

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG ELECTRONICS CO., LTD.,
Petitioner,

v.

WILUS INSTITUTE OF STANDARDS AND TECHNOLOGY INC.,
Patent Owner.

Case No. IPR2026-01164
U.S. Patent No. 12,004,262

DECLARATION OF TODOR COOKLEV, PH.D. IN SUPPORT OF
PATENT OWNER'S RESPONSE

I. INTRODUCTION

1. My name is Todor V. Cooklev. I have been retained as an expert witness to provide my independent opinion in regard to the matters at issue in *inter partes* review of U.S. Patent No. 12,004,262 ("the '262 patent") in IPR2025-01164. I have been retained by Wilus Institute of Standards and Technology, Inc., the Patent Owner in the above proceedings. Petitioner is Samsung Electronics Co. Ltd. ("Petitioner").

2. I am not a legal expert and offer no opinions on the law. However, I have been informed by counsel of the various legal standards that apply, and I have applied those standards in arriving at my conclusions.

II. QUALIFICATIONS

3. I am currently professor of electrical and computer engineering at Purdue University in Fort Wayne, Indiana. I teach several courses related to the hardware and software architectures of wireless systems and wireless devices. My research interests include most aspects of modern wireless systems, including hardware/software architectures.

4. I have received research funding from the National Science Foundation (NSF), the Defense Advanced Research Projects Agency (DARPA), the U.S. Air Force Research Laboratory, the Office of Naval Research, and a number of private companies, including major technology companies.

5. I received a Doctor of Philosophy (Ph.D.) degree in Electrical Engineering from Tokyo Institute of Technology in Tokyo, Japan in 1995.
6. I have authored and co-authored more than 100 peer-reviewed articles. I am also a named inventor on 32 U.S. patents, most of which relate to the hardware or software aspects of communication systems. For part of this work in 2019, I was inducted into the Purdue Inventors Hall of Fame. A list of my publications and patents appears in my *curriculum vitae* attached as Appendix 1. Among my publications is the textbook “Modern Communications Systems: A First Course”, published by the University of Michigan at the beginning of 2024.
7. I have also experience in private industry. My work has been in the areas of communication protocols, software, digital signal processing, and integrated circuit design for communication systems.
8. I have contributed to the development of several major standards for communication systems and numerous amendments. I have participated in many meetings of standards committees. I have prepared, submitted, and presented documents relating to technical matters considered by these committees.
9. Between 2000-2002 and 2005-2008 I was a Voting Member of the IEEE 802.11 Working Group. Around 2005-2007 I was Chair of a Study Group

within IEEE 802.11. For part of my work I received an award from IEEE Standards Association in 2012. I have reviewed and voted on most IEEE 802.11 standards and amendments published since 2000.

10. During this time period I have also reviewed and voted on other standards. Around 2007-2011 I participated in the Software-Defined Radio Forum (later the Wireless Innovation Forum). Around 2011-2012 I participated in the work of the 3GPP.

11. In 2020, I was elected to serve on the Board of Governors of the IEEE Standards Association. The Board of Governors provides overall leadership of the IEEE Standards Association.

12. Between 2017 and 2025 I was Series Editor for Wireless and Radio Communications of the IEEE Communications Standards Magazine (which is the premier journal in the field of communication standards). As a member of the Editorial Board I coordinated the review of scholarly manuscripts submitted to the wireless and radio communications series.

13. I am qualified by education and experience to testify as an expert with respect to subject matter in the fields of wireless communications, wireless communications protocols, hardware and software architectures for wireless devices, signal processing algorithms, and related areas.

14. I have attached a current copy of my *curriculum vitae* as Appendix 1, which includes a list of my publications. My CV also includes a list of cases during at least the last five years in which I have testified as an expert either at a trial or deposition.

III. COMPENSATION

15. I am being compensated at my standard hourly rate for my time spent working in connection with this case. My compensation does not depend on my opinions or on the outcome of this litigation. If called as a witness, I would testify as to the statements and opinions contained in this report.

IV. MATERIALS CONSIDERED

16. In the course of conducting my analysis and forming my opinions, I have reviewed materials including those listed below:

- U.S. Patent No. 12,004,262 (Ex. 1001 (the '262 Patent)) ("the '262 patent");
- The prosecution history of the '262 patent (Ex. 1002);
- The Declaration signed by Dr. Christopher Hansen in IPR2025-01164 (Ex. 1003 (Hansen Decl.)) (the "Hansen Declaration");
- IEEE 802.11ax/D1.0 (Ex. 1005);
- Yang (Ex. 1006);
- The exhibits and other documents cited herein.

V. APPLICABLE LEGAL STANDARDS

A. Level of Ordinary Skill in the Art

17. My opinions in this declaration are based on the understandings of a person of ordinary skill in the art, which I understand is sometimes referred to as an “ordinary artisan” or by the acronyms “POSITA” or “PHOSITA,” as of the time of the invention, which I understand is here assumed to be the April 14, 2017 Critical Date. I understand that the person of ordinary skill in the art is a hypothetical person who is presumed to have known the relevant art at the time of the invention. By “relevant,” I mean relevant to the challenged claims of the ’262 patent.

18. I understand that factual indicators of the level of ordinary skill in the art include the various prior art approaches employed, the types of problems encountered in the art, the rapidity with which innovations are made, the sophistication of the technology involved, and the educational background of those actively working in the field. I understand that, in assessing the level of skill of a person of ordinary skill in the art, one should consider the type of problems encountered in the art, the prior solutions to those problems found in the prior art references, the rapidity with which innovations are made, the sophistication of the technology, the level of education of active workers in the field,

and my own experience working with those of skill in the art at the time of the invention.

19. In this case, Dr. Hansen has asserted in his declaration that a person of ordinary skill in the art as of the time of the '262 patent would have had:

a Bachelor's degree in electrical engineering, computer engineering, computer science, or a related field, and at least 3 years of experience in the research, design or development of wireless communication devices, systems, and/or networks, or the equivalent. Increased educational experience can make up for less work experience, and vice versa.

Ex. 1003 (Hansen Decl.) at ¶ 30.

20. For the purposes of this declaration, I accept Dr. Hansen's proposed qualifications of a POSITA.

21. Although my qualifications exceeded those of a POSITA, my analysis and opinions are from the perspective of a POSITA, as set forth above.

22. As further discussed below, my opinions as stated in this declaration are valid even if the Board adopts a slightly different level of ordinary skill in the art.

B. My Understanding of Legal Standards

23. When considering the '262 patent and stating my opinions, I rely on the following legal standards as described to me by the attorneys for Wilus Institute of Standards and Technology, Inc.

24. I understand that a patent claim is unpatentable if the claimed invention would have been obvious to a person of ordinary skill in the art at the time of the purported invention.

25. I understand that an obviousness analysis involves comparing a claim to the prior art to determine whether the claimed invention would have been obvious to a person of ordinary skill in the art at the time of the invention in view of the prior art and in light of the general knowledge in the art as a whole. I also understand that obviousness is ultimately a legal conclusion based on underlying facts of four general types, all of which must be considered: (1) the scope and content of the prior art; (2) the level of ordinary skill in the art; (3) the differences between the claimed invention and the prior art; and (4) any objective indicia of non-obviousness, including any praise of the invention.

26. I also understand that obviousness may be established under certain circumstances by combining or modifying the teachings of the prior art. Specific teachings, suggestions, or motivations to combine any first prior art reference with a second prior art reference can be explicit or implicit, but must have

existed before the date of purported invention. I understand that prior art references themselves may be one source of a specific teaching or suggestion to combine features of the prior art, but that such suggestions or motivations to combine art may come from the knowledge that a person of ordinary skill in the art would have had.

27. I understand that a reference may be relied upon for all that it teaches, including uses beyond its primary purpose, but also including teachings that lead away from the invention. I understand that a reference may be said to teach away when a person of ordinary skill, upon reading the reference, would be discouraged from following the path set out in the reference, although the mere disclosure of alternative designs does not teach away.

28. I further understand that whether there is a reasonable expectation of success in combining references in a particular way is also relevant to the analysis.

29. I understand that it is improper to use hindsight to combine references or elements of references to reconstruct the invention using the claims as a guide. My analysis of the prior art is made from the perspective of a person of ordinary skill in the art at the time of the invention.

30. I am not offering any legal opinions in this declaration nor am I qualified to do so. I only consider such legal standards in framing my opinions and conclusions as well as placing assertions made by Petitioner in the Petition

into the proper context. Additionally, from a subject matter perspective, I understand that the petitioner always has the burden of persuasion regarding a challenge of patentability of an invention under an *inter partes* review.

VI. OVERVIEW OF THE '262 PATENT

31. The '262 Patent is directed to wireless communication in IEEE 802.11 WLAN (Wi-Fi) systems, and specifically to how a wireless communication terminal (a non-AP station, or "STA") sets the "BSS color" field of a trigger-based PPDU that it transmits in response to a trigger frame from an access point ("AP"). Generally, the technology is implemented in products that support the IEEE 802.11ax (Wi-Fi 6) standard.

32. "BSS color" is a 6-bit identifier that 802.11ax introduced to let devices operating in the same radio channel quickly distinguish frames from their own Basic Service Set (BSS) from frames originating in a neighboring Overlapping BSS (OBSS). Ex. 1001 (the '262 Patent) at FIGS. 1–2. The BSS color is carried in a physical-layer signaling field of the High Efficiency (HE) PPDU — specifically, the HE-SIG-A field — so that a receiving STA can identify the frame's BSS as early as the physical-layer header.

33. In 802.11ax, the AP uses OFDMA (orthogonal frequency-division multiple access) to simultaneously schedule uplink transmissions from multiple non-AP STAs. The AP first sends a Trigger frame identifying which STAs may

transmit and on which resource units; each solicited STA then transmits a “trigger-based PPDU” in response, time-aligned at the AP. *See* Ex. 1001 (the ’262 Patent) at 12:9–13, FIG. 6. Each trigger-based PPDU carries a BSS color in the TXVECTOR parameter BSS_COLOR, which populates the BSS Color subfield of the HE-SIG-A field of the transmitted PPDU.

34. If the Trigger frame that solicits a response is itself carried in an HE PPDU, the receiving STA can obtain the BSS color directly from the HE-SIG-A field of that HE PPDU and use that value for its trigger-based PPDU response. Ex. 1001 (the ’262 Patent) at 20:41–49, FIGS. 14, 20–23. If the Trigger frame is instead carried in a non-HE PPDU — for example, a Very High Throughput (VHT) PPDU inherited from the earlier 802.11-2016 standard — there is no HE-SIG-A field, and so the BSS color is not communicated at the physical layer. The STA has to derive the BSS color for its trigger-based PPDU response from a different source. Ex. 1001 (the ’262 Patent) at 54:19–35.

35. The ’262 Patent describes the technical scenario that arises when the AP changes its BSS color while the STA is responding to non-HE-PPDU trigger frames. Ex. 1001 (the ’262 Patent) at 38:40–55, 39:12–20, FIGS. 22–23. In 802.11ax, an AP that detects an OBSS color collision may change its BSS color. The AP announces the change via a BSS Color Change Announcement element included in Beacon, Probe Response, and (Re)Association Response

frames, and it transitions to the new color at the BSS Color change Target Beacon Transmission Time (TBTT). But a STA will not always receive every beacon the AP transmits. If a STA misses a beacon carrying the updated HE Operation element, the STA's most recently received Operation element will hold the old BSS color even after the BSS Color change TBTT has passed. The '262 Patent's specification depicts this scenario in FIG. 22: STA1 receives the Color Change Announcement and the updated Operation element; STA2 misses the beacon carrying the updated Operation element. When a Trigger frame arrives in a non-HE PPDU after the TBTT, STA1 and STA2 have different BSS color information available.

36. The '262 Patent's solution is to introduce an independent variable called the "active BSS color" that the STA maintains and updates dynamically. Under the claims, the "active BSS color" defaults to the value set by the most recently received Operation element ([1.7]/[4.5]) and is updated to the new color when the AP-announced BSS Color change time point is reached ([1.8]/[4.6]), independently of whether the STA has received an updated Operation element carrying the new color. When the Trigger frame arrives in a non-HE PPDU, the STA sets the BSS color of its trigger-based PPDU according to the active BSS color ([1.5]/[4.3]) rather than reaching directly for the Operation element. Ex. 1001 (the '262 Patent) at 20:49–58, claim 1. This

mechanism reconciles the AP-side color-change announcement with the non-HE-PPDU trigger case — including for a STA that has not received the updated Operation element — by routing the trigger-based PPDU's BSS color through the active-BSS-color variable.

37. The “active BSS color” concept, and the rule that a STA responding to a non-HE-PPDU trigger uses the active BSS color as defined in § 27.11.4, were ultimately adopted into the 802.11ax draft specification at D2.3 in 2018 — after the '262 Patent's inventor raised them through IEEE comment resolution. 802.11ax/D2.3 (Ex. 2012). The history of that adoption is addressed in § 13 of this declaration.

VII. CLAIMS-AT-ISSUE

38. I understand that Petitioner has challenged claims 1-4 of the '262 patent.

VIII. OPINIONS REGARDING CLAIM CONSTRUCTION

39. In this section I discuss the technical meaning of the limitations recited in claim 1 and claim 4 of the '262 Patent. My focus is on the operational rule that elements [1.5]/[4.3] and [1.8]/[4.6] together prescribe for a wireless communication terminal in the non-HE-PPDU trigger scenario. I also explain why, as of the April 14, 2017 Critical Date, the prior art did not recognize the color-change scenario the claims address and did not use the “active BSS color” mechanism the claims require.

A. The Non-HE-PPDU Trigger Scenario

40. Element [1.5] of claim 1 (and the parallel [4.3] of claim 4) applies in a specific technical scenario: the wireless communication terminal receives a trigger frame inside a PPDU whose physical-layer signaling fields do not include a field for indicating the BSS color. Ex. 1001 (the '262 Patent), claim 1. In IEEE 802.11ax terminology, an “HE PPDU” carries an HE-SIG-A field that includes a BSS Color subfield — so an HE PPDU is *not* within element [1.5]’s scope. A “non-HE PPDU” — such as a Very High Throughput (VHT) PPDU from the 802.11-2016 family — does not carry an HE-SIG-A field and therefore does not indicate a BSS color at the physical layer. A POSITA reading claim 1 in light of the specification would understand element [1.5]’s condition (“a PPDU format in which any physical layer signaling field including the field for indicating the BSS color is not included”) to identify the non-HE PPDU case.

41. The non-HE-PPDU trigger case matters technically because it is the case in which the usual physical-layer channel for communicating the BSS color — the HE-SIG-A field — is unavailable. Without that channel, the terminal has to obtain the BSS color for its trigger-based response PPDU from somewhere else. The claims specify that “somewhere else” with the term “active BSS color” in [1.5]/[4.3].

B. Element [1.5]/[4.3] — Terminal Uses “Active BSS Color”

42. Under element [1.5], when the terminal is in the non-HE-PPDU trigger scenario, the terminal sets the BSS color of the trigger-based PPDU “according to an active BSS color of the wireless communication terminal.” Ex. 1001 (the ’262 Patent), claim 1, element [1.5]. The operative phrase is “active BSS color,” and the operative action is that the terminal uses that value — not a value from the physical-layer BSS color field (there is none in a non-HE PPDU), and not a value chosen ad hoc. The terminal uses the particular claim-defined variable.

C. Element [1.8]/[4.6] — The “Active BSS Color” Is Dynamically Maintained

43. Element [1.8] of claim 1 (and the parallel [4.6] of claim 4) prescribes how the “active BSS color” updates: when the wireless communication terminal receives information on a BSS color change from the AP, and when the BSS color change time point indicated by that information is reached, “the active BSS color is set to a value of a BSS color indicated by the information on the BSS color change.” Ex. 1001 (the ’262 Patent), claim 1, element [1.8]. Read with element [1.7] — which defines the active BSS color as “a BSS color actually used by the wireless communication terminal and set by an Operation element” — element [1.8] establishes a time-gated update mechanism. The active BSS color defaults to the value set by the most recently received

Operation element and updates to the new color at the AP-announced change time point. A POSITA would understand the claimed variable as dynamically maintained — not as a static lookup — and would understand that the update happens independently of whether the terminal has also received an updated Operation element carrying the new color.

44. FIG. 22 of the '262 Patent illustrates the operational consequences of this mechanism. The figure depicts two terminals in the same BSS: STA1 and STA2. STA1 receives the AP's BSS Color Change Announcement beacon. STA2 does not. Ex. 1001 (the '262 Patent) at FIG. 22; 38:40–55, 39:12–20. After the BSS Color change TBTT, STA1's active BSS color has been updated to the new color (the announcement was received; the change time point has passed). STA2's active BSS color has not been updated (STA2 missed the announcement). Both STAs practice the claim's rule: element [1.5] directs each to set the BSS color of its trigger-based PPDU “according to an active BSS color,” and each does so — STA1 using the updated value, STA2 using its prior Operation-element value. The claim's rule operates uniformly in both cases; only the run-time state of the active-BSS-color variable differs.

D. The Combined Operational Rule

45. Read together, elements [1.5], [1.7], and [1.8] prescribe a single operational rule: when a wireless communication terminal receives a trigger frame

in a non-HE PPDU, the terminal sets the BSS color of its trigger-based PPDU according to an active BSS color that (a) is the value set by the most recently received Operation element and (b) is updated to the new color at the AP-announced BSS Color change TBTT. The rule is fully specified by the three limitations operating together; removing any one of them removes part of the rule's operational content.

E. The “Active BSS Color” Concept Does Not Appear in 802.11ax Drafts Before D2.3

46. The phrase “active BSS color” does not appear in any 802.11ax draft before D2.3. I have reviewed D1.0 (Ex. 1005) and compared the text with D2.3 (Ex. 2012). The phrase is absent from D1.0, and it is absent from each of the IEEE submissions Petitioner relies on (802.11-17/0250r2 (Ex. 1007); 802.11-16/1415r0 (Ex. 1008); 802.11-17-0230r1 (Ex. 1011)). Petitioner's expert, Dr. Hansen, did not contest this. When asked whether the phrase “active BSS color” appears anywhere in D1.0, Dr. Hansen testified: “I — I'm not certain if — if that particular phrase appears in Draft 1.0 or not.” Ex. 2019 (Hansen Depo.) at 64:12–15.

47. The “active BSS color” concept was formally defined in D2.3, in § 27.11.4. 802.11ax/D2.3 (Ex. 2012). The record of how that definition was added to the specification — through IEEE comment resolution, responding

to CID 11730 submitted by the '262 Patent's named inventor in November 2017 — is discussed in § 13 of this declaration.

F. Technical Corroboration of the Applicant's Distinction of Yang

48. During prosecution of the '262 Patent, the applicant distinguished Yang (Ex. 1006) on the ground that Yang's BSS Color Change procedure operates on the "BSS Color subfield in the HE-SIG-A field of the DL HE PPDU" — that is, on HE PPDU where the physical-layer BSS color field is present. Ex. 1002 at 230 (applicant's December 11, 2023 Response to Office Action). In my opinion that distinction is technically correct. Yang's two-stage BSS Color Change procedure (¶¶ 0051–0059) describes the access point setting the BSS Color subfield in the HE-SIG-A field of DL HE PPDU transmitted by the AP. Yang (Ex. 1006) at [0051]–[0059]. None of Yang's disclosures concerns the scenario in which the PPDU carrying the trigger frame does not include any physical-layer BSS color field — the scenario [1.5]/[4.3] addresses. A POSITA reviewing Yang alongside the asserted claims would reach the same conclusion the applicant advanced to the examiner.

IX. OPINIONS REGARDING GROUND 1A

49. In this section I address the merits of Ground 1A, which asserts that claims 1–4 are unpatentable over IEEE 802.11ax Draft 1.0 (Ex. 1005) alone. I do not in this section opine on whether D1.0 qualifies as a prior-art printed

publication; Mr. Nikolich addresses that question in his declaration. I have been asked to assume, *arguendo*, that D1.0 qualifies as prior art, and I address here why, even on that assumption, D1.0 does not disclose the limitations of [1.5]/[4.3] or [1.8]/[4.6].

A. D1.0 § 27.5.2.3 Describes a Static Rule That Does Not Use the Term or Concept of “Active BSS Color”

50. The relevant portion of D1.0 § 27.5.2.3 reads: “A STA transmitting an HE trigger-based PPDU in response to a Trigger frame sets the TXVECTOR parameter as follows: . . . The BSS_COLOR parameter shall be set as follows: . . . If the Trigger frame was received in a non-HE PPDU, then set to the value of the BSS Color subfield of the most recently received HE Operation element for that BSS.” 802.11ax/D1.0 (Ex. 1005) at 168. The quoted rule tells a non-AP STA, in the non-HE-PPDU trigger case, to populate the trigger-based PPDU’s BSS_COLOR parameter using the value carried in the most recently received HE Operation element.

51. The § 27.5.2.3 rule is static. In my opinion, a POSITA reading D1.0 § 27.5.2.3 would understand that when a non-AP STA is in the non-HE-PPDU trigger case, its BSS_COLOR is set to whatever value is carried in the most recently received HE Operation element for the BSS — regardless of any other event, and without any conditional logic tied to whether the AP has announced a color change. There is no “active BSS color” concept in D1.0

§ 27.5.2.3, no independent variable that the STA maintains and updates, and no time-gated update rule. The text is a single conditional: if the trigger frame arrived in a non-HE PPDU, use the Operation-element value. Nothing more.

52. Dr. Hansen’s deposition testimony is consistent with this reading. When asked whether the § 27.5.2.3 passage “refer[s] to a[n] active BSS color,” Dr. Hansen testified that it “doesn’t use — doesn’t use the label ‘active’ here.” Ex. 2019 (Hansen Depo.) at 64:5–10. When asked whether the phrase “active BSS color” appears anywhere in D1.0, Dr. Hansen testified: “I — I’m not certain if — if that particular phrase appears in Draft 1.0 or not.” *Id.* at 64:12–15. From my review, the phrase does not appear in D1.0.

B. D1.0 Does Not Recognize the Color-Change Scenario That Elements [1.5]/[4.3] and [1.8]/[4.6] Address

53. Because D1.0 § 27.5.2.3’s rule is static, its behavior does not change when the AP has announced a BSS color change. A non-AP STA responding to a trigger frame in a non-HE PPDU will set BSS_COLOR to the value of the most recently received HE Operation element — even when the AP has announced a new BSS color via a BSS Color Change Announcement element, and even when the BSS Color change TBTT has been reached. If the STA has not yet received a beacon carrying the new HE Operation element, the “most recently received” Operation-element value is the *old* color. That is the precise scenario the ’262 Patent identifies and addresses. Ex. 1001 (the ’262 Patent)

at 38:40–55, 39:12–20. D1.0 does not recognize the scenario, and it provides no mechanism to handle it.

C. Table 28-1 Identifies That the BSS Color Field May Be Absent — Not What to Do When It Is

54. Petitioner also cites D1.0 Table 28-1 (Pet. at 30), which identifies the TXVECTOR/RXVECTOR parameter BSS_Color and notes that it may not be present in certain PPDU formats. In my opinion, identifying the absence of a parameter is different from disclosing what a terminal should do when the parameter is absent and the AP has announced a change. Table 28-1 does neither. It is a listing of parameters; it does not prescribe the operational rule required by [1.5]/[4.3] or [1.8]/[4.6].

D. The HE-PPDU Path Is the Opposite of What [1.5]/[4.3] Requires

55. Petitioner also observes that, under D1.0, a STA supporting an HE PPDU sets its BSS color based on the HE-SIG-A field. Pet. at 31–32. That observation, while accurate, is not responsive to element [1.5]/[4.3]. Element [1.5] applies only when the PPDU carrying the trigger frame is “a PPDU format in which any physical layer signaling field including the field for indicating the BSS color is *not* included.” Ex. 1001 (the ’262 Patent), claim 1. An HE PPDU *includes* an HE-SIG-A field, which in turn includes the BSS color subfield —

so the HE-PPDU path is the opposite of the scenario [1.5] addresses. In my opinion, the HE-PPDU behavior Petitioner cites does not satisfy [1.5].

E. D1.0 §§ 27.16.2 and 27.5.2.3 Contradict Each Other in the Non-HE-PPDU Trigger Scenario

56. D1.0 § 27.16.2 (“Selecting and advertising new BSS Color”) contains both AP-side provisions and a terminal-side provision. The AP-side provisions tell the AP how to announce and transition to a new BSS color. *See* 802.11ax/D1.0 (Ex. 1005) at 206. The terminal-side provision, on which my analysis focuses here, reads: “A HE non-AP STA that receives a BSS Color Change Announcement element shall start using the BSS Color specified in the received BSS Color Change Announcement element subsequent to the BSS Color change TBTT.” *Id.* By this rule, once the BSS Color change TBTT is reached, a non-AP STA that received the announcement is instructed to “start using” the new BSS color.

57. When § 27.16.2’s “start using” instruction is read together with § 27.5.2.3’s non-HE-PPDU-trigger rule, the two provisions collide in the scenario [1.5]/[4.3] and [1.8]/[4.6] address. Section 27.16.2 tells the STA, at and after the BSS Color change TBTT, to “start using” the new BSS color. Section 27.5.2.3 tells the STA, in the non-HE-PPDU trigger case, to use “the most recently received HE Operation element” value. If the STA has received the

BSS Color Change Announcement element but has not received a beacon carrying the new HE Operation element, § 27.16.2 points to the new color while § 27.5.2.3 points to the old Operation-element value. In my opinion, a POSITA reviewing these two sections of D1.0 together would recognize the contradiction — and would recognize that D1.0 provides no mechanism to resolve it.

58. The '262 Patent resolves the contradiction D1.0 leaves unresolved. Under [1.7]/[4.5], the active BSS color defaults to “a BSS color actually used by the wireless communication terminal and set by an Operation element.” Under [1.8]/[4.6], the active BSS color is updated to the announced new color at the BSS Color change TBTT, overriding the Operation-element value when the two diverge. Under [1.5]/[4.3], the terminal then uses the active BSS color for the trigger-based PPDU in response to a non-HE PPDU. The active BSS color is the independent variable that reconciles § 27.16.2’s “start using the new color” with § 27.5.2.3’s non-HE-PPDU trigger case. D1.0 does not contain this variable or its reconciliation mechanism.

F. § 27.16.2’s “Start Using” Instruction Is Not a Time-Gated Update of a Dynamic Active-BSS-Color Variable

59. Section 27.16.2’s terminal-side instruction — “start using” — does not teach the time-gated update of a dynamically maintained independent variable that [1.8]/[4.6] require. It does not use the term “active BSS color.” It does not

describe a variable distinct from the Operation-element value. It does not prescribe what the terminal is to do when it has received the announcement but not a beacon carrying the new HE Operation element. In my opinion, § 27.16.2's "start using" sentence, standing alone, is an instruction in the abstract; it is not the operational rule [1.8]/[4.6] require.

60. Dr. Hansen's deposition testimony confirms the AP-side aspects of § 27.16.2. Asked whether § 27.16.2 "is describing the behavior of the access point," Dr. Hansen testified: "It would be an allowed — like, an access point would be allowed to do this." Ex. 2019 (Hansen Depo.) at 73:15–21. Dr. Hansen was not asked about the terminal-side "start using" provision, but as explained above, that provision does not teach a time-gated update of the active BSS color either.

X. OPINIONS REGARDING GROUND 1B

61. Ground 1B asserts that claims 1–4 are unpatentable over D1.0 in view of Yang (Ex. 1006) and 802.11-2016 (Ex. 1010). In this section I explain why, on the technical merits, neither Yang, nor 802.11-2016 cures D1.0's deficiencies on elements [1.5]/[4.3] or [1.8]/[4.6], and why a POSITA would not have been motivated to make the combination Petitioner proposes.

A. Yang Is Used Only for Generic Hardware; It Does Not Teach the Active-BSS-Color Rule

62. The Petition’s Ground 1B mapping uses Yang only for two limitations that describe generic hardware: [1.1] (the transceiver) and [1.2] (the processor). Pet. at 13–14. For the dispositive limitations [1.5]/[4.3] and [1.8]/[4.6], Petitioner relies exclusively on D1.0. In my opinion, Yang does not disclose the active-BSS-color mechanism that those limitations require, for the reasons set out in Section VIII of this declaration regarding the scope of Yang’s two-stage BSS Color Change procedure.

63. Dr. Hansen’s deposition testimony confirms this mapping. Asked whether any portion of Yang was cited in his Ground 1B analysis for limitations 1.3 through 1.9 or for claims 2 or 3, Dr. Hansen testified: “For the Draft 1.0 Yang in 802.11-2016 combination, I — I — I don’t see a specific reference in my declaration, you know, related to those claim elements.” Ex. 2019 (Hansen Depo.) at 43:20–44:10. Asked whether his Ground 1B analysis on the dispositive limitations [1.5]–[1.8] simply “reference[s] back to Ground 1A,” Dr. Hansen agreed. *Id.* at 44:12–21.

B. Yang Addresses a Different Technical Problem from the ’262 Patent

64. Yang is directed to a fundamentally different problem from the one the ’262 Patent addresses. Yang describes how an *access point* selects and

transitions to a new BSS color when the AP detects an OBSS collision — that is, when a neighboring BSS is using the same BSS color as its own. Yang (Ex. 1006) at [0035]–[0039], [0046]. Yang’s two-stage process (set a temporary BSS color; decide on a new permanent BSS color) is an AP-side collision-resolution procedure. *Id.* at [0051]–[0055]. The ’262 Patent, in contrast, addresses how a *wireless communication terminal* (a non-AP STA) sets the BSS color of its own trigger-based PPDU when the trigger frame is received in a non-HE PPDU and the AP has announced a color change. A POSITA would recognize that not only Yang and the ’262 Patent operate on different actors, but also that they address different problems.

C. 802.11-2016 Does Not Contain the 802.11ax BSS-Color Framework at Issue

65. The 802.11-2016 standard (Ex. 1010) is the pre-802.11ax baseline that D1.0 proposed to amend; it does not contain the 802.11ax features on which D1.0 is built. 802.11-2016 defines earlier generations of the 802.11 standard (including VHT and prior). The BSS color concept on which [1.5]/[4.3] and [1.8]/[4.6] turn was not introduced into the 802.11 standards family until 802.11ax. A reference that predates the introduction of the BSS color concept cannot disclose a rule specifying how to set a “BSS color” parameter in a trigger-based PPDU.

66. The Petition's Ground 1B treatment of 802.11-2016 on elements [1.5] and [1.8] is cursory. Pet. at 35 (citing 802.11-2016 (Ex. 1010) at 694, 724 for legacy management-frame features). In my opinion, those legacy management-frame features have no bearing on the non-HE-PPDU trigger-based PPDU rule [1.5]/[4.3] requires or on the time-gated active-BSS-color update [1.8]/[4.6] requires. 802.11-2016's management-frame machinery pre-exists the 802.11ax BSS color framework and does not speak to either limitation.

D. No Motivation to Combine D1.0, Yang, and 802.11-2016

67. In my opinion, a POSITA would not have been motivated to combine D1.0, Yang, and 802.11-2016 as Petitioner proposes in a way that produces the claimed rule. Petitioner uses Yang for generic hardware and 802.11-2016 for an irrelevant management-frame disclosure. Neither reference contains a teaching that would prompt a POSITA to modify D1.0's static Operation-element rule in a way that would arrive at the active-BSS-color mechanism. The mere fact that the three references existed in the art does not supply a motivation; a POSITA needs a technical reason to make the combination, and Ground 1B's references do not provide one.

E. No Reasonable Expectation of Success

68. A POSITA attempting Petitioner's Ground 1B combination would have had no reasonable expectation of arriving at the claimed terminal-side, time-

gated update rule. None of D1.0, Yang, or 802.11-2016 identifies the color-change scenario that [1.5]/[4.3] and [1.8]/[4.6] address. Without recognition of the scenario, a POSITA would have had no basis to expect that combining these three references would produce an operational rule that handles it. In my opinion, the Ground 1B combination, if implemented, would produce a system that retains D1.0's static-rule behavior — not the claimed active-BSS-color mechanism.

XI. OPINIONS REGARDING GROUND 2A

69. Ground 2A asserts that claims 1, 2, and 4 are unpatentable over Yang (Ex. 1006) in view of 802.11-17/0250r2 (Ex. 1007) and 802.11-16/1415r0 (Ex. 1008). In this section I address the technical contents of each of these references and explain why, in my opinion, the combination does not disclose the active-BSS-color rule the claims require and a POSITA would not have been motivated to make the combination Petitioner proposes.

A. Yang's Two-Stage BSS Color Change Procedure Is AP-Side

70. Yang describes a method by which an access point changes the BSS color of its BSS when it detects that a neighboring (overlapping) BSS is using the same color. Yang (Ex. 1006) at [0035]–[0039], [0046]. Yang's principal contribution is a two-stage procedure for the AP to carry out the color change.

71. In Yang’s first stage, the AP sets a “pre-specified Transitory BSS Color value” and signals that temporary color to non-AP STAs by placing it in the BSS Color subfield of the HE-SIG-A field of DL HE PPDU transmitted by the AP. Yang (Ex. 1006) at [0051]–[0053]. The purpose of the temporary stage is to allow the AP to test a candidate new BSS color and find one that is not already in use by another BSS. In the second stage, the AP selects a non-transitory (permanent) new BSS color and begins using it. *Id.* at [0054]–[0059]. Both stages are carried out by the AP and both operate through the HE-SIG-A field of DL HE PPDU — that is, HE PPDU where the physical-layer BSS color field is present.

72. In my opinion, Yang does not disclose a rule for how a non-AP STA sets the BSS color of a trigger-based PPDU when the trigger frame was received in a non-HE PPDU. Yang’s mechanism operates on HE PPDU, where the BSS color is communicated at the physical layer through HE-SIG-A. The scenario element [1.5]/[4.3] addresses — a PPDU format in which any physical-layer field for indicating the BSS color is *not* included — is outside the scope of Yang’s two-stage procedure. Petitioner acknowledges as much when it turns to 802.11-17/0250r2 to attempt to supply element [1.5]. Pet. at 60–62.

B. 802.11-17/0250r2 Duplicates D1.0's Static Rule

73. 802.11-17/0250r2 is an IEEE 802.11 comment-resolution (CR) submission authored by Abhishek Patil of Qualcomm, dated March 2017. 802.11-17/0250r2 (Ex. 1007) at 1. It proposes resolutions for various comments related to § 27.5.2 of the then-current 802.11ax draft. *Id.* at 1 (title). The substantive proposed change on which Petitioner relies reads: “The BSS_COLOR parameter shall be set as follows: . . . If the Trigger frame was received in a non-HE PPDU, then set to the value of the BSS Color subfield of the most recently received HE Operation element for that BSS.” *Id.* at 17. This rule is materially the same as D1.0 § 27.5.2.3, quoted in Section IX of this declaration.

74. 802.11-17/0250r2 does not use the term “active BSS color.” It does not describe a dynamically maintained variable. It does not describe a time-gated update. It replicates, in substantially the same words, the static Operation-element rule that appears in D1.0 § 27.5.2.3. In my opinion, the arguments I have given in § 09 with respect to D1.0 § 27.5.2.3 apply with equal force to 0250r2: it is a static rule that does not disclose the active-BSS-color mechanism of [1.5]/[4.3].

75. Dr. Hansen’s deposition testimony confirms this equivalence. When shown the same “non-HE PPDU → set to most recently received Operation

element” text in both D1.0 and 0250r2, Dr. Hansen agreed the text is the same in both sources. Ex. 2019 (Hansen Depo.) at 65:1–21.

C. 802.11-16/1415r0 Describes the Same AP-Side Color-Change Procedure as D1.0 § 27.16.2

76. 802.11-16/1415r0 is a submission to the IEEE 802.11 Working Group proposing a BSS Color Change procedure for 802.11ax. 802.11-16/1415r0 (Ex. 1008) at 2, 7. Its stated purpose is to “[a]llow an AP to change its Color value during the existence of the BSS.” *Id.* at 2. The proposed procedure is carried out by the AP: the AP announces a color change via a BSS Color Change Announcement element carried in beacons, and the AP transitions to the new color at the BSS Color change TBTT. *Id.* at 7.

77. The procedure 1415r0 describes is the procedure that became D1.0 § 27.16.2. In my opinion, 1415r0 does not teach a terminal-side, time-gated update of a dynamically maintained active BSS color, for the same reasons § 27.16.2 does not. It describes what the AP does; it does not describe a STA maintaining an “active BSS color” variable and updating it at the TBTT for use in trigger-based PPDU responding to non-HE-PPDU triggers. 1415r0 therefore does not supply element [1.8]/[4.6].

D. A POSITA Would Not Have Been Motivated to Combine Yang with IEEE 802.11-2016/1415r0 in the Way Petitioner Proposes

78. The combination of Yang with 1415r0 that Petitioner proposes would collapse Yang's two-stage design into a single-stage color change. In my opinion, a POSITA would not have been motivated to make that combination, for a straightforward technical reason: the first (transitory) stage of Yang serves a specific and non-trivial purpose. The transitory stage allows the AP to test a candidate new BSS color — to ensure the candidate is not already in use by an OBSS — before committing to it. Yang (Ex. 1006) at [0053]–[0054]. Removing that stage eliminates Yang's ability to carry out the collision-avoidance function that is Yang's reason for existence. A POSITA addressing Yang's OBSS-collision problem would not adopt a modification that breaks Yang's solution to that problem.

79. The Petition's only articulated rationale for combining Yang with 1415r0 is that the combination would “increase the number of BSS colors that are in use.” Pet. at 64. In my opinion, that rationale does not supply a technical reason to make this combination. Yang's AP-side two-stage procedure and 1415r0's AP-side single-stage procedure are different methods of accomplishing a related task; the choice between them is an engineering design decision,

not a motivation to substitute one for the other. And the substitution, as discussed above, would defeat Yang's purpose.

E. The Combination, Even If Made, Would Not Reach the Claimed Terminal-Side Rule

80. Even on the assumption a POSITA had combined Yang with 1415r0 (and, for the reasons above, I do not believe a POSITA would have done so), the result of that combination would be an AP-side color-change procedure — not a terminal-side update of a dynamically maintained active-BSS-color variable. In my opinion, combining an AP-side collision-resolution procedure (Yang) with an AP-side color-change procedure (1415r0) yields another AP-side system. It does not yield the non-AP STA operational rule [1.5]/[4.3] and [1.8]/[4.6] together require.

F. No Reasonable Expectation of Success

81. Taking Petitioner's proposed combination at its best, a POSITA would have had no reasonable expectation of arriving at the claimed terminal-side, time-gated update rule. Yang addresses AP-side collisions. 0250r2 duplicates D1.0's static Operation-element rule. 1415r0 adds an AP-side color-change-announcement procedure. None of these three references identifies or addresses the terminal-side color-change scenario that motivates [1.5]/[4.3] and [1.8]/[4.6]. None uses the term "active BSS color." In my opinion, a POSITA

would not have had a reason to expect that assembling these three references, as Petitioner proposes, would produce the '262 Patent's operational rule.

XII.OPINIONS REGARDING GROUND 2B

82. Ground 2B asserts that dependent claim 3 is unpatentable over Yang (Ex. 1006) in view of 802.11-17/0250r2 (Ex. 1007), 802.11-16/1415r0 (Ex. 1008), 802.11ax/D1.0 (Ex. 1005), 802.11-2016 (Ex. 1010), and 802.11-17-0230r1 (Ex. 1011). In this section I address the technical merits of that six-reference combination. As with Ground 1A, I do not here opine on whether D1.0 qualifies as a prior-art printed publication — Mr. Nikolich addresses that question — and I assume D1.0 qualifies for purposes of the technical analysis below.

A. Ground 2B Builds on the Ground 2A Combination and Inherits Its Technical Deficiencies

83. Claim 3 depends from claim 1. Ex. 1001 (the '262 Patent), claim 3. In my opinion, for Ground 2B to establish the obviousness of claim 3, it must first establish the obviousness of claim 1 over the art Ground 2B asserts — which includes, at its core, the same Yang + 0250r2 + 1415r0 combination used in Ground 2A. I have explained in § 11 of this declaration why that underlying combination does not establish the obviousness of claim 1: Yang addresses an AP-side collision problem, 0250r2 duplicates D1.0's static Operation-element rule, and 1415r0 mirrors § 27.16.2's AP-side color-change procedure. Ground 2B inherits those deficiencies.

B. Adding D1.0 and 802.11-2016 Does Not Cure the Deficiencies

84. Petitioner adds D1.0 (Ex. 1005) to the Ground 2A combination as one of the six references in Ground 2B. In my opinion, D1.0 does not cure the Ground 2A deficiencies, for the reasons I set out in § 09 of this declaration: D1.0 § 27.5.2.3 is a static rule, and D1.0 §§ 27.16.2 and 27.5.2.3 together create a contradiction in the non-HE-PPDU trigger scenario that D1.0 does not resolve.

85. Petitioner adds 802.11-2016 (Ex. 1010) as well. In my opinion, 802.11-2016 contributes nothing to the analysis of claim 1's dispositive limitations. As I explained in § 10, 802.11-2016 is the pre-802.11ax baseline that D1.0 proposed to amend; it does not contain the 802.11ax BSS color framework on which [1.5]/[4.3] and [1.8]/[4.6] operate.

C. 802.11-17-0230r1 Addresses the Partial-AID Rule of Claim 3; It Does Not Address [1.5]/[4.3] or [1.8]/[4.6]

86. 802.11-17-0230r1 is a March 2017 IEEE 802.11 submission that proposes a technique for a STA to determine whether a received PPDU is an Intra-BSS or Inter-BSS PPDU based at least in part on the PARTIAL_AID parameter in the received PPDU's RXVECTOR. 802.11-17-0230r1 (Ex. 1011) at 10. Its substantive proposal is framed for VHT PPDU: it compares the value of RXVECTOR parameter PARTIAL_AID[5:8] in a received VHT PPDU (with

RXVECTOR parameter GROUP_ID equal to 63) against “the partial BSS color announced by the AP to which the STA is associated when the Partial BSS Color field in the most recently received HE Operation element is 1.” *Id.*

87. In my opinion, 0230r1 does not disclose the active-BSS-color mechanism of [1.5]/[4.3] or the time-gated update of [1.8]/[4.6]. 0230r1’s focus is on classifying received PPDU as Intra-BSS or Inter-BSS based on Partial AID matching — that is the subject matter relevant to dependent claim 3’s additional limitation. 0230r1 does not use the term “active BSS color,” does not describe a terminal maintaining and updating such a variable, and does not describe a non-HE-PPDU-trigger rule for setting the BSS_COLOR parameter of a trigger-based PPDU. Adding 0230r1 to a combination that fails on [1.5] and [1.8] does not repair that failure.

D. The Six-Reference Combination Reflects Hindsight Assembly, Not Motivated Combination

88. In my opinion, the six-reference combination Ground 2B proposes bears the hallmarks of hindsight assembly rather than a POSITA’s motivated combination. Claim 3 adds only a narrow additional limitation to claim 1: a Partial-AID-based Intra-BSS/Inter-BSS determination when the PPDU indicates a partial BSS color via a Partial AID field. Ex. 1001 (the ’262 Patent), claim 3. To reach that narrow additional subject matter, Petitioner assembles Yang (an AP-side collision procedure), 0250r2 (a static Operation-element rule),

1415r0 (an AP-side color-change procedure), D1.0 (which Petitioner has not shown is available to POSITAs), 802.11-2016 (an earlier standard that pre-dates the 802.11ax BSS color framework), and 0230r1 (a Partial-AID VHT-PPDU proposal). A POSITA reviewing these six references, in isolation from the claim, would have no technical reason to combine them in the particular configuration Ground 2B describes.

89. The Petition’s articulated rationale for assembling the six references is that, because Yang does not address legacy non-HE PPDU formats, a POSITA “would have looked to other references for specific guidance regarding how to perform operations pertaining to signaling and synchronizing BSS color between devices in the context of non-HE PPDU formats.” Pet. at 69. In my opinion, that rationale does not supply a technical motivation. It presupposes that a POSITA starting from Yang would have been trying to extend Yang to legacy non-HE-PPDU formats; Yang itself does not suggest that goal, nor do any of the other five references. The rationale reads the claim’s subject matter back into Yang and treats Yang’s silence as an invitation to assemble a combination that happens to match the claim.

E. No Reasonable Expectation of Success

90. Even assuming a POSITA had undertaken Petitioner's six-reference combination, in my opinion the POSITA would have had no reasonable expectation of arriving at the claimed rule of claim 1 together with claim 3's Partial-AID-based classification. The six references address different problems — AP-side collisions (Yang); static Operation-element lookups (0250r2); AP-side color-change signaling (1415r0, D1.0 § 27.16.2); earlier-generation 802.11 management features (802.11-2016); and Partial-AID-based VHT-PPDU classification (0230r1). None identifies or addresses the color-change scenario the '262 Patent resolves, and none provides the active-BSS-color mechanism on which claim 1 (and, by dependency, claim 3) turns.

XIII. OPINIONS REGARDING THE 802.11AX AMENDMENT HISTORY AND SECONDARY CONSIDERATIONS

91. In this section I offer opinions informed by my personal familiarity with the IEEE 802.11 standards process. I was a Voting Member of the IEEE 802.11 Working Group between 2000–2002 and between 2005–2008, I chaired a Study Group within IEEE 802.11 around 2005–2007, and I have reviewed and voted on most IEEE 802.11 standards and amendments since 2000. *See* ¶¶ 9–11 above. That experience gives me a basis to comment on the 802.11ax

amendment record and on what it shows about how the Working Group understood (and did not understand) the BSS color problem the '262 Patent's inventor identified.

A. The Contemporaneous IEEE Record Did Not Contain the “Active BSS Color” Mechanism

92. I have reviewed each of the IEEE documents Petitioner asserts across Grounds 1A, 1B, 2A, and 2B — 802.11ax/D1.0 (Ex. 1005), 802.11-2016 (Ex. 1010), 802.11-17/0250r2 (Ex. 1007), 802.11-16/1415r0 (Ex. 1008), and 802.11-17-0230r1 (Ex. 1011). All of them predate the April 14, 2017 Critical Date of the '262 Patent. None of them uses the term “active BSS color.” None of them describes a dynamically maintained independent variable that tracks an AP-announced BSS color change. None of them addresses the scenario in which a non-AP STA must respond to a non-HE-PPDU trigger with a trigger-based PPDU after the AP has announced a color change but before the STA has received a beacon carrying the new HE Operation element.

93. The IEEE 802.11 Working Group that drafted 802.11ax is composed of participants from major wireless technology companies — hardware manufacturers, silicon vendors, operating-system vendors, service providers, and others. Each participating organization typically assigns very talented researchers to the Working Group effort, and many—if not all—of the contributors hold advanced degrees and long records of participation in earlier 802.11

amendments. The fact that the 802.11ax amendment had been in development for more than a year (from D1.0 in December 2016 through D2.0 in mid-2017) without any Working Group member identifying the color-change scenario the '262 Patent addresses is, in my opinion, significant. If the solution had been obvious at that time, a Working Group member would very likely have proposed it. No one did.

B. The Inventor Proposed the “Active BSS Color” Solution to IEEE After the Critical Date

94. Geonjung Ko is a named inventor of the '262 Patent. He also submitted comments on the D2.0 draft of 802.11ax in November 2017, more than six months after the '262 Patent's April 14, 2017 Critical Date. TGax D2.0 Comments (Ex. 2013).

95. Mr. Ko's CID 11730 precisely identifies the scenario [1.5]/[4.3] and [1.8]/[4.6] of the '262 Patent address: “When the AP announced the BSS Color Change, for STAs that failed to receive a Beacon frame at the BSS color change TBTT, the value of the BSS Color subfield of the most recently received HE Operation element is the previous BSS color, not the new BSS color. This may cause different HE-SIG-A signals between STAs solicited by the Trigger frame.” TGax D2.0 Comments (Ex. 2013) (CID 11730). The comment then proposes the precise technical fix the '262 Patent's claims embody:

“If the Trigger frame was received in a non-HE PPDU, then the BSS_COLOR shall be set to the active BSS color.” *Id.*

96. The IEEE Working Group agreed with Mr. Ko’s comment and adopted his proposal. The resolution states: “Revised text to indicate that the responding STA shall use the active color as defined in 27.11.4.” 802.11-18/0367r1 (Ex. 2011) (Resolution of CID 11730). The corresponding edits were incorporated in D2.3. *See* 802.11ax/D2.3 (Ex. 2012). In my opinion, this sequence is strong evidence that the mechanism [1.5]/[4.3] and [1.8]/[4.6] require — the “active BSS color” variable — was not something the Working Group had previously identified, considered, or resolved. The Working Group adopted the mechanism only after the ’262 Patent’s inventor proposed it, and only in D2.3, well after the ’262 Patent’s Critical Date.

97. Mr. Ko’s CID 11731, submitted at the same time, identified a related gap in the draft: “There is no BSS_COLOR setting rule when the Trigger frame is in a non-HE PPDU and the STA is an unassociated STA.” TGax D2.0 Comments (Ex. 2013) (CID 11731). For this related gap, Mr. Ko proposed three alternative resolutions: “[u]se the active BSS color,” “use an HE PPDU when soliciting unassociated STAs,” or “define the BSS Color field in the Trigger frame format.” *Id.* The Working Group selected the second alternative (requiring an HE PPDU for soliciting unassociated STAs), with edits incorporated in

D2.2. *Id.* In my opinion, the Working Group's selection among Mr. Ko's three proposed fixes does not weaken the nonobviousness point. Mr. Ko identified a real gap; the Working Group agreed the gap existed and resolved it by adopting one of his three proposals. That the Working Group's default treatment of BSS color in D1.0, 0250r2, and 1415r0 did not address the scenarios he identified, and that his proposals were necessary to fix them, shows that these scenarios were not obvious in the pre-D2.0 state of the 802.11ax draft.

C. Failure of Others and Long-Felt Need

98. The IEEE 802.11ax amendment was drafted over a period exceeding one year before any Working Group contributor identified the color-change scenario the '262 Patent addresses. During that period, dozens of engineers from the leading wireless technology companies reviewed, commented on, and voted on multiple draft revisions (D1.0, D1.1, D1.2, D1.3, D2.0). None of them identified the gap Mr. Ko later identified in CID 11730. In my opinion, that is direct evidence of a failure of others to recognize the problem. The problem was not a hypothetical edge case; it is an operational gap inherent in the pairing of D1.0 § 27.5.2.3 (static non-HE-PPDU-trigger rule) with D1.0 § 27.16.2 (AP-announced color change). The gap existed throughout the D1.0-through-D2.0 drafting period and went unremarked until Mr. Ko raised it.

99. The scenario the gap produces is not hypothetical. Every real-world 802.11ax deployment in which an AP changes its BSS color will encounter STAs that miss the beacon carrying the new HE Operation element. Any such STA that then has to respond to a non-HE-PPDU trigger will face the § 27.16.2 / § 27.5.2.3 contradiction described in § 09 of this declaration. The gap was a persistent and operationally meaningful one. In my opinion, the gap's persistence across the D1.0-through-D2.0 drafts, notwithstanding the depth of expertise available in the Working Group, reflects a long-felt need that was not addressed until Mr. Ko's proposal.

XIV. CONCLUSIONS

100. Although my complete opinions are set forth above, for convenience I summarize several points of my opinions in conclusion. For the foregoing reasons, based on my expertise and experience and the record of this case that I have reviewed, it is my opinion that the claims of the '262 patent are not obvious over the identified prior art.

101. I understand that my opinions discussed above support a legal conclusion that claims of the '262 patent are not obvious.

102. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be

subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required, I will appear for cross-examination within the United States during the time allotted.

103. I hereby declare that all statements made herein of my own knowledge are true and all statements made herein on information and belief were and are believed by me to be true, and that all statements herein were and are made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code and that any such willful false statements may jeopardize the validity of the application or any patents issued thereon.

Appendix 1

Todor Cooklev, PhD.

Curriculum Vitae

Personal

1336 Sycamore Hills Parkway, Fort Wayne, IN 46814

Contact e-mail: tcooklev@gmail.com

Cell: 925-984-5283

Citizenship: United States (by naturalization)

Professional experience

2016 –

Professor of Electrical and Computer Engineering

2101 E Coliseum Blvd., ETCS 349

Purdue University Fort Wayne, Indiana 46805

- Research on most aspects of wireless systems, including hardware, signal processing, and software techniques, in particular for software-defined radios.
- Courses:
 - ECE 428 Communication Systems
 - ECE 549 Software-Defined Radio
 - ECE 543 Wireless Communications and Networks

2013 – 2017

Co-founder and CEO, Adaptive RF, Fort Wayne, IN

- Developed innovative RF technology and served as co-founder of a company that received funding from the Department of Defense

2018 – 2019

Chief Technology Officer, Stryke Industries LLC

- CTO of a company receiving a grant from the Air Force Research Laboratory, Rome, NY

2010 – 2016

ITT Associate Professor of Wireless Communication and Applied Research, Purdue University Fort Wayne

2008 – 2022

Director, Wireless Technology Center *Purdue University Fort Wayne*

2005 – 2008

Consultant, Hitachi America Ltd., San Jose, California

- Voting Member, IEEE 802.11 WG; participated in the work on several 802.11 amendments
- Chair, IEEE 802.11 VTS Study Group; responsible for the proposal and approval to create a Task Group that lead to the IEEE 802.11aa standard

- 2011 – 2012 Consultant, Hitachi America Ltd., San Jose, California**
- Attended meetings of the 3GPP RAN1 standardization committee in Dresden, Germany, Jeju Island, Korea, Prague, Czech Republic, and Qindao, China, 2012.
 - Contributed to several documents submitted to 3GPP
- 2006 – 2008 Consultant, Datamars, Lugano, Switzerland**
- Evaluated and produced reports on certain wireless technologies and standards
 - Participated in the IEEE 802.15.4f committee
- 2004 – 2006 Consultant, Leica Geosystems, Switzerland**
- IEEE 802.16 (WiMAX) and related technologies
- 2005 – 2007 Technical Advisory Board Member, Doceotech, San Ramon, CA**
- 2002 – 2008 Assistant Professor with tenure (2008), San Francisco State University.**
- 2000 – 2002 Member of the Technical Staff, Aware, Inc., Bedford, MA and Lafayette, CA**
- Worked on DSL standards. Participated in the International Telecommunications Union, Study Group 15, Question 4. Chaired the session on coding for DSL at the session in Antwerp, Belgium, June 2000. Participated in the Telecommunications Industry Association T1E1 Committee on DSL
 - Developed advanced coding and decoding methods for DSL
 - Worked on the design of an IEEE 802.11a chipset.
 - Voting member, IEEE 802.15; Co-Founder and First Vice-Chair of IEEE 802.15.3 (High-data rate wireless personal area networking)
- 1998-1999 Consultant, Quantronix, Framingham, Utah**
- Image processing; developed software for edge detection and wrote a report
- 1996-1997 Consultant, Communications Research Center, Government of Canada.**
- Designed digital filter banks for communication systems and wrote two technical reports
- 1997-1999 Senior Engineer, 3Com Corporation**
- Worked on V.90 voice-band modems
 - Implemented data compression and other signal processing algorithms V.42 and V.42bis
 - Worked on the Bluetooth Standard, one of the first contributors to the Host Controller Interface of Bluetooth.
 - Participated in the Bluetooth/IEEE group, which drafted the license agreement between Bluetooth and the IEEE 802, which in turn led to the establishment of the IEEE 802.15 Working Group.

Grants Awarded

1. Office of Naval Research Summer Fellow 2020, Naval Surface Warfare Center Crane
2. National Science Foundation S²ERC I/UCRC, “FPGA implementation of shared-memory middleware”, 2017-2019, PI
3. National Science Foundation S²ERC I/UCRC, “Shared-memory middleware”, 2016-2017, PI
4. City of Fort Wayne, Economic Development Fund, 2013-15, co-PI.
5. Allen County Capital Improvement Board (CIB), 2013-15, co-PI
6. U.S. Defense Advanced Research Projects Agency (DARPA) Small Business Technology Transfer (STTR) Phase I “A flexible and extensible solution to incorporating new RF devices and capabilities into EW/ISR networks, co-PI, August 2013 – February 2014.
7. National Science Foundation S²ERC I/UCRC, “The performance of middleware solutions for SDR”, 2013-2014, PI
8. National Science Foundation S²ERC I/UCRC, “Cognitive decision applications for embedded use,” 2011-2012, PI
9. Visiting Fellowship, National Institute of Communication Technology (Japan), 2011
10. National Science Foundation S²ERC I/UCRC, “Signal processing techniques for multicarrier modulation,” 2009-2011, PI
11. NMDG, Belgium, laboratory grant 2010, PI
12. National Science Foundation, Professional Science Master’s Program, MS in engineering, with concentration in wireless and systems engineering, 2010-2013, Co-PI.
13. Emona Instruments, Sydney, Australia, Laboratory exercises in communications, Principal Investigator, 2008.
14. Lilly Endowment, wireless laboratory grant, 2010, PI.
15. ITT (now Harris) Communications Systems, 2007-2011, PI.
16. State of Indiana, workforce development, 2008-2010, PI
17. National Science Foundation DUE-0442313, “Standards in Education for Product, Process, and Service Design and Development: A Proof-of-Concept Project,” 2005-2008, PI.

18. France Telecom, Paris, France, “New methods for multicarrier modulation for high data-rate wireless systems,” Principal Investigator, 2006.
19. Agilent Technologies/Sun Microsystems, Palo Alto, CA, “Distributed wireless sensor network for environmental monitoring,” Co-principal Investigator, 2005.
20. CSU summer research grant, 2004.
21. U.S. Air-Force Research Laboratory, Wright-Patterson AFB, “Data over voice communications,” Principal Investigator, 2004.

Honors and Awards

- | | |
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| 2012 | IEEE Standards Association, “for outstanding contributions to the development of IEEE 802.11aa” |
| 2006 | Wireless Educator of the Year Award with the citation “In recognition of the pivotal role of educators in preparing tomorrow’s wireless technology leaders”. |
| 2005 | Duke’s Choice Award, Sun Microsystems, (group award) |
| 2003 | IEEE Communications Society Oakland/East Bay Chapter Achievement Award, (group award) |
| 1999 | 3Com Inventor Award |
| 1995-1997 | NATO Science Fellowship |
| 1994 | IEEE Asia - Pacific Conference on Circuits and Systems Best Paper Award for the paper “Theory of filter banks over finite fields” |

Education

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| 1995 | <i>Tokyo Institute of Technology, Tokyo, Japan,</i>
Doctor of Philosophy in Electrical Engineering |
| Dissertation: | Regular Perfect-Reconstruction Filter Banks and Wavelet Bases |
| 1988 | <i>Technical University of Sofia, Bulgaria,</i> Dipl. Eng. in Electrical Engineering |

Professional Activities

Board Membership:

Board of Governors, IEEE Standards Association, 2021-2022

Committee/Editorial Board Membership:

IEEE Communications Standards Magazine, Series Editor, Wireless and Radio Communications, 2017-

Committee Membership:

- IEEE 802.11 Working Group Voting Member, 2001-2003, 2006-present

- IEEE 802.15 Working Group Voting Member 1999-2001
- Chairman, IEEE Standards in Education Committee, 2006 – present
- Member of the Editorial Board, Journal of Networks.
- 2004-2005 Chairman and 2003-2004 Secretary of the Oakland/East Bay Chapter of the IEEE Communication Society.

Program Committee Membership:

- General Chair, Tactical Communications and Interoperability Conference, 2011
- General Chair, Fort Wayne Wireless Summer School 2009 and 2010
- Program Committee Member, Int. Conf. on Wireless Applications and Computing, 2007.
- Program Committee Member, Int. Conference on WLAN, WPAN, and WMAN, Hawaii, Aug. 2007.
- Program Committee Member, Int. Joint Conf. e-Business and Telecommunications, Barcelona, Spain, 2007.
- Program Committee Member, Int. Conf. Wireless Information Networks and Systems, Lisbon, Portugal, 2006.
- Technical Program Committee Member, Int. Conf. Networking and Services, ICNS 2006, Santa Clara, CA.
- Technical Program Committee Member, Advanced Int. Conference on Telecommunications, AICT, Guadeloupe, French Caribbean 2006.
- Program Committee Member, Int. Joint Conf. e-Business and Telecommunications, Reading, UK, 2005.
- Technical Program Committee Member, Int. Conf. Convergent Services and Next-Generation Networks, June 2005, Chicago, IL.
- Technical Program Committee Member, Int. Conference on Service Assurance with Partial and Intermittent Resources, Lisbon, Portugal, July 2005.
- Technical Program Committee Member, Int. Conf. Telecommunications, 2004, Brazil.
- 3rd Int. Workshop on Signal and Image Processing, Manchester, UK, Special session on wavelets in communication systems, signal and image processing, special session co-organizer, Nov. 1996.

Tutorials at International Conferences

- 1) T. Cooklev, “The analog RF-digital interface: the VITA 49 standard and evolution roadmap,” First IEEE Next G Summit, Johns Hopkins University, June 14, 2022.
- 2) T. Cooklev, “Open RF-digital interfaces and wireless ontologies,” IEEE BlackSeaCom, 4th International Black Sea Conference on Communications and Networking, Varna, Bulgaria, June 2016.
- 3) M. Cummings, T. Cooklev, “Software Defined Radio Technology”, Tutorial at the 2008 Symposium System on Chip, Tampere, Finland, Nov. 2008.
- 4) M. Cummings, T. Cooklev, “Software Defined Radio Technology”, Tutorial at the IASTED Int. Conference Computer Communications, Palma de Mallorca, Spain, Sept. 2008.
- 5) M. Cummings, T. Cooklev, “Software Defined Radio Technology”, Tutorial at the 2007 International Conference on Computer Design, Squaw Creek, CA 2007.
- 6) T. Cooklev, “Wireless communication standards: 802.11, 802.15, and 802.16,” Int. Conference Telecommunications, Fortaleza, Brazil, Aug. 2004, tutorial.
- 7) T. Cooklev, “Wireless data communication standards, IEEE Globecom 2003, Dec. 2003, San Francisco, CA, tutorial.

Short Courses and Invited Talks excluding conferences:

- 1) T. Cooklev, "Open RAN", Technical University of Sofia, Bulgaria, November 2019.
- 2) T. Cooklev, "Software-defined radio technology," Oulu University, Finland, Oct. 2017.
- 3) T. Cooklev, "Software-defined radio technology," Aarhus University, Denmark, Oct. 2017.
- 4) T. Cooklev, "Modern wireless systems," Technical University of Sofia, Bulgaria, 2014.
- 5) T. Cooklev, "Modern Wireless Systems," Featured faculty presentation, Feb. 2012, IPFW.
- 6) T. Cooklev, "Software-defined radio technology," Tokyo Institute of Technology, Dec. 2011.
- 7) T. Cooklev, "Software-defined radio technology," University of Akron, OH, 2010.
- 8) T. Cooklev, "Modern wireless systems," Catholic University of Leuven, Leuven, Belgium, 2010
- 9) T. Cooklev, "Modern wireless systems," University of Qatar, Doha, Qatar, 2009.
- 10) T. Cooklev, "Modern wireless systems," Technical University of Sofia, Bulgaria, 2009.
- 11) T. Cooklev, "Modern wireless systems: from Marconi's radio to cognitive radio," Sigma Xi presentation, February 2009, IPFW.
- 12) T. Cooklev "Software-Defined Radio Technology," Talk at IPFW, Oct. 2008.
- 13) M. Cummings, T. Cooklev, "Software Defined Radio Technology", IEEE Communication Society, Oakland/East Bay Chapter, presentation, Oct. 2007, San Ramon, CA.
- 14) T. Cooklev, "Engineering Standards in Engineering Education," presentation and a panel participant, Standards Engineering Society Annual Conference, San Francisco, CA, August. 2007. (panelist and presenter)
- 15) T. Cooklev, "Vector transform for multicarrier modulation", France Telecom, June 2007, Rennes, France.
- 16) T. Cooklev, "Wireless Communication Standards," Distinguished Lecture, IEEE Communication Society, Oct. 2006, University of Maine.
- 17) T. Cooklev, "The IEEE 802.11, 802.15, and 802.16 Families of Standards," Short Course, April 2006, Lietuvos Telekomas, Vilnius, Lithuania,
- 18) T. Cooklev, "The IEEE 802.11, 802.15, and 802.16 Families of Standards," Short Course, Feb. 2006, Austin, TX.
- 19) T. Cooklev, "The IEEE 802.11, 802.15, and 802.16 Families of Standards," Invited Talk, Dec. 2005, Cisco Systems, San Jose, CA.
- 20) Wireless local area networks, Hitachi Ltd., Brisbane, CA, June 2005.
- 21) T. Cooklev, "The IEEE 802.11, 802.15, and 802.16 Families of Standards," Invited Talk, May 2005, Texas Instruments, Dallas, TX.
- 22) T. Cooklev, "Standards for the Wireless Internet", IEEE Communication Society, Oakland/East Bay Chapter, presentation, January 2005. Freemont, CA.
- 23) T. Cooklev, "Wireless data communication standards, IEEE Wescon, Aug. 2003, San Francisco, CA, tutorial.
- 24) Short Course on 802.11, 802.15, 802.16, West Long Branch, NJ, August 2003
- 25) Wireless data communication standards, Lockheed Palo Alto Research Center, June 5, 2003.
- 26) Short Course on IEEE 802.11, 802.15, and 802.16, San Francisco, CA, Dec. 2002.
- 27) Standards for wireless data communications, University of Utah, Salt Lake City, UT, 1999
- 28) OFDM for wireless communications, 3Com Technology Forum, Boston, MA, Nov. 1998.
- 29) Filter banks and wavelets: a modern applied mathematics tool, Invited Lecture at the Analysis Day, Department of Mathematics and Statistics, Carleton University, Ottawa, Canada, 1997
- 30) Filter banks and wavelets for video signal processing, Genesis Microchip Inc, Markham, Ontario, Canada, July 1996.

- 31) Advanced topics in filter banks, wavelets, and their applications in modern communications systems, CRC, Ottawa, March and August 1996.
- 32) Digital filter banks and wavelets, Dept. Elect. Eng., University of Ottawa, March 1996.
- 33) Digital filter banks and wavelets, Dept. Elect. Eng., Queen's University, Kingston, March 1996.
- 34) Perfect-reconstruction filter banks and wavelet bases and their applications in digital communications, Fujitsu Laboratories, Kawasaki, Japan, July 1994.
- 35) Fast algorithms for signal processing, Istanbul University, Istanbul, Turkey, Jan. 1994.

Publications

Books and Monographs

- 1) T. Cooklev and A. Yagle, *Modern Communication Systems: A first course*, Michigan Publishing, 2023. (Available at <https://services.publishing.umich.edu/Books/M/Modern-Communications-Systems>)
- 2) T. Cooklev, *Wireless communications standards: A Study of IEEE 802.11, 802.15, 802.16*, IEEE Press, New York, NY. 2004.

Chapters in Books

- 1) A. Vlahov, D. Elkova, V. Poulkov, T. Cooklev, Virtualized, open, and intelligent: the evolution of the Radio Access Network,” River Publishers, 2021.
- 2) Subbu Ponnuswamy, Todor Cooklev, Yang Xiao, and Krishna Sumanth Velidi, “Security in fixed and mobile IEEE 802.16 networks,” Chapter 4, *WiMAX/MobileFi: Advanced Research and Technology*, edited by Yang Xiao, Taylor and Francis, January 2008.
- 3) T. Cooklev and A. Hristozov, “The Software Communications Architecture,” in *Resource Management in Future Internet*, edited by Ramjee Prasad, River Publishers, Denmark, 2015.

Journal Papers

- 1) V. Kolev, T. Cooklev, F. Keinert, “Bauer’s spectral factorization method for low order multiwavelet filter design”, *Journal of Computational and Applied Mathematics*, vol. 441, May 2024.
- 2) Kolev, T. Cooklev, F. Keinert, “Design of a Simple Orthogonal Multiwavelet Filter by Matrix Spectral Factorization,” *Circuits, Systems, and Signal Processing*, 2019.
- 3) Y. Acar and T. Cooklev, “High performance OFDM with index modulation”, *Physical Communication*, vol. 32, pp. 192-199, 2019.
- 4) M. Sherman and T. Cooklev, “Abstract descriptions of spectrum: VITA 49 and IEEE 1900.5.2”, *IEEE Communications Standards Magazine*, vol. 2, no. 4, pp. 43-48, December 2018.
- 5) T. Cooklev, V. Poulkov, D. Bennett, K. Tonchev, “Enabling RF data analytics services and applications via cloudification,” *IEEE Aerospace Electronic Systems Magazine*, vol. 33, no. 5-6, pp. 44-55, May-June 2018.

- 6) V. Kolev, T. Cooklev, F. Keinert, "Matrix spectral factorization for the SA4 multiwavelet," *Journal of Multidimensional Systems and Signal Processing*, vol.29, Issue 4, pp 1613–1641, 2018.
- 7) H. Dogan, T. Cooklev, and J. Darabi, "Improved low-complexity zero-padded OFDM receivers", *Digital Signal Processing*, vol. 51, pp. 92–100, April 2016.
- 8) P. Baltiiski, I. Iliev, B. Kehaiov, V. Poulkov, and T. Cooklev, "Long-Term Spectrum Monitoring with Big Data Analysis and Machine Learning for Cloud-Based Radio Access Networks," *Wireless Personal Communications*, vol. 87, issue 3, pp. 815-835, April 2016.
- 9) T. Cooklev, J. Darabi, C. McIntosh, and M. Mosaheb, "Cloud-based approach for spectrum monitoring," *IEEE Instrumentation and Measurement Magazine*, vol. 18, no. 2, pp. 33-37, April 2015.
- 10) Sven Bilen, A. Wyglinski, C. Anderson, T. Cooklev, C. Dietrich, B. Farhang-Boroujeny, "On Software-Defined Radio as an integrative educational resource," *IEEE Communications Magazine*, vol. 52, no. 5, pp. 184-193, May 2014.
- 11) Hakan Yıldız, Yusuf Acar, Todor Cooklev, Hakan Dogan, "Generalized Prefix for Space-Time Block Coded OFDM Wireless Systems over Correlated MIMO Channels," *IET Communications*, vol. 8, no. 9, pp. 1589-1598, June 2014.
- 12) T. Cooklev, A. Nishihara, "An Open RF-Digital interface for software-defined radios," *IEEE Micro*, vol. 33, no. 6, pp. 47-55, Dec. 2013.
- 13) T. Cooklev, R. Normoyle, and D. Clendenen, "The VITA 49 RF-digital interface," *IEEE Circuits Systems Magazine*, vol. 12, no. 4, pp. 21-32, Dec. 2012.
- 14) T. Cooklev, "An improved prefix for OFDM-based cognitive radios", *Electron. Lett.*, vol. 48, No. 4, Feb. 2012.
- 15) Y. Alqudah and T. Cooklev, "Hands-on open access broadband wireless technology lab", *Int. J. Interactive Mobile Tech.*, Vol. 6, No 4, 2012, pp. 13-18.
- 16) T. Cooklev, H. Dogan, R. Cintra, H. Yildiz, "Generalized prefix for OFDM wireless systems over quasi-static channels," *IEEE Transactions on Vehicular Technology*, vol. 60, No. 8, pp. 3684 – 3693, Nov. 2011.
- 17) F. Ramirez-Mireles, T. Cooklev, and G. A. Paredes-Orozco, "UWB-FSK: Performance tradeoffs for high-complexity receivers," *IEEE Transactions on Consumer Electronics*, vol. 56, no. 4, pp. 2123-2131, 2010.
- 18) S. Hossain, D. Batovski, and T. Cooklev, "Eight-channel transmultiplexer with binary matrix sequences," *Assumption Univ. Journal of Technology (Thailand)*, vol. 13, No. 4, pp. 193-202, 2010.

- 19) T. Cooklev, "Engineering standards and engineering education," *Journal of IT Standardization Research*, vol. 8, 2010, pp. 1-10.
- 20) R. Cintra and T. Cooklev, "Robust image watermarking using non-regular wavelets," *Journal of Signal, Image, and Video Processing*, 2008.
- 21) T. Cooklev, A. Pakdaman, J. Eidson, "IEEE 1588 over IEEE 802.11 for synchronization of wireless local area nodes," *IEEE Trans. Instrumentation and Measurement*, vol. 56, No. 5, pp. 1632-1639, Oct. 2007.
- 22) T. Cooklev and A. Nishihara, "Analytic constructions of complementary sequences," *IEICE Trans. Fundamentals*, November 2006.
- 23) T. Cooklev, "An efficient architecture for orthogonal wavelet transforms," *IEEE Signal Processing Letters*, Feb. 2006.
- 24) T. Cooklev, "Standards for the wireless Internet," *Annual review of communications*, vol. 57, Dec. 2004.
- 25) T. Cooklev, G. Berbecel and A. N. Venetsanopoulos, "Wavelets and differential-dilation equations," *IEEE Trans. Signal Processing*, vol. 48, pp. 2258-2268, 2000.
- 26) T. Cooklev and A. Nishihara, "Biorthogonal coiflets," *IEEE Trans. Signal Processing*, vol. 47, pp. 2582-2588, 1999.
- 27) T. Cooklev, A. Nishihara, T. Yoshida, and M. Sablatash, "Multidimensional two-channel linear phase FIR filter banks and wavelet bases with vanishing moments," *Journal of Multidimensional Systems and Signal Processing*, vol. 9, pp. 39-76, January 1998.
- 28) T. Cooklev, A. Nishihara and M. Sablatash "Regular orthonormal and biorthogonal wavelet filters," *Signal Processing*, vol. 57, pp. 121-137, Feb. 1997.
- 29) T. Yoshida, T. Cooklev, A. Nishihara, and N. Fujii, "Design of non-separable 3-D QMF banks using McClellan transformations," *IEICE Trans. Fundamentals*, vol. E79-A, No. 5, May 1996, pp. 716-720.
- 30) M. Sablatash and T. Cooklev "Coding of high-quality audio signals by wavelets and wavelet packets," *Digital Signal Processing: A Review Journal*, vol. 6, No. 2, pp. 96-107, April 1996.
- 31) V. Dimitrov, T. Cooklev, and B. Donevsky "Number-theoretic transforms over the golden-section quadratic field," *IEEE Trans. Signal Processing*, No. 8, pp. 1790-1797, August 1995.
- 32) V. Dimitrov and T. Cooklev, "Hybrid algorithm for computing the matrix polynomial," *IEEE Trans. Circuits Syst.*, No. 7, pp. 377-380, July 1995.

- 33) V. Dimitrov and T. Cooklev ``Two algorithms for modular exponentiation based on nonstandard arithmetics,’’ Special issue on cryptography and information security, *IEICE Transactions on Fundamentals*, Jan. 1995.
- 34) M. Sablatash , Todor Cooklev and Takuro Kida, ``The coding of image sequences by wavelets, wavelet packets and adaptive wavelet packets," *IEEE Trans. Broadcasting*, Dec. 1994.
- 35) T. Cooklev and A. Nishihara, ``Partial and generalized FFT," *IEICE Trans. on Fundamentals*, Sept. 1994.
- 36) V. Dimitrov, T. Cooklev and B. Donevsky, "Generalized Fermat-Mersenne number theoretic transforms," *IEEE Trans. Circuits Syst.*, vol. 41, pp. 133-139, Feb. 1994.
- 37) T. Cooklev, T. Yoshida and A. Nishihara, ``Maximally flat half-band diamond-shaped FIR filters using the Bernstein polynomial," *IEEE Trans. Circuits Syst.*, vol. 40, pp. 749-751, Nov. 1993.
- 38) T. Cooklev and A. Nishihara, ``Maximally flat FIR Hilbert transformers," *Int. Journal Circuit Theory and Applications*, vol. 21, pp. 563-570, 1993.
- 39) T. Cooklev, S. Samadi, A. Nishihara and N. Fujii, Efficient implementation of all maximally flat FIR filters of a given order," *Electronics Lett.*, vol. 29, No. 7, pp. 598-599, 1993.
- 40) S. Samadi, T. Cooklev, A. Nishihara and N. Fujii, ``Multiplierless structure for maximally flat linear phase FIR filters," *Electronics Lett.*, vol. 29, No. 2, pp. 184-185, 1993.
- 41) V. Dimitrov, T. Cooklev and B. Donevsky, "Generalized Fermat number transforms," *ASME Journal on Numerical Modeling*, 1992, N. 4 pp. 11-22.
- 42) T. Cooklev, V. Dimitrov and B. Donevsky, "Systolic implementation of the complex Chebyshev structure," *Int. J. Electronics*, vol. 73, pp. 1247-1252, Dec. 1992.
- 43) T. Cooklev and A. Nishihara, "Efficient design of N--D hyperspherically symmetric FIR filters," *IEICE Transactions on Fundamentals of Electronics, Inform. and Comput. Sci.*, vol. E75-A, pp. 1739-1742. Dec. 1992.
- 44) T. Cooklev, V. Dimitrov and B. Donevsky, "An improved systolic implementation of complex digital filters," *Archiv fuer Elektronik und Uebertragungstechnik (Germany)*, vol. 46, pp. 434-436, Nov.-Dec. 1992.
- 45) V. Dimitrov, T. Cooklev and B. Donevsky, "On the multiplication of reduced biquaternions and applications," *Information Processing Letters*, vol. 43, pp. 161-164, Sept. 1992.

Conference Papers

- 1) T. Cooklev, "The analog RF-digital interface: the VITA 49 standard and evolution roadmap" First IEEE Next G Summit, Johns Hopkins University, June 2022.
- 2) Plamen Semov, Pavlina Koleva, Vladimir Poulkov, and Todor Cooklev, "Evolution of Mobile Networks and C-RAN on the Road Beyond 5G," 43rd Int. Conf. on Telecommunications and Signal Processing, Milan, Italy, July 2020.
- 3) Y. Acar, S. Colak, T. Cooklev, "Dual-Mode Index Modulation Aided OFDM with Generalized Prefix", *Int. Symp. Networks, Computers, and Communications*, June 2019, Istanbul, Turkey.
- 4) T. Cooklev, "Making Software Defined Networks Semantic," *Proc. WINSYS*, July 2015, Colmar, France.
- 5) T. Cooklev, L. Stanchev, "A comprehensive and hierarchical ontology for wireless systems," *Wireless World Research Forum*, Marrakech, Morocco, May 2014.
- 6) Yusuf Acar, H. Yildiz, H. Dogan, and H. Dogan, "Generalized Prefix Approach for Alamouti Coded OFDM Systems over Gaussian Channels Correlated in Space," IEEE 2014 World Congress on Computer Applications and Information Systems (WCCAIS), Hammamet, Tunisia, January 17-19, 2014.
- 7) Yusuf Acar, H. Yildiz, H. Dogan, and H. Dogan, "Performance Improvement for Correlated 4x4 MIMO-OFDM Systems by Generalized Prefix Approach," 2013 Int. Conference on Signal Processing and Communications, Dec. 12-14, Noida, Uttar Pradesh, India.
- 8) T. Cooklev, L. Stanchev, C. Chen, "Wireless cloud architecture based on thin clients and ontologies," *Proc. IEEE Midwest Symp. Circuits and Systems*, Columbus, OH, Aug. 2013
- 9) Acar, Y.; Yildiz, H.; Cooklev, T.; Dogan, H., "High-performance MIMO OFDM wireless systems with generalized prefix," *21st Signal Processing and Communications Applications Conference (SIU)*, 2013, 24-26 April 2013, North Cyprus.
- 10) Dogan, H. Yildiz, T. Cooklev, Y. Acar, "Coded OFDM wireless systems with generalized prefix", Int. Conf. on Application of Information and Communication Technologies, Tbilisi, Georgia, Oct. 2012.
- 11) A. Madanayake, C. Wijenayake, Nghi Tran, T. Cooklev, Sean V Hum, L. T. Bruton, "Directional Spectrum Sensing using Tunable Multi-D Space-Time Discrete Filters," First IEEE International Workshop on Emerging COgnitive Radio Applications and aLgorithms (IEEE CORAL), San Francisco, CA June 2012.
- 12) Yazan A. Alqudah and T. Cooklev, Hands-On Open Access Broadband Wireless Technology Lab, *Proc. IEEE Global Engineering Education Conference (IEEE EDUCON)*, Marrakech, Morocco, April 2012.
- 13) Yazan A. Alqudah and T. Cooklev, Hands-On Open Access Broadband Wireless Technology Lab, ASEE Illinois/Indiana Section Conference, Valparaiso, IN, March 2012.

- 14) D. Mueller, T. Cooklev, H. Oloomi, C. Pomalaza-Ráez, and S. Walter, "A Graduate Program In Wireless Technology And Systems Engineering: Overview And Initial Experiences", ASEE Illinois/Indiana Section Conference, Valparaiso, IN, March 2012.
- 15) L. Stanchev and T. Cooklev, "Describing Radio Hardware and Software Using OWL for Over-The-Air Software Download," SDR Forum Tech. Conference, Washington, DC, Dec. 2010.
- 16) A. Marcum, T. Cooklev, and Carlos Pomalaza-Raez, "Simple OFDM," Virginia Tech Wireless Summer School, June 2010.
- 17) C. Chen, Z. Chen, T. Cooklev, and C. Pomalaza-Raez, "On spectrum probing in cognitive radio networks: does randomization matter," IEEE Int. Conf. Communications, May 2010.
- 18) Z. Chen, T. Cooklev, C. Chen, and Carlos Pomalaza-Raez, "Modeling primary user emulation attacks and defenses in cognitive radio networks," Int. Performance Computing and Communications Conference, Dec. 2009, Phoenix, AZ
- 19) T. Cooklev and M. Cummings, "Changing metalanguage landscape," SDR Forum Technical Conference, Washington, DC, Dec. 2009.
- 20) F. Ramirez-Mireles, T. Cooklev, and M. Sablatash, "Analysis of filter-based non-coherent detection of UWB FSK with antenna and multipath effects," IEEE MILCOM 2008.
- 21) T. Cooklev and M. Cummings, "Networking description language for ubiquitous cognitive networking," SDR Forum Technical Conference, Washington, DC, Nov. 2008.
- 22) M. Cummings, T. Cooklev, B. Lyles, P. A. Subrahmanyam, "Commercial wireless metalanguage scenario," Software Defined Radio Technical Conference, Denver, CO, November 2007.
- 23) T. Cooklev and A. Abedi, "Teaching the IEEE wireless communication standards dynamically," 2007 Frontiers in Education Conference, Milwaukee, WI, Oct. 10-13, 2007.
- 24) S. Gaur and T. Cooklev, "Using Finer AIFSN granularity to Accurately Tune the Flow Ratios in IEEE 802.11e," The 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), Sept. 2007, Athens, Greece.
- 25) S. Gaur and T. Cooklev, "'Performance Enhancement of IEEE 802.11e EDCA by Random AIFSN", 2007 3rd International Conference on Testbeds and Research Infrastructures for the Development of Networks & Communities (TridentCom), Grosvenor Resort, Orlando, FL, May 21-23, 2007.
- 26) F. Ramirez-Mireles, and T. Cooklev, "Effects of Antenna and Multipath Frequency Selectivity on UWB Using Non-coherent FSK," World Wireless Forum, Stanford, CA, May 18-20 2007.
- 27) F. Ramirez-Mireles, and T. Cooklev, "An Investigation of Antenna and Multipath Effects on Pulse-Based UWB Using FSK," IEEE Globecom, San Francisco 2006.

- 28) T. Cooklev and P. Siohan "Vector-transform-based OFDM", Asilomar Conf. On Computers and Comm., Pacific Grove, Nov. 2006.
- 29) S. Gaur and Cooklev, T. "Performance enhancement of IEEE 802.11e EDCA by random AIFS_N," IEEE Wireless multimedia communication conf., Vancouver, BC, Canada, July 2006.
- 30) T. Cooklev, Keh-Gang Lu "A wavelet transform approach to the design of complementary sequences for communications, 39th Asilomar Conference on Systems, Signals, and Computers, Pacific Grove, CA Nov. 2005.
- 31) M. Goins, T. Cooklev, and J. W. Hines, "System-on-a-chip design for lab-on-a-chip in space-flight systems," Proc. Information Systems: New Generations, Las Vegas, NV, April 2005.
- 32) Y. Bai and T. Cooklev, "An improved method for lossless data compression" IEEE Data Compression Conference, Snowbird, Utah, March 2005.
- 33) A. Pakdaman, J. Eidson, T. Cooklev, "Synchronization of wireless LAN over IEEE 1588," Int. Conference on IEEE 1588, Baltimore MD, Sept. 2004.
- 34) T. Cooklev, "Dynamic bandwidth allocation and channel coding for providing QoS in wireless networks," Int. Conference on Telecommunications, Feb. 2003, Papeete, Tahiti.
- 35) T. Cooklev and M. Sablatash "A wavelet transform approach to the design of sequences for communications," Wireless Communications'97, Calgary, July 1997.
- 36) M. Sablatash, John Lodge, and T. Cooklev "Transmitter and receiver filter bank designs for bandwidth-on-demand multiple access communications combining wavelet packet filter bank trees and DFT polyphase filter banks" IEEE Int. Conference on Communications, Montreal, 1997.
- 37) G. Berbecel, T. Cooklev and A. N. Venetsanopoulos, "A practical wavelet-based approaches to watermarking digital images," IEEE Conf. on Consumer Electronics, Chicago, IL, 1997.
- 38) T. Cooklev, G. Berbecel, A. N. Venetsanopoulos, "Wavelets and differential-dilation equations" Canadian Workshop on Information Theory, Toronto, June 1997.
- 39) T. Cooklev, G. Berbecel, and A. N. Venetsanopoulos, "Construction of an infinitely differentiable continuous-time wavelet and differential dilations equations," Int. Workshop on Signal and Image Processing, Manchester, UK, Nov. 1996.
- 40) T. Cooklev, A. Nishihara, M. Kato, and M. Sablatash "Lattice structures for two-channel paraunitary filter banks that yield symmetric wavelet bases," EUSIPCO'96, Trieste, Italy, Sept. 1996
- 41) D. Androutsos, T. Cooklev, A. N. Venetsanopoulos, "Multifilter banks and multiwavelets for multispectral image compression," World Congress of Nonlinear Analysts, Athens, July 1996.

- 42) T. Cooklev, "On the design of orthogonal filter banks and wavelets with complex coefficients," Queen's Biennial Symposium on Communications, Kingston, June 1996.
- 43) T. Cooklev, "Filter banks and wavelet transforms over finite fields," Queen's Biennial Symposium on Communications, Kingston, June 1996.
- 44) T. Cooklev, "1-D and 2-D biorthogonal filter banks with vanishing moments and biorthogonal wavelet packets" Queen's Biennial Symposium on Communications, Kingston, June 1996.
- 45) T. Cooklev, "Multichannel filter banks, vector transforms, and multiwavelets with applications in color image compression," Queen's Biennial Symposium on Communications, Kingston, June 1996.
- 46) T. Cooklev, A. Nishihara, M. Kato, and M. Sablatash "Two-channel multifilter banks and multiwavelets," IEEE ICASSP'96, Atlanta, GA, pp. 2769-2773, May 1996.
- 47) T. Cooklev, et. al., "Multifilters and multiwavelets," Wavelets in signal and image processing, Centre de recherche mathematique, Universite de Montreal, Montreal, Quebec, Canada, March 1996.
- 48) T. Cooklev, et al "Regular biorthogonal filter banks and wavelet bases: new design and implementation," Int. Conf. Digital Signal Processing,, Limmasol, Cyprus, 1995.
- 49) T. Cooklev, A. Nishihara, T. Yoshida, and M. Sablatash "Regular multidimensional linear phase FIR perfect-reconstruction filter banks and wavelet bases," IEEE ICASSP'95, Detroit, MI, May 1995.
- 50) T. Cooklev, A. Nishihara, and M. Sablatash "Theory of digital filter banks over finite fields," IEEE Asia-Pacific Conf. Circuits Systems (APCCAS), Taipei, Taiwan, Dec. 1994.
- 51) T. Cooklev, T. Yoshida, A. Nishihara, "Multidimensional linear phase FIR perfect-reconstruction filter banks," DSP Symposium, Nov. 1994, Kyoto, Japan.
- 52) M. Sablatash , Todor Cooklev and Takuro Kida, "The coding of image sequences by wavelets, wavelet packets and adaptive wavelet packets," Int. Broadcasting Convention, Amsterdam, Holland, Sept. 1994.
- 53) Mike Sablatash , Todor Cooklev, "Compression of high quality audio signals by wavelet packets and other methods," Kingston Biennial Symp. Communications, Kingston, Ontario, Canada, June 1994.
- 54) M. Sablatash , Todor Cooklev and Takuro Kida, "The coding of image sequences by wavelets, wavelet packets, adaptive wavelet packets and other subband coding schemes," Kingston Biennial Symp. Communications, Kingston, Ontario, Canada, June 1994.
- 55) M. Sablatash , J. Lodge, and Todor Cooklev, "Wavelets, matrices and filter banks," Canadian Applied Mathematics Symp., Montreal, Canada, June 1994.

- 56) Todor Cooklev, Toshiyuki Yoshida, Akinori Nishihara and Mike Sablatash, "Multidimensional perfect reconstruction linear phase digital filter banks and wavelets," Canadian Applied Mathematics Symp., Montreal, Canada, June 1994.
- 57) V. Dimitrov and T. Cooklev, "Hybrid algorithm for computing the matrix polynomial using a fractal number system," Proc. IEEE ISCAS, pp. 5.129-5.132, London, UK, 1994.
- 58) T. Cooklev and A. Nishihara, "Multidimensional perfect-reconstruction linear-phase digital filter bank," Karuizawa Workshop on Circuits Systems, Karuizawa, Japan, April 1994.
- 59) T. Cooklev and A. Nishihara, "Partial FFT," Proc. 8th Digital Signal Processing Workshop, Sendai, Japan, pp. 37-42, Oct. 1993.
- 60) T. Cooklev, S. Samadi, A. Nishihara and N. Fujii, "Maximally flat approximation for two-dimensional FIR digital filters with applications in sampling structure conversion," ECCTD'95, Davos, Switzerland, pp. 385--390, Aug. 1993.
- 61) T. Cooklev and A. Nishihara, "Maximally flat FIR filters," IEEE ISCAS, Chicago, IL, pp. 96-99, May, 1993.
- 62) T. Cooklev and A. Nishihara, "Maximally flat FIR Hilbert transformers," Karuizawa Workshop on Circuits and Systems, Karuizawa, Japan, pp. 37-42, April 1993.
- 63) T. Cooklev and A. Nishihara, "Systolic structures for linear-phase FIR filters," 1st IEEE Asia Pacific Conference on Circuits and Systems, pp. 304-306, Sydney, Australia, Dec. 1992.
- 64) T. Cooklev and A. Nishihara, "A new class of 2-D FIR maximally-flat digital filters," 7th Digital Signal Processing Symposium, Fuji Res. Inst., Japan, pp. 115-120. Nov. 1992.
- 65) T. Cooklev and A. Nishihara, "Design of N-D hyper spherically symmetric FIR filters," IEICE Fall Conference, pp. A-82, Tokyo, Sept. 1992.
- 66) V. Dimitrov, T. Cooklev, B. Donevsky, "Fibonacci-based complex number theoretic transform," IASTED Int. Symposium Circuits Systems, Zurich, Switzerland, pp. 69-72, July 1991.

United States Patents

- 1) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, "Systems and methods for high rate OFDM communications" U.S. Patent 9,949,148, April 17, 2018.
- 2) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, "Systems and methods for high rate OFDM communications" U.S. Patent 9,936,401, April 3, 2018.
- 3) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, "Systems and methods for high rate OFDM communications" U.S. Patent 9,461,857, October 4, 2016.

- 4) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, "Systems and methods for high rate OFDM communications" U.S. Patent 9,450,794, September 20, 2016.
- 5) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, "Systems and methods for high rate OFDM communications" U.S. Patent 9,148,806, September 29, 2015.
- 6) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, Multicarrier packet communication system, U.S. Patent 9,148,801, September 29, 2015.
- 7) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, "Systems and methods for high rate OFDM communications" U.S. Patent 8,958,350, February 17, 2015.
- 8) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, "Systems and methods for high rate OFDM communications" U.S. Patent 8,842,570, September 23, 2014.
- 9) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, "Systems and methods for high rate OFDM communications" U.S. Patent 8,755,264, June 17, 2014.
- 10) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, "Systems and methods for high rate OFDM communications" U.S. Patent 8,553,579, Oct. 8, 2013.
- 11) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, Multicarrier packet communication system, U.S. Patent 8,537,703, September 17, 2013.
- 12) M. Tzannes, D. Lee, T. Cooklev, and C. Lanzl, Systems and methods for high rate OFDM communications using first and second cyclic prefix lengths and first and second pilot tones, U.S. Patent 8,416,677, April 9, 2013.
- 13) M. Tzannes, D. Lee, T. Cooklev, C. Lanzl, OFDM communications using bit allocation tables, U.S. Patent 8,284,800, October 9, 2012.
- 14) M. Tzannes, D. Lee, T. Cooklev, C. Lanzl, Systems and methods for high rate OFDM communications using first and second cyclic prefix lengths, U.S. Patent 8,159,969, April 17, 2012.
- 15) M. Tzannes, D. Lee, T. Cooklev, C. Lanzl, High rate OFDM communications using bit allocation tables, 7,924,841, May 17, 2011
- 16) M. Tzannes, D. Lee, T. Cooklev, C. Lanzl, Method for packet communication using training packets, U. S. Patent 7,944,851, May 17, 2011
- 17) M. Tzannes, D. Lee, T. Cooklev, C. Lanzl, Method for variable cyclic length in OFDM communications, 7,916,625, March 29, 2011
- 18) M. Tzannes, D. Lee, T. Cooklev, C. Lanzl, High rate OFDM communications with a variable cyclic prefix, 7,804,765, September 28, 2010
- 19) M. Tzannes, D. Lee, T. Cooklev, C. Lanzl, Multicarrier packet communication method, 7,729,281, June 1, 2010
- 20) M. Tzannes, D. Lee, T. Cooklev, C. Lanzl, Systems and methods for high rate OFDM communications, 7,590,071, September 15, 2009
- 21) M. Tzannes, D. Lee, T. Cooklev, C. Lanzl, Systems and methods for high rate OFDM communications, 7,522,514, April 21, 2009
- 22) Kenneth Morley; Todor Cooklev, Mark Gray; Darrin Gibbs; Video signal processing method and apparatus for internet appliances or embedded systems, US Patent 6,795,869, September 2004.
- 23) Todor Cooklev, Darrin Gibbs; Mark Gray; Ken Morley; Method and system for performing speech recognition for an internet appliance using a remotely located speech recognition application, US Patent 6,772,123, August 2004.
- 24) T. Cooklev, Device and method for compensating or creating doppler effect using digital signal processing, US Patent, 6,633,617, Oct. 2003.
- 25) S. Messerly, T. Cooklev, "Adaptive filter size for the efficient computation of wavelet packet trees," US Patent 6,581,081, June 2003.

- 26) T. Cooklev, "Method and system for spatially-disjoint joint source and channel coding for high-quality real-time multimedia streaming over connection-less networks via circuit-switched interface links," US Patent 6,574,218, June 2003.
- 27) T. Cooklev, M. Gray, "System and method for precise DTMF detection," US Patent 6,560,331, May 2003.
- 28) T. Cooklev, K. Smart, "High-speed modem operating over two or more telephone lines," US Patent 6,490,295, Dec. 2002.
- 29) T. Cooklev, M. Gray, D. Gibbs, K. Morley, "Method and apparatus for continuously variable slope delta modulation coding of signals," US Patent 6,486,810, Dec. 2002.
- 30) S. Messerly, T. Cooklev, "Reduced computation system for wavelet transforms," US Patent 6,466,957, Oct. 2002.
- 31) T. Cooklev, "Method and apparatus for wavelet-based digital watermarking of signals", US Patent, March 2002.
- 32) T. Cooklev, "Method for real-time lossless data compression of computer data, US Patent 6,289,130, Sept. 11, 2001.

Selected non-refereed publications

Contributions to 3GPP

- 1) "CQI Definition for CoMP," 3GPP TSG-RAN WG1 Meeting #68 R1-120243, Dresden, Germany, February 6th – 10th 2012. (on behalf of Hitachi)
- 2) "Specification Impact of Non-Zero Power ABS", 3GPP TSG-RAN WG1 Meeting #68 R1-120241, Dresden, Germany, February 6th – 10th 2012. (on behalf of Hitachi)
- 3) "Way Forward on CSI Feedback for CoMP," R1-120901, (authored by a group of companies)
- 4) "WF on CSI-RS based measurement," R1-120895 (authored by a group of companies)
- 5) LS to RAN3 – "X2 enhancements in support of non-zero power ABS," 3GPP TSG RAN WG1 Meeting #69, Prague, Czech Republic, May 2012 (on behalf of Hitachi)
- 6) "WF on signalling details for non-zero transmit power ABS," R1-123948, (co-authored with representatives from several companies), Prague, Czech Republic, May 2012 (on behalf of Hitachi)
- 7) "WF on X2 signalling for reduced power ABS for FeICIC," (co-authored with representatives from several companies) R1-123881, Prague, Czech Republic, May 2012

Contributions to IEEE 802.11

- 8) G. Venkatesan, A. Ashley, Ed Reuss, and T. Cooklev, "IEEE 802 Tutorial: Video over 802.11," March 2007. (on behalf of Hitachi America Ltd)
- 9) T. Cooklev, "Video over WLAN", doc. 11-07-0105r0, 2007. (on behalf of Hitachi America Ltd)
- 10) S. Gaur, T. Cooklev, "MAC improvement using random AIFS", doc. 802.11-06/0657, July 2006. (on behalf of Hitachi America Ltd)
- 11) C. Tavares, T. Cooklev, S. Gaur, "On video over 802.11," doc. 802.11-06/0039, Jan. 2006. (on behalf of Hitachi America Ltd)

- 12) C. Tavares, T. Cooklev, "MAC extensions for HDTV," doc. 802.11-05/0632, July 2005. (on behalf of Hitachi America Ltd)
- 13) M. Tzannes, T. Cooklev, D. Lee, C. Lanzl, "Extended data rate 802.11a", doc. 802.11-02/232, March 2002. (on behalf of Aware, Inc.)
- 14) S. Prestwich, D. Ostermiller, K. Dobson, T. Cooklev, "Dynamic frequency hopping," IEEE 802.15, Tel Aviv, Israel, January 2000. (on behalf of Aware, Inc.)

Contributions to ITU-T SG15 Q4 on DSL technology

- 15) T. Cooklev, A. Freedman, and M. Tzannes, "Low-density parity check codes (LDPC) for ADSL," ITU-T SG15 Q4 BI-068, Bangalore, India, Nov. 2000. (on behalf of Aware, Inc.)
- 16) T. Cooklev, M. Tzannes, A. Freedman, "Low-density parity check coded modulation for ADSL," ITU-T SG15 Q4 BI-081, Bangalore, India, 2000. (on behalf of Aware, Inc.)
- 17) T. Cooklev, "Error-correcting codes for ADSL," ITU-T SG15 Q4, BA-108, Antwerp, Belgium, June 2000. (on behalf of Aware, Inc.)

Other non-referred publications and technical reports

- 18) T. Cooklev, "Standards, regulation, and compliance," IEEE Standards University, [online] <https://www.standardsuniversity.org/e-magazine/september-2017/standards-regulation-compliance/>
- 19) T. Cooklev A wavelet transform approach to the design of sequences for communications, Communications Research Centre, Ottawa, Tech. Report U6800-6-2438, 1997.
- 20) I. Rabinovitch, A. N. Venetsanopoulos, and T. Cooklev, "Perceptually lossless still image compression using the wavelet transform, considering the properties of the Human Visual System," ITRC, Kingston, Ontario, 1996.
- 21) T. Cooklev, On the design and implementation of filter banks and filter bank trees with finite wordlength, Communications Research Centre, Ottawa, Tech. Report 67CRC-5-3315, 1996.
- 22) T. Cooklev, M. Kato, A. Nishihara, M. Sablatash "Multifilter banks and multiwavelets," IEICE Tech. Report, Tokyo, Japan, May 1995.
- 23) T. Cooklev, A. Nishihara, "Regular biorthogonal filter banks and wavelet bases: new design and implementation," IEICE Tech. Report, presented at KDD Research Institute, Kamifukuoka, Saitama, Japan, April 1995.
- 24) V. Dimitrov and T. Cooklev, "Two algorithms for modular exponentiation using non-standard arithmetics," IEICE Tech. Report, ISEC93-98, 1994. (in Japanese), presented at the IEICE meeting on information security and cryptography, Osaka, Japan, March 1994.
- 25) T. Cooklev and A. Nishihara, "Pruning the real-valued FFT algorithms for efficient time-domain interpolation and linear convolution," IEICE Tech. Report, CAS93-14, VLD93-14, DSP93-24, May 1993.
- 26) T. Cooklev and A. Nishihara, "Band pass maximally flat FIR filters and Hilbert transformers," IEICE Tech. Report, CS92-88, DSP92-88, Jan. 1993.

Expert Witness Engagements

- 2025 – Expert for Pantech
- Law firm: Mayer Brown LLP
 - ITC Investigation: No. 337-TA-1456
- 2025 – Expert for Vasu Holdings, LLC
- Law firm: Herbert Smith Freehills Kramer LLP, Redwood City, CA
 - Case names: *Vasu Holdings, LLC v. Samsung Electronics Co. Ltd., and Samsung Electronics America, Inc.*
 - Civil Action No. 2:24-cv-00034-JRG-RSP (*E. D. Tex.*)
 - Submitted infringement report
 - Technology at issue: switching between Wi-Fi and cellular communications
- 2024 – Expert for XR Communications LLC
- Law firm: Russ August Kabat, Los Angeles, CA
 - Case names: *XR Communications LLC v. AT&T Services Inc., AT&T Mobility LLC, and AT&T Corp.*
 - Civil Action No. 2:23-cv-00202-JRG-RSP (*E. D. Tex.*)
 - Submitted infringement and validity reports
 - Testified at deposition
 - PTAB Case IPR2024-00868, submitted declaration
 - Technology at issue: beamforming in cellular communications
- 2025 – Expert for D-Link
- Law firm: Pillsbury Winthrop Shaw Pittman LLP
 - ITC Investigation: No. 337-TA-1454
- 2025 – Expert for Intellectual Ventures II LLC
- Law firm: Volpe Koenig, Philadelphia, PA
 - Case name: *Tesla, Inc., v. Intellectual Ventures II LLC*
 - Case Nos. IPR2025-00220
 - Submitted declaration
 - Technology at issue: cellular communication
- 2025 – Expert for Ford Motor Company
- Law firm: Brooks Kushman P.C.
 - Case name: Ford Motor Company v. Autoconnect Holdings LLC
 - Case Nos. IPR2026-00171
 - Technology at issue: vehicle communication systems, sensors, and infotainment systems
- 2025 – Expert for TOT Power Control, S.L.
- Law firm: DiNovo Price, Austin, TX

- Case name: *TOT Power Control, S.L. v. AT&T Mobility, Inc.*,
- Case name: *TOT Power Control, S.L. v. AT&T USA Inc.*,
- Case name: *TOT Power Control, S.L. v. T-Mobile USA Inc.*,
- Civil action No. 2:21-CV-00107-ADA, No. 2:21-CV-00109-ADA (*W.D. Tex.*)
- Technology at issue: cellular communication

2025 – 2025

Expert for Netflix, Inc.

- Law firm: Baker Botts LLP, San Francisco, CA
- Case names: *Netflix, Inc. v. Broadcom, Inc.*, and *VM Ware, LLC*
- Civil Action No. 3:25-cv-3738-TLT (*N. D. Cal.*)
- Submitted declaration
- Technology at issue: IEEE 1588

2024 – 2025

Expert for Headwater Research LLC

- Law firm: Russ August Kabat, Los Angeles, CA
- Case names: *Headwater Research LLC v. Cellco Partnership D/B/A Verizon Wireless and Corporate Services Group, Inc.*
- Civil Action No. 2:23-cv-00352-JRG-RSP (*E. D. Tex.*)
- Submitted infringement and validity reports
- Testified at deposition
- Technology at issue: cellular communications

2023 – 2024

Expert for Pantech Corporation

- Law firm: Mayer Brown LLP
- Case names: *Pantech Corporation and Pantech Wireless LLC v. LG Electronics Inc.*, and *LG Electronics U.S.A., Inc. and Pantech Corporation and Pantech Wireless LLC v. OnePlus Technology (Shenzhen) Co. Ltd.*
- Civil Action Nos. 5:22-cv-00113-RWS-JBB, 5:22-cv-00069-RWS (*E. D. Tex.*)
- Submitted report in connection with claim construction, infringement and validity reports
- Testified at a deposition and at trial
- Technology at issue: cellular communications

2024 –

Expert for Sckipio Technologies SI, Ltd.

- Law firm: Fish & Richardson, New York, NY
- Technology at issue: DSL communications

2024 – 2025

Expert for Scosche Industries, Inc.

- Law firm: ArentFox Schiff, LLP, Los Angeles, CA
- Case name: *Fleet Connect Solutions, LLC v. Scosche Industries, Inc.*
- Civil action No. 2:23-CV-09324 HDV (AJRx) (*C.D. Cal.*)
- Technology at issue: Wi-Fi and Bluetooth wireless communication

2023 – 2024

Expert for Hytera Communications Corporation,

- Law firm: Steptoe LLP, Washington, DC

- Case name: *United States of America v. Hytera Communications Corporation*
- Case No. 1:20-cr-00688 (N. D. Ill.)
- Technology at issue: software-defined radio

2024 –

Expert for Cobblestone Wireless LLC

- Law firm: Russ August Kabat, Los Angeles, CA
- Case name: *Hewlett Packard Enterprise Company and Cisco Systems, Inc., v. Cobblestone Wireless, LLC*
- Case No. IPR2024-00707
- Submitted declaration
- Technology at issue: hardware architecture of wireless devices

2024 – 2024

Expert for Broadphone LLC

- Law firm: Russ August Kabat, Los Angeles, CA
- Case name: *Samsung Electronics Co. Ltd., v. Broadphone, LLC*
- Case Nos. IPR2024-00153, IPR2024-00154, IPR2024-00155
- Submitted declaration
- Technology at issue: wireless communication systems

2020 –

Expert for Smart Mobile Technologies LLC

- Law firm: Hagens Berman Sobol Shapiro, Pasadena, CA (2020-2022); Graves and Shaw LLP, Los Angeles, CA (2022 – present).
- Case names: *Smart Mobile Technologies LLC v. Apple Inc., and Smart Mobile Technologies LLC v. Samsung Electronics Co. Ltd. and Samsung Electronics America, Inc.*
- Case Nos: 6:21-cv-00603, 6:21-cv-00701 (W.D. Tex.)
- PTAB case Nos. IPR2022-00766, IPR2022-00807, IPR2022-00808, IPR2022-01002, IPR2022-01003, IPR2022-01004, IPR2022-01005, IPR2022-00979, IPR2022-00980, IPR2022-00981, IPR2022-00982, IPR2022-01222, IPR2022-01223, IPR2022-01248, IPR2022-01249
- Submitted multiple declarations
- Testified at multiple depositions
- Technology at issue: cellular and Wi-Fi communications and networking

2022 – 2023

Expert for XR Communications, LLC d/b/a Vivato Technologies

- Law firm: Russ August Kabat, Los Angeles, CA
- Case name: *XR Communications, LLC, dba Vivato Technologies v. Asustek Computer, Inc.*
- Case No. 6:21-cv-00622-ADA (W. D. Texas)
- Reports on infringement and technical scope of license
- Testified at a deposition
- Technology at issue: beamforming in wireless communications

2023 – 2023

Expert for Metrom Rail LLC

- Law firm: McAndrews, Held & Malloy, Chicago, IL

- Case name: *Siemens Mobility, Inc., Ground Transportation Systems USA, Inc., Humatics Corp., and Piper Networks, Inc., v. Metrom Rail LLC*
- Case Nos. IPR2023-00468 & IPR2023-00470
- Submitted declaration
- Technology at issue: ultra-wideband (UWB) sensing for collision avoidance

2023 – 2024

Expert for Mitsubishi Electric Corporation

- Law firm: Xsensus LLP, Alexandria, VA
- Case name: *TCL Communication Technology Holdings Limited, TCT Mobile International Limited, TCT Mobile, Inc., TCT Mobile (US) Inc., TCT Mobile (US) Holdings Inc. v. Mitsubishi Electric Corp.*
- PTAB Case Nos. IPR2023-00957, IPR2023-00997
- Submitted declarations
- Law firm: Devlin Law Firm, LLC, Wilmington, DE
- Case name: *Mitsubishi Electric Corporation and Sisvel International S.A., vs. TCL Communication Technology Holdings Limited, TCT Mobile International Limited, TCT Mobile (US) Inc., and TCT Mobile (US) Holdings Inc.*
- Case No. 8:22-cv-01073-GW-DFM (C.D. Cal.)
- Submitted declarations
- Technology at issue: cellular communications

2023 – 2023

Expert for Lemko Corp.

- Law firm: Kramer Levin, New York, NY
- Case name: *Microsoft Corporation and Affirmed Networks, Inc. v. Lemko Corporation*
- PTAB Case Nos. IPR2023-00529, IPR2023-00530, IPR2023-00531, IPR2023-00570
- Technology at issue: implementation of cellular networks
- Submitted a declaration
- Testified at deposition

2022 – 2025

Expert for Ford Motor Company

- Law firm: Latham and Watkins (2022-2023); Brooks Kushman P.C. (2023-)
- Case name: *Neo Wireless LLC v. Ford Motor Company, General Motors, and Nissan North America, Inc.*
- PTAB Case No. IPR 2023-00763
- Submitted declarations in support of petitions for *Inter Partes* review
- Testified at depositions
- Technology at issue: wireless communications

2021 – 2024

Expert for Flexiworld Technologies

- Law firm: Nelson Bumgardner Conroy, Dallas, TX
- Case name: *Roku, Inc. v. Flexiworld Technologies*

- PTAB Case Nos. IPR2021-00713, IPR2021-00714, IPR2021-00715, PGR2021-00112, IPR2022-00775
- Submitted multiple declarations
- Testified at multiple depositions

2014 – 2023

Expert for TQ Delta, Austin, TX

- Law firm: McAndrews, Chicago, IL
- Case name: TQ Delta, LLC v. Adtran
Civil Action No. 14-cv-00954-RGA (D-Del.), Civil Action No. 15-cv-00121-RGA (D-Del.)
- Case name: TQ Delta, LLC v. 2Wire
Civil Action No. 13-cv-1835-RGA (D-Del.)
- Case name: TQ Delta, LLC v. Zhong Technologies, Inc.
Civil Action No. 13-cv-1836-RGA (D-Del.)
- Case name: TQ Delta, LLC v. Zyxel Communications, Inc. and Zyxel Communications Corporation
Civil Action No. 13-cv-2013-RGA (D-Del.)
- Submitted product testing reports, computer simulation reports, a report on the terms of a license agreement, a report on standards essentiality, infringement reports, validity reports
- Testified at depositions and trials
- Technology at issue: Digital signal processing in Digital Subscriber Line communication systems

2022 – 2024

Expert for Bell Northern Research

- Law firm: Devlin Law Firm LLC
- Case name: *Bell Northern Research, LLC v. HMD America, Inc. et al.*,
- Civil Action No. 1:22-cv-22706-RNS (S.D. Fla)
- ITC Investigation: No. 337-TA-1367
- Technology at issue: wireless communications
- Submitted declaration
- Testified at deposition

2023 – 2024

Expert for Bell Northern Research

- Law firm: Devlin Law Firm LLC
- Case Name: International Trade Commission Investigation No. 337-TA-3568, Certain Electronic Devices Having Wireless Communication Capabilities and Components Thereof
- Technology at issue: wireless local area networking
- Submitted declaration and reports
- Testified at deposition

2023 – 2023

Expert for WSOU Investments, LLC d/b/a Brazos Licensing and Development

- Law firm: Folio Law Group

- Case name: *WSOU Investments, LLC d/b/a Brazos Licensing and Development v. Google, LLC.*,
- Case No. *6:20-cv-00585-ADA (W.D. Tex.)*
- Submitted a validity report
- Testified at a deposition
- Technology at issue: determining a location of a mobile device and location-based services

2021 – 2023

Expert for TQ Delta, Austin, TX

- Law firm: Davis Law Firm, P.C., Longview TX, and McAndrews, Chicago, IL
- Case name: TQ Delta, LLC, v. Commscope Holding Company, Inc., Commscope Inc., Arris International Limited, Arris Global Ltd, Arris US Holdings, Inc., Arris Solutions, Inc., Arris Technology, Inc., and Arris Enterprises, LLC
- Civil Action No: 2:21-cv-310-JRG, 2:21-cv-309-JRG (*E.D. Tex.*)
- Submitted a declaration in connection with claim construction, infringement report, validity report, and reports on testing and simulation
- Testified at two depositions and at trial

2021 – 2023

Expert for WSOU Investments, LLC d/b/a Brazos Licensing and Development

- Law firm: Kasowitz Benson Torres LLP
- Case name: *WSOU Investments, LLC d/b/a Brazos Licensing and Development v. Canon, Inc.*,
- Case Nos. *6:20-cv-00980-ADA, 6:20-cv-00981-ADA (W.D. Tex.)*
- Submitted a declaration in connection with claim construction.
- Testified at a deposition
- Technology at issue: frequency-hopping wireless communication

2021 – 2022

Expert for NXP

- Law firm: Jones Day, Washington, DC
- Case name: Certain Integrated Circuits, Chipsets, and Electronic Devices, and Products Containing the Same, ITC 337-TA-1287
- Technology at issue: IEEE 802.11
- Submitted a validity report
- Deposition

2021 – 2022

Expert for Barkan Wireless IP Holdings, L.P.

- Law firm: Heim, Payne & Chorush, LLP, Houston, TX
- Case name: *Barkan Wireless v. T-Mobile, Inc. and Nokia of America Corp.*
- Civil Action No. *2:21-CV-00034-JRG (E. D. Tex.)*
- Submitted a validity report
- Testified at a deposition
- Technology at issue: cellular network architecture involving home base stations (femtocells)

- 2021 – 2022 Expert for 3G Licensing
- Law firm: Devlin Law Firm LLC
 - Case name: *Cradlepoint, Inc., Dell Inc., Honeywell International, Inc., Sierra Wireless, Inc., TCL Communication Technology Holdings Limited, TCT Mobile International Limited, TCT Mobile, Inc., TCT Mobile (US) Inc., TCT Mobile (US) Holdings Inc., Thales DIS AIS Deutschland GmbH, ZTE Corporation, and ZTE (USA) Inc. v. 3G Licensing, S.A.*
 - PTAB Case Nos. IPR2021-00640, IPR2021-01141
 - Technology at issue: cellular communications
 - Submitted declarations
 - Testified at a deposition
- 2019 – 2022 Expert for Evolved Wireless LLC, Austin, TX
- Law firm: Nelson Bumgardner Albritton P.C., Fort Worth, TX (2019–22); Bruster PLLC, Southlake, TX (2022–present)
 - Patent portfolio review
 - IPR2021-00943
 - Technology at issue: 4G cellular communications
- 2020 – 2021 Expert for General Access Solutions, Dallas, TX
- Law firm: Bartlit Beck, Denver, CO
 - Case name: *General Access Solutions, LTD. v. Virgin Mobile USA, L.P., Boost Mobile, LLC, and Sprint Spectrum L.P.*
 - Civil Action No. 2:20-cv-00007-RWS (E. D. Tex.)
 - Submitted a report on standards essentiality
 - Testified at a deposition
 - Technology at issue: protocol architecture to support beamforming in 4G and 5G cellular standards
- 2015 – 2019 Expert for Evolved Wireless, Austin, TX
- Law firm: Robins Kaplan, Minneapolis, MN
 - Civil Actions No. 15-cv-542-SLR-SRF, No. 15-cv-543-SLR-SRF, No. 15-cv-544-SLR-SRF, No. 15-cv-545-SLR-SRF, No. 15-cv-546-SLR-SRF, and No. 15-cv-547-SLR-SRF (D-Del.) brought against Apple, HTC, Lenovo, Samsung, ZTE, and Microsoft.
 - Submitted infringement and validity reports
 - Testified at deposition and trial
 - Technologies at issue: 4G cellular communications
- 2013 – 2015 Expert for Inter-Digital
- Law firm: Latham and Watkins
 - Subject matter: dual-mode 3G cellular/Wi-Fi devices in connection with Civil Actions No. 13-cv-00009-RGA and No. 13-cv-00010-RGA (D-Del.) brought against ZTE and Microsoft Mobile Oy.

- For the purpose of infringement analysis wrote a 3G mobile phone application and server software
- Produced six expert reports, deposed twice and testified at jury trial