed in the '629 patent by disclosing the full 63-subcarrier sequence. EX1014, Fig. 4 (L2). Jones additionally disclosed that any of 53 to 63 subcarriers could be used, explicitly teaching (or at least rendering obvious) the use of exactly 56 subcarriers. EX1014, 6:11-23, 8:23-41.

75. On 5/27/2004, the Zelst inventors (including Allert van Zelst, who by then worked for Airgo, Vincent Jones and Richard Van Nee) filed the Zelst

Provisional. The Zelst Provisional taught (like Boer and Jones) that an “Extended Long Training Sequence” of 56 subcarriers could be used. EX1011, FIG. 3. The Zelst Provisional disclosed the precise encoding claimed in the ’629 patent by disclosing the full 63-subcarrier sequence and disclosing that exactly 56 subcarriers could be used for the ELTS (the “Zelst 56-subcarrier ELTS”). EX1011, 4, FIG. 3.

76. Thus, by 5/27/2004, there is no question that the overlapping Jones/Zelst inventors at Airgo had already identified the precise encoding sequence, and identified with specificity that exactly 56-subcarriers could be used.

77. On 7/27/2004, the named inventors of the ’629 patent filed the ’104 Provisional disclosing a 56-subcarrier sequence and a 63-subcarrier sequence. EX1002, 2. The 56-subcarrier sequence is the same sequence disclosed earlier by Boer, Jones and Zelst and eventually claimed in the ’629 patent. EX1002, 7. However, the 63-subcarrier sequence differs from Jones and Zelst and the ’629 patent by encoding bit 27 as +1. EX1002, 9.

78. In August 2004, the WWiSE industry consortium submitted a proposal to the IEEE TGn. EX1016. The WWiSE proposal included the same 56-subcarrier sequence previously disclosed in Boer, Zelst and the ’104 Provisional. EX1016, 37. The WWiSE consortium was led by Airgo, the assignee of Jones and Zelst and included Broadcom, the assignee of the ’104 Provisional. EX1016, 2.

The WWiSE proposal identified named inventors from each reference as contributors. EX1016, 2.

79. On 12/8/2004, the named inventors of the '629 patent filed a second provisional, disclosing significant new matter and changing the 63-subcarrier sequence to match the 63-subcarrier sequence previously disclosed by Jones, Zelst and WWiSE. EX1030, FIG. 5 (changing the encoding of bit 27 to -1).

80. On 7/26/2005, the named inventors filed the first non-provisional application to which the '629 patent claims priority. EX1001, Cover.

X. LEVEL OF ORDINARY SKILL IN THE ART

81. I have considered the level of ordinary skill in the art relevant to the '629 patent. I understand that factors such as the education level of those working in the field, the sophistication of the technology, the types of problems encountered in the art, the prior art solutions to those problems, and the speed at which innovations are made may help establish the level of skill in the art.

82. After reviewing the '629 patent, the relevant portions of the prosecution history of the '629 patent, and cited references, it is my opinion that the relevant art of the '629 patent is in the field of wireless orthogonal frequency-division multiplexing ("OFDM") communications systems.

Based upon my knowledge of this field, I conclude that a person of ordinary skill in the art ("POSITA") at the time of the earliest alleged filing date of the '629

patent (July 27, 2004), and for that matter, at all subsequent times through the present, would have had a bachelor's degree in electrical engineering, computer engineering, computer science, or a related field, and at least 2-4 years of experience in the field of wireless communication. Equivalent education, work, or experience in this field could substitute for the foregoing qualifications. Based on my educational background and experience, I was at least a person of ordinary skill in the art at the earliest alleged priority date of the '629 patent.

XI. GROUND 1: JONES, 802.11A, 802.11-1999, ZELST AND BOER

A. Combination Rationale

83. Jones and Boer incorporate by reference 802.11a (EX1014, 5:32-38; EX1012, 1:33-36) which is an extension of 802.11-1999. 802.11a and 802.11-1999 should be considered a single reference or, in the alternative, it would have been obvious to combine them.

84. Jones, Zelst and Boer each explicitly teaches improvements to 802.11a. These references were from the same field, include common inventors, and were all directed to improving 802.11a to add extended long training sequences. Thus, it would have been obvious to a POSITA to consider their teachings for that common purpose.

85. Jones teaches the prior art functional blocks used to create and transmit an 802.11a preamble including a long training sequence, including 1) a

symbol mapper (Encoder 312) to map symbols to 64 subcarriers (some of which can be zero), which is coupled to 2) a signal generator (Packet Formation block 314) to generate the training symbol using only 52 subcarriers and inserting zeros for unused subcarriers, which is coupled to 3) a 64-bit Inverse Fourier Transformer (IFFT 314) for converting from frequency domain to time domain. EX1014, Fig. 3, 1:29-39, 5:5-6:10.

86. Jones teaches 802.11a should be improved by using additional subcarriers along with an extended long training sequence to increase the data rate. EX1014, 6:11-23, 8:23-42. Jones explains this improvement can be implemented by having the symbol generator (Packet Formation block 312) use “any or all” of the currently unused subcarriers to transmit data as well as to generate a longer training sequence and continue (as it did in 802.11a) to fill any unused subcarriers with zeros. EX1014, 6:11-23. Jones discloses the encodings for the full sequence (63 values if one does not count the zero subcarrier). EX1014, Fig. 4 (L2), 8:23-42. The sequence in L2 includes the 56-value sequence required by limitation 1[f] in the '629 patent.

87. Jones's teaching that “any or all” of the additional subcarriers defined in L2 could be used (1 extra for 53 subcarriers or up to 11 extra for 63 subcarriers), discloses to a POSITA that exactly 4 subcarriers could be used for a total of exactly 56 subcarriers as required by limitation 1[e] in the '629 patent.

Alternatively, disclosing such a small range (53-63) renders obvious each value in that range, including exactly 56, given the predictable nature of this art. Further, based on the spectral mask provided in 802.11a, a POSITA would have found 56 to be an obvious choice, since the spectral mask supports up to 56 subcarriers.

88. Based on its positions in the ITC, PO is expected to argue that Jones's teaching is insufficient to show "exactly 56 subcarriers." Accordingly, I additionally rely on the teachings of Zelst and Boer as described below. Because Zelst and Boer each disclose precisely the same encodings as Jones for limitation [1f], the only question is whether the combination of teachings of Jones, Zelst and Boer sufficiently render "exactly 56 subcarriers" obvious. I believe they do.

1. It would have been obvious in the combination to use the Zelst 56-Subcarrier ELTS

89. It would have been obvious to combine Jones (along with the incorporated 802.11a standard and original 802.11-1999 standard) with the teachings of Zelst and Boer, which each teach that an extended long training sequence for 802.11a of the type disclosed in Jones should use exactly 56-subcarriers because that is the number that will fit within the spectral mask of 802.11a.

90. Zelst teaches an improvement on 802.11a, including an "Extended Long Training Sequence" (ELTS) that is "carried by exactly 56 subcarriers" and is represented by the claimed encoding scheme (the "Zelst 56-subcarrier ELTS").

- $$\mathbf{L}_{-32,31} = \begin{Bmatrix} -1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, \\ 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, \\ 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, \\ 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, -1, -1, -1, 1, -1 \end{Bmatrix}$$

92. These highlighted sequences in Zelst and the Zelst Provisional are identical to the 56 values disclosed and claimed in the '629 patent (and Jones) for the same subcarriers.

The table of encodings in [1f] is difficult to read because the index zero subcarrier has been removed and is referenced in the language before the table, but as shown below, the encoding sequence in 1[f] is identical to that of Zelst and the Zelst Provisional, with the legacy 52 subcarriers -26 to +26 highlighted in blue and the four additional subcarriers (-28, -27, +27, +28) highlighted in yellow. For comparison, Figure 4 of the '629 patent is shown below showing the same highlighting of the legacy, new and zero subcarriers.

<i>Sub-carrier</i>	-28	-27	-26	-25	-24	-23	-22
<i>Encoding</i>	+1	+1	+1	+1	-1	-1	+1
<i>Sub-carrier</i>	-14	-13	-12	-11	-10	-9	-8
<i>Encoding</i>	+1	+1	+1	-1	-1	+1	+1
<i>Sub-carrier</i>	1	2	3	4	5	6	7
<i>Encoding</i>	+1	-1	-1	+1	+1	-1	+1
<i>Sub-carrier</i>	15	16	17	18	19	20	21
<i>Encoding</i>	+1	+1	-1	-1	+1	-1	+1
<i>Sub-carrier</i>	-21	-20	-19	-18	-17	-16	-15
<i>Encoding</i>	+1	-1	+1	-1	+1	+1	+1
<i>Sub-carrier</i>	-7	-6	-5	-4	-3	-2	-1
<i>Encoding</i>	-1	+1	-1	+1	+1	+1	+1
<i>Sub-carrier</i>	8	9	10	11	12	13	14
<i>Encoding</i>	-1	+1	-1	-1	-1	-1	-1
<i>Sub-carrier</i>	22	23	24	25	26	27	28
<i>Encoding</i>	-1	+1	+1	+1	+1	-1	-1

+1	+1	1	1	-1	-1	1	1	-1	1	-1	1	1	1
-28	-27	-26	-25	-24	-23	-22	-21	-20	-19	-18	-17	-16	-15

Sub-carrier index

1	1	1	-1	-1	1	1	-1	1	-1	1	1	1	0
-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1

Sub-carrier index

+1	-1	-1	1	1	-1	1	-1	1	-1	-1	-1	-1	-1
1	2	3	4	5	6	7	8	9	10	11	12	13	14

Sub-carrier index

1	1	-1	-1	1	-1	1	-1	1	1	1	1	-1	-1
15	16	17	18	19	20	21	22	23	24	25	26	27	28

Sub-carrier index

LONG TRAINING SEQUENCE FOR 56 ACTIVE
FIGURE 4

EX1001, FIG. 4, limitation 1[f].

93. Although the above sequences in Zelst and the Zelst Provisional disclose 64 subcarriers, the Zelst Provisional also discloses the use of exactly 56 subcarriers for the extended long training sequence. Figure 3 of the Zelst Provisional (annotated below), recommends 56 subcarriers “Including the Extended Long Training Sequence.”

Example PSD of TX Signal

- 20 MHz mode
- Realistic filtering
- 1000 byte packet
- 56 subcarriers
- Including the Extended Long Training Sequence

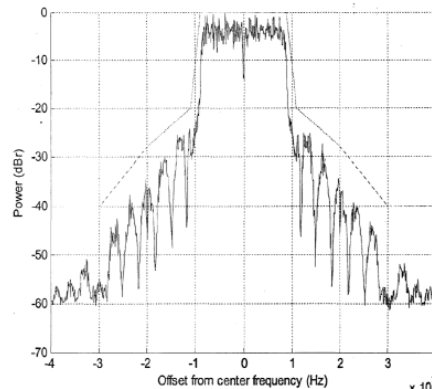


Fig. 3

EX1011, FIG. 3.

94. The Zelst Provisional explains the reason for the extended long training sequence is “to prevent interpolation issues.” EX1011, 2, 9, 13. The same rationale for extending the number of subcarriers to 56 is disclosed in Boer.

EX1012, 4:1-59.

95. To arrive at the '629 patent's encoding sequence for 56 subcarriers, a POSITA would simply truncate the 63-subcarrier sequence taught by Jones and Zelst sequence so as not to use the seven sub-carriers at the highest and lowest frequencies; *i.e.*, sub-carriers -32, -31, -30, -29, +29, +30 and +31. As taught by Jones, those subcarriers would be set to zero by the signal generator. Stated another way, only the middle 56 subcarriers from -28 to +28 would be used.

96. It would have been obvious for a POSITA to use only the middle 56 subcarriers from the Jones and Zelst sequence because, as Zelst explains, the 802.11 spectral mask only supports 56 subcarriers, the sequence is chosen to have

a peak-to-average power within a few tenths of a dB of the original, and the goal is “to allow for coexistence and interoperability [aka backwards compatibility] between 802.11a devices and higher data rate ... devices.” EX1010, Title, 15:45-48; EX1011, Fig. 3. Jones explains the same goal. EX1014, 8:37-40. Zelst explains to achieve this, “[i]n some embodiments, the modified preamble includes both legacy 802.11a Sequences as well as modified preamble Sequences.” EX1010, 3:3-5. In other words, they maintain the same encoding sequence as the legacy 802.11a standard for the center 52 subcarriers.

97. Boer also confirms that the particular encoding of the Zelst 56-subcarrier ELTS would have been obvious. The Boer Provisional discloses 56 subcarriers should be used to enhance channel estimation, and that there are only 16 possible encoding schemes when adding four subcarriers to the 52 subcarriers already present in 802.11a. That is, since each subcarrier can be encoded using either a +1 or -1, there are only two possibilities per subcarrier, and $2^4=16$. All 16 possibilities are disclosed in the Boer Provisional, one of which (highlighted below) is the same encoding disclosed in Zelst and claimed in the '629 patent.

Diagonal-4	1111	1	2.9337	1.0179	2.8822
		2	4.3393	1.0179	4.2632
		3	2.7409	0.9643	2.8424
	111-1	1	2.9337	1.0179	2.8822
		2	4.3393	1.0179	4.2632
		3	2.7409	0.9643	2.8424
	11-11	1	3.0600	1.0179	3.0063
		2	4.3393	1.0179	4.2632
		3	2.7409	0.9643	2.8424
	11-1-1	1	3.0600	1.0179	3.0063
		2	4.3393	1.0179	4.2632
		3	2.7409	0.9643	2.8424
	1-111	1	2.9337	1.0179	2.8822
		2	3.0265	1.0179	2.9734
		3	2.7409	0.9643	2.8424
	1-11-1	1	2.9337	1.0179	2.8822
		2	2.7592	1.0179	2.7108
		3	2.7409	0.9643	2.8424
	1-1-11	1	3.0600	1.0179	3.0063
		2	3.0265	1.0179	2.9734
		3	2.7409	0.9643	2.8424
	1-1-1-1	1	3.0600	1.0179	3.0063
		2	2.7592	1.0179	2.7108
		3	2.7409	0.9643	2.8424
	-1111	1	2.6520	1.0179	2.6055
		2	4.3393	1.0179	4.2632
		3	2.7409	0.9643	2.8424
	-111-1	1	2.6520	1.0179	2.6055
		2	4.3393	1.0179	4.2632

EX1013, 45.

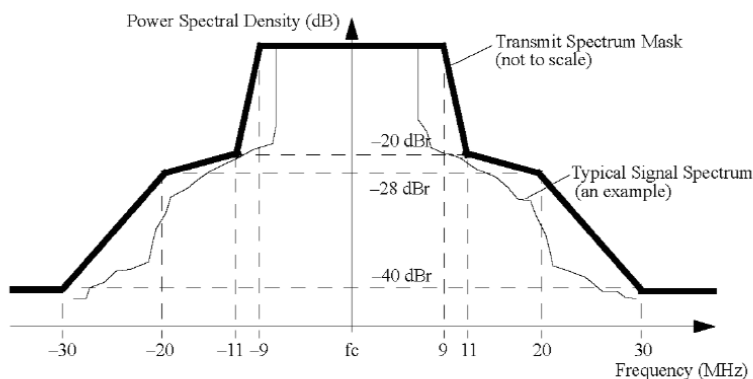
98. The legacy 802.11a LTS encoding, which the Boer Provisional improves upon, is shown below with active subcarriers -26 to -1 and 1 to +26 highlighted in blue, and the indexed subcarrier 0 which is set to zero highlighted in red.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26, 26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, 1, 1, 1\} \quad (8)$$

EX1008, 13.

99. A POSITA would have understood based on the teachings of Zelst and Boer that 56 subcarriers could be used to carry the ELTS based on the room available in the 802.11a spectral mask (shown below).



EX1008, FIG. 120.

100. 802.11a states the “[t]he transmitted spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz” and that “[t]he transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 120.” EX1008, 28. 802.11a further states that the subcarrier frequency spacing is “0.3125 MHz (=20 MHz/64).” EX1008, 9. A POSITA would have understood the spectral mask’s 0dBr bandwidth of 18 MHz could fit up to 57.6 subcarriers, because $18 \text{ MHz} / 0.3125 \text{ MHz} = 57.6$.

101. Boer discloses an extended long training sequence, stating: “since the training technique defined by the IEEE 802.11a/g standard only modulates 52 out of the 64 subcarriers, additional spectrum is available to specify additional

subcarriers. For example, it can be shown that ***the addition of four extra training subcarriers***, two at each side of the spectrum, conforms with the IEEE 802.11a/g transmit mask defined in the IEEE 11a/g standard.” EX1012, 4:40-48.

102. Boer’s 56-subcarrier long training sequence also maintains the same 52 subcarriers from 802.11a and adds four more. The Boer long training sequence is “extended” because it is 4 subcarriers longer than the 802.11a long training sequence of 52 subcarriers, as shown below.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26, 26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 0, \\ 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1\} \quad (8)$$

EX1008, 13.

103. The Boer Provisional also teaches that adding four subcarriers to 802.11a still complies with 802.11a’s spectral mask: “As can be seen from Figure 5 [below], the PSDs of the training sequences still fulfill the transmit spectral mask requirements, when extended with four additional subcarriers. From this it can be concluded that the extension with extra subcarriers at the edge is allowed and is in line with the IEEE 802.11a specifications.”

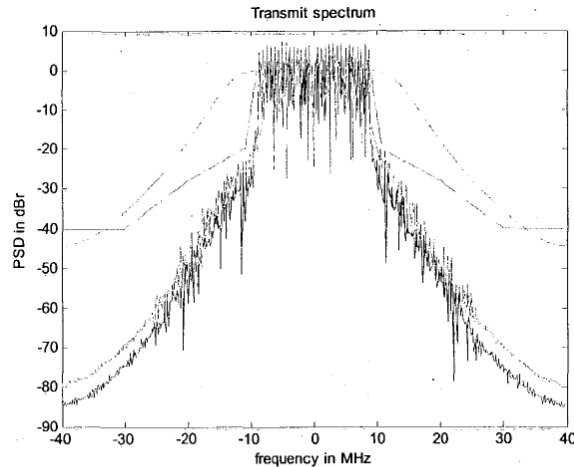


Figure 5: Transmit spectrum of the filtered and PA distorted training sequences

EX1013, 24-25.

104. A POSITA also would have realized that increasing the number of subcarriers from 52 to 56 could be achieved using reasonable transmit filters to attenuate out-of-band subcarriers to conform with the transmit spectral mask based on the teachings of Zelst. EX1010, 15:64-16:2; EX1011, 5.

105. Boer also discloses that the 56 subcarriers could be distributed amongst three transmit antennas, but that does not detract from Boer's teaching that all 56 subcarriers could be transmitted without violating the spectral mask requirements of 802.11a. Specifically, the disclosure is based on the largest (i.e., furthest from DC) subcarriers used, regardless of the number of antennas. Thus, the teaching does not depend specifically on the number of transmit or receive antennas.

106. Zelst and Jones expressly teach a POSITA that the combination should provide for enhanced modes by extending the long training sequence

provided by 802.11a while maintaining backward compatibility with 802.11a legacy devices. EX1010, Abstract; EX1014, 20:21-25.

107. Further, a POSITA would have been motivated to make the combination because adding four subcarriers to 802.11a data and training fields increases data rate throughput as taught in Zelst and Jones. EX1010, 2:38-45; EX1014, 2:62-3:11.

108. This combination would combine known elements to yield a predictable result – a system that utilized an extended long training sequence of 56 non-zero subcarriers for the advantages taught by Zelst, Boer and Jones while remaining backwards-compatible with 802.11a as taught by Zelst and Jones.

109. Further, a POSITA would have been motivated to make the combination because adding additional side carriers allows for improved channel estimation by allowing for interpolation instead of extrapolation of edge subcarriers as taught by Boer. EX1012, 4:45-59.

110. The combination would involve the application of a known technique (*e.g.*, generating a training sequence) to a known system (802.11a's functional blocks as described by Jones) ready for improvement to yield predictable results. For example, 802.11a discloses a 64-point Inverse Fast Fourier Transform that operates on 64 subcarrier values. A POSITA would have understood that a 64-point Inverse Fast Fourier Transform could operate on an ELTS of up to 64 values,

which is greater than 52. EX1008, 12. Similarly, Jones teaches that in 802.11a systems, the signal generator populates unused subcarriers with zero before providing the training sequence to the IFFT. EX1014, 2:14-30. A POSITA would have understood that they could simply use the four additional subcarriers (as taught by Jones and very specifically by Zelst and Boer) using the encodings of Jones, Zelst and Boer, to achieve the benefits taught by Jones, Zelst and Boer.

111. The reasoning above also shows that a POSITA would have had a reasonable expectation of success in making the combination to implement Zelst's 56-subcarrier ELTS. Notably, the '629 patent itself does not describe any problems or provide any other implementation details to overcome any such problems. To the contrary, the '629 patent admits that 56-subcarrier ELTS's were under consideration for 802.11n, and the '629 merely states that one of the 16 possible sequences should be used, when that one was previously disclosed by Jones, Zelst and Boer.

112. In sum, the claimed ELTS—the number of subcarriers and the particular encodings—would have been obvious. A POSITA looking to extend 802.11a and maintain backwards compatibility with legacy 802.11a devices (as taught by Zelst and Jones) would have used an ELTS of either 56 or 63 subcarriers as taught by Zelst, Jones and Boer. Extending to 63 would have been an obvious number because that is the maximum that can be used in a 20MHz channel and 64-

bit IFFT as defined by 802.11a as taught by Zelst and Jones. Extending to 56 also would have been obvious because that is the maximum number that can be used within the spectral mask defined by 802.11a with reasonable filtering as taught by Zelst and Boer. Thus, to accomplish the known goals of increasing the number of subcarriers to increase bandwidth (as taught by Zelst and Jones) and enhance channel estimation (as taught by Boer), the two most obvious choices are to use either 56 or 63 subcarriers (the two choices that the Applicant Admitted Prior Art admits were being considered).

113. A POSITA extending an LTS to 56 would want to use the same 52 center bits to maintain backwards compatibility as taught by Zelst, Jones and Boer. Thus, a POSITA would only have to choose the encoding (1 or -1) for the 4 extra bits. There are only 16 choices, none of which is patentable because of the predictability of this art. More importantly, Zelst, Jones and Boer each disclose the precise encodings of those extra bits (1,1,-1,-1).

2. It would have been obvious in the combination to use the functional blocks disclosed in Jones

114. Jones also teaches the claimed functional blocks (e.g., a symbol mapper (Encoder 312)) coupled to a signal generator (Packet Formation block 314) coupled to an Inverse Fourier Transformer (IFFT 316), which could each be implemented as a processor) and it would have been obvious to use those functional blocks in the combination. A POSITA would have been motivated to

use the hardware implementation details in Jones based on the express teachings in Jones that those implementation details should be used to support 802.11a legacy devices while simultaneously supporting an improvement to 802.11a that utilized extended long training sequences between 53 and 64 subcarriers. A POSITA also would have been motivated by the lack of any conflicting implementation details in Zelst, 802.11a and Boer to use the functional blocks in Jones.

115. It would also have been obvious in the combination to include an IFFT operatively coupled to the signal generator as taught by Jones because each of Zelst, 802.11a, and Boer teach an IFT (e.g., IFFT) should be operatively coupled to the source of the training signal (e.g., Packet Formation block 314) in order to perform an IFT operation (e.g., IFFT).

116. A POSITA would have had a reasonable expectation of success in making the combination as Jones expressly teaches that its functional blocks can support both legacy and improved 802.11a devices with extended long training sequences. Jones incorporates by reference 802.11a (EX1014, 5:33-38) and Jones, Zelst, and Boer each purport to improve 802.11a using an ELTS. Jones's functional blocks are known components used for their known purposes and, therefore, would produce predictable results. Jones teaches a POSITA all they would need to make the combination.

B. Claim 1¹

1. [1pre]

117. The combination discloses “A wireless communications device (transmitter system 302²), comprising (*see* 1[a]-1[f]).”

118. Jones discloses a wireless communication device. EX1014, Fig. 3 (devices 302, 304), 8:1 (“two transmitter MIMO device.”).

119. Zelst also discloses extensions to 802.11a communications protocol for wireless communications devices. EX1010, Fig. 3, (wireless communications devices 102(1), 102(2) and 104); 4:24-26.

¹ Claim language is reproduced above in the Table of Claims and is usually quoted in the introductory sentence of each section.

² In the introductory sentence, I sometimes include parentheticals within the claim limitation to assist the reader to exemplary opinions and evidence. Those cites are just exemplary, and I rely on all of the opinions and evidence included in my declaration.

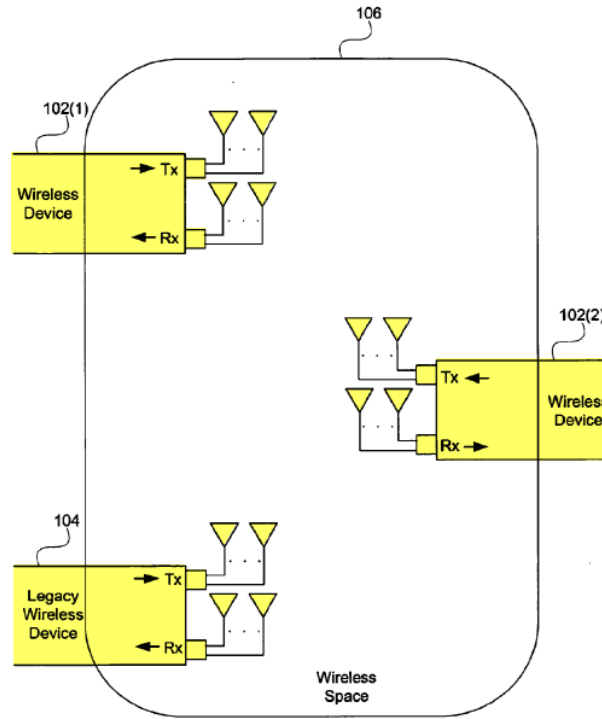
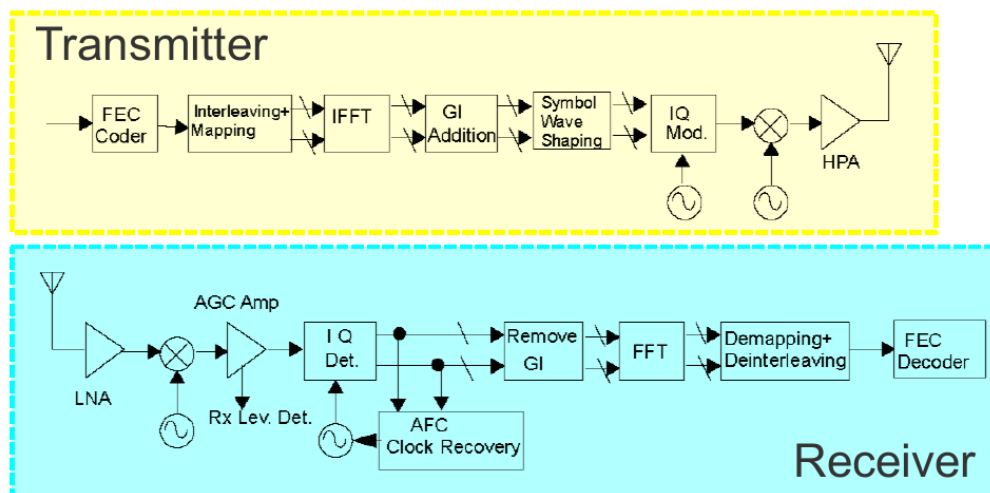


Fig. 3

120. The Zelst Provisional also discloses extensions to the 802.11a wireless protocol for wireless communication devices. EX1011, 3 (“packets sent over a wireless network, such as an 802.11a compliant wireless network. . . may be received by legacy receivers”).

121. 802.11a also discloses a wireless communications device. EX1008, Fig. 118 (disclosing transmitter and a receiver, both of which are wireless communication devices).



122. Thus, it would have been obvious in the combination to have a wireless communication device implementing an extension to 802.11a.

2. 1[a]

123. The combination discloses “a signal generator (Packet Formation block 314) that generates an extended long training sequence (Zelst 56-subcarrier ELTS).”

124. Jones discloses a signal generator (Packet Formation block 314) (highlighted below) “advantageously pre-pends a preamble to each transmitted packet,” which may include “a preamble suitable for extended-rate 802.11a communication systems.” EX1014, 7:38-42. Jones states that in “an extended mode long training sequence,” $L[k]$ may “contain more than 52 non-zero subcarriers” such as sequence L2 in FIG. 4. EX1014, 8:22-27. Jones discloses the same 63-value encoding sequence (shown below) taught in Zelst Figure 15A and

disclosed in the '629 patent. Jones also teaches that the extended LTS could use more than 52 but fewer than all 63 subcarriers. EX1014, 6:11-23, 8:22-41.

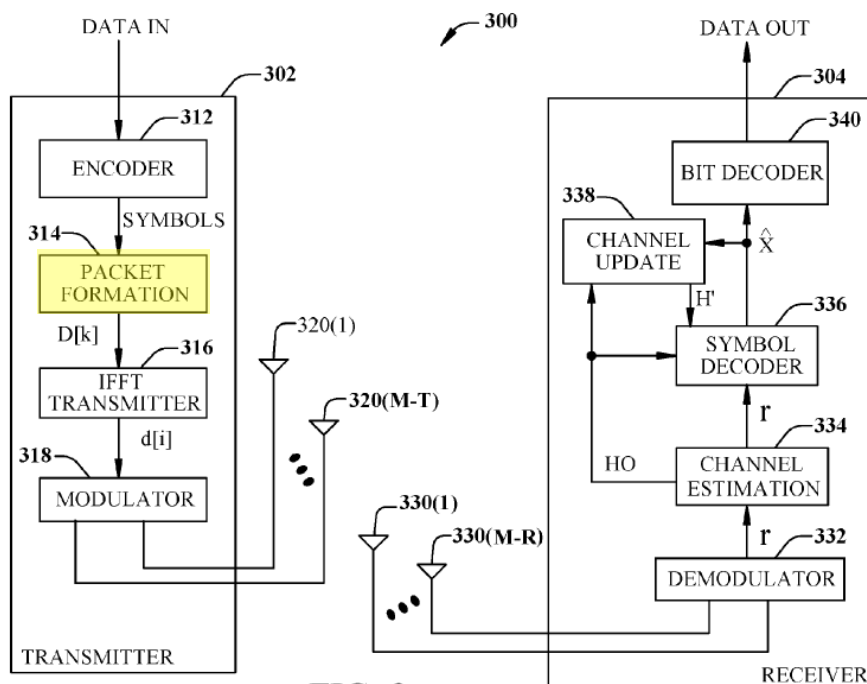


FIG. 3

125. Jones teaches the same 63-subcarrier ELTS as Zelst and, like Zelst, explicitly teaches that fewer than all of the extra subcarriers could be used. EX1014, FIG. 4 (L2), 6:11-23. As illustrated in the annotated L2 sequence below, Jones lists the sequence from index 0 to 31 followed by index -32 to -1. EX1014, 2:14-30, 8:24-28. Zelst and the '629 patent use a different convention, listing the sequence from index -32 to +31. EX1010, FIG. 15A; EX1001, FIG. 5. For ease of reference, an annotated version of L2 in Jones is included below, with the subcarrier indexes added in red.

$$L2 = \left\{ \begin{array}{cccccccccccccccccccccccccccccccccccc} 0 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 \\ 16 & 17 & 18 & 19 & 20 & 21 & 22 & 23 & 24 & 25 & 26 & 27 & 28 & 29 & 30 & 31 \\ 1 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & 1 & -1 \\ -32 & -31 & -30 & -29 & -28 & -27 & -26 & -25 & -24 & -23 & -22 & -21 & -20 & -19 & -18 & -17 \\ -1 & -1 & 1 & 1 & 1 & 1 & 1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 & -1 \\ -16 & -15 & -14 & -13 & -12 & -11 & -10 & -9 & -8 & -7 & -6 & -5 & -4 & -3 & -2 & -1 \end{array} \right\}$$

126. Zelst discloses the same ELTS as Jones in Figure 4 (L2), and reformats it in Figure 15A, shown below.

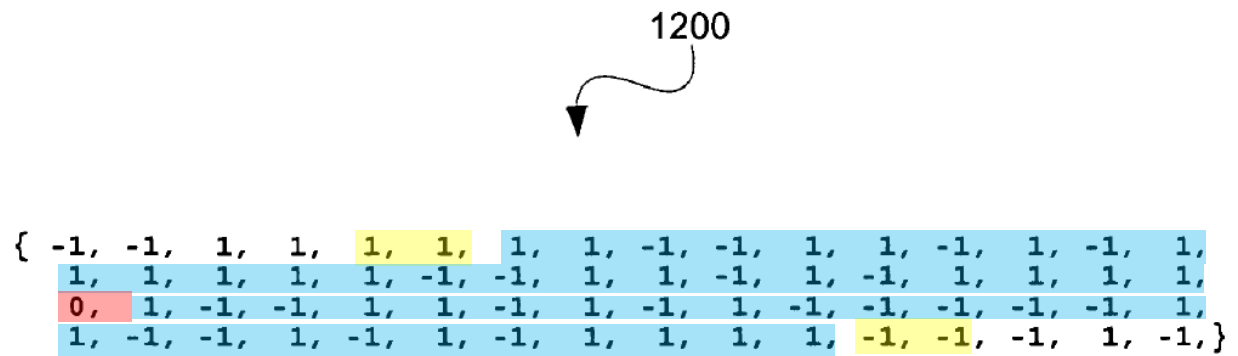


FIG. 15A

EX1010, FIG. 15A. Zelst states “FIG. 15A . . . shows the 64 tones of an ELT sequence 1200 adapted for a 20 MHz channel.” EX1010, 15:34-37.

127. The incorporated Zelst Provisional discloses the same “Extended Long Training (ELT)” sequence.

20 MHz & 40 MHz Extended Long Training (ELT)

- ELT for 20 MHz:

$$L_{-32,31} = \{-1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1\}$$

EX1011, 4.

128. The incorporated Zelst Provisional goes on to teach that exactly 56 subcarriers can be used for the ELT sequence. EX1011, FIG. 3. This is the Zelst 56-subcarrier ELTS, and it would have been obvious to use that ELTS in the combination. *See* Section XI.A (Combination Rationale).

129. Boer similarly teaches that exactly 56 subcarriers can be used for the ELTS, discloses the same encodings for the four additional subcarriers as Zelst and Jones, and it would have been obvious to use that (same) ELTS in the combination. *See* Section VII.A (Combination Rationale).

130. The ELTS is “extended” since it is longer than a “long training sequence” from a legacy standard, such as 802.11a, which has 52 active subcarriers (below).

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L , given by

$$L_{-26,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, 1, 1, 1\} \quad (8)$$

EX1008, 13.

131. Moreover, 802.11a itself repeatedly states that the long training sequence is “generated.” EX1008, 13 (“A long OFDM training symbol shall be generated according to the following equation.... An illustration of the long training sequence generation is given in Annex G.”), 59 (“G.3.2 Generation of the long sequences”). 802.11a’s teaching that the LTS is “generated” renders obvious a “signal generator” to a POSITA because using a “signal generator” would have been an obvious way to perform the disclosed function of generating. Jones teaches its Packet Formation block 314 can generate 802.11a compliant long training sequences. EX1014, 6:11-22. Zelst and Jones emphasize the need to support legacy 802.11a devices, so it would have been obvious to use the same Packet Formation block 314 (signal generator) that generates the 802.11a LTS to generate the improved Zelst 56-subcarrier ELTS.

132. In the combination, it would have been obvious for Jones’s Packet Formation block 314 (signal generator) to generate the Zelst 56-subcarrier ELTS as taught by Zelst and Boer and zeros for the unused subcarriers. Jones expressly teaches that the extended sequence could use fewer than all of the subcarriers, and the Packet Formation Block 314 (signal generator) would insert zeros for unused carriers “as is known in the art.” EX1014, 6:11-23. Furthermore, a POSITA would have understood there would have been no reason to generate all 63 values just to

discard unused values. Thus, it would have been obvious to a POSITA that in the combination the signal generator would generate the Zelst 56-subcarrier ELTS that would be used and zeros for the other subcarriers.

133. Lastly, it should be noted that in the related ITC Investigation, PO asserted claim 1 (and other claims) of the '629 patent were “essential” to practicing the 802.11n standard because using the ELTS defined by the 802.11n standard necessarily required the use of the claimed “signal generator.” EX1022, 6-8. Thus, according to PO’s contentions on which it sought to exclude Petitioner’s products from the United States, the definition of a training sequence by a standard inherently requires the claimed “signal generator.” EX1022, 6-8. In light of PO’s inherency arguments before the ITC, the Board should be skeptical of any argument by PO in this IPR that the definitions of training sequences by Zelst and 802.11a do not (at least) render obvious the claimed “signal generator.”

3. 1[b]

134. The combination discloses “an Inverse Fourier Transformer (IFFT) operatively coupled to the signal generator (Packet Formation block 314).”

135. Jones discloses an Inverse Fourier Transformer (IFFT block 316) operatively coupled to the signal generator (Packet Formation block 314). EX1014, 5:5-20, 5:65-6:10.

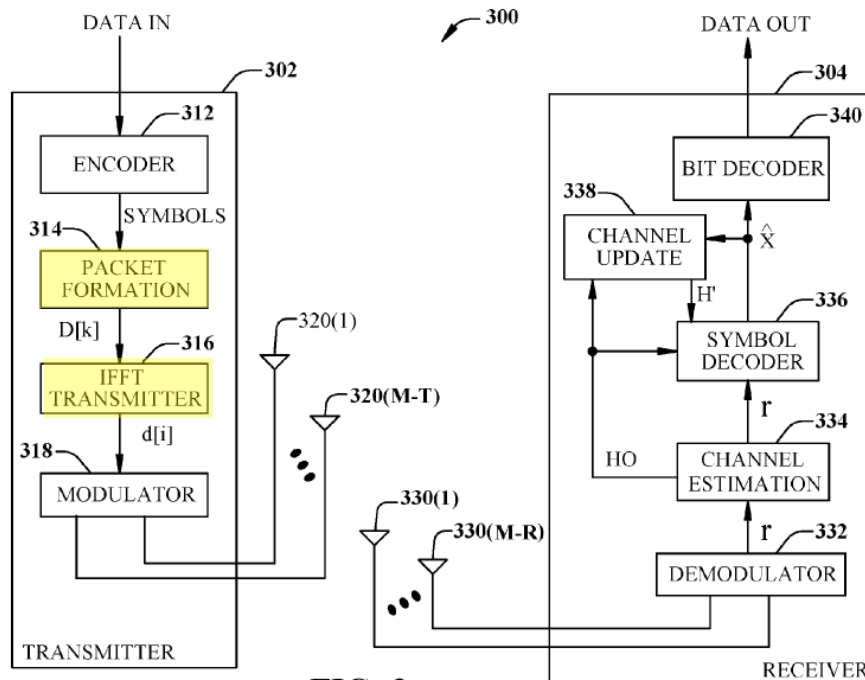


FIG. 3

EX1014, FIG. 3 (annotated). Jones discloses that IFFT would process the legacy and any extended long training sequence from the signal generator, Packet Formation block 314, with zeros for any unused subcarriers. EX1014, 5:65-6:10, 9:21-29.

136. Zelst also discloses this limitation, stating “The samples are obtained by taking a 64-point IFFT (inverse fast-Fourier transform) of the long training sequence, L1 in this example.” EX1010, 2:28-34. A POSITA would have understood that “in this example” means Zelst’s teaching of using an IFFT applied to the other long training sequences (in fact any long training sequence that uses 64 or fewer sub-carriers), including the Zelst 56-subcarrier ELTS.

137. The incorporated Zelst Provisional also discloses this limitation, stating that on the receiver side, one would “perform an FFT on the received samples corresponding to the transmitted long training symbol(s).” EX1011, 18. This disclosure conveys to a POSITA that because the receiver includes a FFT, the transmitter must include an IFT (i.e., the inverse of the FFT) that is processing the long training symbols.

138. 802.11a also discloses an IFFT as part of the transmitter in Figure 118, annotated below.

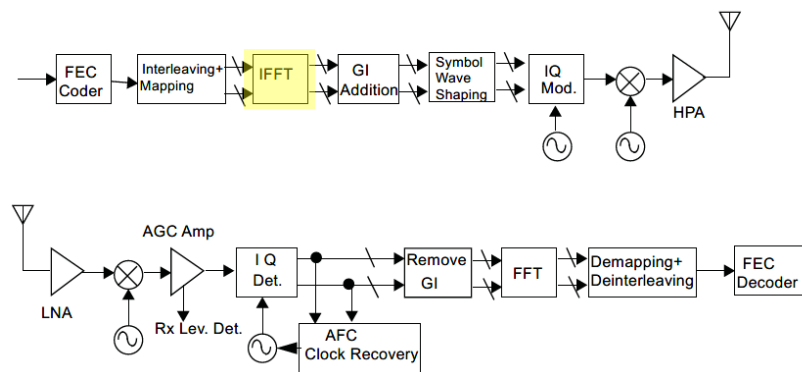


Figure 118—Transmitter and receiver block diagram for the OFDM PHY

EX1008, FIG. 118. And 802.11a also discloses that an IFFT is performed on the long training sequence (in Table G.5).

Table G.5—Frequency domain representation of the long sequences

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
-32	0.000	0.000	-16	1.000	0.000	0	0.000	0.000	16	1.000	0.000
-31	0.000	0.000	-15	1.000	0.000	1	1.000	0.000	17	-1.000	0.000
-30	0.000	0.000	-14	1.000	0.000	2	-1.000	0.000	18	-1.000	0.000
-29	0.000	0.000	-13	1.000	0.000	3	-1.000	0.000	19	1.000	0.000
-28	0.000	0.000	-12	1.000	0.000	4	1.000	0.000	20	-1.000	0.000
-27	0.000	0.000	-11	-1.000	0.000	5	1.000	0.000	21	1.000	0.000
-26	1.000	0.000	-10	-1.000	0.000	6	-1.000	0.000	22	-1.000	0.000
-25	1.000	0.000	-9	1.000	0.000	7	1.000	0.000	23	1.000	0.000
-24	-1.000	0.000	-8	1.000	0.000	8	-1.000	0.000	24	1.000	0.000
-23	-1.000	0.000	-7	-1.000	0.000	9	1.000	0.000	25	1.000	0.000
-22	1.000	0.000	-6	1.000	0.000	10	-1.000	0.000	26	1.000	0.000
-21	1.000	0.000	-5	-1.000	0.000	11	-1.000	0.000	27	0.000	0.000
-20	-1.000	0.000	-4	1.000	0.000	12	-1.000	0.000	28	0.000	0.000
-19	1.000	0.000	-3	1.000	0.000	13	-1.000	0.000	29	0.000	0.000
-18	-1.000	0.000	-2	1.000	0.000	14	-1.000	0.000	30	0.000	0.000
-17	1.000	0.000	-1	1.000	0.000	15	1.000	0.000	31	0.000	0.000

The time domain representation is derived by performing IFFT on the contents of Table G.5, cyclically extending the result to get the cyclic prefix, and then multiplying with the window function given in G.3.1. The resulting 161 points vector is shown in Table G.6. The samples are appended to the short sequence section by overlapping and adding element 160 of Table G.4 to element 0 of Table G.6.

EX1008, Table G.5 (“The time domain representation is derived by performing IFFT on the contents of Table G.5.”). Because the IFFT is receiving the long training sequence in Table G5, this disclosure teaches the limitation “an Inverse Fourier Transformer operatively coupled to the signal generator.”

139. Boer also discloses “a conventional long training symbol according to the IEEE 802.11a/g standard consisting of 64 subcarriers, seen at the input of the Inverse Fast Fourier Transform (IFFT).” EX1012, 2:49-52.

4. 1[c]

140. The combination discloses “wherein the Inverse Fourier Transformer (IFFT) processes the extended long training sequence (Zelst’s 56-subcarrier ELTS) from the signal generator (Packet Formation block 314), and provides an optimal

extended long training sequence with a minimal peak-to-average ratio (Zelst 56-subcarrier ELTS processed by the IFFT).”

141. As explained for limitation 1[b], in the combination, the IFFT processes Zelst’s 56-subcarrier ELTS from the Packet Formation block 314. *See* [1a]. Thus, the only remaining issue for this limitation is whether the output of the IFFT is “an optimal extended long training sequence with a minimal peak-to-average ration.” It is. Zelst’s 56-subcarrier ELTS is identical to the disclosed and claimed sequence and, therefore, the output of the IFFT for each sequence is identical. As discussed above for claim construction, the patent admits (and requires in the claim) that this is “optimal” and has a minimal PAPR. *See* Section VII (claim construction). Nothing else is required.

142. Notably, dependent claim 4 depends on this claim and adds the limitation that “the optimal extended long training sequence has a minimum peak-to-average power ratio of 3.6 dB.” EX1001, Claim 4. Thus, independent claim 1 must at least encompass a sequence with a PAPR of 3.6 dB. The ’629 patent admits the claimed sequence (which is the Zelst 56-subcarrier ELTS) results in a PAPR of 3.6 dB and I have confirmed the same. *See* claim 4.

143. Zelst’s 56-subcarrier ELTS can also be considered optimal for the additional reason that the middle 52 subcarriers are identical to the long training sequence in 802.11a. *Compare* EX1010, FIG. 15A with EX1008, 13. Thus, a

device that uses the Zelst 56-subcarrier ELTS can coexist with a legacy 802.11a device that uses only the 52 subcarriers from 802.11a. Zelst explicitly teaches this advantage. EX1010, 8:54-58; EX1011, 3 (“[p]ackets containing preambles of the present invention may be received by legacy receivers that are not configured to receive and interpret these preambles”). Similarly, Jones teaches the same advantage. EX1014, 20:21-25. The ’629 patent also teaches this is a desirable feature of the same ELTS. EX1001, 4:21-25.

5. 1[d]

144. The combination discloses “wherein at least the optimal extended long training sequence (Zelst’s 56-subcarrier ELTS processed by an IFFT) is carried by a greater number of subcarriers (56 subcarriers) than a standard wireless networking configuration (52 subcarriers) for an [OFDM] scheme (802.11a).”

145. As explained above for limitations [1a]-[1c], it would have been obvious in the combination to use the Zelst 56-subcarrier ELTS. Zelst and Boer disclose increasing the number of OFDM subcarriers used to carry the ELTS to 56, up from the 52 in 802.11a, and Jones discloses increasing the number above the 52 in 802.11a and up to 63. 802.11a is an OFDM scheme. EX1008, Cover. Thus, Zelst, Boer and Jones each disclose this limitation.

6. 1[e]

146. The combination discloses “wherein the optimal extended long training sequence (Zelst’s 56-subcarrier ELTS processed by IFFT) is carried by exactly 56 active sub-carriers.” As shown above, it would have been obvious in light of Jones, Zelst and Boer to use the Zelst 56-subcarrier ELTS, which is carried by exactly 56 active subcarriers. See Section XI.A (Combination Rationale); see [1a]-[1d].

7. 1[f]

147. The combination discloses “wherein the optimal extended long training sequence (Zelst’s 56-subcarrier ELTS processed by IFFT) is represented by encodings for indexed sub-carriers -28 to +28, excluding indexed sub-carrier 0 which is set to zero, as follows:

<i>Sub-carrier</i>	-28	-27	-26	-25	-24	-23	-22
<i>Encoding</i>	+1	+1	+1	+1	-1	-1	+1
<i>Sub-carrier</i>	-14	-13	-12	-11	-10	-9	-8
<i>Encoding</i>	+1	+1	+1	-1	-1	+1	+1
<i>Sub-carrier</i>	1	2	3	4	5	6	7
<i>Encoding</i>	+1	-1	-1	+1	+1	-1	+1
<i>Sub-carrier</i>	15	16	17	18	19	20	21
<i>Encoding</i>	+1	+1	-1	-1	+1	-1	+1
<i>Sub-carrier</i>	-21	-20	-19	-18	-17	-16	-15
<i>Encoding</i>	+1	-1	+1	-1	+1	+1	+1
<i>Sub-carrier</i>	-7	-6	-5	-4	-3	-2	-1
<i>Encoding</i>	-1	+1	-1	+1	+1	+1	+1
<i>Sub-carrier</i>	8	9	10	11	12	13	14
<i>Encoding</i>	-1	+1	-1	-1	-1	-1	-1
<i>Sub-carrier</i>	22	23	24	25	26	27	28
<i>Encoding</i>	-1	+1	+1	+1	+1	-1	-1

”

148. As shown above, in the combination it would have been obvious to use the Zelst 56-subcarrier ELTS which has this sequence. See Section XI.A (Combination Rationale). I've annotated [1f] above by highlighting "indexed sub-carrier 0 which is set to zero" in red, highlighting the 52-subcarriers that comprise the legacy 802.11a LTS in blue, and highlighted the four extra subcarriers that define the 56-subcarrier ELTS in yellow. The table in [1f] is difficult to read. Figure 4 of the '629 patent contains the same sequence in much better format, and is reproduced below and annotated in the same way.

+1	+1	1	1	-1	-1	1	1	-1	1	-1	1	1	1
-28	-27	-26	-25	-24	-23	-22	-21	-20	-19	-18	-17	-16	-15
Sub-carrier index													

1	1	1	-1	-1	1	1	-1	1	-1	1	1	1	1	0
-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0
Sub-carrier index														

+1	-1	-1	1	1	-1	1	-1	1	-1	-1	-1	-1	-1
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sub-carrier index													

1	1	-1	-1	1	-1	1	-1	1	1	1	1	-1	-1
15	16	17	18	19	20	21	22	23	24	25	26	27	28
Sub-carrier index													

LONG TRAINING SEQUENCE FOR 56 ACTIVE
FIGURE 4

EX1001, FIG. 4.

149. Jones at Figure 4 discloses the claimed sequence as part of L2, which is annotated below to highlight sub-carrier 0 in red (set to zero), highlight the 52-

subcarriers of the legacy 802.11a LTS in blue, and highlight the four extra subcarriers for the claimed 56-subcarrier ELTS in yellow.

$$L2 = \left\{ \begin{array}{cccccccccccccccccccccccccccccccccccccccc} 0 & 1 & -1 & -1 & 1 & 1 & -1 & 1 & -1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 & -1 & -1 & -1 & -1 & 1 & 1 & -1 & -1 & 1 & 1 \\ 16 & -1 & -1 & 1 & -1 & 1 & -1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ -32 & -31 & -30 & -29 & -28 & -27 & -26 & -25 & -24 & -23 & -22 & -21 & -20 & -19 & -18 & -17 & -16 & -15 & -14 & -13 & -12 & -11 & -10 & -9 & -8 & -7 & -6 & -5 & -4 & -3 & -2 & -1 \end{array} \right\}$$

EX1014, Fig.4, 2:14-30 (explaining subcarrier numbering convention). The Jones Provisional discloses the same L2 sequence. EX1030, Fig. 2 (L2).

150. Zelst at Figure 15A reformats the claimed sequence as explained at 15:34-40 to show in a different format. The reformatted sequence is shown below and highlighted in the same manner.

1200
↙

$$\left\{ \begin{array}{cccccccccccccccccccccccccccccccccccccccc} -1, & -1, & 1, & 1, & 1, & 1, & 1, & 1, & -1, & -1, & 1, & 1, & -1, & 1, & -1, & 1, & -1, & 1, & 1, & 1, & -1, & -1, & 1, & 1, & -1, & 1, & -1, & 1, & -1, & 1 \\ 1, & 1, & 1, & 1, & 1, & -1, & -1, & 1, & 1, & -1, & 1, & -1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1 \\ 0, & 1, & -1, & -1, & 1, & 1, & -1, & 1, & -1, & 1, & -1, & -1, & -1, & -1, & -1, & -1, & -1, & -1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1 \\ 1, & -1, & -1, & 1, & -1, & 1, & -1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & -1, & -1, & -1, & 1, & -1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1, & 1 \end{array} \right\}$$

FIG. 15A

EX1010, Fig. 15A. The Zelst Provisional discloses the same sequence in the same format as Zelst Fig. 15A. EX1011, 4 (ELT for 20 MHz).

151. The Boer Provisional (incorporated into Boer) discloses the same sequence by disclosing the 802.11a 52-subcarrier LTS and stating it could be expanded by adding the same four extra subcarriers (highlighted in yellow) to create the claimed sequence.

Diagonal-4	1111	1	2.9337	1.0179	2.8822
		2	4.3393	1.0179	4.2632
		3	2.7409	0.9643	2.8424
		1	2.9337	1.0179	2.8822
	111-1	2	4.3393	1.0179	4.2632
		3	2.7409	0.9643	2.8424
	11-11	1	3.0600	1.0179	3.0063
		2	4.3393	1.0179	4.2632
		3	2.7409	0.9643	2.8424
		1	3.0600	1.0179	3.0063
	11-1-1	2	4.3393	1.0179	4.2632
		3	2.7409	0.9643	2.8424
	1-111	1	2.9337	1.0179	2.8822
		2	3.0265	1.0179	2.9734
		3	2.7409	0.9643	2.8424
		1	2.9337	1.0179	2.8822
	1-11-1	2	2.7592	1.0179	2.7108
		3	2.7409	0.9643	2.8424
	1-1-11	1	3.0600	1.0179	3.0063
		2	3.0265	1.0179	2.9734
		3	2.7409	0.9643	2.8424
		1	3.0600	1.0179	3.0063
	1-1-1-1	2	2.7592	1.0179	2.7108
		3	2.7409	0.9643	2.8424
	-1111	1	2.6520	1.0179	2.6055
		2	4.3393	1.0179	4.2632
		3	2.7409	0.9643	2.8424
		1	2.6520	1.0179	2.6055
	-111-1	2	4.3393	1.0179	4.2632

152. The legacy 802.11a LTS encoding, which the Boer Provisional improves upon, is shown below with active subcarriers -26 to -1 and 1 to +26 highlighted in blue, and the indexed subcarrier 0 which is set to zero highlighted in red.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26, 26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, 1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (8)$$

EX1008, 13.

153. As shown above, each of Jones, Zelst, and Boer disclose the claimed sequence. Specifically, each maintains the legacy 52-bit training sequence from 802.11a and adds the same four encodings to the same four subcarriers (+1/-28, +1/-27, -1/27, -1/28) to arrive at the claimed sequence, i.e., the Zelst 56-subcarrier ELTS. As shown at length in the Combination Rationale (XI.A) and for limitations [1pre]-[1f], the encoding scheme for the Zelst 56-subcarrier ELTS used in the combination is identical to the claimed encoding scheme.

C. Claim 4

154. The combination (see claim 1) inherently discloses “wherein the optimal extended long training sequence (Zelst 56-subcarrier ELTS processed by IFFT) has a minimum peak-to-average power ratio of 3.6 dB.”

155. As explained for limitation 1[c], the Zelst 56-subcarrier ELTS is identical to the 56-subcarrier sequence disclosed and claimed in the '629 patent, which the '629 patent admits results in a 3.6 dB PAPR. EX1001, 5:30-35. Additionally, a POSITA would have known how to calculate the PAPR of an ELTS and I calculated the PAPR of the Zelst 56-subcarrier ELTS using that

method to confirm it is 3.6 dB as admitted in the '629 patent and claimed in this claim.

D. Claim 8

156. The combination (see claim 1) discloses “wherein a binary phase shift key encoding is used for each sub-carrier above the +26 indexed sub-carrier and below the -26 indexed sub-carrier.”

157. Both Zelst and Jones expressly teach using BPSK encoding on all of the active subcarriers, including the extended subcarriers. EX1010, 16:14; EX1011, 6; EX1014, 5:49. Boer also discloses BPSK encoding is used for all 56 subcarriers (including the new 4 subcarriers) by stating: “The SIGNAL-field in a SISO-OFDM system is always modulated and encoded in the same robust way using BPSK modulation and rate $\frac{1}{2}$ convolutional encoding, which facilitates good reception.” E1012, 9:7-10.

158. The training sequences in each of the references are defined as a sequence of +1 or -1. A POSITA would have understood that defining the sequences that way teaches binary phase shift keying is used for each subcarrier, including the extended subcarriers above +26 and below -26. More specifically, bit values are 0 and 1. However, as is well-known by a POSITA, in BPSK the bit values of 0 and 1 are mapped to phase values of π and 0. Modulating the phase of a subcarrier using a value of 0 is the same as multiplying that subcarrier by 1,

while modulating the phase of a subcarrier by π is the same as multiplying that subcarrier by -1. Thus, inputting values of 1 and -1 into an IFFT is equivalent to using BPSK on each subcarrier.

159. In fact, 802.11a defines the term “BPSK” to be “binary phase shift keying.” E1008, 2. And 802.11a states that all of the 52 subcarriers are modulated using BPSK. E1008, 3. A POSITA would have been motivated to use the same BPSK encoding for any additional subcarriers so that all subcarriers would be encoded using the same scheme. This would allow for the simplest and most straightforward implementation of the additional four subcarriers.

E. Claim 9

160. See [1b] (the IFT in each of Jones, Zelst, Boer and 802.11a is an IFFT).

F. Claim 10

161. The combination discloses “wherein the wireless communication device (see claim 1) comprises ... a processor (processing device running software).”

162. Jones teaches that its functional blocks “may be implemented using hardware (e.g., suitable integrated circuit components), software (e.g., program instructions) executing on appropriate processing devices, or any combination thereof.” EX1014, 20:26-30. A POSITA would have understood a processing

device that executes software to perform the functional blocks of Jones to constitute a “processor” as claimed under the ordinary meaning of “processor.” Accordingly, in the combination, it would have been obvious for the device to comprise a processor implementing one or more of Jones’s functional blocks, e.g., the Encoder, Packet Formation block, and/or IFFT.

G. Claim 11

163. The combination discloses or renders obvious “wherein the wireless communications device (see claim 1) comprises a wireless mobile communications device (portable or hand-held device).”

164. 802.11-1999 states “The purpose of this standard is to provide wireless connectivity to automatic machinery, equipment, or stations . . . **which may be portable or hand-held**, or which may be mounted on moving vehicles within a local area.” EX1006, 1 (emphasis added). A POSITA would have understood that portable or hand-held stations that communicate using WiFi are wireless mobile communications devices as claimed. Known examples at the time include cellular phones, processors, personal digital assistants and laptops.

H. Claim 12

165. The combination discloses “wherein the wireless communications device (see claim 1) comprises one or more of the following: an access point and a base station.”

166. Each of Jones, Zelst, Boer and 802.11a is an improvement on 802.11-1999, which defines an infrastructure wireless system comprised of access points and base stations.

3.2 access point (AP): Any entity that has station functionality and provides access to the distribution services, via the wireless medium (WM) for associated stations.

EX1006, 3. Figure 2 of 802.11-1999 (below, annotated) shows a distribution system with mobile stations (STA 2, STA 3) acting as access points (AP).

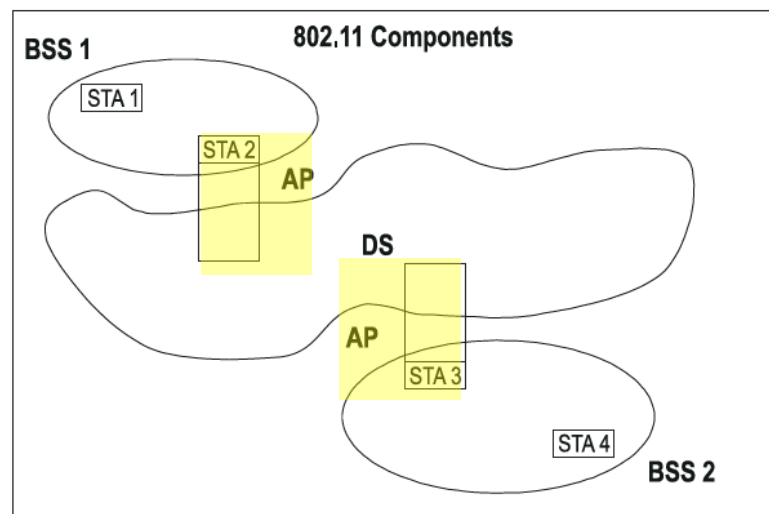


Figure 2—Distribution systems and access points

EX1006, FIG. 2.

I. Claim 13

167. The combination discloses “wherein the wireless communications device (see claim 1) is backwards compatible with legacy wireless local area network devices.”

168. The title of Zelst is “Modified Preamble Structure for IEEE 802.11a Extensions to Allow for ***Coexistence and Interoperability Between 802.11a Devices and Higher Data Rate***, MIMO or Otherwise Extended Devices.” EX1010, Cover. This alone tells a POSITA that the disclosed higher data rate devices are backwards compatible (i.e., they coexist and interoperate) with lower-rate 802.11a devices.

169. Zelst also discloses that “[t]he modified preamble preferably includes properties that facilitate detection of conventional and/or extended modes (“mode detection”) and provides some level of ***coexistence with legacy IEEE 802.11a devices***.” EX1010, 2:65-3:1.

170. The Zelst Provisional also discloses that “packets containing preambles of the present invention may be received by legacy receivers that are not configured to receive and interpret these preambles.” EX1011, 1.

171. The Zelst Provisional also discloses a mixed-mode preamble that is detectable by legacy devices.

- “Mixed-mode” preamble
 - Use long preamble detectable by legacy devices

EX1011, 8. In other words, the disclosed devices are backwards compatible with 802.11a legacy devices.

172. Jones expressly teaches a POSITA that the combination should provide for enhanced modes by extending the long training sequence provided by 802.11a while maintaining backward compatibility with 802.11a legacy devices. EX1014, 20:21-25.

173. Moreover, a POSITA would have been motivated to make the wireless communications device backwards compatible with legacy wireless local area network devices. Backwards compatibility ensures that both higher level devices and legacy devices could still communicate on the improved wireless communication system. In addition, it would have been obvious to try this combination because a POSITA understood legacy 802.11a devices were already successfully used, so it would make sense that the combined system of 802.11a and Zelst would be backwards-compatible with 802.11a and that any newer wireless communications devices that implement the combination would also be able to communicate with those same legacy devices.

174. This combination was also obvious because of the predictability of market demand for wireless communication devices operating on an improved wireless communication system with increased data throughput capabilities while maintaining accuracy and reliability. The market would desire to have still-operational legacy devices used on the new and improved wireless communications system. Thus, consumers would not be forced to purchase new

equipment each time the wireless communication system was improved. A POSITA additionally would have been motivated to combine these references in order to improve the reliability, performance, and efficiency of a wireless communication device for communicating on a wireless communication system.

J. Claim 14

175. The combination discloses “wherein the optimal extended long training sequence (Zelt’s 56 subcarrier ELTS) is longer than a long training sequence (52 subcarrier LTS) used by a legacy wireless local area network device (802.11a device) in accordance with a legacy wireless networking protocol standard (802.11a). *See* [1d].

K. Claim 15

176. The combination discloses this claim because 802.11a discloses that legacy wireless devices use the training sequence for carrier frequency offset. As explained for claim 13, the combination teaches compatibility with 802.11a legacy devices so that those legacy devices can use the 52 values of the LTS and simply ignore the additional 4 values of the ELTS. *See* [13]; *see also, e.g.*, EX1010, 4:51-67; EX1011, 1. Claim 15 merely recites one of the uses of the 52-value LTS specified by 802.11a, i.e., to estimate a carrier frequency offset, as shown in Figure 110 reproduced below.

17.3.3 PLCP preamble (SYNC)

The PLCP preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 110 and described in this subclause.

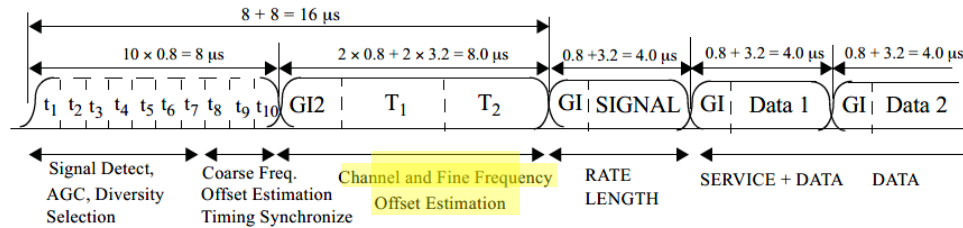


Figure 110—OFDM training structure

EX1008, FIG. 110.

L. Claim 16

177. As explained in the Combination Rationale and for limitation 1[c], in the combination, the LTS specified by 802.11a is maintained in the Zelst 56-subcarrier ELTS. The middle 52 subcarriers (+26 to -26) of the Zelst 56-subcarrier ELTS are identical to the LTS specified by 802.11a. Compare EX1010, FIG. 15A and EX1011, 4 with EX1008, 13. That is why it is backward compatible. Thus, the long training sequence specified by the legacy standard is maintained in the extended long training sequence.

M. Claim 17

178. The combination discloses the device “decreases power back-off.” This claim recites a well-known property of a low PAPR; *i.e.*, decreased power back-off. The ’629 patent admits that “The present invention provides an expanded long training sequence of minimum peak-to-average power ratio ***and thereby***

decreases power back-off.” EX1001, 4:15-17. The prior art provides the identical sequence and, therefore, identically decreases power back-off.

179. Boer similarly states: “the extra subcarriers at the edges are modulated in such a way that the peak-to-average power ratio (PAP) is lowest to minimize the effect of non-linearity of the power amplifiers.” EX1012, 5:1-3. A POSITA would have understood this statement to mean the expanded long training sequence, with its desirable low PAP, decreases power back-off. As a POSITA would have known, amplifiers have a non-linear region that can distort large signal values. When the PAP is high, the input signal (going into the amplifier) must be reduced (i.e., back off) to prevent the larger values from being distorted by the non-linear region of the amplifier. When the PAP is low, the input signal power can be increased (less back-off) since it is less likely to have a signal value that is impacted by the non-linear region.

N. Claim 18

180. As explained for claim 12, Figure 2 of 802.11-1999 discloses a wireless communications device (e.g., STA 2, STA 3) as an access point (AP). Figure 2 also discloses a wireless communications device (STA 1, STA 4, blue highlighting) registered with their respective access points (STA 2, STA 3, yellow highlighting). More specifically, 802.11-1999 describes the association process

where a wireless device (viz., a STA) associates (i.e., registers) with an access point. EX1006, 109-114.

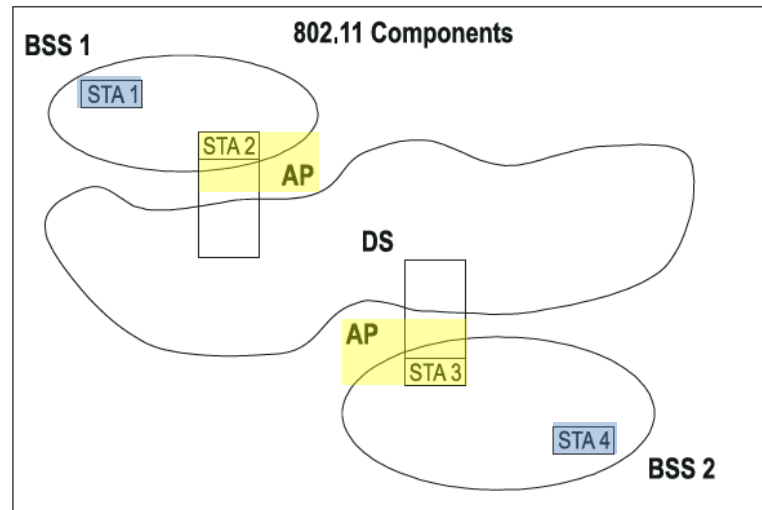


Figure 2—Distribution systems and access points

EX1006, FIG. 2.

O. Claim 19

181. See claim 8 (BPSK used for all subcarriers). As explained in claim 8, 802.11a defines the term “BPSK” to be “binary phase shift keying.” E1008, 2. 802.11a states that all of the 52 subcarriers can be modulated using BPSK. E1008, 3. Both Zelst and Jones also discloses BPSK encoding. EX1010, 16:14; EX1011, 6; EX1014, 5:49. In connection with Zelst’s FIG. 15A, each value of the 56 active indexed subcarriers, which includes the same 52 middle subcarriers as 802.11a (highlighted below), is either -1 or +1. The use of -1 and +1 tells a POSITA that binary phase shift key (“BPSK”) encoding is used for each sub-carrier, as required by this claim. More specifically, as discussed above, BPSK is well-known to use

one bit to determine the phase of the carrier (or sub-carrier in the case of OFDM). Those two phase values are 0 and π which correspond to multiplying the subcarriers by either 1 or -1 respectively as discussed above. Zelst also discloses the use of BPSK.

1200
↓

```
{ -1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1,
  1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1,
  0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1,
  1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1, }
```

FIG. 15A

EX1010, FIG. 15A.

182. The Zelst Provisional also discloses using +1 and -1 for each of 56 active subcarriers (highlighted below) of an extended long training sequence.

EX1011, 4.

20 MHz & 40 MHz Extended Long Training (ELT)

- **ELT for 20 MHz:**

$L_{-32,31} = \{-1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, 1, 1, 1, -1, -1, -1, 1, -1\}$

P. Claim 20

183. The combination discloses “a symbol mapper operatively coupled to the signal generator wherein the symbol mapper receives coded bits and generates symbols for each of 64 subcarriers of [an OFDM] sequence.”

184. 802.11a discloses an “Interleaving+Mapping” block that interacts with the IFFT.

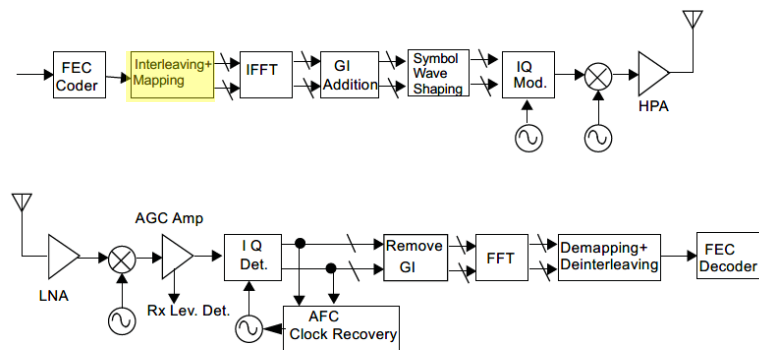


Figure 118— Transmitter and receiver block diagram for the OFDM PHY

EX1008, Figure 118 (annotated).

185. 802.11a explains: “[t]he OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM modulation, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of NBPSC (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 116, with the input bit, b0, being the earliest in the stream.”

EX1008, 19. This describes a symbol mapper that receives coded bits (the encoded

and interleaved binary serial input data) and generates symbols according to BPSK or another modulation scheme.

186. Annex G of 802.11a provides “an example of encoding a frame for the OFDM PHY.” EX1008, 54. Section G.6.3 describes mapping coded bits into symbols: “The frequency domain symbols are generated by grouping 4 coded bits and mapping into complex 16-QAM symbols according to Table 84...The frequency domain is shown in Table G.22.” EX1008, 71-74. Table G.22 is titled “Frequency domain of the first DATA symbol” and contains real and imaginary values for 64 sub-carriers of which 52 are non-zero. EX1008, 74. This disclosure shows that the “symbol mapper receives coded bits and generates symbols for each of 64 subcarriers of an Orthogonal Frequency Division Multiplexing sequence” as required by the claim.

187. Further, Jones, which incorporates by reference 802.11a (EX1014, 5:32-40), discloses in connection with Figure 3, that “input data is provided (generally as a bit stream) to encoder 312 (highlighted below) which encodes the data stream into a sequence of complex numbers (symbols)” and that “encoding may include ... mapping groups of bits to symbols in a signaling constellation.” EX1014, 5:42-49, 1:29-39.

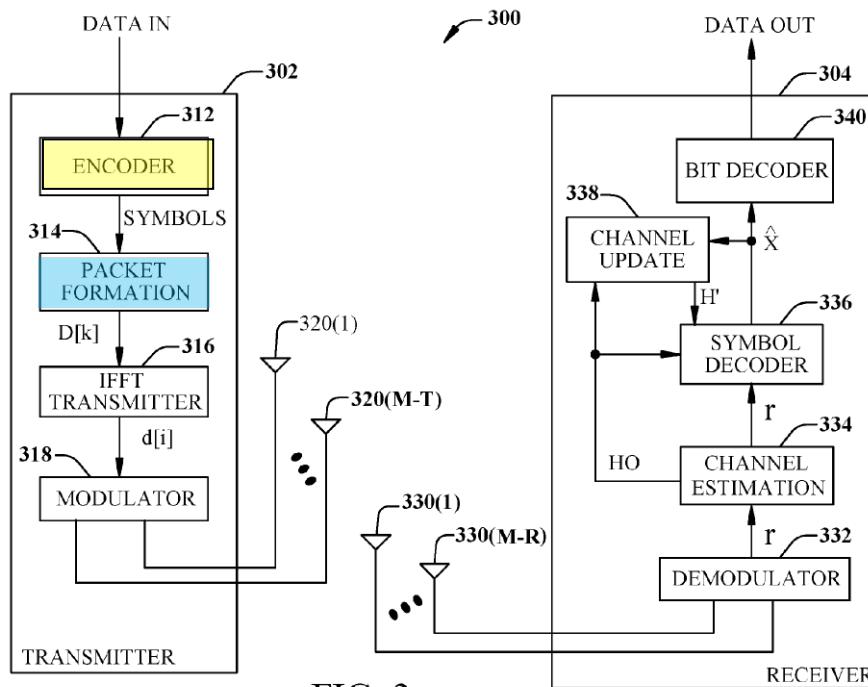


FIG. 3

188. Jones also discloses that “packet formation block 314 provides groups of symbols to IFFT module 316, which uses the group of symbols to modulate a group of OFDM subcarriers” and that “IFFT module 316 generates 64 time-domain samples $d[i]$.” EX1014, 5:65-6:2.

189. As explained above for limitation 1[a], packet formation block 312 (highlighted above in blue) is the recited signal generator. Thus, Jones discloses a symbol mapper (encoder 312) operatively coupled to the signal generator (packet formation block 314). Jones states that the IFFT is provided 64 frequency-domain symbols at its input from encoder block 312. EX1014, 5:56-6:10.

Q. Claim 21

190. In the combination, “the legacy wireless networking protocol standard for the [OFDM] scheme (802.11a) corresponds to exactly 52 active subcarriers (52-subcarrier LTS).” *See* Combination Rationale, 1[a].

R. Claim 22

191. In the combination, the LTS in 802.11a is identical to the recited sequence in claim 22 because it has 52 active subcarriers (blue) with the 0 index subcarrier set to zero (red). *See* [1f].

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, 1, 1, 1, 0, \\ 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, 1, 1, 1\} \quad (8)$$

EX1008, 13.

S. Claim 23

192. The combination discloses claim 23 which merely aggregates the limitations in dependent claims already addressed above.

1. 23[pre]

193. *See* [1pre].

2. 23[a]

194. *See* claim 9.

3. 23[b]

195. *See* claim 10.

4. 23[c]

196. *See* claim 13.

5. 23[d]

197. *See* claim 15.

6. 23[e]

198. *See* claim 17.

7. 23[f]

199. *See* claim 19.

8. 23[g]

200. *See* claim 20.

T. Claim 27

201. The combination discloses “wherein, an output of the Inverse Fourier Transformer is operatively coupled to a time-domain windower.”

202. Zelst, Boer and Jones are improvements on 802.11a, which states “[t]he time domain representation is derived by performing IFFT on the contents of Table G.5, cyclically extending the result to get the cyclic prefix, and then multiplying with the window function given in G.3.1.” E1008, 59. The window function in G.3.1 is:

$$W(k) = \begin{bmatrix} 0.5 & k = 0 \\ 1 & 1 \leq k \leq 16 \\ 0.5 & k = 60 \end{bmatrix}$$

E1008, 57. The functional block applying the window function in G.3.1 is a time-domain windower.

203. A POSITA would have understood that the combination would have to operatively couple the output of the IFFT to a time-domain windower as claimed because that was required by 802.11a in order to ensure backwards compatibility, which Zelst, Boer and Jones state is desirable and achieved. Moreover, a POSITA would have understood that the above-described improvements to 802.11a disclosed in Zelst, increasing the number of subcarriers from 52 to 56 and 63, also require a time-domain windower operatively coupled to the output of the IFFT because a time-domain windower provides spectral shaping which is required regardless of the number of sub-carriers used by the data and/or training sequences. Time-domain windowing is used to help ensure the spectral mask is met, which is a requirement regardless of the number of subcarriers used.

XII. GROUND 2: JONES, 802.11A, 802.11-1999 AND BOER

204. Ground 2 is largely duplicative of Ground 1 with one exception; Zelst is not included in Ground 2. PO has asserted in the related litigation that Zelst (EX1010) is not prior art since it is not entitled to the filing date of the Zelst Provisional (EX1011). But as demonstrated above, Zelst is entitled to the filing date of its Provisional and therefore, is prior art to the '629 patent. Out of an abundance of caution, I include this separate Ground 2 which relies on all of the

evidence and opinions in Ground 1, except the evidence and opinions regarding Zelst.

A. Combination Rationale

205. Jones, 802.11a and 802.11-1999 set the same foundation for Ground 2 as they do for Ground 1 (*see* XI.A), which is incorporated by reference. Specifically, Jones teaches an ELTS could use any of 53-63 subcarriers (including exactly 56 subcarriers) as required by [1e], and teaches the precise encodings required by [1f].

1. It would have been obvious in the combination to use the Boer 56-Subcarrier ELTS

206. In Ground 1, I relied on Zelst and Boer's teaching that exactly 56 subcarriers should be used as required by [1e] and Zelst and Boer's teaching (with Jones) of the precise encodings required by [1f]. I referred to this ELTS as the "Zelst 56-Subcarrier ELTS" to distinguish Grounds 1 and 2. Here, in Ground 2, I rely on Boer's teachings (in addition to Jones) and so I refer to the ELTS as the "Boer 56-Subcarrier ELTS" to distinguish from Ground 1.

207. It would have been obvious for a POSITA to use the Boer 56-Subcarrier ELTS in view of the same teachings and opinions explained in Ground 1 for Jones, Boer, 802.11a and 802.11-1999. In short, Boer's express teaching (including the teachings incorporated from the Boer Provisional) that 56 subcarriers would fit within the 802.11a spectral mask would have rendered

obvious to a POSITA to implement Jones's ELTS using exactly 56-subcarriers.

The opinions and evidence from Ground 1 (*see* XI) are incorporated by reference here in Ground 2.

2. It would have been obvious in the combination to use the functional blocks disclosed in Jones

208. *See* XI.A.2, which is incorporated by reference here.

B. Claims 1, 4, 8-23 and 27

209. I incorporate the opinions and evidence from the corresponding limitations of these claims in Ground 1 (XI.B-T), excluding the citations to Zelst. References to "Zelst 56-Subcarrier ELTS" in the incorporated opinions should be replaced with "Boer 56-Subcarrier ELTS" for this ground, to reflect that only the teachings of Boer and Jones (along with 802.11a and 802.11-1999) are being relied on to teach 56-subcarriers in this ground.

XIII. CONCLUSION

210. Claims 1, 4, 8-23 and 27 of the '629 patent are invalid for the reasons discussed above.

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

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Teaching

Undergraduate Courses

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

Graduate Courses

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

Teaching Evaluations (Fall 2001 through Spring 2011)

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

Teaching Evaluations (Fall 2011 through Spring 2023)

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

Short Courses Given

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

Advising

Current

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

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

Former

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

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17. Heba Shaban, "A Novel Highly Accurate Wireless Wearable Human Locomotion," Ph.D., April 2010, *currently employed by Arab Academy of Science and Technology.*
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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.*
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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: "Design and Control of Multi-modal Sensors and Sensor Networks,"
Sponsor: Army Research Lab,
Funding: \$200,000 (\$910,962 max)
Period of Performance: , Septemper 1, 2023 - August 31, 2024
Percent: 100
2. Title: "Multi-Target Detection and Tracking with Multi-Mode Radar Networks,"
Sponsor: Lockheed Martin,
Funding: \$150,000,
Period of Performance: August 1, 2023 - July 31, 2024
Percent: 50
3. Title: "Mobile Distributed MIMO: Learning Meets Spreading in Networking,"
Sponsor: Advanced Technology International,
Funding: \$358,531 (max \$8,741,427),
Period of Performance: September 19, 2023 - July 17, 2026
Percent: 10
4. Title: "Development of Machine Learning Methodologies for Radar Signal Classification,"
Sponsor: Alion,
Fudning: \$118,000,
Period of Performance: January 26, 2023 – December 31, 2024
Percent: 100
5. Title: "Prototyping 5G-enabled Indoor Geolocation System for Fire Fighters using UAVs,"
Sponsor: National Institutes of Standards and Technology (through George Mason University),
Fudning: \$849,994,
Period of Performance: June 1, 2022 – May 31, 2025
Percent: 34

6. 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%.
7. 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%.
8. 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%.
9. 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%
10. 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%
11. 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%
12. 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%
13. 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%
14. Title: “Cognitive Radar for C-SCoRE: Enhancing Radar Functionality through Interference Analysis and Avoidance,”
Sponsor: Georgia Tech Research Institute (AFRL)
Funding: \$285,000
Period of Performance: December 15, 2018 – May 30, 2022
Percent: 100%

15. 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%
16. Title: "MU-MIMO Channel Characterization"
Sponsor: GIRD Systems
Funding: \$117,712
Period of Performance: April 1, 2017 - March 31, 2019.
Percent: 100%
17. 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%
18. 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%
19. Title: "Hyper-wideband Communications"
Sponsor: Defense Advanced Research Projects Agency
Funding: \$182,451
Period of Performance: May 1, 2015 - April 30, 2016.
Percent: 50%
20. 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%
21. 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%
22. 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%
23. Title: "Improving Cellular Positioning through Collaboration"
Sponsor: Polaris Wireless
Funding: \$82,813
Period of Performance: 11/01/2013 - 10/31/2014
Percent: 100%
24. 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%
25. 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%
26. 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%
27. 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%
28. 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%
29. 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%
30. 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%
31. 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%

32. 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%
33. 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%
34. 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%
35. 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%
36. 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%
37. 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%
38. 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%
39. 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%

40. 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%
41. Title: UWB Communications
Sponsor: Motorola
Period of Performance: 12/15/03 – 12/14/04
Funding: \$35,000
PI: Buehrer
Percentage: 100%
42. 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%
43. 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%
44. Title: Indoor Propagation
Sponsor: Qualcomm, Inc.
Funding: \$14,000
Period of Performance: 12/1/03 – 5/15/04
PI: R.M. Buehrer
Percent: 100%
45. 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%
46. 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%
47. 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%

48. 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%

49. 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%

50. 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. 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.
2. 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.
3. J. Yu, W. Howard, Y. Xu, and R.M. Buehrer, "Model Order Estimation in the Presence of multipath Interference using Residual Convolutional Neural Networks," *to appear in IEEE Transactions on Wireless Communications*, Nov. 2023, DOI: 10.1109/TWC.2023.3339803.
4. 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.
5. 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.
6. 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.
7. 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.
8. 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.

9. 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.
10. 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.
11. 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
12. 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.
13. 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
14. 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.
15. 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
16. 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>.
17. 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
18. 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.
19. 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.
20. 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.
21. 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.
22. 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.
23. 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.

24. 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.
25. 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.
26. 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.
27. 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.
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Conference Publications

1. M. Moore, C.W. Headley, and R.M. Buehrer, "Time-Diverse Doppler-Only PNT: Initial Solution," accepted for *The ION GNSS+ 2024 Conference*, September 16-20, 2024, Baltimore, Maryland.
2. G. Duggal, H. S. Dhillon and R.M. Buehrer, "3D Positioning using a New Diffraction Path Model," accepted for presentation at the *2024 IEEE International Communication Conference (ICC 2024), 3rd Workshop on Synergies of Communication, Localization, and Sensing towards 6G*, Denver, CO, June 9-13, 2024.
3. 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.
4. 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.
5. Z. Schutz, C.E. Thornton, D.J. Jakubisin, and R.M. Buehrer, "Linear Jamming Bandits: Learning to Jam OFDM-Modulated Signals," *accepted for presentation/publication at the 2024 IEEE International Communications Conference (ICC'24)*, 9–13 June 2024, Denver, CO, USA.
6. 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 (NRSM)*, Jan. 9 - 13, 2024, Boulder, CO.
7. 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 (NRSM)*, Jan. 9 - 13, 2024, Boulder, CO.

8. 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**.
9. H. Hu, H.S. Dhillon and R.M. Buehrer, "Landmark-based Localization using Pairwise Constraints: A Stochastic Geometry Perspective," *Proceedings of SpaSWiN 2023*.
10. 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.
11. 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.
12. 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.
13. 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.
14. 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*.
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16. 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.
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20. 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.
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22. 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.
23. 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.
24. 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.

25. 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)
26. 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.
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29. 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.
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33. 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.
34. 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.
35. 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.
36. 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.
37. 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.
38. 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.
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152. N. V. Rivera, S. Venkatesh, and R.M. Buehrer, "Non-invasive Wireless Application of Ultra Wideband (UWB) for Estimation of Single and Multiple Person Vital-Signs," *2006 Engineering in Medicine and Biology Conference*, New York, August 30-September 3, 2006.
153. 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.

154. 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.
155. 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.
156. 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)**
157. 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.
158. 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.
159. 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.
160. 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.
161. 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.
162. 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.
163. 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.
164. 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.
165. 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.
166. 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.
167. 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.
168. 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.
169. 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.

170. 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.
171. 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.
172. 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.
173. 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
174. 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.
175. 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.
176. 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.
177. 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.
178. 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.
179. 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.
180. 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.
181. 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.
182. 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.
183. 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.
184. 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.
185. 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.
186. 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.

187. 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.
188. 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.
189. 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.
190. 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.
191. 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.
192. 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.
193. 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.
194. 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.
195. 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.
196. 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.
197. 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.
198. 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.
199. 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.
200. 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.
201. 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.
202. 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.
203. 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.
204. 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.

205. 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.
206. 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.
207. 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.
208. 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.
209. 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.
210. 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.
211. 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.
212. 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.
213. 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.
214. 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.
215. 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.
216. 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.
217. 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
- Organizer and Technical Co-Chair, 2015 IEEE Global Communications Conference Workshop on Localization and Tracking: Indoors, Outdoors and Emerging Networks (GC - LION '15), December 6, 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

- 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.
 - 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: Torys, LLP.
 - Represented: TELUS Communications, Bell Mobility, and Rogers Communications
 - Served as testifying expert. Analyzed certain patents (and the prior art) and provided technical reports on sufficiency, validity and potential double-patenting.
 - Technology: Resource allocation in wireless networks
 - Dates: January 2019 - November 2019
- Samsung vs. Sharp
 - Law firm: Fish and Richardson
 - Represented: Samsung
 - Analyzed technical aspects of patent to aid validity/invalidity analysis.
 - Technology: Feedback in MIMO-OFDM systems
 - Dates: April 2019 - July 2019
- American Patents, LLC vs. HP, Inc.
 - Law firm: DLA Piper
 - Represented: HP, Inc.
 - Analyzed technical aspects of two patents to aid validity/invalidity analysis.
 - Case 18-cv-700 (E.D. Tex.)
 - Technology: MIMO/OFDM synchronization in cellular systems
 - Dates: June 2019
- Blackberry vs. Uniloc, LLC.
 - Law firm: Oblon
 - Represented: Blackberry (Petitioner)
 - Wrote declaration to the USPTO concerning the disclosure of certain features of two patents in previous references.
 - Technology: Traffic mapping between logical channels and transport channels in wireless systems
 - Dates: June 2019.
- Apple, Inc. vs. Wi-LAN
 - Law firm: DLA Piper
 - Represented: Apple (Plaintiff)
 - Served as testifying expert witness for litigation (non-infringing alternatives). **Was deposed. Testified at trial.**
 - Case 3:14-cv-2235-DMS-BLM
 - Technology: Resource Allocation in Wireless Systems
 - District: Southern District of California
 - Dates: November '17 - July '18

- Apple, Inc., LG Electronics Inc., Samsung Electronics Co., Ltd., and Samsung Electronics America, Inc. vs. Uniloc, LLC.
 - Law firm: Fish and Richardson
 - Represented: Apple, Inc., LG Electronics Inc., Samsung Electronics Co., Ltd., and Samsung Electronics America, Inc. (Petitioner)
 - Wrote declarations to the USPTO concerning the disclosure of certain features of two patents in previous references.
 - IPR2019-00219, IPR2019-00222
 - Technology: Traffic mapping between logical channels and transport channels in Wireless Systems; Multi-mode transceivers
 - Dates: September 2018 - November 2019.
- CCE vs. Apple, Inc.
 - Law firm: DLA Piper
 - Represented: Apple (Defendant)
 - Served as testifying expert witness for litigation (infringement analysis). **Was deposed.**
 - 2:15-cv-00576-RWS-RSP
 - Technology: Power Headroom Reporting in Cellular Systems
 - District: Eastern District of Texas
 - Dates: January 2017 - July 2017
- Nokia Technologies vs. Apple, Inc.
 - Law firm: Wilmer-Hale
 - Represented: Apple (Defendant)
 - Served as testifying expert witness for litigation (infringement analysis)
 - Technology: antennas for handheld mobile devices
 - District: Eastern District of Texas
 - Dates: January 2017 - June 2017
- Core Wireless vs. Apple, Inc.
 - Law Firm: Wilmer-Hale
 - Represented: Apple (Defendant)
 - Role: Served as testifying expert witness for litigation (infringement and validity analysis). **Was deposed. Testified at trial.**
 - Case 5:15-cv-5008
 - Technology: Control Channels and Frame Stealing in 2G (GSM) cellular networks.
 - District: The US District Court for the Northern District of California
 - Dates: May 2015 - December 2016.
- AMERICAN SYSTEMS vs. US Navy
 - Law Firm: Miles and Stockbridge
 - Represented: AMERICAN SYSTEMS (Plaintiff)
 - Role: Served as testifying expert witness for litigation (case settled prior to expert reports being filed).
 - Technology: Wireless mesh networks.

- Dates: Nov. 2014 - June 2015.
- TruPosition, Inc. vs. LM Ericsson Telephone Company, et. al.
 - Law Firm: Constantine-Cannon LLP
 - Represented: TruePosition (Plaintiff)
 - Role: Served as testifying expert witness for litigation. Case settled prior to depositions being taken.
 - Case 2:11-cv-04574-RK
 - Technology: Cellular-based geolocation for 4G (LTE) cellular networks.
 - District: The US District Court for the Eastern District of Pennsylvania
 - Dates: March 2013 - July 2014.
- Andrew, LLC vs TruPosition, Inc.
 - Law Firm: Patterson Belknap Webb & Tyler LLP
 - Represented: Andrew, LLC (Plaintiff)
 - Role: Served as testifying expert witness for patent litigation. **Was deposed.**
 - Civil Action 09-669
 - Technology: Cellular-based (2G, 3G) geolocation.
 - District: The US District Court for the District of Delaware
 - Dates: Nov. 2009 - March 2010.
- TCL vs. 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.