1d2UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

APPLE, INC.,

Petitioner

v.

APEX BEAM TECHNOLOGIES LLC,

Patent Owner

Case IPR2025-00904

U.S. Patent No. 11,626,904

DECLARATION OF DR. ROBERT AKL, D.SC.
IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW

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I, Robert Akl, D.Sc., declare and state as follows:

I. INTRODUCTION

1. I am over the age of 18 and am competent to make this Declaration. I have personal knowledge, or have developed knowledge, of the matters set forth herein based upon my education, training, and/or experience. If called upon to do so, I would testify competently thereto.

2. I have been retained by counsel for Petitioner Apple Inc. ("Petitioner" or "Apple") as a technical expert in the above matter. I am submitting this Declaration to address the validity of claims 1-20 ("Challenged Claims") in U.S. Patent No. 11,626,904 ("the '904 patent"). For the purposes of this Declaration, I have not been asked to opine on any other issues not addressed below.

3. My opinions are based on my years of education, research and experience, as well as my investigation and study of relevant materials, including those identified in this Declaration. I may rely upon these materials, my knowledge and experience, and/or additional materials in forming any necessary opinions. Further, I may also consider additional documents and information to rebut arguments raised by the Patent Owner Apex Beam Technologies LLC ("Patent Owner" or "Apex"). I reserve any right that I may have to supplement this Declaration if further information becomes available or if I am asked to consider additional information. Furthermore, I reserve any right that I may have to consider

and comment on any additional expert statements or testimony of Apex's expert(s) in this matter.

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

II. BACKGROUND AND QUALIFICATIONS

5. I am an expert in the field of cellular networks. I have studied, taught, practiced, and researched this field for over 30 years. I have summarized in this section my educational background, work experience, and other relevant qualifications. A true and accurate copy of my *curriculum vitae* is attached in the Appendix.

6. I earned two Bachelor of Science degrees in Electrical Engineering and Computer Science summa cum laude with a grade point average of 4.0/4.0 and a ranking of first in my undergraduate class from Washington University in St. Louis in 1994. In 1996, I earned my Master of Science degree in Electrical Engineering from Washington University in St. Louis with a grade point average of 4.0/4.0. I earned my Doctor of Science in Electrical Engineering from Washington University in St. Louis in 2000, again with a grade point average of 4.0/4.0, with my dissertation

being on “Cell Design to Maximize Capacity in Cellular Code Division Multiple Access (CDMA) Networks.”

7. While a graduate student, from 1997 through 1999, I worked at MinMax Corporation in St. Louis, where I designed software packages that provided tools to flexibly allocate capacity in a CDMA communications network and maximize the number of subscribers. I also validated the hardware architecture for an Asynchronous Transfer Mode (ATM) switch capable of channel group switching, as well as performed logical and timing simulations, and developed the hardware architecture for the ATM switch. I also worked with Teleware Corporation in Seoul, South Korea, where I designed and developed algorithms that were commercially deployed in a software package suite for analyzing the capacity in a CDMA network implementing the IS-95 standard to maximize the number of subscribers.

8. After obtaining my Doctor of Science degree, I worked as a Senior Systems Engineer at Comspace Corporation from October of 2000 to December of 2001. At Comspace, I designed and developed advanced data coding and modulation methods for improving reliability and increasing the available data rates for cellular communications. I coded and simulated different encoding schemes (including Turbo coding, Viterbi decoding, trellis coded modulation, and Reed- Muller codes) and modulation techniques using amplitude and phase characteristics and multilevel star constellations. This work further entailed the optimization of soft decision

parameters and interleavers for additive white Gaussian and Rayleigh faded channels. In addition, I also extended the control and trunking of Logic Trunked Radio (LTR) to include one-to-one and one-to- many voice and data messaging.

9. In January of 2002, I joined the faculty of the University of New Orleans in Louisiana as an Assistant Professor in the Department of Electrical Engineering. While in this position, I designed and taught two new courses called "Computer Systems Design I and II." I also developed a Computer Engineering Curriculum with a strong hardware-design emphasis, formed a wireless research group, and advised graduate and undergraduate students.

10. In September 2002, I received an appointment as an Assistant Professor in the Department of Computer Science and Engineering at the University of North Texas (UNT), in Denton, Texas. In May of 2008, I earned tenure and was promoted to the rank of Associate Professor. As a faculty member, I have taught courses and directed research in networking and telecommunications, including 2G, 3G, 4G, 5G, CDMA/WCDMA, GPS, GSM, UMTS, LTE, ad-hoc networks, antenna design and beamforming, Bluetooth, call admission control, channel coding, channel estimation, communication interfaces and standards, compression, computer architecture, fault recovery, link aggregation, Internet Protocols, MIMO systems, multi-cell network optimization, network routing, network security, network self-test, packet-networks, ring networks, routing, telephony, VoIP, VPLS, Wi-Fi

(802.11), 802.15.4, Zigbee, wireless communication, and wireless sensors. Between January 2015 and August 2022, I was appointed to Associate Chair of Graduate Studies in the Department of Computer Science and Engineering. In May of 2023, I was promoted to the rank of Professor.

11. I am also the director of the Wireless Sensor Lab ("WiSL") at UNT. I am a member of the Center for Information and Cyber Security (CICS). It is the only program in the U.S. to be federally certified by the National Security Agency as a Center of Academic Excellence in Information Assurance Education and Research and Cyber Defense Research. I was also a member of the NSF Net-Centric & Cloud Software & Systems: Industry-University Cooperative Research Center (I/UCRC). Several of my research projects are funded by industry and the National Science Foundation and published in *IEEE* conference proceedings and journals.

12. In addition to advising and mentoring students at UNT, I was asked to join the faculty of the University of Arkansas in Little Rock as an Adjunct Assistant Professor from 2004 to 2008 to supervise the research of two Ph.D. graduate students who were doing research in wireless communications. At UNT, I have advised and supervised more than 250 undergraduate and graduate students, several of whom received a master's or doctorate degree under my guidance.

13. Between 2005 and 2017, I have received over a million dollars in funding from the State of Texas, Texas Higher Education Coordination Board, the

National Science Foundation, and industry to design and conduct robotics, video, and mobile gaming (*e.g.*, Xbox, PC, mobile device) programming summer camps for middle and high school students at UNT. By using video and mobile gaming as the backdrop, participants have learned coding and programming principles and developed an understanding of the role of physics and mathematics in video game design.

14. Between 2011 and 2013, I was director of the Bio-Com Project that was funded by Raytheon. The project evaluated the feasibility study using Surface Electromyography (EMG) and bend resistive sensors, which are attached to each of the five fingers of the hand, for hand gesture recognition. This approach is sometimes known as a "data glove." A prototype was developed and demonstrated at Raytheon, to help soldiers in close-combat situations communicate with hand gestures and hand signals that would be recognized and transmitted to other soldiers' Head Up Display (HUD) without breaking radio silence.

15. In addition to my academic work, I have remained active in the communication industry through my consulting work. In 2002, I consulted for Input/Output Inc. and designed and implemented algorithms for optimizing the frequency selection process used by sonar for scanning the bottom of the ocean. In 2004, I worked with Allegiant Integrated Solutions in Ft. Worth, Texas to design and develop an integrated set of tools for fast deployment of wireless networks, using

the 802.11 standard. Among other features, these tools optimize the placement of Access Points and determine their respective channel allocations to minimize interference and maximize capacity. I also assisted the Collin County Sheriff's Office (Texas) in a double homicide investigation, analyzing cellular record data to determine user location.

16. I have authored and co-authored over 100 journal publications, conference proceedings, technical papers, book chapters, and technical presentations in a broad array of communications-related technologies, including networking and wireless communication. I have also developed and taught over 100 courses related to communications and computer systems, switches and routers, including several courses on signals and systems, 4G/LTE and 5G/NR, OFDM, Internet Protocols, VoIP, VPLS, Wi-Fi (802.11), 802.15.4, Zigbee, wireless communication, antenna design and beamforming, communications systems, communication interfaces and standards, channel estimation, fault recovery, link aggregation, location management, sensor networks, source coding and compression, network security, network self-test, computer systems design, game and app design, and computer architecture. These courses have included introductory courses on communication networks and signals and systems, as well as more advanced courses on wireless communications, networking and routing. A complete list of my publications and the courses I have developed and/or taught is also contained in my curriculum vitae.

17. My professional affiliations include services in various professional organizations and serving as a reviewer for a number of technical publications, journals, and conferences. I have also received a number of awards and recognitions, including the *IEEE* Professionalism Award (2008), UNT College of Engineering Outstanding Teacher Award (2008), and Tech Titan of the Future (2010) among others, which are listed in my curriculum vitae.

18. I have also served as an expert in certain legal proceedings. A list of cases in which I have testified at trial, hearing, or by deposition (including those during the past four years) is provided in my curriculum vitae. Over the years, I have been retained by both patent owners and petitioners, as well as plaintiffs and defendants.

19. I am being compensated for my work in this case at my standard rate of $995 per hour (plus reimbursement for expenses) in connection with my preparation of this declaration, as well as for each hour spent providing deposition or testimony. This compensation is not contingent upon my performance, the outcome of this case, or any issues involved in or related to this case. I have no financial interest in this matter.

III. DOCUMENTS AND MATERIALS CONSIDERED

20. In preparing my opinions, I have reviewed the ’904 patent and its prosecution history and have also reviewed the other documents and materials cited

herein and the materials listed below. When citing from these references, all emphasis is added unless otherwise noted.

Ex.	Description
Exhibit 1001	U.S. Patent 11,626,904
Exhibit 1002	Prosecution File History for U.S. Patent 11,626,904
Exhibit 1004	U.S. Patent Application Publication No. 2015/0036612 ("Kim")
Exhibit 1005	International Publication WO2015/131494 to Chen
Exhibit 1006	Certified English translation of International Publication WO2015/131494 to Chen ("Chen")
Exhibit 1007	U.S. Patent No. 10,951,271 File History
Exhibit 1008	Farhana Afroz et al., *SINR, RSRP, RSSI and RSRQ Measurements in Long Term Evolution Networks*, International Journal of Wireless & Mobile Networks (IJWMN), Vol. 7, No. 4, pp. 113-123 (Aug. 2015) ("Afroz")
Exhibit 1009	International Publication WO2016/126099 A1 to Park et al.
Exhibit 1010	Certified English translation of International Publication WO2016/126099 A1 to Park et al. ("Park")
Exhibit 1011	International Publication WO2016/015307 A1 to Liu et al.
Exhibit 1012	Certified English translation of International Publication WO2016/015307 A1 to Liu et al. ("Liu")
Exhibit 1013	Excerpts from Stefania Sesia et al., LTE – *The UMTS Long Term Evolution from Theory to Practice* (John Wiley & Sons, Ltd. 2d ed. 2011) ("Sesia LTE")
Exhibit 1014	US Patent Application Publication No, 20160218778A1 to Ng et al ("Ng")
Exhibit 1015	3GPP TS 36.133 v13.2.0 ("Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for support of radio resource management (Release 13)") (Jan. 2016)
Exhibit 1016	U.S. Patent Application Publication No. 2013/0308608 A1 to Hu et al. ("Hu")
Exhibit 1017	U.S. Patent Application Publication No. 2011/0038330 A1 to Luo et al. ("Luo")
Exhibit 1018	U.S. Patent Application Publication No. 2011/0176519 A1 to Vitthaladevuni et al. ("Vitthaladevuni")
Exhibit 1019	3GPP TS 36.211 v13.0.0 ("Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio

	Access (E-UTRA); Physical channels and modulation (Release 13)") (Dec. 2015)
Exhibit 1020	3GPP TS 36.212 v13.0.0 ("Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding (Release 13)") (Dec. 2015)
Exhibit 1021	3GPP TS 36.213 v13.0.0 ("Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 13)") (Dec. 2015)
Exhibit 1022	3GPP TS 36.214 v13.0.0 ("Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; Measurements (Release 13)") (Dec. 2015)
Exhibit 1023	3GPP TS 36.331 v13.0.0 ("Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification (Release 13)") (Dec. 2015)
Exhibit 1024	US Patent Application Publication No. US 2016/0142189A1 to Shin et al ("Shin")

21. My opinions are also based upon my education, training, research, knowledge, and personal and professional experience. I reserve the right to supplement or amend this Declaration in the event that I hereafter become aware of additional relevant information.

IV. UNDERSTANDING OF LEGAL STANDARDS

22. I am not an attorney and have not been asked to offer an opinion on the law. I understand, however, that certain aspects of the law are relevant to my evaluation and opinions set forth herein. I have therefore been informed of and asked to apply the legal principles summarized below.

A. Priority Date

23. I understand that the "priority date" of a patent is the date on which it is filed. I further understand that a patent may be entitled to the filing date of an earlier-filed application or foreign patent filing. In this case I understand the '904 patent claims priority to December 28, 2016.

B. Burden of Proof

24. I understand that Apple as the Petitioner bears the burden of proof in this proceeding and that that burden is to establish by a preponderance of the evidence that the claims are invalid.

C. Claim Construction

25. I understand that the words of a claim are generally given their ordinary and customary meaning, which I understand is the meaning that the term would have to a person of ordinary skill in the art in question at the time of the invention, *i.e.*, as of the effective filing date of the patent application. I understand the person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification and prosecution history. Additionally, I understand other extrinsic evidence external to the patent and prosecution history, such as dictionaries and treatises, may also be useful in determining the meaning that the term would have to a person of ordinary skill in the art in question at the time of the invention. I understand that such extrinsic evidence, however, is

generally afforded less weight than intrinsic evidence in determining the meaning of claim terms, and overall is unlikely to result in a reliable interpretation of a patent claim scope unless considered in the context of the intrinsic evidence. I have applied the plain and ordinary meaning in my analysis herein. Additionally, I have provided analysis of the construction of particular terms in the alternative, if deemed necessary, including in my analysis of Elements [1.d1] and [1.d5], for example.

D. Obviousness Under 35 U.S.C. § 103

26. I understand that a claim is invalid if the invention recited in the claim would have been obvious to one of ordinary skill in the art at the time the invention was made. I understand this means that even if all the requirements of the claim cannot be found in a single prior art reference that would anticipate the claim, a person of ordinary skill in the field of the invention knowledgeable of the prior art would have come up with the claimed invention. In considering whether a claim is obvious, I have been asked to consider (a) the level of skill in the art at the time of the claimed invention, (b) the scope and content of the prior art, (c) any differences between the prior art and the claims of the patent-in-suit, and (d) any "secondary factors" tending to show non-obviousness of the claimed invention, including commercial success, long-felt but unresolved need, failure of others, copying, praise by others, unexpected results, and simultaneous invention by others.

27. I understand that a claim composed of several elements is not proved obvious merely by demonstrating that each of its elements was independently known in the prior art. I also understand that obviousness should not be analyzed using the benefit of hindsight. Instead, it must be analyzed from the standpoint of what was known and understood by a POSITA at the time of the claimed invention. I further understand demonstrating that a modification to a reference or the combination of multiple references is obvious requires providing a reason for why a POSITA would modify a reference or combine multiple references and that reason must be supported with some rationale underpinning. Merely pointing out that two references are similar or in the same field of endeavor is not sufficient.

E. Secondary Considerations of Non-Obviousness

28. I understand that in determining whether the claims are obvious I must also consider certain factors that may help determine that a particular concept was not obvious. These include practical factors relating to the concept, including (1) commercial success, (2) a long-felt need for a solution to the problem facing the inventors, (3) whether others tried and failed to solve the problem, (4) whether others copied the claimed invention, (5) whether the invention achieved unexpected results, (6) whether the prior art teaches away from combining certain known elements, and (7) whether others in the field praised the invention.

F. Level of Ordinary Skill

29. I understand there is a concept in patent law known as a person having ordinary skill in the art (POSITA). I understand that this concept refers to a person who is trained in the relevant technical field of a patent without possessing extraordinary or otherwise exceptional skill. I further understand that factors such as the education level of those working in the field, the sophistication of the technology, the types of problems encountered in the art, prior art solutions to those problems, and the speed at which innovations are made may help establish the level of skill in the art.

30. Taking these factors into consideration, in my opinion, with regard to the ’904 patent, a person of ordinary skill in the art would have a bachelor’s degree in electrical engineering, computer engineering, computer science, or a similar field, along with two years of experience designing or developing wireless networks, including long-term evolution LTE/4G or 5G new radio (NR) cellular technology. Additional education might substitute for some of the experience, and additional substantial experience might substitute for some of the educational background.

31. Based at least on my educational and work experience, I was at least a person of ordinary skill in the art as of the effective filing date of the ’904 patent. And while I note that my qualifications and experiences exceed this definition of a person of ordinary skill of the art, in arriving at the conclusions in this Declaration,

I have considered the issues from the perspective of a person of ordinary skill of the art at the relevant time.

32. Unless otherwise stated, I have applied this level of ordinary skill in the art for the purposes of this Declaration.

V. TECHNOLOGY BACKGROUND AND STATE OF PRIOR ART

33. The development of wireless communications has been rapid, fueled in no small part by the world-wide adoption and usage of services made possible by wireless communications. One of the sub-areas within the broad area of wireless communications is the development of techniques to enable (and capitalize on the resulting benefits of) transmissions using multi-antennas, which the ’904 patent relates to. EX1001, cover page.

34. Well before the earliest claimed priority date of the ’904 patent (which I have been asked to assume is December 28, 2016), a large body of knowledge and associated techniques had been developed. This section will provide an overview of the state of the related art that would have been well known to a POSITA at the earliest claimed priority date.

35. To facilitate these explanations and to provide support for my opinions contained herein, I will use prior technical specifications developed by 3GPP, consistent with the named inventors’ reference to 3GPP in the section titled “Related Art.” EX1001, 1:33-37. In my explanations, I will use 3GPP references from the

2015-2016 time frame, although many of these concepts were developed in earlier years and can be found in earlier versions of the technical specifications.

36. To enable a user equipment ("UE") to communicate with a base station, several steps have to take place, ideally in a manner "invisible" to the end-user so as to "hide" the complexities involved. This makes the steps appear as simple as possible to the end-user or the user may even be unaware of the steps taking place. I will focus the discussion herein to the subset of such steps that are related to the '904 patent, which were well known in the time frame before the earliest priority date of the '904 patent.

37. One of these steps is the base station transmitting, and the UE receiving, control information, which informs the UE how the base station operates. This is necessary for the UE to be in a position to communicate with the base station. This includes what is called "System information" which "is divided into the *MasterInformationBlock* (MIB) and a number of *SystemInformationBlocks* (SIBs). The MIB includes a limited number of most essential and most frequently transmitted parameters that are needed to acquire other information from the cell, and is transmitted on BCH" (Broadcast Channel). *See* EX1022 (3GPP TS 36.331 v13.0.0), §5.2.1.1 (emphasis in original).

38. A Broadcast Channel ("BCH") is one of the Transport Channels in the set of Transport Channels ("TrCh") broadcast by the base station. Transport

Channels are mapped to Physical Channels, which transmit the corresponding information after appropriate processing. As shown below, the BCH is mapped to the Physical Broadcast Channel ("PBCH"). *See* EX1020 (3GPP TS 36.212 v13.0.0), §4.2:

4.2 Downlink

Table 4.2-1 specifies the mapping of the downlink transport channels to their corresponding physical channels. Table 4.2-2 specifies the mapping of the downlink control channel information to its corresponding physical channel.

Table 4.2-1

TrCH	Physical Channel
DL-SCH	PDSCH
BCH	PBCH
PCH	PDSCH
MCH	PMCH

3GPP TS 36.212 v13.0.0, Table 4.2-1.

39. In the interest of conciseness, I will not describe the specifics of the information transmitted in the MIB. But, there is at least one piece of information that is conveyed by the PBCH that is relevant to the '904 patent which I will discuss below.

40. By way of example, a base station may use 1, 2, or 4 antenna ports for its transmissions. A simple discussion of the relationship between an "antenna" and an "antenna port" may be useful: At the most basic level, an "antenna" (also referred to as an "antenna element" or a "physical antenna") is a radiating device for transmitting or receiving wireless signals. It is often desirable to build an "antenna" that has certain desired properties by placing several "antenna elements" in a

specific, well-designed configuration that achieves the desired overall behavior by the collective action of all the antenna elements involved. The result is that the so-configured "antenna elements" are no longer "an antenna" as it actually consists of several "antennas," namely the individual antenna elements. However, the antenna elements, working together, appear to act as a single antenna, which is referred to as an "antenna port." Thus, signals transmitted using an "antenna port" present the same characteristics from the perspective of the user equipment, even though the "antenna port" may actually consist of one physical antenna or more than one physical antenna acting together. The radiating pattern that results from the combination of these physical antennas is the radiation pattern of the corresponding "antenna port." This is explained, for example, by *Sesia LTE* as shown below:

> Each RS pattern is transmitted from an *antenna port* at the eNodeB. An antenna port may in practice be implemented either as a single physical transmit antenna, or as a combination of multiple physical antenna elements. In either case, the signal transmitted from each antenna port is not designed to be further deconstructed by the UE receiver: the transmitted RS corresponding to a given antenna port defines the antenna port from the point of view of the UE, and enables the UE to derive a channel estimate for all data transmitted on that antenna port – regardless of whether it represents a single radio channel from one physical antenna or a composite channel from a multiplicity of physical antenna elements together comprising the antenna port. The designations of the antenna ports available in LTE are summarized below:

EX1013 (Sesia LTE) at 167.

41. Returning to the transmission of the PBCH, the base station may use 1, or 2, or 4 antenna ports for the transmission of the PBCH. *See* EX1019 (3GPP TS 36.211 v13.0.0), §6.6.3. Depending on how many antenna ports are to be used, the

base station also transmits "reference signals" corresponding to each of the antenna ports on specific time and frequency occasions (Resource Elements), as shown below. *See* EX1019 (3GPP TS 36.211 v13.0.0), §6.10.1.2. The figure below illustrates the transmission of reference signals at a high level, which I discuss further below.

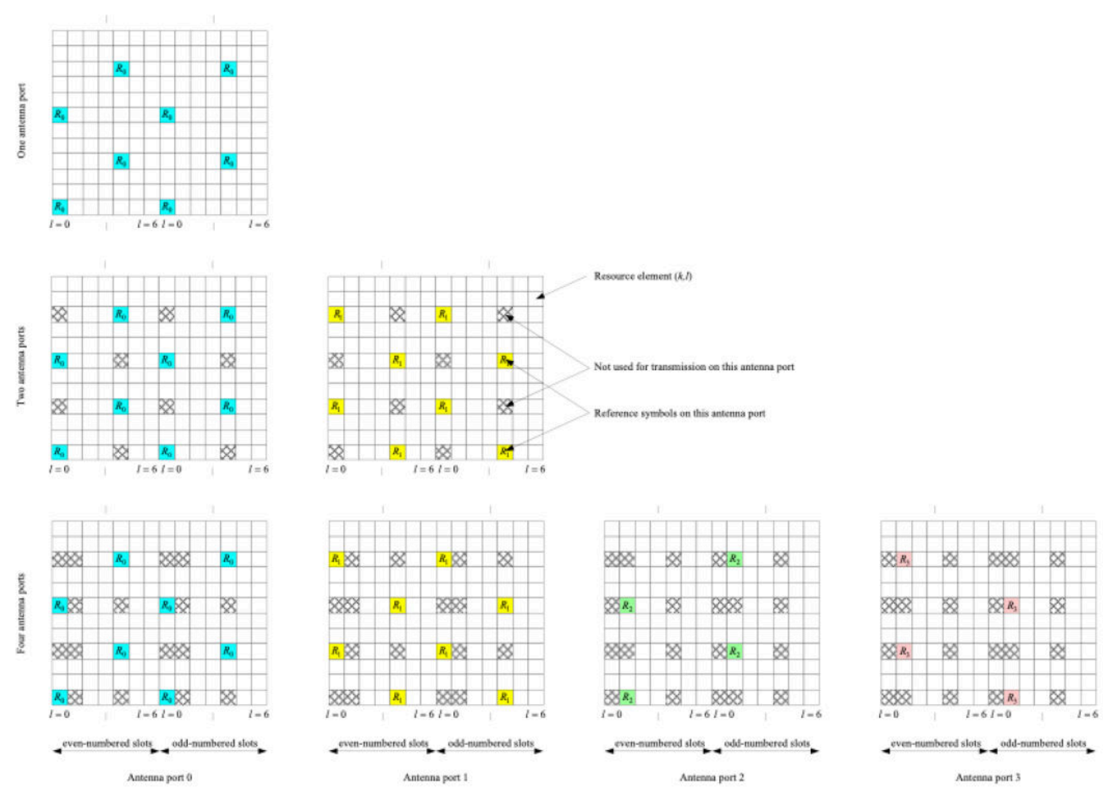


Figure 6.10.1.2-1. Mapping of downlink reference signals (normal cyclic prefix).

See EX1019 (3GPP TS 36.211 v13.0.0), Figure 6.10.1.2-1.

42. Referring to the figure above, each "large square" represents what the LTE standard calls a "Resource Block" ("RB"). Each RB consists of a number of Resource Elements ("RE"), wherein each RE corresponds to a specific subcarrier (in

the frequency domain) and a specific symbol (in the time domain). which is used for the transmission of one modulation symbol. In the example above, each Resource Block ("RB") consists of 12 subcarriers and 14 symbols corresponding to 12*14=168 Resource Elements ("RE"). In the figure above, the first row (consisting of a single RB) represents the case of transmitting on only one antenna port (port0), while the second and third row (consisting of 2 and 4 RBs, respectively) represent the case of transmitting on 2 and 4 antenna ports, respectively. Furthermore, each column of the Resource Blocks ("RB") represents how the RB is used for transmission on a particular antenna port. The first, leftmost RB column (wherein some of the RE are colored blue) represents the transmission on antenna port0; similarly, the second RB column (wherein some RE are colored yellow) represents antenna port1; similarly, the third RB column (wherein some RE are colored green) represents antenna port2; and the fourth, rightmost RB column (wherein some RE are colored red) represents antenna port3.

43. The RB rows, from top to bottom represent whether one antenna port is being used (topmost RB row, port0 (blue) only), two antenna ports are being used (middle RB row of ports0,1 (blue, yellow)), and all four antenna ports are being used (bottom RB row of ports0,1,2,3 (blue, yellow, green, red). The respective colored RE in each grid are Resource Elements used for transmitting reference signals on a particular antenna port. The cross-hatched cells are not used for **any** transmission,

because they correspond to resource elements of another antenna port, which is why there are more cross-hatched cells in the bottom row for port 0 in the bottom row, and no cross-hatched cells in the top row for port 0. The blank cells in each grid are available for transmission of other information, *e.g.*, user data. Thus, for example, if two antenna ports are used (antenna port 0 and antenna port 1) the "blue" resource elements are used for transmission of reference signals on antenna port 0 and the yellow ones for transmission of reference signals on antenna port 1. In contrast, *nothing* is transmitted by an antenna port on the resource elements on which another antenna port is transmitting reference signals (cross-hatched cells). I will return to this information below.

44. The UE needs to know how many antenna ports are being used (1, 2, or 4). The way the UE knows how many ports are being used by the base station is provided by 3GPP TS 36.212, v13.0.0, using a Cyclic Redundancy Code ("CRC") mask. EX1020 (3GPP TS 36.212 v13.0.0), §5.3.1.1. The specifics of the CRC mask are not necessary to understand the '904 patent's disclosure. The UE uses the transmitted reference signals to determine the effect of the channel on the transmitted signal from each antenna port. In other words, the reference signals are known ahead of time, but the UE receives a distorted version of the original reference signal and knowing the reference signal allows the UE to calculate the difference between the received signal and the transmitted reference signal. To use a simple analogy, if the

UE knows that on antenna port 0 the base station transmits the value "5" and the UE receives the value "7," the UE knows that the difference between "5" and "7", *i.e.*, the distortion, was caused by the channel, because no other antenna port is transmitting using that RE. The UE can make similar evaluations of the channel conditions for each of the antenna ports that is being used by the base station. In addition, the UE can determine the received power, referred to as the Reference Signal Received Power, or RSRP, for each of the antenna ports that is being used.

45. A UE will generally report different types of information to a base station. These are generally called Channel State Information, or CSI. EX1013 (Sesia LTE) at 280-281. A transmitter, such as a base station "can configure the UE to report measurement information to support the control of UE mobility." Sesia LTE at 75. These requirements can be transmitted by the base station using, for example, the "RRCConnectionReconfiguration message." Sesia LTE at 75. One such configuration is a "Reporting configuration" that "cause[s] the UE to send a measurement report," which may include information such as Reference Signal Received Power (RSRP)" for a given antenna port. Sesia LTE at 75. The Reference Signals are used to determine the downlink quality of the signal. "Each RS pattern is transmitted from an antenna port at the eNodeB." Sesia LTE at 167. In particular, it was well known that "RSRP is measured by the UE over the cell-specific Reference Signals (RS) within the measurement bandwidth over a measurement

period. RSRP is a type of signal strength measurement and is indicative of the cell coverage. It is defined as the linear average over the power contributions (in Watts) of the REs that carry sell-specific RSs within the considered measurement frequency bandwidth …. RSRP is therefore considered to be the most important measurement quantity for E-UTRAN." Sesia LTE at 513.

46. A POSITA would have known that "[a]n antenna port may in practice be implemented either as a single physical transmit antenna, or as a combination of multiple physical antenna elements." EX1013 (Sesia LTE) at 167. The antenna port, whether a single antenna or combination of antennas transmits a wireless signal, such as the Reference Signal, and "the transmitted RS corresponding to a given antenna port defines the antenna port from the point of view of the UE, and enables the UE to derive a channel estimate for all data transmitted on that antenna port – regardless of whether it represents a single radio channel from one physical antenna or a composite channel from a multiplicity of physical antenna elements together comprising the antenna port." Sesia LTE at 167. Thus, the UE measures the RSRP of a particular antenna port, which represents the state of, or information about, the channel being measured, and transmits the RSRP back to the base station. *See* Sesia LTE at 167. When the UE reports back to the base station, it provides a measurement report for each antenna port measured. Various reporting criteria can cause the UE to send a measurement report, such a periodic or event-triggered criteria. Sesia LTE

at 75. One of the details that the UE may report to the base station is Reference Signal Received Power (RSRP). Sesia LTE at 75.

47. As one example, EX1015 (3GPP TS 36.133 v13.2.0), Section 9.1.4, specifies a mapping table of the RSRP range measured by the UE for a given transmission cell. For example, "[t]he reporting range of RSRP is defined from -140 dBm to -44 dBm with 1 dB resolution. The mapping of measured quantity is defined in Table 9.1.4-1. The range in the signaling may be larger than the guaranteed accuracy range." EX1015 (3GPP TS 36.133 v13.2.0), §9.1.4. In particular, "[t]he measurement report mapping for RSRP measurements is as defined in Section 9.1.4." EX1015 (3GPP TS 36.133 v13.2.0), §9.1.18.2.1. Table 9.1.4-1: RSRP measurement report mapping, for reporting RSRP values from the UE is shown below:

Table 9.1.4-1: RSRP measurement report mapping

Reported value	Measured quantity value	Unit
RSRP_00	RSRP < -140	dBm
RSRP_01	-140 ≤ RSRP < -139	dBm
RSRP_02	-139 ≤ RSRP < -138	dBm
…	…	…
RSRP_95	-46 ≤ RSRP < -45	dBm
RSRP_96	-45 ≤ RSRP < -44	dBm
RSRP_97	-44 ≤ RSRP	dBm

EX1015 (3GPP TS 36.133 v13.2.0), §9.1.4. Table 9.1.4-1. Similarly, the measurement report may also report the CSI-RSRP, as shown in EX1015 (3GPP TS

36.133 v13.2.0), §9.1.14.3.3. Table 9.1.143.3-1: CSI-RSRP measurement report mapping, shown below:

Table 9.1.14.3.3-1: CSI-RSRP measurement report mapping

Reported value	Measured quantity value	Unit
CSI_RSRP_00	CSI_RSRP < -140	dBm
CSI_RSRP _01	-140 ≤ CSI_RSRP < -139	dBm
CSI_RSRP _02	-139 ≤ CSI_RSRP < -138	dBm
…	…	…
CSI_RSRP _95	-46 ≤ CSI_RSRP < -45	dBm
CSI_RSRP _96	-45 ≤ CSI_RSRP < -44	dBm
CSI_RSRP _97	-44 ≤ CSI_RSRP	dBm

EX1015 (3GPP TS 36.133 v13.2.0), §9.1.14.3.3.

48. Other 3GPP standards also state that RSRP may be reported as *rsrpResult*, which is the measured RSRP of a particular antenna port, or cell, measured by the UE. *See* EX1022 (3GPP TS 36.331 v13.0.0) at 365 ("*MeasResults* field descriptions", "*rsrpResult*"). This is done, for example, using the *reportCRS-Meas* parameter, which "indicates that the UE shall report rsrp, rsrp together with csi-rsrp in the measurement report, if possible." *See* EX1022 (3GPP TS 36.331 v13.0.0) at 370 ("*ReportConfigEUTRA field descriptions*").

49. The base station also uses precoding matrices, which are applied to the signals to be transmitted by the particular antenna ports, as discussed and illustrated below. *See* EX1019 (3GPP TS 36.211 v13.0.0), §6.3.

6.3 General structure for downlink physical channels

This section describes a general structure, applicable to more than one physical channel.

The baseband signal representing a downlink physical channel is defined in terms of the following steps:

- scrambling of coded bits in each of the codewords to be transmitted on a physical channel
- modulation of scrambled bits to generate complex-valued modulation symbols
- mapping of the complex-valued modulation symbols onto one or several transmission layers
- precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports
- mapping of complex-valued modulation symbols for each antenna port to resource elements
- generation of complex-valued time-domain OFDM signal for each antenna port

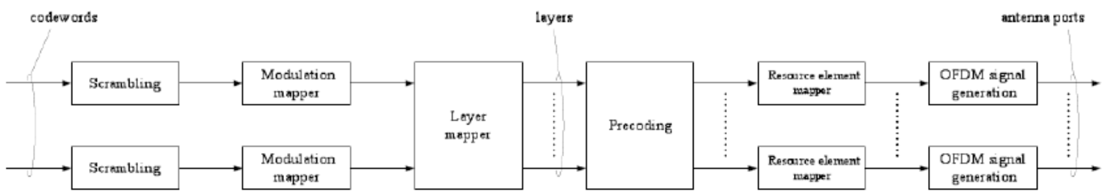


Figure 6.3-1: Overview of physical channel processing.

50. When the UE receives the Reference Signals, it determines which precoding matrix will result in the best correction of the distortion that the channel will cause during transmission. The precoding matrix that the UE determines is the best one to be used is identified by an index, referred to as the Precoding Matrix Indicator (PMI). *See e.g.*, EX1021 (3GPP TS 36.213 v13.0.0), §7.2; EX1013 (Sesia LTE) at 272-273, section 11.2.2.4). The PMI is then sent back to the base station as part of the CSI. The base station, in turn, can apply the precoding matrix identified by the UE to preemptively compensate for the distortion caused by the channel to the transmissions to the UE. The base station can also use a different precoding matrix than the one suggested by the UE. In either case, the precoding matrix used by the base station is reported to the UE so that the UE can properly account for the

impact of the channel to the received Reference Signal. *See* EX1020 (3GPP TS 36.212 v13.0.0), §5.3.3.1.3A, "Format 1B"; *see also* EX1013 (Sesia LTE) at 273-274 ("this enables the UE to derive the correct phase reference relative to the cell-specific RSs in order to demodulate the PDSCH data"), Sesia LTE at 266-267.

51. In some cases, the base station may supply predetermined set of precoding matrices to the UE, and the UE selects the best precoding matrix to indicate to the base station from that set. To simplify the measurements and reporting by the UE, the "eNodeB [base station] may also restrict the set of precoders which the UE may evaluate and report." EX1013 (Sesia LTE) at 273. "This is known as codebook subset restriction" and "enables the eNodeB to prevent the UE from reporting precoders which are not useful …." Sesia LTE at 273.

52. Other examples of CSI reported by the UE to the base station include Channel Quality Indicator (CQI), a Precoding Matrix Indicator (PMI) as discussed above, and Rank Indicator (RI), as shown below:

7.2 UE procedure for reporting Channel State Information (CSI)

If the UE is configured with a PUCCH-SCell, the UE shall apply the procedures described in this clause for both primary PUCCH group and secondary PUCCH group unless stated otherwise

- When the procedures are applied for the primary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell', and 'serving cells' in this clause refer to secondary cell, secondary cells, serving cell or serving cells belonging to the primary PUCCH group respectively unless stated otherwise.
- When the procedures are applied for secondary PUCCH group, the terms 'secondary cell', 'secondary cells', 'serving cell' and 'serving cells' in this clause refer to secondary cell, secondary cells (not including the PUCCH-SCell), serving cell, serving cells belonging to the secondary PUCCH group respectively unless stated otherwise. The term 'primary cell' in this clause refers to the PUCCH-SCell of the secondary PUCCH group.

The time and frequency resources that can be used by the UE to report CSI which consists of Channel Quality Indicator (CQI), precoding matrix indicator (PMI), precoding type indicator (PTI), CSI-RS resource indicator (CRI), and/or rank indication (RI) are controlled by the eNB. For spatial multiplexing, as given in [3], the UE shall determine a RI corresponding to the number of useful transmission layers. For transmit diversity as given in [3], RI is equal to one.

EX1021 (3GPP TS 36.213 v13.0.0), § 7.2.

The CQI identifies the modulation scheme and the coding scheme for the base station to transmit subsequent information to the UE. *See* EX1021 (3GPP TS 36.213 v13.0.0), Table 7.2.3-1. Ever since Release 10 of the LTE standards, the base station was capable of transmitting data to the UE using up to eight antenna ports indicated in the measurement report from the UE.

6.3.4.4 Precoding for spatial multiplexing using antenna ports with UE-specific reference signals

Precoding for spatial multiplexing using antenna ports with UE-specific reference signals is only used in combination with layer mapping for spatial multiplexing as described in clause 6.3.3.2. Spatial multiplexing using antenna ports with UE-specific reference signals supports up to eight antenna ports and the set of antenna ports used is $p = 7,8,\ldots,\upsilon+6$.

EX1019 (3GPP TS 36.211 v13.0.0), §6.3.4.4; *see also* EX1004 (Kim), [0071], [0164] ("CSI-RSs may be transmitted through 1, 2, 4 or 8 antenna ports" and "although CSI-RSs contained in 'set_l' may be selected from number of antenna ports (1, 2, 4, 8), the number of antenna ports of CSI-RSs contained in the remaining set_n(n> 1) may be set to a predetermined number, for example, 1 or 2.").

Table 7.2.3-1: 4-bit CQI Table

CQI index	modulation	code rate x 1024	efficiency
0	out of range		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3770
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	772	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

See EX1021 (3GPP TS 36.213 v13.0.0), Table 7.2.3-1.

53. Thus, a POSITA in 2016 would have recognized that it was well known in the art to provide (a) for a base station to transmit signaling information, which is received by the UE, (b) the UE uses the signaling information to determine the number of antenna ports used by the base station and thus identifies the RS used by each antenna port, (c) for the base station to transmit reference signals (wireless signals) using the antenna ports, which are received by the UE, (d) the UE uses the reference signals to determine, among other things, the RSRP and channel quality,

(e) for the UE to transmit information to the base station, such as in a measurement report, which enables the base station to make decisions about what resources to use for the given transmission to the UE and how to transmit to the given UE on the given resources available.

VI. OVERVIEW OF THE '904 PATENT

54. The '904 patent describes a technique for "improving transmission quality" in which a base station obtains "a proportional relationship among reception qualities corresponding to multiple beams" and generates "a more accurate serving beam for the UE according to the proportional relationship." 2:19-24. To achieve these features, the '904 patent describes a method that includes "receiving a first signaling; receiving a first wireless signal; and transmitting first information." EX1001, Abstract. In particular, the '904 patent purports to teach, "K antenna port groups are used to transmit the first wireless signal," and "the first signaling is used to determine the K antenna port groups." *Id.*, 1:64-67. "[T]he K antenna port groups respectively correspond to K channel quality values," which are "Reference Signal Received Power[s] (RSRP[s])." *Id.*, 1:67-2:2, 3:63-65. "K1 antenna port groups" correspond to "K1 channel quality values of the K channel quality values," where K1 is "less than or equal to the K." *Id.*, 2:2-5. Moreover, "a first proportional sequence corresponds to a ratio(ratios) among the K1 channel quality values," and "the first information is used to determine []the K1 antenna port groups[and] the

first proportional sequence[].” *Id.*, 2:5-9. The “K1 channel quality values” include “a first channel quality [that] is a best channel quality value” and “a second channel quality [that] is a worse channel quality value,” and “a ratio between the second channel quality and the first channel quality [being] greater than or equal to [a] target threshold” determined from the first signaling. *Id.*, 2:9-16. The ’904 patent further explains that an “antenna port group” may be “composed of one antenna port.” *Id.*, 2:45-46, 13:64-65.

55. The independent claims recite transmitting “first information,” which “is *used to determine*…the first proportional sequence,” but without requiring the proportional sequence to be sent as part of the recited first information. *Id.*, 27:20-21, 27:37-39.

VII. PROSECUTION HISTORY OF THE ’904 PATENT

56. Only double patenting rejections were issued, which were addressed by terminal disclaimers with respect to claims 1-20 of the parent, namely, US 10,951,271 (the ’271 patent). EX1002, 492-500 (Notice of Allowance).

57. During prosecution that led to the parent ’271 patent, the Applicant argued that prior art (*e.g.*, US9,520,973 (“Kim-973”)) teaches parameters that “**do not depend on the results of channel measurement nor do they include channel quality information such as RSRP or SINR**” whereas “the first proportional sequence of the claims is calculated based on the results of channel measurements

indicated by channel quality values of RSRP or SINR." EX1007, 464 (Applicant-Response) (emphasis in original). Applicant further argued that Kim-973 teaches "a threshold of **delay spread or Doppler**," rather than "a threshold of a ratio between two channel qualities such as **RSRP and SINR**." *Id.*, 464-65 (emphasis in original). The Examiner subsequently allowed the claims, stating: "prior art of record…appears to fail or fairly show or suggest…novel and unobvious limitations of [1.d], as recited in group claims 1-5 and 11-15; and [6.d], as recited in group claims 6-10 and 16-20." *Id.*, 479-485 (Notice of Allowance).

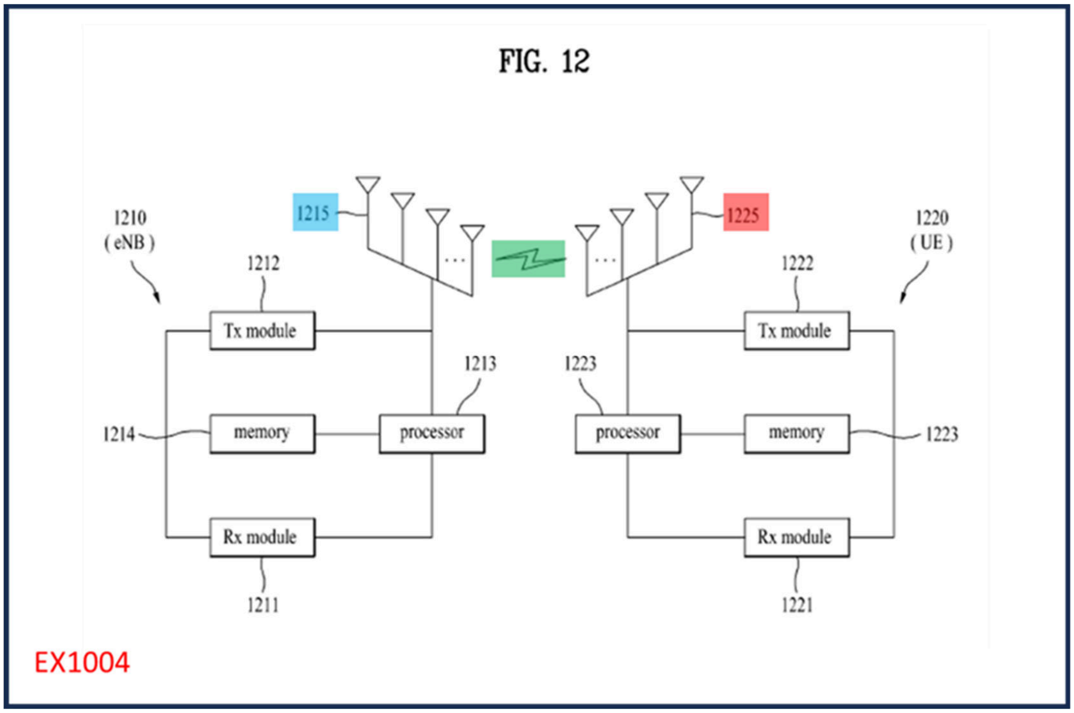
58. But, as I will demonstrate below, the Challenged Claims are obvious, and this conclusion would have been apparent if the Examiner had considered more pertinent prior art, such as Kim, Chen, Liu, or Park.

VIII. OVERVIEW OF THE CITED REFERENCES

A. Kim

59. Like the '904 patent, Kim "relates to a wireless communication system" and "a method and apparatus for performing measurement report[s]" in MIMO systems. EX1004, [0001], [0053], [0102]. In FIG. 12 (below), Kim depicts a "UE device 1220" that "include[s] an Rx module 1221, a Tx module 1222,…and a plurality of antennas 1225," and a "BS [base station] device 1210" that "include[s] a reception (Rx) module 1211, a transmission (Tx) module 1212,…and a plurality of antennas 1215." *Id.*, [0174], [0177]. The "plurality of antennas" of the base

station and UE indicate the devices "supporting MIMO transmission and reception." *Id.*

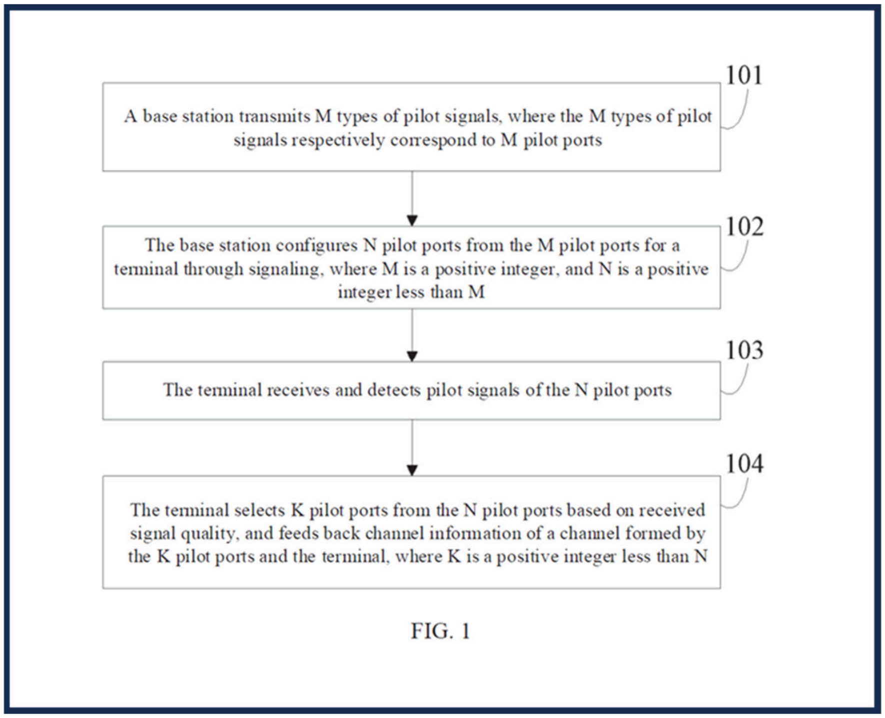


60. Kim's base station transmits, to the UE, signaling that includes "CSI-RS [Channel State Information-Reference Signal] config information element[s]," such as "antennaPortsCount-r10" that "indicates the number of antennas" used for transmitting CSI-RS pilot signals to the UE. EX1004, [0079]-[0080], Table 3. In one example, Kim's base station "inform[s] the UE of specific information through RRC [Radio Resource Control] signaling," including "CSI-RS configuration" information that identifies an "antenna port pair" transmitting a particular CSI-RS signal. *Id.*, [0142]. These reference signals "may be transmitted through 1, 2, 4 or 8 antenna ports" of the base station, and each CSI-RS "may be mapped to REs

[Resource Elements of a Resource Block ("RB")] on a per-antenna port basis." *Id.*, [0071], [0074], [0076]. When receiving the CSI-RSs from the base station, "the UE performs RSRP measurement reporting" of the received signals and transmits a measurement report back to the base station. *Id.*, [0111]. Kim's "UE may report… indexes of a maximum of M CSI-RSs" having a "ratio (RSRP_n/max(RSRP_i))… which is higher than a predetermined threshold value" and "the RSRP estimation result of the corresponding CSI-RS." *Id.*, [0135-0136] ("measurement report value for the n-th CSI-RS" can be "the ratio of the n-th CSI-RS average Rx power level to the best CSI-RS average Rx power level"), [0148-0149].

B. Chen

61. Like the '904 patent, Chen relates to "a wireless communication system where "a transmit end and a receive end use a spatial multiplexing to obtain a higher data transmission rate by using a plurality of antennas." EX1006, 1-3 ("massive MIMO technology"). Chen particularly describes "a channel information feedback method" in which a UE receives and detects "pilot signals from the N pilot ports" of a base station, selects "K pilot ports from the N pilot ports according to received signal quality, and feeds back channel information of channels formed by the K pilot ports" to the base station. *Id.*, 3.



EX1006, FIG. 1

62. According to *Chen*, a base station configures "the N pilot ports from the M pilot ports for the terminal based on terminal information reported by the terminal." EX1006, 10, FIG. 1 (above). The terminal (UE) receives and detects "pilot signals from the N pilot ports" and detects N types of pilot signals of the N pilot ports based on the port information, to obtain received power corresponding to the N types of pilot signals." *Id.*, 11, FIG. 1. "[T]he terminal selects K pilot ports from the N pilot ports based on the received power corresponding to the N types of pilot signal," and "sends channel information of the K pilot ports to the base station," where the K pilot ports are selected "based on a power threshold configured by the base station." *Id.*, 14, FIG. 1. The pilot ports and threshold are configured "through

signaling" by the base station to the UE. *Id.*, Abstract, 11, 18, 21, 23. Chen's "power threshold," whether "a relative threshold or an absolute threshold," is "configured by the base station," (*id.*, 12, 20, 22), which would be through a form of signaling from the base station to the UE. One example of Chen's "relative threshold" is based on a "power ratio," *i.e.*, determining whether "the ratio of a received power of a pilot signal of a selected pilot port to the maximum received power is greater than or equal to the preset threshold." EX1006, 12-13.

IX. GROUND 1: KIM IN VIEW OF CHEN RENDERS OBVIOUS ALL OF THE CHALLENGED CLAIMS.

A. The Combination, Reasons to Combine & Reasonable Expectation of Success

63. Based on my experience and knowledge as well as my review of Kim and Chen, my opinion is that would have found it obvious to use a single base station equipped with a multitude of antenna port groups, and to have the base station configure the relative threshold used by the UE, in accordance with Chen's suggestions, when implementing a MIMO system in accordance with Kim, to achieve known benefits. As I further explain below, multiple reasons would have prompted a POSITA to combine Kim and Chen.

64. In my opinion, a POSITA would have been motivated to combine Kim and Chen to implement the base station to configure the relative power threshold used by the UE, as taught by Chen, using a RRC signaling originated from the base

station side, as taught in Kim, facilitating seamless operational control. I note that Kim already teaches that "different threshold values may be signaled to the UE" by the base station. EX1004, [0163]. While Kim does not expressly recite the power threshold as one of the "different threshold values," Chen, also directed to measurement report of antenna ports, expressly does so. Chen teaches "a power threshold configured by the base station" where the power threshold can be "a relative threshold" (*e.g.*, RSRP ratio). EX1006, 4, 5, 7, 9, 12-13. In the combined system, the threshold values "signaled to the UE," as taught in Kim, include the power threshold, in accordance with Chen's suggestions.

65. Significantly, my opinion is that a POSITA would have found it obvious from Kim's description that, for Kim's UE to identify "M CSI-RSs (the RSRP ratio (RSRP_n/max(RSRP_i)) of which is higher than a predetermined threshold value) from among N CSI-RSs," the predetermined threshold value would need to be known. EX1004, [0148]. And, also in my opinion, a POSITA would have found obvious that the base station beneficially provides it because, among other things, a static configuration cannot handle dynamic adjustment and hence may not be realistic for mobile communication.

66. Here, Kim already teaches that "N, M, [and other parameters] may be signaled to the UE through RRC signaling" provided by the base station. EX1004, [0148]. Adding the threshold value to the RRC signaling would have been

operationally convenient because it requires no extra signaling mechanism, while providing the essential parameter for UE's continued operation, namely, the threshold value based on which better quality antenna ports can be identified. This inclusion was rather ubiquitous by 2016. For example, Ng (US20160218778A1) discloses: "The threshold can be configured by higher layer signaling (*e.g.*, by radio resource control (RRC) signaling) by the network." EX1014 at [0152]; *see also* EX1012 ("Liu"), 16-17, 22-23; EX1024 ("Shin"), [0009] ("The terminal is configured with the CSI-RS through <u>user equipment (UE)-specific radio resource control (RRC) signaling</u>"). Moreover, in my opinion, a POSITA would have been prompted to implement Kim's system such that the first signaling is used to determine a target threshold because doing so would have predictably facilitated enhanced control by the base station of the distribution of wireless signals selected by UEs. Signaling the UEs to select signals that are proportional strong would have facilitated overly system performance and consistency because the reported results will be sufficient for its system balancing and scheduling.

67. In my opinion, a POSITA would have been prompted to combine Kim and Chen because doing so was the application of known techniques (single base station equipped with a multitude of antenna port groups, and the base station configuring the relative power threshold used by the UE) to a known system (Kim's MIMO system) ready for improvement to yield predictable results (benefits

articulated above). Moreover, my opinion is that a POSITA would have had a reasonable expectation of success at combining Kim's MIMO system with features from Chen because doing so merely involves "the predictable use of prior art elements according to their established functions" (*e.g.*, single base station with a multitude of antenna ports, and RRC signaling) to "yield predictable results" (*e.g.*, transmitting pilot signals from respective antenna port groups at a base station, and using RRC signaling to additionally provide power threshold value to the UE) without more while the fundamental operations of Kim's MIMO system remain intact. I note that Kim and Chen describe analogous subject matter in the same field of endeavor as the '904 patent and pertinent to common challenges faced by the '904 patent. This is true for at least the reasons I discuss above.

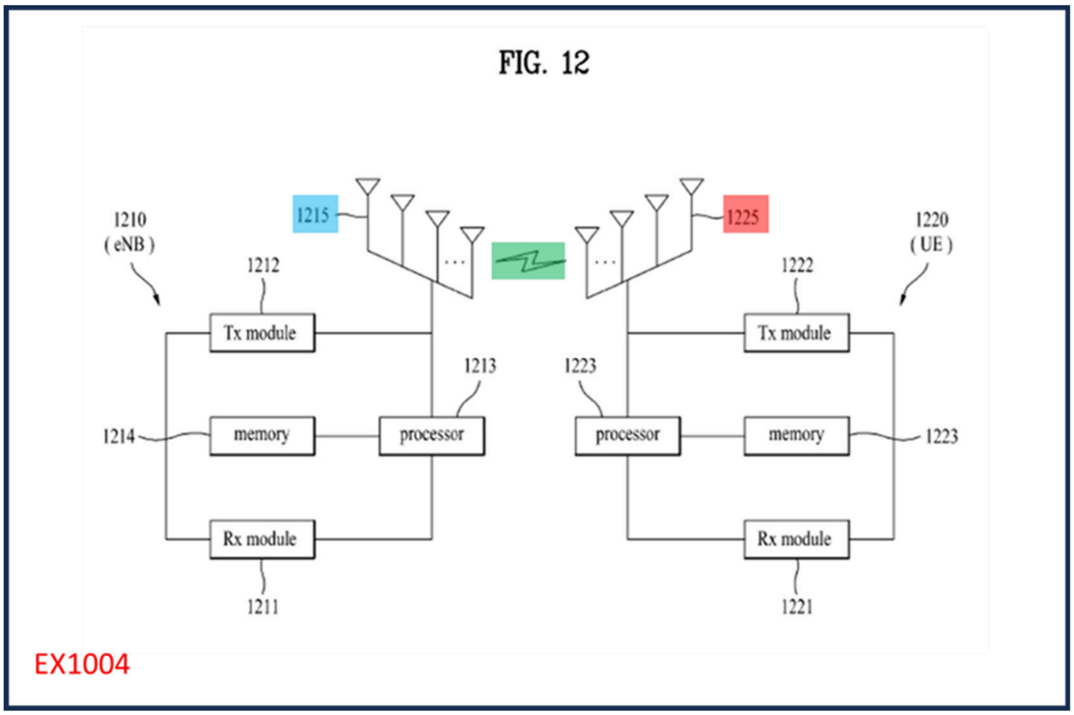
B. Analysis

1) Claim 1

[1.pre]: A method for multi-antenna transmission in a user equipment (UE), comprising:

68. If the preamble is limiting, then the Kim-Chen combination discloses it. For example, Kim describes "***a method*** for a terminal carrying out a measurement report in a wireless communication system." EX1004, Abstract, [0001]. Kim's base station and UE each engage in multi-antenna transmission where multiple base station ("BS") antennas transmit to the UE and multiple "terminal" (UE) antennas transmit to the base station. *Id.*, [0174], [0177], [0036]. This is illustrated in FIG.

12, shown below. Kim's UE and base station are "device[s] for supporting MIMO transmission and reception" where "UE device 1220" includes an "Rx module 1221," "Tx module 1222," and "a plurality of antennas 1225," whereas the "BS device 1210" includes a "reception (Rx) module 1211," "transmission (Tx) module 1212," and "a plurality of antennas 1215." *Id.*, [0174], [0177]; §VIII.A.



69. Kim explains that "[i]f data is transmitted and received using multiple antennas, a channel state between each transmission antenna and each reception antenna should be known in order to accurately receive a signal." EX1004, [0053]. To probe each channel state, Kim discloses using "a reference signal per transmission antenna and, more particularly, per antenna port." *Id.*, [0069-81] ("Channel State Information-Reference Signal (CSI-RS)"), FIG. 6. Kim's method

of transmission provides "a measurement report based on various reference signals (RSs)." *Id.*, [0003].

[1.a]: receiving a first signaling:

70. The Kim-Chen combination performs [1.a]. As I have explained under Section VIII.A, Kim discloses its UE receiving ***first signaling***, *e.g.*, "RRC [Radio Resource Control] signaling" that includes "CSI-RS [Channel State Information-Reference Signal] configuration," originating from the base station. EX1004, [0142], [0146], [0148]. Kim explains that "CSI-RS config information element" signaled to the UE includes "antennaPortsCount-r10," which "indicates the number of antennas needed for CSI-RS transmission (for example, one, two, four, or eight antennas may be selected)," and "resourceConfig-r10," which "indicate[s] a CSI-RS transmission position" such as the "RE [Resource Element] of a single RB [Resource Block]" to be used by the CSI-RS transmission. *Id.*, [0079-81], Table 3 ("CSI-RS-configur-r10"). The "CSI-RS configuration" information in the RRC signaling can also indicate an "antenna port pair" allocated on the base station for the CSI-RS transmission. *Id.*, [0142].

71. Once received, the RRC signaling can be used by the UE to identify a set of antenna port groups for measuring channel quality values. *Id.*, [0146]. For example, the UE measures the RSRP (Reference Signal Received Power) based on the CSI-RS transmission from the base station and selects and reports the "M CSI-

RS values each having the best quality," "where M…may be previously designated by the BS through RRC signaling." *Id.*

72. Kim's RRC signaling thus corresponds to the claimed "***first signaling***" in that it provides CSI-RS configuration information for the UE to determine a set (*e.g.*, N) of antenna port groups on the base station where the CSI-RS transmission qualities of a subset (*e.g.*, M of the N antenna port groups) are measured and the measurement report is fed back to the base station. EX1004, [0148] (UE providing "M CSI-RSs indicating the best RSRP result from among N CSI-RS" where "N, M…may be signaled to the UE through RRC signaling"), [0149] ("maximum of M CSI-RSs (the RSRP ratio (RSRP_n/max(RSRP_i)) of which is higher than a predetermined threshold value) from among N CSI-RSs"). Significantly, Kim's disclosure parallels those of the '904 patent. *Compare*, *e.g.*, EX1004 [0038], [0078]-[0081], [0106], [0110]-[0111], [0119], [0135]-[0136] with EX1001, 3:48-50 ("first signaling is a Radio Resource Control (RRC) signaling"), 3:18-19, 4:15-16.

73. Therefore, my opinion is that Kim-Chen combination renders obvious Element 1.a.

[1.b]: receiving a first wireless signal; and

74. In the combined system, the UE receives ***a first wireless signal*** (*e.g.*, composed of a set of CSI-RSs (Channel State Information-Reference Signals)), originating from the base station (*e.g.*, the corresponding antenna ports), just like the

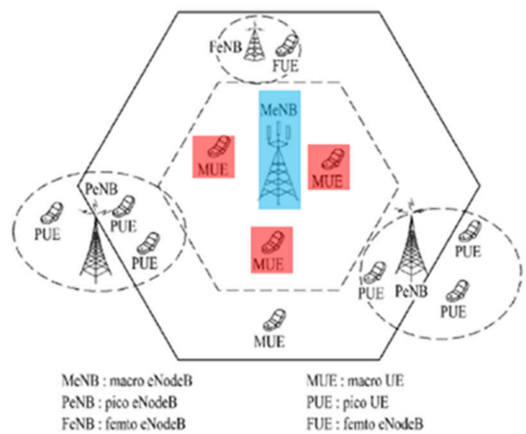
descriptions from the ’904 patent. EX1004, [0052], [0057-64]; EX1001, 3:18-19 (“the first wireless signal is an CSI-RS burst”).

75. In Kim, the set of CSI-RSs constitute a wireless signal originating from the base station because “CSI-RSs may be transmitted through 1, 2, 4 or 8 antenna ports” on the base station to the UE. *Id.*, [0071]. Referring to FIG. 6, Kim explains that “[a]ntenna port 15 may be used for one antenna port, antenna ports 15 and 16 for two antenna ports, antenna ports 15 to 18 for four antenna ports, and antenna ports 15 to 22 for eight antenna port.” *Id.* As illustrated in FIG. 6, each CSI-RS “may be mapped to REs [(resource elements)] on a per-antenna port basis” at the base station for transmission of the first wireless signal. *Id.* [0074], [0076]. While the REs are distributed on a RB (resource block) horizontally (*i.e.*, symbols) and vertically (*i.e.*, subcarriers), the set of CSI-RSs can be transmitted as a burst of CSI-RSs. Kim explains that “CSI-RS is an RS used for channel measurement in an LTE-A system supporting up to eight antenna ports on downlink,” but “it is not necessary to transmit CSI-RSs in every subframe.” *Id.*, [0070]. “The UE receives the reference signal [such as the CSI-RSs] to perform channel measurement.” *Id.*, [0064] (“for acquiring channel information”).

76. Kim teaches using one base station to transmit the set of CSI-RSs. In one example, Kim’s “[b]ase station (BS)” includes “a fixed station, a Node B, an eNode B (eNB), an access point (AP) and the like,” and a “‘cell’ may be understood

as a base station (BS or eNB)" or "Remote Radio Head (RRH)…, etc." EX1004, [0036]. "[C]ells" may be "configured in the form of a distributed antenna or RRH of a single BS," indicating a single base station transmits multiple CSI-RSs to the UE. *Id.*, [0103]. As depicted in the example of FIG. 7 (below), only a single base station (MeNB) services three macro UEs within the cell.

FIG. 7



EX1004

77. Further, even if Kim's express description alone did not reveal a single base station with multiple antenna ports (which it does), the Kim-Chen combination renders this obvious, as I have explained under Section IX.A.3 and further discussed under [1.d1].

78. Accordingly, it is my opinion that, in the Kim-Chen combination, the CSI-RSs from corresponding antenna ports of the base station provides a ***first wireless signal***, as claimed. EX1004, [0069-81] ("Channel State Information-

Reference Signal (CSI-RS)"); EX1001, 3:18-19 ("the first wireless signal is an CSI-RS burst").

79. Therefore, my opinion is that the Kim-Chen combination renders obvious Element 1.b.

[1.c]: transmitting first information;

80. In the Kim-Chen combination, Kim's UE transmits to the base station ***first information*** (*e.g.*, a "measurement report" containing such information as antenna port indices, RSRP values, RSRP-to-max(RSRP) ratios based on measuring the CSI-RS transmission). EX1004, [0149] ("UE may report not only indexes of a maximum of M CSI-RSs (the RSRP ratio (RSRP_n/max(RSRP_i)) of which is higher than a predetermined threshold value) from among N CSI-RSs…but also the RSRP estimation result of the corresponding CSI-RS").

81. The measurement report "covers Radio Resource Management (RRM) measurement of measuring the signal strengths…of a serving cell…including Reference Signal Received Power (RSRP)." EX1004, [0106] ("a UE may perform…measurement of received signal strength"), [0113] ("CSI-RS based RSRP/RSRQ measurement reporting"), [0136] ("if CSI-RS having the best average Rx power level is selected from among a plurality of CSI-RSs, the measurement report value for the n-th CSI-RS may be defined as the ratio of the n-th CSI-RS average Rx power level to the best CSI-RS average Rx power level"), [0148-149].

82. Kim's "measurement report" is just like the specification of the '904 patent specification, which mentions this conventional technique. *See e.g.*, EX1001, 4:3-10 ("the first information…indicates the K1 antenna port groups" and "indicates the first proportional sequence"); EX1010 ("Park"), [368-378] (UE reports RSRP of antenna ports).

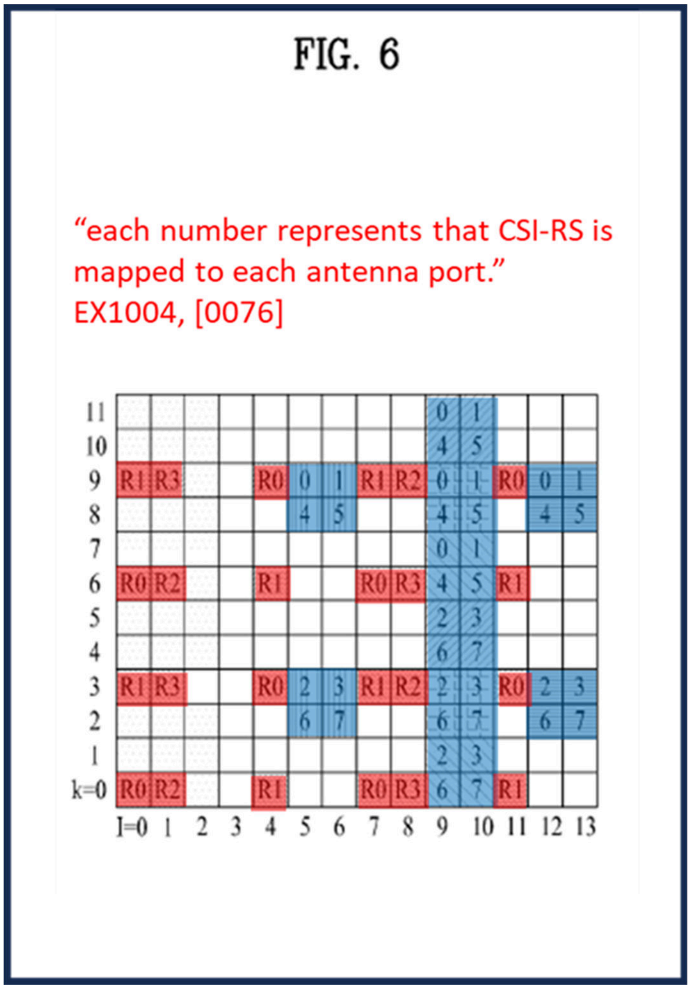
83. Therefore, my opinion is that the Kim-Chen combination renders obvious Element 1.c.

[1.d1]: wherein, K antenna port groups are used to transmit the first wireless signal;

84. In the Kim-Chen combination, ***K antenna port groups*** of the base station ***are used to transmit the first wireless signal*** (*e.g.*, composed of a set of CSI-RSs). EX1004, [0057-0063], [0076], [0053]; *supra* Element [1.b]. The antenna port groups are identified by corresponding Resource Elements ("REs") of the transmitting base station. EX1004, [0079-81].

85. In more detail, Kim states that the CSI-RSs "may be transmitted" to the UE "through 1, 2, 4 or 8 antenna ports" of the base station. *Id.*, [0071], [0080]. In FIG. 6 (below), Kim illustrates an example in which the base station identifies ***K*** CSI-RS antenna port groups using configuration information. EX1004, [0076]. In this example, "CSI-RSs are mapped to REs on a per-antenna port basis according to a specific CSI-RS configuration," where "each number represents that CSI-RS is mapped to each antenna port." *Id.*; *see also* [0048] ("One resource block [depicted

in the example of FIG. 2] includes 12×7 resource elements," namely, "12 subcarriers in frequency domain", *i.e.*, the vertical axis, and as shown in FIG. 6 below, two slots of "7 OFDM symbols" in time domain, *i.e.* the horizontal axis, resulting in 14 symbols).



EX1004, FIG. 6 (annotated)

86. As illustrated in FIG. 6 (above), "RE denoted by 0 or 1 may be mapped to CSI-RS corresponding to antenna port 0 or 1," so on for each of the antenna ports 0 through 7 (*e.g.*, 8 antenna port groups in hatch patterns). EX1004, [0076] ("each number represents that CSI-RS is mapped to each antenna port"). As I discussed

above, 3GPP TS 36.211 v13.0.0 (Exhibit 1019) provides an example that uses one diagram when one antenna port is used, two diagrams when two antenna ports are used, and so on. Kim, in FIG. 6, similarly shows the mapping of antenna ports by collapsing into a single diagram. *Supra*, §V (Technology Background and State of Prior Art). Kim also states that "R0 to R3 [in shaded patterns] denote that CRS are mapped to [four] respective antenna ports" according to "the number of transmit antennas of the base station." *Id.*, [0065] ("The CRS…is transmitted per subframe"), [0070] ("not necessary to transmit CSI-RSs in every subframe"). For context, cell-specific Reference Signals (CRS) and Channel State Information Reference Signals (CSI-RS) are used to help the receiver estimate the channel conditions for better communication. CRS is transmitted across the entire cell and used for channel estimation, synchronization, and measurements like Reference Signal Received Power (RSRP) and Reference Signal Received Quality (RSRQ). CSI-RS is designed specifically for downlink channel quality estimation to enable advanced techniques like beamforming and Massive MIMO. It is transmitted only when needed and to specific users) Moreover, in cases where a pair (group) of two CSI-RS antenna ports are "mapped to the same RE," each CSI-RS in the pair "may be identified by different orthogonal codes." *Id.*, [0076], [0132] ("CSI-RS of the CDM (Code Division Multiplexing)-processed antenna pair"). A CSI-RS thus involves using an "antenna port group" having (1) one port per group or (2) an antenna port pair having two antenna ports per group, for example. *Id.*

87. Significantly, I note that Kim's example performs transmission of a first wireless signal from the corresponding antenna ports. Here again, this is like the '904 patent, which recites "the first wireless signal is an *CSI-RS burst*" and "is composed of the *K reference signal groups*" that "are *respectively* transmitted through the K antenna port groups," and each "reference signal group" may include "only one reference signal." EX1001, claim 5, 3:18-19, 3:25-28, 14:7-8; *see also id.*, 3:29-31 ("K different analog beamforming vectors" are used to send the wireless signal), 2:58-59 (each "antenna port corresponds to a reference signal"), 3:5-6 (each "reference signal is a Channel State Information Reference Signal (CSI-RS)"), 14:5-6 (each "antenna port group includes only one antenna port"). Indeed, the '904 patent explains examples in which "the first wireless signal is composed of K beam-formed CSI-RSs," where the K beam-formed CSI-RSs respectively "correspond[] to [the] K antenna port groups." *Id.*, 14:16-17, 3-4; *see also id.*, 3:5-6, 3:25-28, 14:3-8. The '904 patent also describes these as a "CSI-RS burst," and the "first wireless signal" may be a "CSI-RS burst." *Id.*, 3:5-6, 3:18-19. In fact, it was conventional to transmit the CSI-RS as a burst of signals. *See e.g.*, EX1012, at 1, 15, FIG. 1 (describing signal burst).

88. Kim's example in FIG. 6 demonstrates multiple antenna port groups are used for CSI-RS transmission (***transmitting the first wireless signal***). Kim's FIG. 12 shows one base station ("BS device 1210" with "a plurality of antennas 1215") engaging in multi-antenna communication with a UE ("UE device 1220"). EX1004, [0173-179]. Kim follows up by stating: "The specific configurations of the BS device and the UE device [of FIG. 12] may be implemented such that the various embodiments of the present invention [including FIG. 6] are performed independently…." *Id.*, [0180], *see also* [0103] ("[C]ells" may be "configured in the form of a distributed antenna or RRH of a single BS"). Therefore, Kim teaches [1.d1]. To be clear, the plain and ordinary meaning of [1.d1] was readily understandable to a POSITA, and thus construction is not believed necessary. *Supra*, §V (Claim Construction). Alternatively, if construed, Kim-Chen likewise renders obvious [1.d1] for the reasons described herein, as construction of [1.d1] must take account of the context of the claim language and the specification. For example, as set forth in the '904 specification, a first wireless signal includes one or more sub-components, of which CSI-RSs are provided as an express example in which "the first wireless signal is composed of K beam-formed CSI-RSs" using "K different analog beamforming vectors," where the K beamformed CSI-RSs respectively "correspond[] to [the] K antenna port groups." EX1001, 14:16-17, 3:29-31,3-4; *see also id.*, 3:5-6, 3:25-28, 14:3-8 ("antenna port group includes only one

antenna port”). Accordingly, in my opinion, the Kim-Chen combination likewise renders obvious [1.d1] construed consistent with the specification, for the same reasons described above, based on Kim’s description of multiple antenna port groups that are used to transmit CSI-RSs.

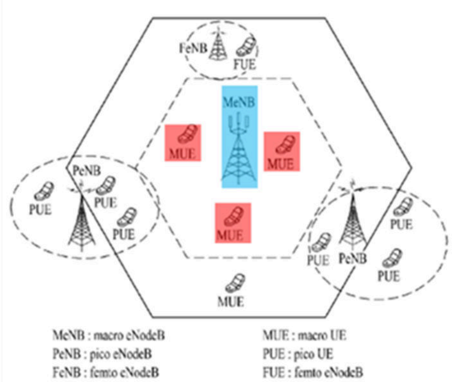
89. Kim’s MIMO system can include “a multi-cell environment” where “[a] UE can receive data from multi-cell base stations collaboratively using the CoMP system.” EX1004, [0092], [0100]; *see generally* [0090-100] (explaining “Coordinated Multi-Point”). While claim 1 recites “a base station,” “a” means “one or more.” Thus, a single base station is not required.

90. Even if Kim did not expressly delineate K antenna port groups of a single base station being used to transmit the first wireless signal (which it does), this conventional configuration was obvious in view of Kim and Chen. As explained *supra* §VIII.B, Chen discloses that “a large-scale antenna array is configured on a base station side, for example, 100 antennas or more antennas are configured.” EX1006, 2. Chen describes the same transmission and reporting process as Kim, where “a base station transmits M types of pilot signals” using “M pilot ports,” where “N pilot ports” of the M ports are configured for and identified to the UE “through signaling.” *Id.*, Abstract, 3-5, 11, 18. The UE “receives and detects pilot signals from the N pilot ports” using the signaling and selects a subset of pilot ports to report to the base station. *Id.*, Abstract, 3, 5, 13, 19. Chen discloses forming N pilot ports are

formed by virtualization of a same group of antennas, *Id.*, 3, 5, 7, 9, 16, which corresponds to a group of antennas at a single base station. Chen also explains that the transmitting antenna ports form "a linear array" or "two-dimensional" array of antennas, which similarly describes the antenna ports being located at a single base station. *Id.*, 14.

91. In my opinion, a POSITA would have been motivated to utilize multiple antenna port groups, in a serving cell with only one base station, as already envisioned by Kim (*e.g.*, [0036], FIG. 7 (below)), to optimize transmission to various UEs within range of the base station at least for the following independent reasons.

FIG. 7



EX1004

92. As a *first* reason, multiple antenna ports would have added up to provide more transmitted power, thereby facilitating improved signal reception at each UE, when needed. Here, a single base station may have more than 100 antennas

arranged in arrays to provide multiple antenna port groups, as specifically taught by Chen, that communicate with various UEs so that the base station can provide improved transmission to the UEs within its broadcast range, as revealed in Kim and Chen, and confirmed by Liu, Park, and the 3GPP standards as conventional activities. EX1004, [0103]; EX1006, 6-7, 9, 11, 15, 22; EX1012, 1, 16, 18; EX1010, [0206], [0208], [0205-222]; EX1013, 155, 167, 169, 654. For example, it was well known that data transfer rate can be increased when the number of transmitting antennas is higher or using transmit diversity. EX1006, 1; EX1008 ("Afroz"), 115, 118, 120, 122, FIG. 7.

93. As a *second* reason, multiple antenna ports would have allowed each UE to measure the received signal strengths of the full set of antenna ports and select a subset of antenna ports that result in better reception quality at the UE, which would have improved data transmission and accommodated dynamic selection of antenna ports. EX1006, 4, 6, 7, 9, 11, 15, 22. For example, data throughput has been shown to be generally proportional to the signal strength, RSRP, and SNR. EX1006, 1; EX1008 ("Afroz"), 115, 118, 120, 122, FIG. 7.

94. As explained *supra* §IX.A, a POSITA would have a reasonable expectation of success at combining Kim's MIMO system with these features from Chen because doing so merely involves "the predictable use of prior art elements according to their established functions" (*e.g.*, single base station with a multitude

of antenna ports) to "yield predictable results" (*e.g.*, transmitting pilot signals from respective antenna port groups at a base station) without more while the fundamental operations of Kim's MIMO system remain intact.

95. Accordingly, my opinion is that the Kim-Chen combination renders obvious Element 1.d1.

[1.d2]: the first signaling is used to determine the K antenna port groups transmitting the first wireless signal; the K is a positive integer greater than 1;

96. In the Kim-Chen combination, Kim's UE uses RRC (***the first signaling***) ***to determine the K antenna port groups*** that will be ***transmitting*** the CSI-RS (***first wireless signal)***, which K antenna port groups are identified in the Resource Block by the corresponding Resource Elements ("REs"). *Supra* Elements [1.a] and [1.d2]. ***K is a positive integer greater than 1***, for example, 2, 4, or 8 antenna ports for CSI-RS transmission. *Id*.

97. In more detail, Kim explains that the base station "may inform the UE of specific information through RRC signaling," including "CSI-RS configuration" information that identifies a CSI-RS "antenna port pair" transmitting from a single RE. EX1004, [0142]. For example, the UE receives, from the base station, first signaling, such as "CSI-RS config information element[s]," which includes "antennaPortsCount-r10" that "indicates the number of antennas needed for CSI-RS transmission (for example, one, two, four, or eight antennas may be selected)," and

"resourceConfig-r10" that "indicates which RE [Resource Element]" is transmitting the CSI-RS. *Id.*, [0079-81], Table 3. The base station uses this signaling information to "designate[] a plurality of configurations of CSI-RSs" to be measured and "inform[] the UE" of the CSI-RSs to be measured. *Id.*, [0119], [0111], [0137] ("BS [base station] independently designates the number of antenna ports to be used for RSRP measurement according to each CSI-RS configuration"), [0142] (base station "inform[s] the UE of specific information through RRC signaling" to indicate CSI-RS configuration and antenna ports), [0143], [0146-148] (CSI-RS "previously designated by the BS through RRC signaling" and "N, M, T1, and T2 may be signaled to the UE through RRC signaling").

98. The antenna port groups specified for CSI-RS measurements may include a "management set" of transmitted signals where the subset or "measurement set" meeting a particular criterion (such as RSRP ratio threshold, *infra* Element [1.d5]) is reported back to the base station. EX1004, [0130]. Kim's FIG. 9 (below) illustrates an example where the management set of CSI-RS #1-#7 is identified by the base station for reporting RSRP values in the configuration information to the base station, and the measurement set of CSI-RS #2, CSI-RS #4, and CSI-RS #6 is measured and the measurement values are reported back to the base station. *Id.*, [0111] ("BS sets configurations of [CSI-RSs] each of which will perform RSPR [sic: RSRP]…measurement…, and informs the UE of the resultant

configurations," and UE "perform[s] RSRP…measurement of CSI-RSs transmitted from cells contained in the CoMP management set" and reports those where "the measurement result satisfies a specific condition"), [0119] ("BS designates a plurality of configurations of CSI-RSs to be RSRP/RSRQ-measured as a CoMP management set"), [0136], [0148]-[0149].

99. Therefore, my opinion is that the Kim-Chen combination renders obvious Element 1.d2.

[1.d3]: the K antenna port groups respectively correspond to K channel quality values; the K channel quality values are K non-negative real numbers; the K channel quality values are Reference Signal Received Powers (RSRPs) or Signal to Interference plus Noise Ratios (SINRs)

100. In the Kim-Chen combination, Kim discloses that each antenna port transmitting the CSI-RSs has a corresponding ***channel quality value*** (*e.g.*, ***RSRP***). EX1004, [0111], [0132], [0135], [0148-149]. In Kim, the RSRP is measured in milliwatts (mW), which are ***non-negative real numbers***. *Id.*, [0135].

101. After receiving the configuration information used to determine the K antenna port groups (*supra* [1.d2]), "[t]he UE may perform RSRP…measurement of CSI-RSs transmitted from cells contained in the CoMP management set." EX1004, [0111]. "If the measurement result satisfies a specific condition, the UE may perform reporting." *Id.*, [0136], [0148-149].

102. "[T]he UE may report…indexes of a maximum of M CSI-RSs (the RSRP ratio (RSRP_*n*/max(RSRP_*i*)) of which is higher than a predetermined threshold value) from among N CSI-RSs contained in the CoMP management set," as well as "the RSRP estimation result of the corresponding CSI-RS." EX1004, [0149]. To determine the "M CSI-RSs" (reported measurement set) from among the "N CSI-RSs" (management set), the UE determines the RSRP (channel quality value) of each of the N CSI-RSs in the management set. *Id.*, [0111], [0148-0149]. Here, each of Kim's N antenna port groups in the management set (K antenna port groups) has a corresponding channel quality RSRP value that is non-negative real numbers (*e.g.*, measured in mW). *Id.*, [0135].

103. Therefore, my opinion is that the Kim-Chen combination renders obvious Element 1.d3.

[1.d4]: K1 antenna port groups of the K antenna port groups correspond to K1 channel quality values of the K channel quality values; the K1 is a positive integer less than or equal to the K;

104. As I have explained *supra* Element 1.d3, in the Kim-Chen combination, Kim discloses measuring ***K antenna port groups*** (*e.g.*, management set of N antenna ports) that have real, non-negative RSRP channel quality values. Kim also teaches ***K1 antenna port groups of the K antenna port groups*** (*i.e.*, the measurement set of M antenna port groups included within the N antenna port groups) by reporting "a maximum of M CSI-RSs (the RSRP ratio (RSRP_*n*/max(RSRP_*i*)) of which is

higher than a predetermined threshold value) from among [the] N CSI-RSs contained in the CoMP management set" to the base station. EX1004, [0149]. The M reported RSRP values (measurement set) of Kim correspond to the ***K1 antenna port groups*** each with a measured RSRP ratio that is "higher than a predetermined threshold value. *Id.*, [0111], [0136]. Because "a maximum of M" CSI-RS port groups are reported, and M is "a maximum" number selected "from among N" antenna ports, M is a positive integer less than or equal to N. *Id.*, [0149]. Kim therefore teaches ***K1 antenna port groups of the K antenna port groups having K1 channel quality values*** (*e.g.*, M RSRP of measured N CSI-RSs), where the ***K1*** (*e.g.*, M) is ***a positive integer less than or equal to the K*** (*e.g.*, N).

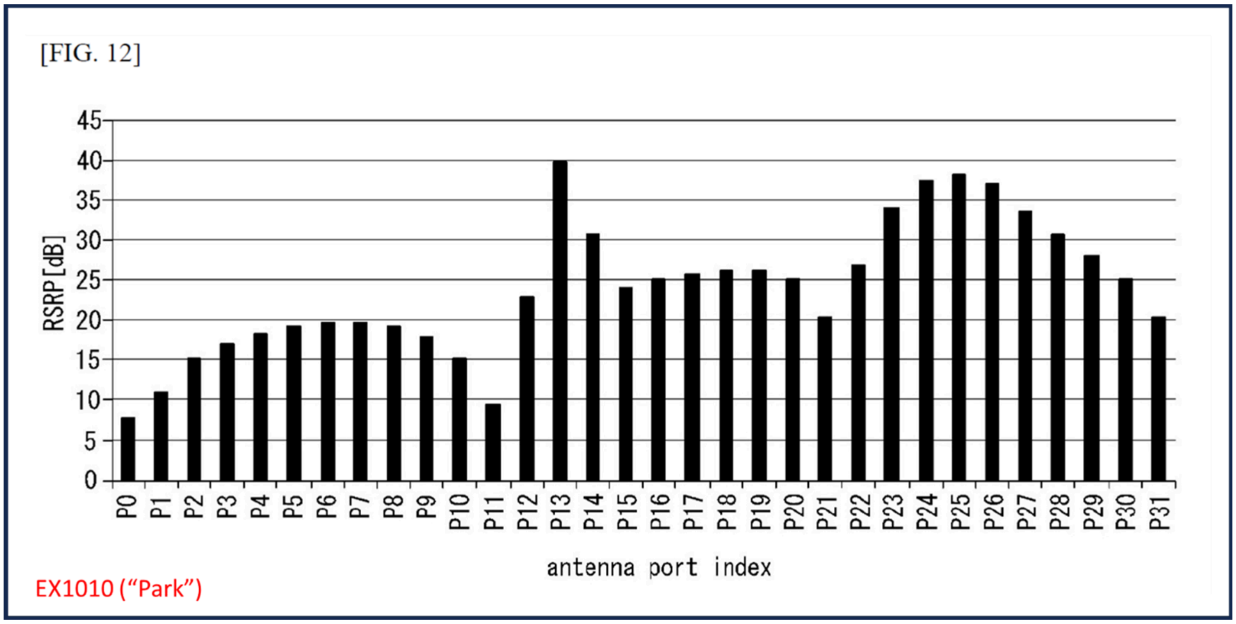
[1.d5]: a first proportional sequence corresponds to a ratio(ratios) among the K1 channel quality values;

105. As I have explained above under Element [1.d4], Kim discloses reporting the K1 antenna ports that satisfy "the RSRP ratio" (when measured from the CSI-RS on a corresponding antenna port group and compared to the maximum received RSRP) being "higher than a predetermined threshold value." EX1004, [0149], [0136]. To qualify for reporting, "the RSRP ratio (RSRP_*n*/max(RSRP_*i*)) needs to "satisfy Equation 4" which provides: "RSRP_*n*/max(RSRP_*i*)>Threshold." *Id.*, [0149], [0136]. Kim further teaches reporting "not only <u>indexes</u> of a maximum of M CSI-RSs…but also the <u>RSRP estimation result</u> of the corresponding CSI-RS." *Id.* [0149].

106. Kim's report includes a sequence of indexes of the antenna port groups, which provide the claimed ***first proportional sequence that corresponds to ratios among the K1 channel quality values***—Kim teaches reporting the indexes of those antennal port groups (*e.g.*, a maximum of M) that correspond to CSI-RSs with RSRP measurement values "higher than a predetermined threshold value." EX1004, [0149]. Indeed, this is consistent with the description of the '904 patent itself (EX1001, 14:52-54 ("the first proportional sequence is composed of K1 non-negative real numbers not greater than one"). Notably, the indices are non-negative numbers.

107. Kim's report additionally includes "RSRP estimation result of the corresponding CSI-RS" for those qualifying antenna port groups. EX1004, [0149]. The sequence of these RSRP estimation results is based on the RSRP ratios (*e.g.*, "RSRP_*n*/max(RSRP_*i*)," as provided by Equation 4) such that the sequence would be proportional. *Id*, [0149], [0136] ("measurement report value for the n-th CSI-RS may be defined as the ratio of the n-th CSI-RS average Rx power level to the best CSI-RS average Rx power level"). For this reason, the sequence of these RSRP estimation results, which are non-negative real numbers and indexed by the antenna port group numbers, also qualify for the claimed ***first proportional sequence that corresponds to ratios among the K1 channel quality values***. In fact, it was ubiquitous to report a report a sequence of measurement values based on antenna

port indices. *See e.g.*, EX1010 at FIG. 12 (annotated below showing RSRP reported as ordered by the antenna port indexes).



108. To Wit, Element [1.d5] does not recite a specific “ratio between one channel quality value to itself or to another of the K1 channel quality values.” The plain language of Element [1.d5] recites that the proportional sequence “***corresponds to***” ratios. EX1001, 27:40-42. Moreover, dependent claims 2, 7, 12, and 17 recite the “first proportional sequence comprises *quantized values* ***corresponding to*** [K1/K1-1] positive real numbers,” rather than the proportions or ratios. *Id.*, 27:60-28:8, 29:12-27, 30:32-47, 31:50-32:16. To be clear, Element [1.d5] is rendered obvious based on the plain and ordinary meaning of [1.d5] which, based on my knowledge and experience in the field, would have been readily understood by a POSITA. Moreover, even if [1.d5] were construed, which appears unnecessary given the similarity between Kim-Chen and the ’904 patent examples,

such construction would account for the context in the claims and the specification of the ’904 patent. As I discussed above, the ’904 patent specification indicates that the sequence can have a number other than exactly K1 values, and describe examples that the “first proportional sequence comprises quantized values corresponding to [K1/K1-1] positive real numbers.” EX1001, 27:35-28:8, 29:12-27, 30:32-47, 31:50-32:16. Thus, the Kim-Chen combination likewise renders obvious [1.d5] construed consistent with the specification, for the same reasons described above.

109. Thus, my opinion is that the Kim-Chen combination renders obvious Element [1.d5].

[1.d6]: the first information is used to determine the K1 antenna port groups and the first proportional sequence;

110. As explained I have explained under Element [1.d5], in the Kim-Chen combination, Kim teaches that ***the first information*** (antenna port indices, RSRP values, and RSRP-to-max(RSRP) ratios) is used (*e.g.*, by the base station, to determine the ***K1 antenna port groups*** (*e.g.*, the M reported antenna port groups satisfying the threshold of Equation 4) and the ***first proportional sequence*** (*e.g.*, the proportional sequence of RSRP-to-max(RSRP) values). EX1004, [0149] (“the UE may report not only indexes of a maximum of M CSI-RSs…from among N CSI-RSs contained in the CoMP management set, but also the RSRP estimation result of the corresponding CSI-RS”), [0148], [0150].

111. Therefore, my opinion is that the Kim-Chen combination renders obvious Element [1.d6].

[1.d7]: the first signaling is used to determine a target threshold; the target threshold is a non-negative real number;

112. In the Kim-Chen combination, Kim explains that the UE reports "a maximum of M CSI-RSs (the RSRP ratio (RSRP_n/max(RSRP_i)) of which is higher than a predetermined threshold value) from among N CSI-RSs contained in the CoMP management set" that satisfy "RSRP_n/max(RSRP_i)>Threshold." EX1004, [0149], [0136], [0150-151]. Kim's threshold is a non-negative real number because it corresponds to the "linear value" in milliwatts (mW), which is itself a positive non-negative real number and the ratio of two non-negative real numbers is also a non-negative real number. *Id.*, [0135-136]. Kim teaches that "different threshold values may be signaled to the UE" by the base station. *Id.*, [0163]. To the extent that Kim is argued to be without specific teaching on how the RSRP ratio threshold (*e.g.*, Equation 4) is determined by the UE, Chen provides the details.

113. As I have explained above in Section VIII.B, Chen teaches that UE selects antenna ports "according to a power threshold configured by the base station" where the power threshold can be "a relative threshold" (*e.g.*, RSRP ratio). EX1006, 7, 9, 11, 13, 16-19 (reporting antenna port "when the ratio of the received power [RSRP] to the maximum received power [max(RSRP)] is greater than or equal to a

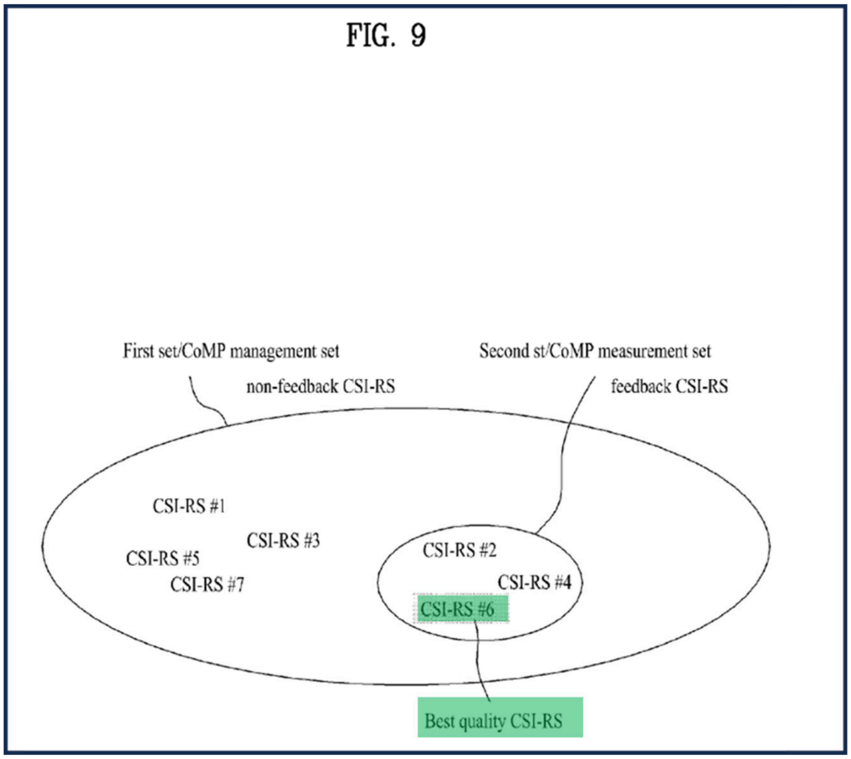
preset threshold value"), 23, 26, 28. Chen's base station configures the pilot signals "through signaling." *Id.*, Abstract, 10, 13, 19, 23, 26.

114. As I have explained above in Section IX.A, it would have been obvious use the first signaling (*e.g.*, RRC signaling as taught by Kim) to determine a target threshold (*e.g.*, to have the base station configure the relative power threshold used by the UE, as taught by Chen and suggested by Kim's transmitting other threshold values for antenna port selection) to provide seamless operational control. EX1004 [0163]; EX1006, Abstract, 13-14, 16-17, 19-20, 22.

115. Therefore, my opinion is that the Kim-Chen combination renders obvious Element 1.d7.

[1.d8]: a first channel quality is a best channel quality value among the K1 channel quality values; a second channel quality is a worse channel quality value among the K1 channel quality values;

116. As I have explained above under Section IX.A and Elements [1.b]/[1.d3-1.d5], Kim discloses ***a first channel quality is a best channel quality*** (*e.g.*, "max(RSRP_i)" or "best CSI-RS average Rx power level") ***among the K1 channel quality values*** (*e.g.*, the selected M antenna ports). EX1004, [0136], [0149]. In FIG. 9, *Kim* shows an example for identifying the "[b]est quality CSI-RS" (CSI-RS #6) from "CSI-RSs (#2, #4, #6) contained in the CoMP measurement set." *Id.*, [0119].



EX1004, FIG. 9

117. Kim discloses ***a second channel quality is a worse channel quality among the selected K1 antenna ports***, such as when RSRP_n is less than max(RSRP_i) while the ratio of RSRP_n/max(RSRP_i) is greater than the threshold value (for example, CSI-RS #2 or #4 in FIG. 9 (above)). EX1004, [0148-149], [0136]. In this example, Kim selects "CSI-RSs (#2, #4, #6)", which correspond to the selected ant K1 antenna ports, "from among CSI-RSs (#1~#7)." *Id.*, [0119], [0149] ("a maximum of M CSI-RSs"), [0146] ("The UE may periodically report the quality of M CSI-RS values"), [0148].

118. Therefore, my opinion is that the Kim-Chen combination renders obvious Element 1.d8.

[1.d9]: a ratio between the second channel quality and the first channel quality is greater than or equal to the target threshold;

119. As I have explained above in Section IX.A and Elements [1.d5]-[1.d8], Kim discloses that ***a ratio between the second*** ("worse") ***channel quality*** (RSRP_n) ***and first*** ("best") ***channel quality*** (max(RSRP_i)) ***is greater than a threshold*** (Equation 4's target threshold). EX1004, [0136] ("the measurement report value for the n-th CSI-RS may be defined as the ratio of the n-th CSI-RS average Rx power level to the best CSI-RS average Rx power level"), [0148-149]. Kim's RSRP_n (*e.g.*, CSI-RS #2 or #4) thus corresponds to a second ("worse") channel quality, where the ratio RSRP_n/max(RSRP_i) is greater than the threshold of Equation 4 and thus is one of the M antenna ports being reported in the measurement set. *Id.*, [0136], [0148-149].

120. Therefore, my opinion is that the Kim-Chen combination renders obvious Element 1.d9.

[1.d10]: the first signaling is a RRC (Radio Resource Control) signaling; the first information is transmitted in a CSI (Channel State Information) report; the first information is carried by a PUSCH (Physical Uplink Shared Channel) or a PUCCH (Physical Uplink Control Channel).

121. As I have explained above under Element [1.a] and Sections VIII.A &IX.A, Kim's ***first signaling is a RRC (Radio Resource Control) signaling***. EX1004, [0146] ("the quality of M CSI-RS values…can be reported" and "M may

be predetermined or may be previously designated by the BS through RRC signaling"), [0142] ("the BS or eNB may inform the UE of specific information through RRC signaling").

122. In the Kim-Chen combination, ***the first information is transmitted in a CSI report*** because Kim's "UE may perform RSRP measurements on the CRS and CSI-RS signals transmitted by the base station and report the RSRP values and RSRP-to-max(RSRP) ratios back to the base station." EX1004, [0113], [0136], [0148-149].

123. In the Kim-Chen combination, ***the first information is carried by a PUSCH (Physical Uplink Shared Channel) or a PUCCH (Physical Uplink Control Channel)***. Kim provides using an uplink reference signal to convey "channel estimation" from the UE to the base station, *e.g.*, "via a PUSCH and a PUCCH." EX1004, [0055], [0050] (discussing "a physical UL shared channel (PUSCH)…for one user equipment is assigned to a resource block pair (RB pair) in a subframe"). In my opinion, it would have been obvious for the Kim-Chen combination to use one of the PUSCH and PUCCH, as already disclosed in Kim, to carry the CSI-RS measurement report, as provided by *supra* [1.c]/[1.d6], so that the base station is apprised of the results of the measurements by the UE. Here, a POSITA would have been motivated to inform the base station of the measurement results when the PUSCH and PUCCH channels present ready-to-use uplink channels for feedbacking

the first information to the base station. Moreover, a POSITA would have a reasonable expectation of success at doing so because using one of the PUSCH and PUCCH channels to carry the CSI-RS measurement report merely involves "the predictable use of prior art elements according to their established functions" to "yield predictable results" while retaining the fundamental operations of Kim's MIMO system.

124. Accordingly, my opinion is that Kim-Chen combination renders obvious all limitations of claim 1.

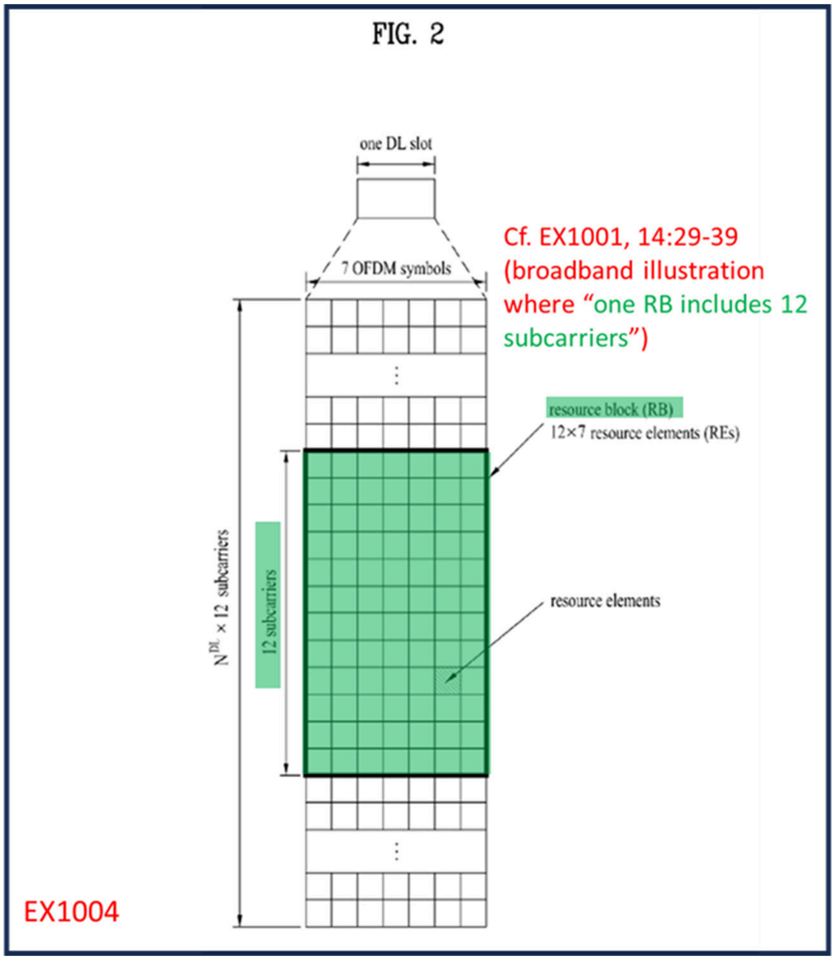
2) Claim 2

> ***2. The method of claim 1, wherein the K channel quality values are broadband channel quality values; or the first proportional sequence comprises K1 positive real numbers less than or equal to 1, and the first proportional sequence comprises at least one 1; or the first proportional sequence comprises quantized values corresponding to K1 positive real numbers; or the first proportional sequence is composed of K1 positive real numbers, and the K1 positive real numbers are respectively ratios between the K1 channel quality values and the best channel quality value of the K1 channel quality values; or the first proportional sequence comprises K1-1 positive real number(s), and the K1-1 positive real number(s) is(are) a ratio(ratios) between a channel quality value(s) other than the best channel quality value among the K1 channel quality values and the best channel quality value; or the first proportional sequence comprises quantized values corresponding to K1-1 positive real number(s).***

125. Each and every element of claim 1 is obvious as explained above. In the context of claim 1, the Kim-Chen combination also renders obvious claim 2,

which recites five alternative options in disjunctive so that meeting any one of the options would satisfy claim 2.

126. In the Kim-Chen combination, Kim teaches ***the K channel quality values are broadband channel quality values***. Kim teaches using "a reference signal" for estimating "channel state between each transmission antenna and each reception antenna." EX1004, [0052] ("detecting channel information using a distortion degree when the signal is received via the channel"), [0053] ("a reference signal is present per transmission antenna and, more particularly, per antenna port"). Kim teaches "the reference signal is transmitted over a wide band." *Id.*, [0064]. In FIG. 2 (below), Kim shows an example of "a resource grid" in which "one downlink (DL) slot includes 7 OFDM symbols and one resource block (RB) includes 12 subcarriers in frequency domain." *Id.*, [0048]. Kim's description parallels the descriptions of the '904 patent. *See e.g.*, EX1001, 14:29-39 ("the broadband is composed of a plurality of sub-bands, and the sub-bands are composed of one or more Resource Blocks (RBs)" and "one RB includes 12 subcarriers").



127. In the Kim-Chen combination, the first proportional sequence comprises K1 positive real numbers less than or equal to 1, and the first proportional sequence comprises at least one 1. As I have explained above under Elements [1.d5]-[1.d9], Kim discloses a proportional sequence comprising, e.g., a maximum of M RSRP-to-max(RSRP) ratios (i.e., "RSRP_n/max(RSRP_i)"), which are positive real numbers less than or equal to 1. EX1004, [0149]. When RSRP_n is less than max(RSRP_i), but still satisfies Equation 4 (i.e., "RSRP_n/max(RSRP_i)>Threshold"), the ratio will be a positive real number less than 1. Id., [0135-136],

[0148-149]. Similarly, when the ratio is computed for the maximum of RSRP values (e.g., CSI-RS #6 in FIG. 9), the ratio value will be 1. Id., [0135-136], [0148-149].

128. For similar reasons, ***the first proportional sequence*** in the Kim-Chen combination ***is composed of K1 positive real numbers*** (*e.g.*, a maximum of M RSRP-to-max(RSRP) ratios (*i.e.*, "RSRP_n/max(RSRP_i)"), which are positive real numbers), ***and the K1 positive real numbers are respectively ratios between the K1 channel quality values and the best channel quality value of the K1 channel quality values*** (*e.g.*, the ratios of "RSRP_n/max(RSRP_i)"). *Supra* Elements [1.d5]-[1.d9]; EX1004, [0135-136], [0148-149].

129. In the Kim-Chen combination, ***the first proportional sequence comprises quantized values corresponding to K1 positive real*** numbers at least for the same reason above and additionally because the ratio values in the proportional sequence are quantized values when reported back to the base station. Reporting the ratios (*e.g.* "RSRP_n/max(RSRP_i)") from the UE to the base station would have entailed encoding each ratio in a quantized digital format so that the UE can "perform data modulation." EX1004, [0149], [0064].

130. To the extent that Kim is argued to lack express teaching of quantizing the ratios (*i.e.*, RSRP-to-max(RSRP) ratios or "RSRP_n/max(RSRP_i)") when modulating the information for reporting back to the base station, Chen specifically teaches quantizing reported "amplitude/power ratio." EX1006, 18 ("a magnitude

level of an amplitude or power is first indicated, and then a coefficient at the magnitude level is indicated," and "[t]he coefficient may be uniformly quantized."), 1 (background discussion of "quantized feedback" of "codebook-based channel information").

131. In my opinion, a POSITA would have been motivated to apply quantization, as expressly taught in Chen, to the ratios of Kim so that the measurement report can be encoded efficiently and transmitted with reduced overhead from the UE to the base station.

132. It is also my opinion that a POSITA would have had a reasonable expectation of success in implementing quantized values for reporting because transmitting quantized values was well known to limit the amount of reported data based on the number of bits allocated to the quantization. *Id.*; EX1006, 15-16, 1, 15; *see* EX1013 ("Sesia LTE"), 390-391 (quantization of codebook configurations), 663 (reporting "quantized" values "to reduce the overhead to a reasonable level"). In fact, the quantization was already implemented in the 3GPP standards. EX1015 ("3GPP TS 36.133 v13.2.0"), § 9.1.4, Table 9.1.4-1 (RSRP quantized into 1dBm intervals). Having the first proportional sequence comprise quantized values corresponding to K1 positive real numbers would therefore have been a straightforward operation that applies only known, conventional operations

(quantized reporting of the ratio) used according to their known functions to yield predictable results (transmitting a quantized value).

133. Accordingly, my opinion is that the Kim-Chen combination renders obvious claim 2.

3) Claim 3

> ***3. The method according to claim 1, wherein the first signaling is UE specific; or, the unit of the target threshold is dB; or, the first signaling implicitly indicates the target threshold; or, the K antenna port groups correspond to K reference signal groups, the time domain resources occupied by any two of the K reference signal groups are orthogonal, the analog beamforming vectors corresponding to any two of the K reference signal groups cannot be considered to be the same, the K reference signal groups occupy K time windows, and the K time windows are orthogonal in the time domain.***

134. Each and every element of claim 1 is obvious as explained above. In the context of claim 1, the Kim-Chen combination further renders obvious claim 3. In Kim, "the BS or eNB may inform <u>the UE</u> of specific information through RRC signaling." EX1004, [0142], [0143], [0146] (parameter "M may be…previously designated by the BS through RRC signaling"), [0147-148] (parameters "N, M, T1, and T2 may be signaled to <u>the UE</u> through RRC signaling"), [0079-81], Table 3. Here, Kim specifically uses a singular form when referring to the UE being configured "through RRC signaling" (*e.g.*, *id.*, [0142], [0148]) while multiple UEs

are depicted within the range of a single base station. *Id.*, FIG. 7 (depicting three macro UEs served by one MeNB).

135. Moreover, Kim's RRC signaling configures "M CSI-RSs indicating the best RSRP result from among N CSI-RS contained in the CoMP management set," as well as "a predetermined time (T1)" (*i.e.*, "after the above result is reported once to avoid the occurrence of frequent reporting") and "a predetermined time (T2)" (to trigger reporting "[i]f the reporting is not triggered [during T2]").

136. In my opinion, a POSITA would have found apparent, or at least obvious, that at least some of these parameters, namely, N, M, T1 and T2, are specific to a UE because each UE can have "UE-specific power control," leading to UE-specific configurations for channel state estimation (*e.g.*, "[d]eciding CoMP measurement set of a specific UE"). *Id.*, [0092], [0111]. Indeed, Kim acknowledges that "the BS or eNB may inform the UE of specific information through RRC signaling" so that information specifying "antenna port pair is transmitted through a CSI-RS configuration in which only the corresponding antenna port is established through the above RRC signaling." *Id.*, [0142]. To the extent that these parameters (*e.g.*, the measurement set of antenna ports) being configured via RRC signaling are specific to a UE, the RRC signaling (*i.e.*, the claimed first signaling) is UE specific. *See also, id.*, [0059] ("a UE-specific reference signal for a specific UE").

137. The Kim-Chen combination also renders obvious that ***the first signaling implicitly indicates the target threshold***. As I have explained above under Element [1.d7] and Section IX.A, the Kim-Chen combination renders obvious that the first signaling is used to determine a target threshold. EX1004 [0163]; EX1006, Abstract, 11, 18, 21, 23.

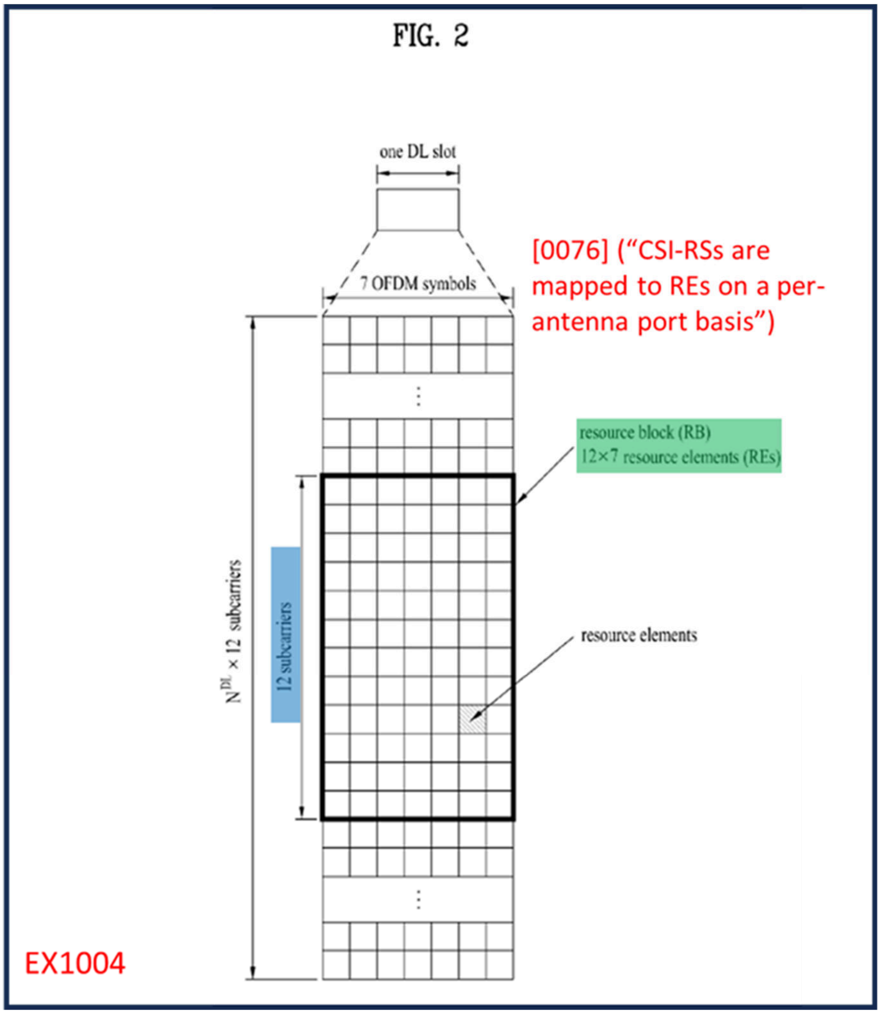
138. When the first signaling (*e.g.*, RRC signaling as taught by Kim) is used by the receiving UE to determine a target threshold provided by the base station (as taught by Chen), the first signaling ***implicitly indicates the target threshold***. I note that the UE needs to decode the target threshold information from the received RRC signaling. Tellingly, the specification of the '904 reveals nothing specific about implicitly indicating and hence acknowledges that this would have been within a POSITA's knowledge and skill, based on my experience.

139. Accordingly, my opinion is that the Kim-Chen combination renders obvious claim 3.

4) Claim 4

> ***4. The method according to claim 1, wherein any two antenna ports in the K1 antenna port groups are co-located or quasi-co-located (QCL); or any two antenna ports in the K1 antenna port groups are on a same carrier; or the first signaling is further used to determine the K1, and the first information is further used to determine the first channel quality***

140. Each and every element of claim 1 is obvious as explained above. In this context, the Kim-Chen combination further renders obvious ***any two antenna ports in the K1 antenna port*** groups ***are on a same carrier*** because Kim teaches same carrier operation, namely, "single carrier frequency division multiple access" or "SC-FDMA," for its MIMO network. EX1004, [0039], [0002]. In examples of its same carrier operation, Kim further describes using "<u>SC-FDMA</u> symbol" in the time domain and "contiguous subcarriers" in the frequency domain for transmitting from the base station to the UE. *Id.*, [0043]. Specifically, "one downlink (DL) slot includes 7 OFDM symbols and one resource block (RB) includes 12 subcarriers in frequency domain." *Id.*, [0048], FIG. 2 (below), 6 (example mapping to one RB).



141. In my experience, it was general knowledge that a single carrier contains multiple subcarriers within the single carrier's bandwidth. *See e.g.*, EX1013 ("Sesia LTE")). Kim thus teaches same carrier operation using a "single carrier" with multiple "contiguous subcarriers" where "CSI-RSs [for prompting measurement report] are mapped to REs [of the RB] on a per-antenna port basis." EX1004, [0039], [0043], [0076]. As illustrated in FIG. 2 (above), the antenna ports, as mapped to one of the "12×7 resource elements," are on the same carrier, the bandwidth of which includes "12 subcarriers." *Id.*, [0048]

142. The Kim-Chen combination also renders obvious the first signaling is further used to determine the K1, and the first information is further used to determine the first channel quality, as I explain below.

143. First, in the Kim-Chen combination, ***the first signaling is used by the UE to determine the K antenna port groups***, *supra* Elements [1.d2]/[1.d5], *e.g.*, the N antenna ports (corresponding to "N CSI-RS contained in the CoMP management set") for which channel status information are sought, as taught in Kim. EX1004, [0148] ("N, M, T1, and T2 may be signaled to the UE through RRC signaling"), [0142] (base station "inform[s] the UE of specific information through RRC signaling" to indicate CSI-RS configuration and antenna ports, *e.g.*, "a CSI-RS configuration in which only the corresponding antenna port is established through the above RRC signaling").

144. As I have explained above under Element [1.d7], in the Kim-Chen combination, the ***first signaling*** (*e.g.*, RRC signaling as taught by Kim) ***is used to determine a target threshold*** (*e.g.*, to have the base station configure the relative power threshold used in the UE, as taught by Chen). EX1004 [0163]; EX1006, Abstract, 11, 18, 21, 23.

145. Therefore, in the Kim-Chen combination, the first signaling is ***further used to determine the K1***, *i.e.*, the number of antenna ports with corresponding RSRP measurement values over the threshold value. EX1004, [0149] ("a maximum

of M CSI-RSs (the RSRP ratio (RSRP_n/max(RSRP_i)) of which is higher than a predetermined threshold value) from among N CSI-RSs." EX1004, [0149] ("M CSI_RSs configured to satisfy… RSRP_*n*/max(RSRP_*i*)>Threshold"), [0111] ("BS sets configurations of [CSI-RSs]…, and informs the UE of the resultant configurations," and UE "perform[s] RSRP…measurement of CSI-RSs transmitted from cells contained in the CoMP management set" and reports those where "the measurement result satisfies a specific condition"); EX1006, 4, 5, 7, 9, 14-15, 19, 22, 24.

146. Second, in the Kim-Chen combination, ***the first information is further used to determine the first channel quality*** because the measurement report (*i.e.*, ***the first information***) indicates whether the corresponding RSRP of an antenna port is over a threshold, which indication is ***used to determine the first channel quality***. EX1004, [0149] (citing Equation 4).

147. Therefore, my opinion is that the Kim-Chen combination renders obvious claim 4.

5) Claim 5

> ***5. The method according to claim 1, wherein the K antenna port groups respectively correspond to K reference signal groups; the K reference signal groups are respectively transmitted through the K antenna port groups; the first wireless signal is composed of the K reference signal groups; the antenna port group is composed of one antenna port, or, the antenna port group is composed of a plurality of antenna ports; the antenna port corresponds to***

a reference signal; the reference signal is transmitted through the antenna port; the reference signal is a SS (Synchronization Signal) or a CSI-RS (Channel State Information Reference Signal) or a DMRS of a PBCH (Physical Broadcast Channel).

148. Each and every element of claim 1 is obvious as explained above. In this context, the Kim-Chen combination further renders obvious all clauses of claim 5, treated as recited in the conjunctive solely for this declaration.

149. First, in the Kim-Chen combination, Kim teaches that the K antenna port groups respectively correspond to K reference signal groups. As I have explained above under Element [1.d3], Kim discloses that the K antenna port groups respectively correspond to K channel quality values (e.g., Reference Signal Received Powers (RSRPs)). Kim also discloses that the RSRP value of each antenna port is measured from a corresponding CSI-RS transmitted from the base station to the UE. EX1004, [0140] ("if the BS configures only one antenna port for CSI-RS configuration, RSRP of the corresponding antenna port is measured and reported"), [0132] ("CSI-RS RSRP is defined as Rx power of a reference signal (RS) of a CSI-RS transmission RE"). As explained supra [1.d1], "CSI-RSs are mapped to REs [of a resource block] on a per-antenna port basis" so that "[one] CSI-RS is mapped to each antenna port." Id., [0076] (explaining details of FIG. 6 where each "antenna port group" can have one port per group), [0065], [0141]. Kim's teachings thus parallel the disclosure of the '904 patent. EX1001, 14:5-12 (explaining that "the

antenna port group includes only one antenna port," "the reference signal group includes only one reference signal," and "the reference signal is a CSI-RS"). Hence, Kim from the combination teaches the K antenna port groups (supra [1.d3]) respectively correspond to K reference signal groups (e.g., "the CSI-RSs mapped to REs on a per-antenna port basis" when each antenna port group includes one antenna port and each reference signal group includes one reference signal, namely, a CSI-RS). Id., [0076].

150. Second, in the Kim-Chen combination, Kim also teaches that ***the K reference signal groups are respectively transmitted through the K antenna port group.*** As I have explained above and under Element [1.d1], Kim teaches that "the CSI-RSs [are] mapped to REs on a per-antenna port basis" where a "CSI-RS is mapped to each antenna port." EX1004, [0076], [0071] ("CSI-RSs may be transmitted through 1, 2, 4 or 8 antenna ports").

151. Third, in the combination, Kim also teaches that ***the first wireless signal is composed of the K reference signal groups***. As I have explained above under Element [1.d1], Kim teaches CSI-RS transmission using multiple signals (*e.g.*, "CSI-RSs may be transmitted through 1, 2, 4 or 8 antenna ports" using a per-antenna port assignment in which "[one] CSI-RS is mapped to each antenna port," EX1004, [0076], [0071]), which comports with the description of '904 Patent. EX1001, 3:27-29 ("K different analog beamforming vectors for analog beamforming of the K

antenna port groups" to provide the first wireless signal), 2:58-60 (each "antenna port corresponds to a reference signal" and "[t]he reference signal is transmitted through the antenna port"), 3:5-6 (each "reference signal is a Channel State Information Reference Signal (CSI-RS)").

152. Fourth, in the combination, Kim also teaches that ***the antenna port group is composed of one antenna port….*** As I have explained above and under Element [1.d1], Kim teaches an example where an "antenna port group" has one antenna port. EX1004, [0076], [0141].

153. Fifth, in the combination, Kim further teaches ***the antenna port corresponds to a reference signal.*** As explained above and *supra* [1.d1] and [1.d3], Kim teaches that "CSI-RSs are mapped to REs [of a resource block] on a per-antenna port basis" so that "[one] CSI-RS is mapped to each antenna port." EX1004, [0076], [0065], [0141].

154. Sixth, in the combination, Kim additionally teaches the reference signal is transmitted through the antenna port; the reference signal is…a CSI-RS (Channel State Information Reference Signal). As I have explained above and under Element [1.d1], Kim teaches that "the CSI-RSs [are] mapped to REs on a per-antenna port basis" where a "CSI-RS is mapped to each antenna port." EX1004, [0076]; see generally [0069-75] ("Channel State Information-Reference Signal (CSI-RS)" as "an RS used for channel measurement").

155. Therefore, my opinion is that the Kim-Chen combination renders obvious claim 5.

6) Claim 6

156. Claim 6 is substantively identical to claim 1, except for reciting the base station as performing the method. *Compare* [6.pre] *with* [1.pre]. As shown below, each element of claim 6 is met by the Kim-Chen combination at least for the same reasons as I have provided above for claim 1. §IX.B.1.

[6.pre]: A method for multi-antenna transmission in a base station, comprising:

157. To the extent the preamble is limiting, the Kim-Chen combination discloses [6.pre] at least for the same reasons as I have explained above under Section IX.B.1 (Element [1.pre]).

[6.a]-[6.c]

158. The Kim-Chen combination discloses [6.a]-[6.c] at least for the same reasons as articulated *supra* §V.A.4.a (Elements [1a]-[1c]).

[6.d1]-[6.d10];

159. The Kim-Chen combination renders obvious Elements [6.d1]-[6.d10], which are substantively identical to elements [1.d10]-[1.d10]. *Supra* §§V.A.1.a (Elements [1.d1]-[1.d10]).

160. My opinion is that the Kim-Chen combination renders obvious claim 6.

7) Claims 7-10

161. Claims 7-10 depend from claim 6, which, as discussed above, is met by the Kim-Chen combination. Claims 7-10 are substantively identical to claims 2-5, and likewise met by the Kim-Chen combination, at least for the same reasons as I have explained above under Sections IX.B.2-5 (claims 2-5).

162. Accordingly, my opinion is that the Kim-Chen combination renders obvious claims 7-10.

8) Claim 11

163. Claim 11 is substantively similar to claim 1, with Elements [11a]-[11c] reciting a "first receiver," "second receiver," and "third transmitter" performing functions substantially identical to the method recited by Elements [1.a]-[1.c]. The elements of claim 11 are met by the Kim-Chen combination for reasons articulated *supra* § V.A.4(a) (claim 1) and further discussed below (with respect to additionally recited "receiver[s]" and "transmitter").

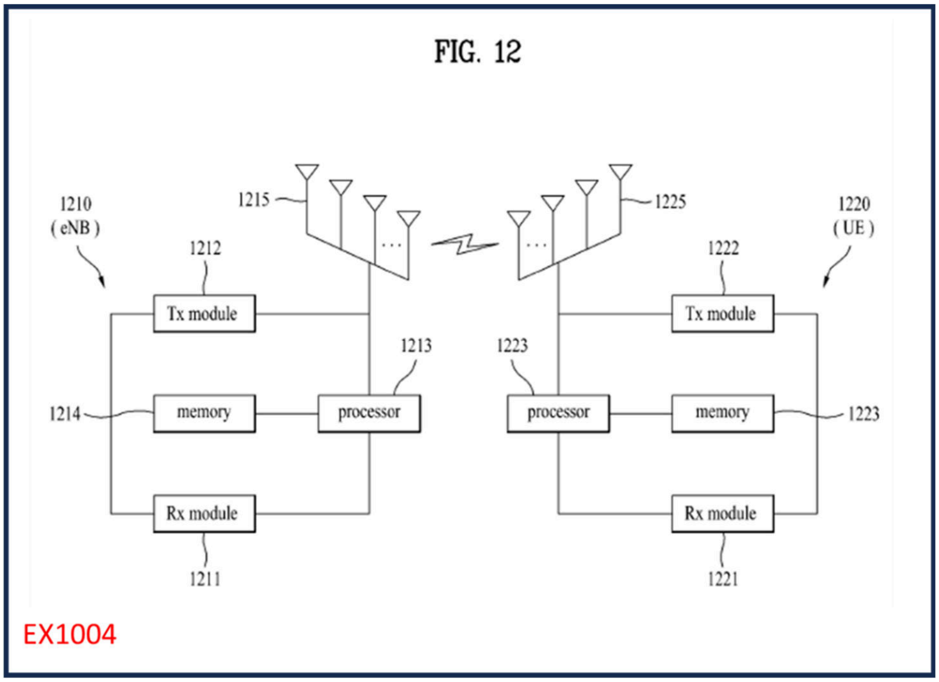
[11.pre]: A user equipment (UE) for multi-antenna transmission comprising:

164. To the extent the preamble is limiting, the Kim-Chen combination discloses [11.pre] at least for the same reasons as I have explained above under IX.B.1.a (Element [1.pre]).

[11.a]-[11.b]

165. Kim discloses the functions of receiving a first signaling and a first wireless signal, as respectively recited by Elements [11.a]-[11.b] and [1.a]-[1.b]. *Supra* §IX.B.1 (Elements [1.a]-[1.b]). Further, the Kim-Chen combination at least renders obvious the claimed "***first receiver***," "***second receiver***," as I further explain below.

166. Kim discloses a MIMO receiver or receiving unit (*supra* claim 1), which includes multiple receivers because MIMO operation requires "multiple output." Thus, Kim's UE has multiple receivers to receive the first signaling (*e.g.*, RRC signaling) and the first wireless signal (*e.g.*, CSI-RSs) transmitted from the BS. *Id.* As illustrated in FIG. 12 (below), Kim's UE receives the first signaling and the first wireless signal at "<u>a plurality of antenna**s** 1225</u>" (*supra* Elements ([1.a]-[1.b])), and processes these signals at "Rx module 1221," which may "receive downlink signals, data and information from the BS." EX1004, [0177].



167. In my experience, it was ubiquitous to use multiple antennas for transmission and reception in a MIMO system, like the one in the Kim-Chen combination. *See e.g.*, EX1010 ("Park") at [0207] ("transmission/reception data efficiency may be improved by adopting a plurality of transmitting antennas and a plurality of receiving antennas"). Under the MIMO operation, each of Kim's antenna**s** 1225 would have a corresponding receiver to receive the incoming CSI-RS signals and RRC signaling and pass these signals to Rx module 1221, as was ubiquitously known in the art and corroborated by, *e.g.*, EX1016 ("Luo") at FIG. 2, [0037], EX1017 ("Vitthaladevuni") at FIG. 10, [0116], [0118]-[0119], and EX1018 ("Hu") at FIG. 12, [0140-141].

168. Specifically, Luo explains that "transmitted modulated signals are received by NR antennas 252a through 252r and the received signal from each

antenna 252 is provided to a respective receiver (RCVR) 254a through 254r" at the UE, as depicted in FIG. 2 (below). EX1016 ("Luo"), [0037]. Notably, Luo's FIG. 2 generally matches FIG. 4 of the '904 patent, both showing one receiver per antenna.

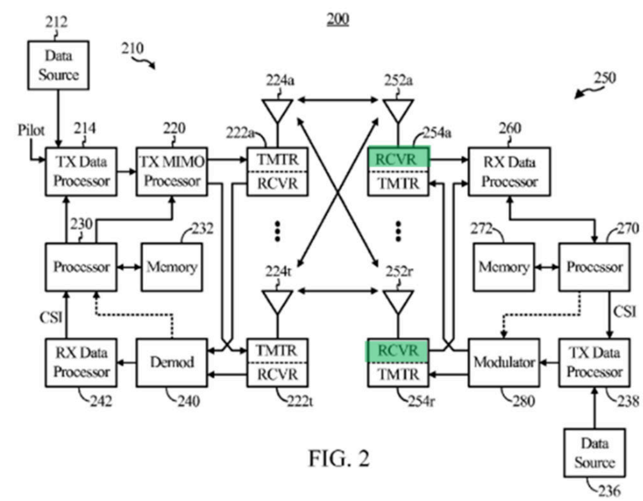


FIG. 2

Luo

169. In my opinion, a POSITA would have found it apparent that Kim's disclosure provides respective receivers for each of Kim's antenna**s** 1225, or at a minimum found this obvious in view of the general knowledge of a POSITA.

170. Specifically, it is also my opinion that a POSITA would have been motivated to include multiple receivers (*e.g.*, using one receiver for each of Kim's antennas) on the MIMO system of the Kim-Chen combination for increased throughout and improved reliability. *First*, a multiple-receiver configuration would have more advantageously utilized each antenna during operation. In comparison, one receiver shared among multiple antennas would have limited access to each

antenna at the expense of overall throughput to the detriment of MIMO operations. Notably, communication throughput would generally scale up with the number of antennas using the multi-receiver configuration. *Second*, a multiple-receiver configuration would have improved operational reliability when multiple receivers can complement each other during operation. On this note, using multiple receivers can provide a level of redundancy to alleviate single-point failure.

171. A POSITA would have reasonably expected success at using the multi-receiver combination because doing so merely involves incorporating well-established components operating according to their known functions to yield predictable results, namely, improved reception of incoming signals.

172. In the Kim-Chen combination where each of Kim's antenna**s** 1225 has a respective receiver, one of the receivers would qualify as the claimed first receiver, and another one of the receivers would qualify as the claimed second receiver, just like the descriptions from the '904 patent. For example, FIG. 4 of the '904 patent merely shows each antenna coupled to a receiver (or transceiver), which, as demonstrated above, was general knowledge because the configuration was ubiquitous by the time of the purported invention. I note that the Applicant never relied on FIG. 4 during prosecution and the Notice of Allowance never mentioned FIG. 4 as reason for allowance.

[11.c]: a third transmitter, transmitting first information;

173. Kim discloses the function transmitting first information, as recited by Elements [11.c] and [1.c]. *Supra* §IX.B.1 (Element [1.c]). Kim's UE includes a "Tx module 1222 [that] may transmit uplink signals, data and information to the BS (eNB)" using antennas 1225. EX1004, [0177], FIG. 12. Kim thus describes a transmitter (*e.g.*, Tx module 1222 along with antennas 1225 and other conventional components) transmitting the first information, such as the measurement report, to the base station, as I have explained above under Section IX.B.1 (Element [1c]).

[11d1]-[11d10]

174. The Kim-Chen combination meets elements [11.d1]-[11.d10], which are substantively identical to elements [1.d10]-[1.d10]. *Supra* §§IX.B.1 (Elements [1.d1]-[1.d10])

175. Accordingly, my opinion is that the Kim-Chen combination renders obvious all limitations of claim 11.

9) Claims 12-15

176. Each and every element of claim 11 is obvious as I have explained above. Claims 12-13, 15, which depend from claim 11, are substantively identical to claims 2-3, 5, and likewise are met by the Kim-Chen combination at least for the same reasons as articulated *supra* §§IX.A.2-3,5 (claims 2-3,5). Claim 14 depends from claim 13, which is met by the Kim-Chen combination. Claims 14 is substantively identical to claim 4, and likewise is met by the Kim-Chen combination,

at least for the same reasons as I have explained above under Section IX.A.4 (claim 4).

177. Accordingly, my opinion is that the Kim-Chen combination renders obvious claims 12-15.

10) Claim 16

178. Claim 16 is substantively identical to claim 6, with Elements [16a]-[16c] reciting a "first transmitter," "second transmitter," and "third receiver" performing functions substantially identical to the method recited by Elements [6.a]-[6.c]. The elements of claim 16 are met by the Kim-Chen combination for reasons that I have explained above under Sections IX.B.1&6 (claims 1 and 6) and further discussed below (with respect to additionally recited "transmitter[s]" and "receiver").

[16.pre]: A base station for multi-antenna transmission, comprising:

179. To the extent the preamble is limiting, the Kim-Chen combination discloses [16.pre] at least for the same reasons as I have explained above under Sections IX.A.1&6 (Element [1.pre]/[6.pre]).

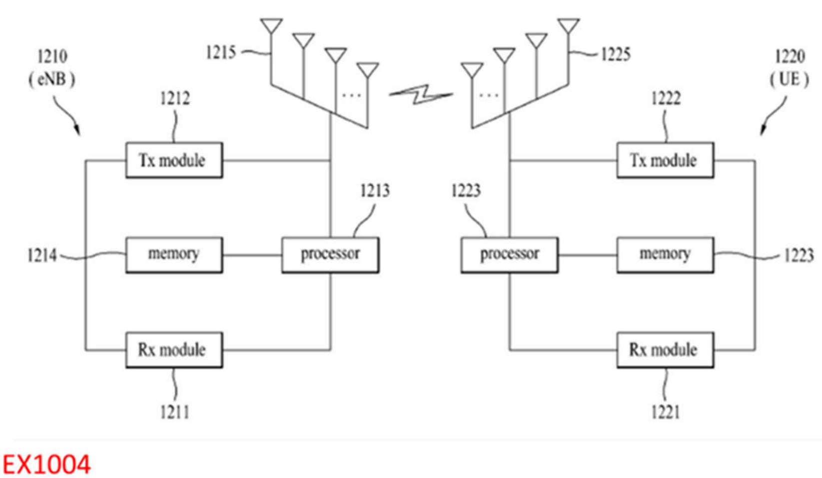
[16.a]-[16.b]

180. Kim discloses the functions of transmitting a first signaling and a first wireless signal, as respectively recited by Elements [16.a]-[16.b] and [1.a]-[1.b]. *Supra* §IX.B.1 (Elements [1.a]-[1.b]); Further, the Kim-Chen combination at least

renders obvious the claimed "first receiver," "second receiver," as I further explain below.

181. Kim discloses a MIMO transmitter at the base station which includes multiple transmitters because MIMO operation requires "multiple input." Thus, Kim's base station has multiple transmitters to transmit the first signaling (*e.g.*, RRC signaling) and the first radio signal (*e.g.*, CSI-RS signals) to the UE. *Id.* As illustrated in FIG. 12 (below), Kim's base station transmits the first signaling and the first radio signal at "a plurality of antennas 1215" using "transmission (Tx) module 1212." EX1004, [0174] ("may transmit a variety of signals, data and information on a downlink for the UE")

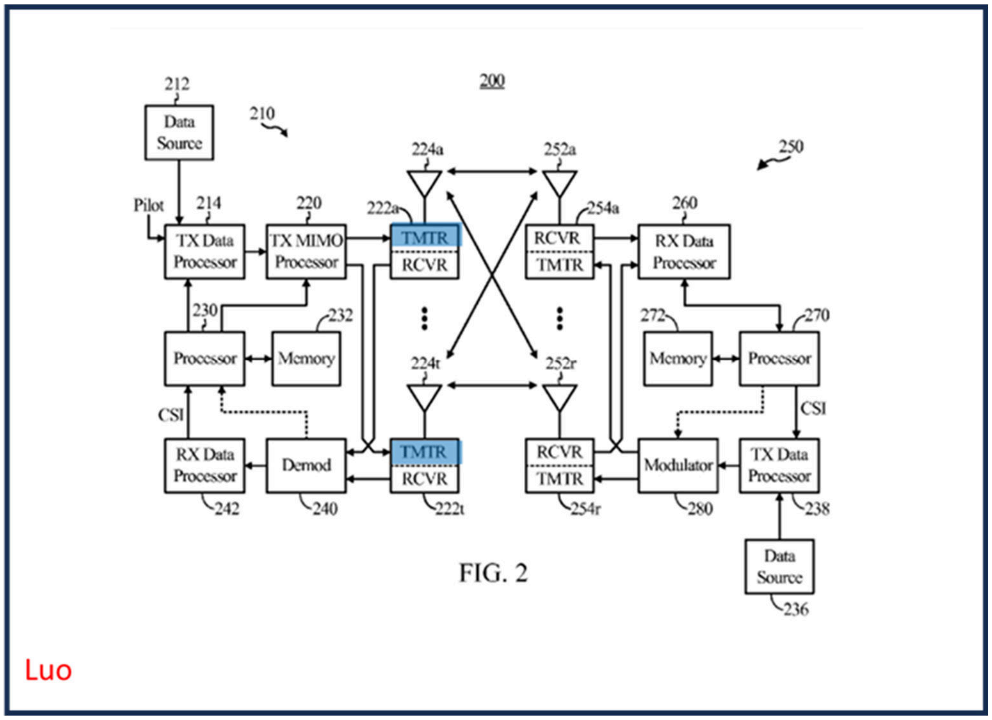
FIG. 12



182. In my experience, it was ubiquitous to use multiple antennas for transmission and reception in a MIMO system, like the one in the Kim-Chen

combination. *See e.g.*, EX1010 ("Park") at [0207] ("transmission/reception data efficiency may be improved by adopting a plurality of transmitting antennas and a plurality of receiving antennas"). Under the MIMO operation, each of Kim's antennas 1215 would have a corresponding transmitter to transmit the out bounding CSI-RS signals and RRC signaling, as was ubiquitously known in the art and confirmed by, *e.g.*, EX1017 ("Luo") at FIG. 2, [0036], EX1018 ("Vitthaladevuni") at FIG. 10, [0116], [0118]-[0119], and EX1016 ("Hu") at FIG. 12, [0140-141].

183. Specifically, Luo explains that "[e]ach transmitter [("TMTR")] 222 receives and processes a respective symbol stream," and "NT modulated signals from transmitters 222a through 222t are then transmitted from NT antennas 224a through 224t, respectively" at the base station, as depicted in FIG. 2 (below). EX1017 ("Luo"), [0036]. As I noted above under claim 6, Luo's FIG. 2 generally matches FIG. 4 of the '904 patent, both showing one transmitter per antenna.



184. In my opinion, a POSITA would have found it apparent that Kim's disclosure provides respective transmitters for each of Kim's antenna**s** 1215, or at a minimum found this obvious in view of the general knowledge of a POSITA, as I further explain below.

185. It is also my opinion that a POSITA would have been motivated to include multiple transmitters (*e.g.*, using one transmitter for each of Kim's antennas) on the MIMO system of the Kim-Chen combination for increased throughout and improved reliability. ***First***, a multiple-receiver configuration would have more advantageously utilized the accessibility of each antenna during operation. In comparison, one receiver shared among multiple antennas would have limited access to each antenna at the expense of overall throughput to the detriment of MIMO

operations. Notably, communication throughput would generally scale up with the number of antennas using the multi-receiver configuration). ***Second***, a multiple-receiver configuration would have improved operational reliability when multiple receivers can complement each other during operation. For example, using multiple receivers can provide a level of redundancy to alleviate single-point failure.

186. Based on my experience, a POSITA would have reasonably expected success at using the multi-transmitter combination because doing so merely involves incorporating well-established components operating according to their known functions to yield predictable results, namely, improved transmission of out bounding signals.

187. In the Kim-Chen combination where each of Kim's antenna**s** 1215 has a respective transmitter, one of the transmitters would qualify as the claimed first receiver, and another one of the transmitters would qualify as the claimed second receiver, just like the descriptions of the '904 patent. For example, FIG. 4 of the '904 patent merely shows each antenna coupled to a transmitter (or transceiver), which, as demonstrated above, was general knowledge because the configuration was ubiquitous by the time of the purported invention. As I have explained above under Section VII, Applicant never relied on FIG. 4 during prosecution and the Notice of Allowance of neither the '904 patent nor the '271 patent ever mentioned FIG. 4 as reason for allowance.

[16.c]: a third receiver, receiving first information from the UE;

188. Kim discloses the function of receiving first information, as recited by Elements [16.c] and [6.c]. *Supra* §IX.B.6 (Element [6.c]). Kim's base station includes "reception (Rx) module 1211" that receives "signals, data and information" from the UE using antenna 1215. EX1004, [0174], FIG. 12. Kim thus describes a receiver (*e.g.*, Rx module 1221 along with antennas 1215 and other conventional components) receiving first information, such as the measurement report, from the UE, as discussed *supra* §IX.B.6 (Element [6.c]).

[16.d1]-[16.d10]

189. The Kim-Chen combination meets elements [6.d1]-[6.d10], which are substantively identical to elements [1.d10]-[1.d10]. *Supra* §§IX.A.1 (Elements [1.d1]-[1.d10]).

190. Accordingly, my opinion is that the Kim-Chen combination renders obvious claim 16.

11) Claims 17-20

191. Each and every element of claim 16 is obvious as I have explained above. Claims 17-19, which depend from claim 16, are substantively identical to claims 2-4 and 7-9. Claims 17-19 are likewise met by the Kim-Chen combination at least for the same reasons as I have explained above under Sections IX.B.2-4&7 (claims 2-4, 7-9). Claims 20, which depends from claim 18, is substantively identical

to claims 5, 10, and 15, and likewise is met by the Kim-Chen combination at least for the same reasons as I have explained above under Sections IX.B.5, 7, & 9 (claims 5, 10, 15).

X. CONCLUSION

192. For the reasons I explain above, all of the Challenged Claims of the ’904 patent are rendered obvious by the prior art at issue.

XI. ADDITIONAL REMARKS

193. 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 of me, I will appear for cross examination within the United States during the time as mutually agreed between the parties.

194. I currently hold the opinions expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations. Therefore, I reserve the right to revise, supplement, and/or amend my opinions stated herein based on new information that becomes available to me and on my continuing analysis of the materials already provided.

I hereby declare that all statements made are of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare that these statements were 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 the Title 18 of the United States Code and that such willful false statements may jeopardize the validity of this proceeding.

Executed on May 2, 2025 in Dallas, Texas.

Robert Akl

Dr. Robert Akl, D.Sc.

APPENDIX A

Professor Robert Akl, D.Sc.

Professional Summary

Dr. Akl has over three decades of industry and academic experience. He is currently a Tenured Professor at the University of North Texas and a Senior Member of *IEEE*. He has designed, implemented, and optimized both hardware and software aspects of several wireless communication systems for CDMA, Wi-Fi, and sensor networks. Dr. Akl has broad expertise in wireless communication, Bluetooth, CDMA/WCDMA network optimization, GSM, LTE, VoIP, telephony, computer architecture, and computer networks. He is a very active researcher and is well published and cited. He has been awarded many research grants by leading companies in the industry and the National Science Foundation. He has developed and taught over 100 courses in his field. Dr. Akl has received several awards and commendations for his work, including the 2008 *IEEE* Professionalism Award and was the winner of the 2010 Tech Titan of the Future Award.

Dr. Akl has extensive experience with patents in the wireless and networking industry. In the past ten years, he has worked as a technical expert in dozens of patent related matters, involving thousands of hours of research, investigation, and study. He has repeatedly been qualified as an expert by Courts, and has provided numerous technology tutorials to Courts, and given testimony by deposition and at trial. He has worked with companies large and small, both for and against the validity and infringement of patents, and has also helped counsel and Courts to understand technology that often seems complex. In doing so, he has become familiar with, and actively worked with, the legal principles that underlie patentability and validity and claim interpretation in the wireless and networking industries.

Areas of Expertise

2G, 3G, 4G, 5G, 6G, CDMA/WCDMA, GPS, GSM, UMTS, LTE, Ad-hoc Networks, Antenna Design, Bluetooth, Call Admission Control, Channel Coding, Channel Estimation, Communication Interfaces and Standards, Compression, Computer Architecture, Internet protocols, MIMO Systems, Multi-cell Network Optimization, Network Security, Packet-networks, Ring-networks, Switches and Routers, Telephony, VoIP, VPLS, Wi-Fi, Wireless Communication, Wireless Sensors.

Education

Year	College/University	Degree	GPA
2000	Washington University in Saint Louis	D.Sc. in Electrical Engineering	**4.0 / 4.0**
1996	Washington University in Saint Louis	M.Sc. in Electrical Engineering	**4.0 / 4.0**
1994	Washington University in Saint Louis	B.Sc. in Electrical Engineering	**4.0 / 4.0**
1994	Washington University in Saint Louis	B.Sc. in Computer Science	**4.0 / 4.0**

Graduated *summa cum laude* and ranked first in undergraduate class.

Dissertation: "Cell Design to Maximize Capacity in Cellular Code Division Multiple Access (CDMA) Networks." Advisors: Dr. Manju Hegde and Dr. Paul Min.

Litigation Support and Expert Witness Experience

L1. 2025 **Fish & Richardson, P.C.**
Case: Apple Inc. v. Apex Beam Technologies LLC
IPR2025-00896; IPR2025-00898; IPR2025-00909; IPR2025-00910; IPR2025-00911; IPR2025-00922; IPR2025-*To be Assigned*
Matter: *Inter Partes* Review, multi-antenna transmission
Project: Twelve declarations to support twelve IPR Petitions

L2. 2025 **Milbank LLP**
Case: Samsung Electronics Co, LTD., Samsung Electronics America, Inc v. Empire Technology Development LLC
IPR2024-00896
Matter: *Inter Partes* Review, MIMO wireless communication, energy consumption
Project: Declaration to support Patent Owner's response

L3. 2025 **Bayes PLLC**
Case: OnePlus Technology (Shenzhen) Co. Ltd. v. Pantech Corporation
IPR2025-00637; IPR2025-00783
Matter: *Inter Partes* Review, radio link failure
Project: Two declarations to support two IPR Petitions

L4. 2025 **Folio Law Group PLLP**
Case: K.Mizra LLC v. Ciena Corporation
Northern district of Georgia, Atlanta division, Case No. 1:24-cv-05442-SDG
Matter: Patent infringement, telecommunication systems, switches and routers
Project: Declaration in support of plaintiff's amended complaint

L5. 2025 **Carter Arnett**
Case: Katana Silicon Technologies, LLC v. GlobalFoundries, Inc, et al.
Western district of Texas, Austin division, Case No. 1:22-cv-00852-RP
Matter: Patent infringement, telecommunication systems
Project: Declaration

L6. 2025 **Bunsow De Mory LLP**
Case: Secure Wi-Fi, LLC v. Samsung Electronics Co, LTD., Samsung Electronics America, Inc.
Eastern district of Texas, Marshall division, Case No. 2:24-cv-00047-JRG-RSP
Matter: Patent infringement, Wi-Fi access and security

Project: Declaration regarding claim construction

L7. 2024 **Steptoe LLP**
Case: Corrigent Corporation and Nahum Communication NTB LTD v. Dell Technologies Inc. and Dell Inc.; Corrigent Corporation and Nahum Communication NTB LTD v. Arista Networks Inc.
District of Delaware, Case No. 1:22-cv-496-RGA; Case No. 1:22-cv-497-RGA
Matter: Patent infringement, telecommunication systems, switches and routers
Project: Source code review, two expert reports regarding infringement, two rebuttal expert reports regarding validity, two reply expert reports, two supplemental rebuttal expert reports, two depositions

L8. 2024 **Kilpatrick Townsend & Stockton LLP**
Case: Intellectual Ventures I LLC and Intellectual Ventures II LLC v. Lenovo Group Limited; Intellectual Ventures I LLC and Intellectual Ventures II LLC v. Zebra Technologies Corporation
Western district of Texas, Waco division, Case No. 6:23-cv-000307-ADA; Case No. 6:23-cv-00292-ADA
Matter: Patent infringement, cyclic diversity methods
Project: Source code review, expert report regarding invalidity

L9. 2024 **Perkins Coie LLP**
Case: ParkerVision, Inc. v. MediaTek Inc and MediaTek USA Inc.
Western district of Texas, Waco division, Case No. 6:22-cv-01163-ADA
Matter: Patent infringement, frequency translation
Project: Non-infringement consulting

L10. 2024 **Steptoe LLP**
Case: Stingray IP Solutions v. Leedarson IOT Technology, Inc. et al.
Eastern district of Texas, Marshall division, Case No. 2:23-cv-00499-JRG-RSP
Matter: Patent infringement, mobile ad-hoc networks
Project: Declaration regarding claim construction

L11. 2024 **Milbank LLP**
Case: Empire Technology Development LLC v. Samsung Electronics Co, LTD., Samsung Electronics America, Inc.
Eastern district of Texas, Marshall division, Case No. 2:23-cv-00427-JRG-RSP
Matter: Patent infringement, MIMO wireless communication, energy consumption
Project: Source code review, declaration regarding claim construction, expert report regarding infringement, expert report regarding validity, deposition

L12. 2024 **Folio Law Group PLLP**
Case: Valve Corporation v. Immersion Corporation
IPR2024-00477; IPR2024-00478; IPR2024-00557; IPR2024-00582; IPR2024-00714
Matter: *Inter Partes* Review, virtual reality and augmented reality
Project: Five declarations to support five Patent Owner's responses, deposition

L13. 2024 **Hicks Johnson PLLC**
Case: Cardtek International, Inc. v. The Kroger Co.
Eastern district of Texas, Marshall division, Case No. 2:23-cv-0045-JRG-RSP
Matter: Patent infringement, payment convergence system
Project: Expert report regarding infringement, rebuttal expert report regarding validity, deposition

L14. 2024 **Kilpatrick Townsend & Stockton LLP**
Case: PLR Worldwide Sales Limited v. Flip Phone Games Inc.
IPR2024-00132; IPR2024-00171; IPR2024-00200; IPR2024-00209; IPR2024-00133
Matter: *Inter Partes* Review, mobile gaming
Project: Four declarations to support four Patent Owner's responses, deposition

L15. 2024 **K & L Gates LLP**
Case: STA Group, LLC v. Motorola Solutions, Inc.
Eastern district of Texas, Marshall division, Case No. 2:23-cv-00300-JRG-RSP
Matter: Patent infringement, emergency communication networks
Project: Expert report regarding licenses, rebuttal expert report regarding validity, deposition

L16. 2024 **K & L Gates LLP**
Case: Motorola Solutions, Inc. v. STA Group, LLC
IPR2023-01292; IPR2023-01295 ; IPR2024-00511; IPR2024-00207
Matter: *Inter Partes* Review, emergency communication networks
Project: Four declarations to support four Patent Owner's responses

L17. 2024 **K & L Gates LLP**
Case: STA Group, LLC v. Motorola Solutions, Inc.
Eastern district of Texas, Marshall division, Case No. 2:22-cv-00381-JRG-RSP
Matter: Patent infringement, emergency communication networks
Project: Declaration regarding claim construction, deposition, expert report regarding infringement, rebuttal expert report regarding validity

L18. 2024 **White & Case, LLP**
Case: Wangs Alliance Corporation d/b/a WAC Lighting. v. Minka Lighting, LLC
In the Matter of Certain Smart Ceiling Fans, Components Thereof, and Associated Systems and Software Thereof, ITC Investigation No. 337-TA-1374
Matter: Patent infringement, smart ceiling fans
Project: Expert report regarding invalidity, expert rebuttal report, two-day depositions

L19. 2024 **Folio Law Group PLLP**
Case: Immersion Corporation v. Valve Corporation.
Western district of Washington, Seattle, Case No. 2:23-CV-00712-TL
Matter: Patent infringement, virtual reality and augmented reality
Project: Declaration regarding claim construction

L20. 2024 **Latham & Watkins LLP**
Case: AX Wireless LLC v. Dell Inc., et al.; AX Wireless LLC, v. HP Inc.
Eastern district of Texas, Marshall division, Case No. 2:22-cv-277-RWS-RSP; Case No. 2:22-cv-279-JRG-RSP
Matter: Patent infringement, Wi-Fi networks
Project: Source code review, expert report regarding infringement, rebuttal expert report regarding validity, deposition

L21. 2024 **Perkins Coie LLP**
Case: Wi-LAN Inc. et al. v. Huizhou TCL Mobile Communication Co. Ltd., et al.
Central district of California, Southern division, Case No. 8:19-cv-00870-JVS-ADS
Matter: Patent infringement, QoS enhancements for wireless IP networks
Project: Declaration regarding claim construction

L22. 2024 **Kilpatrick Townsend & Stockton LLP**
Case: Flip Phone Games Inc. v. PLR Worldwide Sales Limited
Eastern district of Texas, Marshall division, Case No. 2:23-cv-00139-JRG
Matter: Patent infringement, mobile gaming
Project: Declaration regarding claim construction, deposition

L23. 2024 **K & L Gates LLP**
Case: STA Group, LLC v. Motorola Solutions, Inc.
Eastern district of Texas, Marshall division, Case No. 2:22-cv-00381-JRG-RSP
Matter: Patent infringement, emergency communication networks
Project: Declaration regarding claim construction, deposition, expert report regarding infringement, rebuttal expert report regarding validity

L24. 2024 **Alston & Bird LLP**
Case: Stingray IP Solutions v. Snap One Holdings Corp., et al.
Eastern district of Texas, Marshall division, Case No. 2:23-cv-00003-JRG-RSP
Matter: Patent infringement, mobile ad-hoc networks
Project: Declaration regarding claim construction, deposition

L25. 2024 **Kilpatrick Townsend & Stockton LLP**
Case: Askeladden LLC v. Calabrese Stemer LLC
IPR2024-00367; IPR2024-00368; IPR2024-00369
Matter: *Inter Partes* Review, secure transactions and payments
Project: Declaration to support three IPR petitions

L26. 2023 **McGuireWoods LLP**
Case: VoIP-Pal.com, Inc. v. Huawei Technologies Co., Ltd., et al.
Northern district of Texas, Dallas division, Case No. 3:23-cv-0151-X
Matter: Patent infringement, call routing
Project: Declaration regarding 101 Motion

L27. 2023 **Steptoe LLP**
Case: Corrigent Corporation v. Cisco Systems, Inc.
Western district of Texas, Waco division, Case No. 6:22-cv-00396-ADA
Matter: Patent infringement, telecommunication systems, switches and routers
Project: Source code review, expert report regarding infringement, expert report regarding validity, two-day depositions, supplemental expert report, jury trial testimony

L28. 2023 **Latham & Watkins LLP**
Case: Netgear Inc. v. TP-Link Technologies Co., Ltd., TP-Link Corporation Limited, TP-Link USA Corporation, and TP-Link Research America Corp.
In the Matter of Certain Wi-Fi Routers, Wi-Fi Devices, Mesh Wi-Fi Network Devices, and Hardware and Software Components Thereof, ITC Investigation No. 337-TA-1361
Matter: Patent infringement, Wi-Fi and mesh networks
Project: Source code review, expert report regarding infringement and domestic industry, expert report regarding validity, supplemental expert report, deposition, ITC hearing testimony

L29. 2023 **Winston & Strawn LLP**
Case: Google, LLC. v. Flypsi, Inc.
IPR2023-00357; IPR2023-00358; IPR2023-00359; IPR2023-00360; IPR2023-00361
Matter: *Inter Partes* Review, primary and secondary call processing

Project: Five declarations to support five Patent Owner's responses, deposition

L30. 2023 **Carter Arnett**
Case: Correct Transmission, LLC v. Nokia Corporation, et al.
Eastern district of Texas, Marshall division, Case No. 2:22-cv-00343-JRG-RSP
Matter: Patent infringement, telecommunication systems, switches and routers
Project: Declaration regarding claim construction

L31. 2023 **Carter Arnett**
Case: Smart Path Connections, LLC v. Nokia Corporation, et al.
Eastern district of Texas, Marshall division, Case No. 2:22-cv-00296-JRG
Matter: Patent infringement, network communication systems, switches and routers
Project: Two declarations regarding claim construction

L32. 2023 **Devlin Law Firm**
Case: Google, LLC. v. Motion Offense, LLC
IPR2022-01311; IPR2022-01312; IPR2022-01313
Matter: *Inter Partes* Review, cloud storage and file requests
Project: Three declarations to support three Patent Owner's responses, deposition

L33. 2023 **Carter Arnett**
Case: Cisco Systems, Inc. v. Zilkr Cloud Technologies, LLC
IPR2023-00553; IPR2023-00663; IPR2023-00822
Matter: *Inter Partes* Review, integration of communication services
Project: Two declarations to support two Patent Owner's preliminary responses

L34. 2023 **Friedman, Suder & Cooke; Kane Russell Coleman Logan PC**
Case: Q Technologies, Inc. v. Walmart Inc.
Western district of Texas, Waco division, Case No. 4W-21-CV-00321-ADA
Matter: Patent infringement, content sharing and payment systems
Project: Validity expert report, deposition

L35. 2023 **K & L Gates LLP**
Case: Entropic Communications, LLC v. DirectTV, LLC, Dish Network Corporation et al.
Central district of California, Southern division, Case No. 2:22-cv-07775-JWH-JEM, 2:22-cv-07959
Matter: Patent infringement, satellite and cable receivers and systems
Project: Declaration regarding claim construction, deposition, tech tutorial testimony

L36. 2023 **Folio Law Group PLLP**

Case: Immersion Corporation v. Meta Platforms, Inc., f/k/a Facebook, Inc. Western district of Texas, Waco division, Case No. 6:22-cv-00541-ADA

Matter: Patent infringement, virtual reality and augmented reality

Project: Source code review, expert report regarding infringement, supplemental expert report regarding infringement, rebuttal expert report regarding validity, two depositions

L37. 2023 **Cole Schotz P.C.**

Case: SB IP Holdings, Inc. v. Vivint Smart Home, Inc., Vivint, Inc. Eastern district of Texas, Sherman division, Case No. 4:20-cv-00886-ALM

Matter: Patent infringement, wireless telecommunication systems

Project: Source code review, expert report regarding infringement, expert report regarding validity, two-day depositions, rebuttal expert report regarding non-infringing alternatives, 2 additional depositions, jury trial testimony

L38. 2023 **Cole Schotz P.C.**

Case: Vivint Inc. v. SB IP Holdings LLC
IPR2022-00812; IPR2022-01449

Matter: *Inter Partes* Review, wireless telecommunication systems

Project: Two declarations to support Patent Owner's responses, deposition

L39. 2023 **Carter Arnett**

Case: Samsung Electronics Co., LTD v. G+ Communications, LLC
IPR2022-01598; IPR2023-00171; IPR2023-00665

Matter: *Inter Partes* Review, 4G/5G cellular systems

Project: Three declarations to support three Patent Owner's preliminary responses, two declarations to support Patent Owner's responses, two depositions

L40. 2023 **Fish & Richardson, P.C.**

Case: Neo Wireless, LLC v. General Motors Co. et al.;
Neo Wireless, LLC v. Tesla Inc.
Eastern district of Michigan, Southern division, Case No. 2:22-cv-11407-TGB; Case No. 2:22-cv-11408-TGB

Matter: Patent infringement, 4G/LTE wireless communication

Project: Tech tutorial testimony, declaration regarding claim construction

L41. 2023 **Carter Arnett**
Case: G+ Communications v. Samsung Electronics Co., LTD et al.
Eastern district of Texas, Marshall division, Case No. 2:22-cv-00078-JRG
Matter: Patent infringement, 4G/5G cellular systems
Project: Source code review, declaration regarding claim construction, supplemental declaration regarding claim construction, infringement expert report, rebuttal expert report regarding validity, deposition, two supplemental reports, second deposition, jury trial testimony, jury retrial testimony (for damages)

L42. 2022 **Kilpatrick Townsend & Stockton LLP**
Case: TP-Link Technologies Co., Ltd. and TP-Link Corporation Limited v. Stingray IP Solutions
IPR2022- *To be Assigned*; IPR2022-*To be Assigned*
Matter: *Inter Partes* Review, security and intrusion detection in wireless systems
Project: Two declarations to support two IPR petitions

L43. 2022 **Devlin Law Firm**
Case: CDN Innovations, LLC v. Mediacom Communication Corporation
Middle district of Georgia, Columbus division
Matter: Patent infringement, telecommunication systems
Project: Declaration to support infringement contentions

L44. 2022 **Jenner & Block LLP**
Case: WSOU Investments, LLC v. Netgear, Inc.
District of Delaware, Case No. 21-cv-01117-MN-CJB, 21-cv-01119-MN-CJB, 21-cv-01120-MN-CJB
Matter: Patent infringement, adaptive antennas, routers
Project: Declaration regarding claim construction

L45. 2022 **Simpson Thacher & Bartlett LLP**
Case: XR Communications, LLC. v. Ubiquiti Networks, Inc.
Central district of California, Case No. 2:21-cv-1065-DOC(JDE)
Matter: Patent infringement, Wi-Fi and adaptive antennas
Project: Non-infringement expert report, deposition

L46. 2022 **Ropes & Gray LLP**
Case: Speir Technologies Ltd. v. Apple Inc.
Western district of Texas, Waco division, Case No. 6:22-cv-00077-ADA
Matter: Patent infringement, channel estimation
Project: Declaration regarding claim construction

L47. 2022 **Fish & Richardson, P.C.**
Case: Constellation Designs, LLC v. LG Electronics, Inc. et al.
Eastern district of Texas, Marshall division, Case No. 2:21-cv-448
Matter: Patent infringement, channel coding
Project: Source code review, invalidity expert report, non-infringement expert report, two-day depositions, jury trial testimony

L48. 2022 **Calfee, Halter & Griswold LLP**
Case: Resi Media LLC v. BoxCast Inc.
IPR2022-00066; IPR2022-00067
Matter: *Inter Partes* Review, autonomous broadcasting
Project: Combined declaration to support Patent Owner's response, declaration to support Patent Owner's sur-reply, deposition

L49. 2022 **Fish & Richardson, P.C.**
Case: FedEx Corporation v. Transcend Shipping Systems, LLC
IPR2022-01117; IPR2022-01219; IPR2022-01252;
IPR2022-01261; IPR2022-01314
Matter: *Inter Partes* Review, location management
Project: Five declarations to support five IPR petitions

L50. 2022 **Finnegan Henderson Farabow Garrett & Dunner LLP**
Case: Toyota Motor Corp and Continental Automotive Systems. v. Intellectual Ventures II, LLC
IPR2022-00971; IPR2022-00972; IPR2022-00973; IPR2022-00974;
IPR2022-01130
Matter: *Inter Partes* Review, multicarrier communication
Project: Five declarations to support five IPR petitions, four depositions, three supplemental declarations, two depositions

L51. 2022 **Fenwick & West LLP**
Case: TrackThings LLC v. Amazon.com, Inc. et al.
Western district of Texas, Waco division, Case No. 6:21-cv-00720
Matter: Patent infringement, mobile ad-hoc networks
Project: Invalidity consulting

L52. 2022 **Fenwick & West LLP**
Case: Stingray IP Solutions v. Amazon.com, Inc. et al.
Eastern district of Texas, Marshall division, Case No. 2:21-cv-00193-JRG; Case No. 2:21-cv-00194-JRG
Matter: Patent infringement, mobile ad-hoc networks
Project: Noninfringement consulting

L53. 2022 **Fitch, Even, Tabin & Flannery**
Case: L2 Mobile Technologies LLC v. Ford Motor Company
District of Delaware, Case No. 1:21-cv-01409-JLH
Matter: Patent infringement, wireless communication systems
Project: Standard essentiality consulting

L54. 2022 **Susman Godfrey LLP**
Case: California Institute of Technology v. Samsung Electronics Co., Ltd. et al.
Eastern district of Texas, Marshall division, Case No. 2:21-cv-00446-JRG
Matter: Patent infringement, low-density parity-check codes
Project: Source code review, infringement expert report, deposition, supplemental infringement expert report

L55. 2022 **Devlin Law Firm**
Case: Dropbox, Inc. v. Motion Offense, LLC; Motion Offense, LLC v. Dropbox, Inc.
Western district of Texas, Waco division, Case No. 6:20-cv-00251-ADA; 6:21-cv-00758-ADA
Matter: Patent infringement, telecommunication systems and networking
Project: Source code review, infringement expert report, supplemental infringement expert report, validity expert report, supplemental validity expert report, deposition, jury trial testimony

L56. 2022 **Bayes PLLC**
Case: Guangdong OPPO Mobile Telecommunications Corp., Ltd. v. Nokia Solutions and Networks Oy
IPR2022-00632
Matter: *Inter Partes* Review, PDU and SDU
Project: Declaration to support IPR petition, deposition, supplemental declaration, second deposition

L57. 2022 **Finnegan Henderson Farabow Garrett & Dunner LLP**
Case: NetApp, Inc. v. Proven Networks, LLC
IPR2022-00644
Matter: *Inter Partes* Review, allocating resources
Project: Declaration to support IPR petition

L58. 2022 **Devlin Law Firm**
Case: Motion Offense, LLC v. Google, LLC
Western district of Texas, Waco division, Case No. 6:21-cv-00514-ADA
Matter: Patent infringement, telecommunication systems and networking
Project: Declaration regarding claim construction

L59. 2022 **Jenner & Block LLP**
Case: Netgear, Inc. v. WSOU Investments, LLC
IPR2022-00516; IPR2022-00606
Matter: *Inter Partes* Review, telecommunication systems
Project: Two declarations to support two IPR petitions

L60. 2022 **Calfee, Halter & Griswold LLP**
Case: BoxCast Inc. v. Resi Media LLC
Eastern district of Texas, Marshall division, Case No. 2:21-cv-00217-JRG
Matter: Patent infringement, autonomous broadcasting
Project: Source code review, declaration regarding claim construction, declaration regarding validity, declaration regarding infringement, deposition

L61. 2022 **Fish & Richardson, P.C.**
Case: Apple Inc. v. Ericsson Inc.
IPR2022-00341; IPR2022-00346;
IPR2022-*To be assigned*; IPR2022-*To be assigned*;
IPR2022-*To be assigned*
Matter: *Inter Partes* Review, wireless communication systems
Project: Five declarations to support five IPR petitions, deposition

L62. 2022 **Ropes & Gray LLP**
Case: Godo Kaisha IP Bridge 1 v. Nokia Corporation, Ericsson Inc. et al.
Eastern district of Texas, Marshall division, Case No. 2:21-CV-213-JRG; Case No. 2:21-CV-215-JRG
Matter: Patent infringement, wireless communication systems
Project: Declaration regarding claim construction

L63. 2022 **Fish & Richardson, P.C.**
Case: Apple Inc. and HP Inc. v. XR Communication Inc
IPR2022-00367; IPR2022-01155; IPR2022-01362
Matter: *Inter Partes* Review, adaptive antennas
Project: Two declarations to support two IPR petitions, deposition, declaration to support petitioners' reply

L64. 2021 **Mayer Brown LLP**
Case: Pantech Corp. v. Coolpad Group Ltd.
Eastern district of Texas, Texarkana division, Case No. 5:21-cv00065
Matter: Patent infringement, LTE wireless communication systems
Project: Infringement consulting

L65. 2021 **Fitch, Even, Tabin & Flannery**
Case: L2 Mobile Technologies LLC v. Google LLC
Western district of Texas, Waco division, Case No. 6:21-cv-00358-ADA
Matter: Patent infringement, wireless communication systems
Project: Claim construction consulting

L66. 2021 **Morgan Lewis & Bockius LLP**
Case: Intellectual Tech LLC v. Zebra Technologies Corporation
Western district of Texas, Waco division, Case No. 6:19-cv-00628-ADA
Matter: Patent infringement, RFID tags
Project: Source code review, claim construction consulting, invalidity expert report

L67. 2021 **Carter Arnett**
Case: Correct Transmission LLC v. Adtran, Inc.
Northern district of Alabama, Northeastern division, Case No. 5:21-cv-00690-LCB
Matter: Patent infringement, telecommunication systems, switches and routers
Project: Declaration regarding claim construction

L68. 2021 **Carter Arnett**
Case: Juniper Networks, Inc. v. Correct Transmission, LLC
IPR2021-00463; IPR2021-00682; IPR2022-00815
Matter: *Inter Partes* Review, network communication systems, switches and routers
Project: Two declarations to support 2 Patent Owner's responses, two depositions; declaration to support Patent Owner's preliminary response

L69. 2021 **King & Wood Mallesons LLP**
Case: ToT Power Control, S.L. v. AT&T Mobility et al.; ToT Power Control, S.L. v. T-Mobile USA, Inc. et al.
Western district of Texas, Waco division, Case No. 6:21-CV-00107-ADA; 6:21-CV-00109-ADA
Matter: Patent infringement, WCDMA cellular systems
Project: Declaration regarding claim construction

L70. 2021 **Finnegan Henderson Farabow Garrett & Dunner LLP**
Case: Xiaomi Communications Co., Ltd. v. Koninklijke KPN N.V.
IPR2022-00025
Matter: *Inter Partes* Review, network communication systems
Project: Declaration to support IPR petition

L71. 2021 **Carter Arnett**
Case: Juniper Networks, Inc. v. Smart Path Connections, LLC
IPR2021-001170; IPR2021-01356; IPR2022-00240; IPR2022-00815
Matter: *Inter Partes* Review, network communication systems, switches and routers
Project: Declaration to support Patent Owner's preliminary response, three declarations to support three Patent Owner's responses, two depositions

L72. 2021 **Devlin Law Firm**
Case: Dyfan LLC v. Target Corporation
District of Delaware, Case No. 6:19-cv-00179-ADA
Matter: Patent infringement, network communications
Project: Declaration to support summary judgement, deposition

L73. 2021 **Alston & Bird LLP**
Case: Stingray IP Solutions v. Signify N.V., et al.
Eastern district of Texas, Marshall division, Case No. 2:21-cv-00043-JRG; Case No. 2:21-cv-00044-JRG
Matter: Patent infringement, mobile ad-hoc networks
Project: Declaration regarding claim construction

L74. 2021 **Cole Schotz P.C.**
Case: SkyBell Technologies, Inc. v. Vivint Smart Home, Inc., SimpliSafe, Inc., and Arlo Technologies Inc
In the Matter of Certain IP Camera Systems Including Video Doorbells and Components Thereof, ITC Investigation No. 337-TA-1242
Matter: Patent infringement, wireless telecommunication systems
Project: Source code review, expert report infringement and domestic industry, rebuttal expert report, three-day depositions

L75. 2021 **Axinn, Veltrop & Harkrider LLP**
Case: Koninklijke Philips N.V. v. Thales DIS AIS USA, LLC et al.
In the Matter of Certain UMTS and LTE Cellular Communication Modules and Products Containing the Same, ITC Investigation No. 337-TA-1240
Matter: Patent infringement, wireless communication systems
Project: Expert report regarding non-infringement and no domestic industry, deposition, ITC hearing testimony

L76. 2021 **Morgan Lewis & Bockius LLP**
Case: SIPCO, LLC v. Aruba Networks, LLC and Hewlett Packard Enterprise Company
District of Delaware, Case No. 1:20-cv-00537-MN
Matter: Patent infringement, wireless communication systems

Project: Declaration regarding claim construction

L77. 2021 **Ropes & Gray LLP**
Case: Palo Alto Networks Inc. v. Centripetal Networks, Inc.
IPR2021-01150, IPR2021-01151, IPR2021-01155, IPR2021-01156, IPR2021-01270, PGR2021-00108, IPR2021-01520, IPR2021-01521
Matter: *Inter Partes* Review, network security systems
Project: Seven declarations to support seven IPR petitions, declaration to support post grant review, deposition

L78. 2021 **Devlin Law Firm**
Case: CDN Innovations, LLC v. Grande Communications Networks, LLC
Eastern district of Texas, Sherman division, Case No. 4:20-cv-653-SDJ
Matter: Patent infringement, telecommunication systems
Project: Declaration to support infringement contentions

L79. 2021 **Banner Witcoff**
Case: Sisvel International S.A., 3G Licensing S.A. v. ZTE (USA) Inc. et al.
Northern district of Texas, Case No. 3:20-cv-01289-M
Matter: Patent infringement, wireless communication systems
Project: Declaration regarding claim construction, deposition

L80. 2021 **Paul Hastings LLP**
Case: G. Holdings Ltd. v. Samsung Electronics Co., et al.
Eastern district of Texas, Marshall division, Case No. 2:20-cv-00342-JRG
Matter: Patent infringement, electronic payment systems
Project: Declaration regarding claim construction

L81. 2021 **Morgan Lewis & Bockius LLP**
Case: Aruba Networks, LLC and Hewlett Packard Enterprise Company v. SIPCO, LLC
IPR2021-00787
Matter: *Inter Partes* Review, wireless communication systems
Project: Declaration to support IPR petition

L82. 2021 **Jenner & Block LLP**
Case: Virentem Ventures LLC D/B/A Enounce v. TiVo Corp and Xperi Holding Corporation
District of Delaware, Case No. 20-787-MN
Matter: Patent infringement, telecommunication systems
Project: Declaration regarding claim construction

L83. 2021 **Carter Arnett**
Case: Correct Transmission LLC v. Adtran, Inc. and Juniper Networks, Inc.
Western district of Texas, Waco division, Case No. 6:20-cv-669-ADA
Matter: Patent infringement, telecommunication systems
Project: Source code review, declaration regarding claim construction

L84. 2021 **Fish & Richardson, P.C.**
Case: Quectel Wireless Solutions Co. Ltd. v. Koninklijke Philips N.V.
IPR2021-00558, IPR2021-00559, IPR2021-00561
Matter: *Inter Partes* Review, wireless communication systems
Project: Three declarations to support three IPR petitions, declaration to support reply, two depositions

L85. 2021 **Goldberg Kohn Ltd**
Case: United States ex. rel. Todd Heath v. Wisconsin Bell, Inc
District of Columbia, Case No. 11-cv-01897
Matter: Networking systems
Project: Technology consulting

L86. 2021 **Fish & Richardson, P.C.**
Case: Samsung Electronics Co. Ltd. v. Ericsson Inc.
IPR2021-00447, IPR2021-00588, IPR2021-00613, IPR2021-00614, IPR2021-00643, IPR2021-00645, IPR2021-00684
Matter: *Inter Partes* Review, wireless communication systems
Project: Seven declarations to support seven IPR petitions

L87. 2020 **Kilpatrick Townsend & Stockton LLP**
Case: GREE Inc. v. Supercell Oy
Eastern district of Texas, Marshall division, Case No. 2:19-cv-00413-JRG-RSP
Matter: Patent infringement, mobile gaming
Project: Source code review, infringement expert report, supplemental expert report, validity expert report, deposition

L88. 2020 **Banner Witcoff**
Case: Sisvel International S.A., 3G Licensing S.A. v. ZTE (USA) Inc. et al.
Northern district of Texas, Case No. 3:19-cv-01694-N
Matter: Patent infringement, wireless communication systems
Project: Declaration regarding claim construction, deposition

L89. 2020 **Fish & Richardson, P.C.**
Case: Cellco Partnership D/B/A Verizon Wireless v. Huawei Technologies Co., Ltd
IPR2020-01352, IPR202-01356, IPR2020-01357
Matter: *Inter Partes* Review, network communication systems
Project: Three declarations to support 3 Patent Owner' responses

L90. 2020 **Kilpatrick Townsend & Stockton LLP**
Case: GREE Inc. v. Supercell Oy
Eastern district of Texas, Marshall division, Case No. 2:20-cv-00113-JRG-RSP
Matter: Patent infringement, mobile gaming
Project: Source code review, declaration supporting claim construction, infringement expert report, validity expert report, supplemental report, deposition

L91. 2020 **Kilpatrick Townsend & Stockton LLP**
Case: GREE Inc. v. Supercell Oy
Eastern district of Texas, Marshall division, Case No. 2:19-cv-00200-JRG-RSP, Case No. 2:19-cv-00237-JRG-RSP, Case No. 2:19-cv-00310-JRG-RSP; Case No. 2:19-cv-00311-JRG-RSP
Matter: Patent infringement, mobile gaming
Project: Source code review, four infringement expert reports, two supplemental infringement expert reports, four validity expert reports, two supplemental expert reports, two second supplemental expert reports, three-day depositions, jury trial testimony

L92. 2020 **Sheridan Ross P.C.**
Case: Justservice.net LLC v. Dropbox, Inc.
Western district of Texas, Waco division, Case No. 6:20-CV-00070-ADA
Matter: Patent infringement, computer systems and networking
Project: Source code review, declaration regarding claim construction

L93. 2020 **Perkins Coie LLP**
Case: Huizhou TCL Mobile Communication Co. Ltd., TCT Mobile (US) Inc., and TCL Mobile Communication (HK) Co., Ltd. v. Wi-LAN Inc.
Matter: *Ex Partes* Reexamination, QoS enhancements for wireless IP networks
Project: Declaration to support Requesters

L94. 2020 **Perkins Coie LLP**
Case: Intel Corporation v. UNM Rainforest Innovations
IPR2020-01576, IPR2020-01578, IPR2020-*to be assigned*
Matter: *Inter Partes* Review, wireless broadband
Project: Three declarations to support three IPR petitions

L95. 2020 **Calfee, Halter & Griswold LLP**
Case: Motorola Solutions, Inc. v. Hytera Communications Corp. Ltd. et al.
Northern district of Illinois, Case No. 1:17-cv-01972
Matter: Patent infringement, two-way radios

Project: Declaration regarding claim construction, deposition, expert report regarding invalidity, rebuttal expert report regarding non-infringement, three-day depositions

L96. 2020 **Fish & Richardson, P.C.**
Case: Huawei Technologies Co., Ltd et al. v. Verizon Communications, Inc. et al.
Western district of Texas, Waco division, Case No. 6-20-cv-00090
Matter: Patent infringement, video communication
Project: Source code review, declaration regarding claim construction, infringement expert report, validity expert report, deposition

L97. 2020 **Kilpatrick Townsend & Stockton LLP**
Case: GREE Inc. v. Supercell Oy
Eastern district of Texas, Marshall division, Case No. 2:19-cv-00070-JRG-RSP, Case No. 2:19-cv-00071-JRG-RSP
Matter: Patent infringement, mobile gaming
Project: Source code review, two infringement expert reports, two supplemental infringement expert reports, two second supplemental infringement expert reports, two rebuttal expert reports on validity, two-day depositions, seven declarations supporting Gree's opposition to Supercell's motions for summary judgement, jury trial testimony

L98. 2020 **Cooley LLP**
Case: Saint Lawrence Communications, LLC v. Amazon.com, Inc., et al.
Eastern district of Texas, Marshall division, Case No. 2:19-cv-00027-JRG
Matter: Patent infringement, AMR-WB, speech compression, coding and decoding
Project: Invalidity expert report

L99. 2020 **Prince Lobel Tye LLP**
Case: Intellectual Ventures I and II LLC v. VMware, Inc.
Western district of Texas, Austin division, Case No. 1:19-cv-01075-ADA
Matter: Patent infringement, networking systems
Project: Declaration regarding claim construction

L100. 2020 **Gibson, Dun & Crutcher LLP**
Case: Cellular Evolution LLC v. T-Mobile US, Inc. et al.
Eastern district of Texas, Marshall division, Case No. 2:19-cv-232-JRG
Matter: Patent infringement, cellular systems
Project: Invalidity consulting

L101. 2020 **Faegre Baker Daniels LLP**
Case: CommScope, Inc. v. Rosenberger Technology, et al.
District of New Jersey, Case No. 19-cv-15962-MCA-LDW
Matter: Trade secret software, base station antenna design
Project: Declaration, deposition

L102. 2020 **Ropes & Gray LLP**
Case: Canon, Inc. v. TCL Electronics Holdings Ltd., et al.
Eastern district of Texas, Marshall division, Case No. 2:18-cv-546-JRG
Matter: Patent infringement, communication interfaces
Project: Source code review, declaration regarding claim construction, deposition

L103. 2019 **Perkins Coie LLP**
Case: Huizhou TCL Mobile Communication Co. Ltd., TCT Mobile (US) Inc., and TCL Mobile Communication (HK) Co., Ltd. v. Wi-LAN Inc.
IPR2020-00302, IPR2020-00303
Matter: *Inter Partes* Review, QoS enhancements for wireless IP networks
Project: Two declarations to support two IPR petitions

L104. 2019 **Fish & Richardson**
Case: Bell Northern Research v. Huawei, et al.
Southern district of California, Case No. 3:18-cv-1784-CAB-BLM
Matter: Patent infringement, wireless networks
Project: Invalidity consulting

L105. 2019 **K & L Gates LLP**
Case: EVS CODEC Technologies, LLC and Saint Lawrence Communications, LLC v. ZTE Corporation, et al.
Northern district of Texas, Dallas division, Case No. 3:19-cv-00385-MBH
Matter: Patent infringement, EVS, speech compression, coding and decoding
Project: Invalidity expert report

L106. 2019 **Feinberg Day Alberti Lim & Belloli LLP**
Case: Uniloc 2017 LLC v. AT&T Mobility LLC, et al.
Eastern district of Texas, Marshall division, Case No. 2:18-cv-00514-JRG
Matter: Patent infringement, wireless frequency bands and devices
Project: Two declarations regarding claim construction, deposition

L107. 2019 **Susman Godfrey LLP**
Case: Sol IP, LLC v. AT&T Mobility LLC, et al.
Eastern district of Texas, Marshall division, Case No. 2:18-cv-00526; 2:18- cv-00527; and 2:18-cv-00528
Matter: Patent infringement, Wi-Fi and LTE
Project: Validity consulting

L108. 2019 **Ropes & Gray LLP**
Case: Huawei Technologies Co. Ltd. v. Harris Global Communications, Inc.
IPR2019-01512, IPR2019-01631
Matter: *Inter Partes* Review, routing and security in wireless networks
Project: Two declarations to support two IPR petitions

L109. 2019 **Ropes & Gray LLP**
Case: Harris Corporation v. Huawei Device USA, Inc. et al.
Eastern district of Texas, Marshall division, Case No. 2:18-cv-00439-JRG
Matter: Patent infringement, routing and security in wireless networks
Project: Declaration regarding claim construction

L110. 2019 **Erise IP**
Case: Semcon IP Inc. v. ASUSTeK Computer Inc.
Eastern district of Texas, Marshall division, Case No. 2:18-cv-00193-JRG
Matter: Patent infringement, adaptive power control
Project: Non-infringement expert report

L111. 2019 **Cooley LLP**
Case: Facebook Inc. v. BlackBerry Corp. et al.
Northern District of California, Oakland division, Case No. 4:18-cv-05434-JSW
Matter: Patent infringement, mobile computing
Project: Declaration regarding claim construction

L112. 2019 **Sidley Austin LLP**
Case: Semcon IP Inc. v. Amazon.com, Inc.
Eastern district of Texas, Marshall division, Case No. 2:18-cv-00192-JRG
Matter: Patent infringement, adaptive power control
Project: Expert report regarding patent marking, rebuttal report regarding patent marking, deposition

L113. 2019 **Oblon, McClelland, Maier & Neustadt, LLP**
Case: MV3 Partners LLC v. Roku, Inc.
Western district of Texas, Waco division, Case No. 6:18-cv-308-ADA
Matter: Patent infringement, mobile set top box

Project: Declaration regarding claim construction, deposition, Markman hearing and tech tutorial testimony

L114. 2019 **Banner & Witcoff, LTD.**
Case: Kathrein USA, Inc. v. Fractus S.A.
IPR2019-00954, IPR2019-00955, IPR2019-00956, IPR2019-00957
Matter: *Inter Partes* Review, multiband antenna arrays
Project: Four declarations to support four IPR petitions

L115. 2019 **Fish & Richardson, P.C.**
Case: LG Electronics Inc. v. Saint Lawrence Communications LLC
Southern district of New York, Case No. 1:18-cv-11082-DLC
Matter: Patent infringement, EVS, speech compression, coding and decoding
Project: Declaration relating to motion for summary judgment, expert report, deposition

L116. 2019 **Ropes & Gray LLP**
Case: SIPCO, LLC v. Emerson Electric Co.
In the Matter of Certain Wireless Mesh Networking Products and Related Components Thereof, ITC Investigation No. 337-TA-1131
Matter: Patent infringement, links in wireless networks and remote monitoring
Project: Source code review, declaration regarding claim construction, invalidity expert report, rebuttal expert report regarding non-infringement and no domestic industry

L117. 2019 **Fish & Richardson, P.C.**
Case: Maxell Ltd. v. Huawei Technologies Co. Ltd., ZTE, et al.
Eastern district of Texas, Texarkana division, Case No. 5:18-cv-0033-RWS
Matter: Patent infringement, portable computing devices
Project: Declaration regarding claim construction

L118. 2019 **Ropes & Gray LLP**
Case: Emerson Electric Co. v. SIPCO, LLC
IPR2019-00548, IPR2019-00549
Matter: *Inter Partes* Review, routing in wireless networks
Project: Two declarations to support two IPR petitions

L119. 2018 **Mishcon de Reya New York LLP; King & Wood Mallesons LLP**
Case: ChanBond, LLC v. Cox Communications, Inc.
District of Delaware, Case No. 1:15-cv-00849-RGA
Matter: Patent infringement, wideband signal distribution system
Project: Validity expert report, deposition, sur-reply expert report, second sur-reply expert report, second deposition, jury trial with settlement mid-trial

L120. 2018 **Fish & Richardson, P.C.**
Case: In re: Qualcomm Antitrust Litigation (Client: Apple)
Southern district of California, Case No. 3:17-cv-00108-GPC-MDD
Matter: Qualcomm antitrust litigation
Project: Two expert rebuttal reports, deposition

L121. 2018 **Susman Godfrey LLP**
Case: In re: Qualcomm Antitrust Litigation (Client: Class Action)
Northern district of California, Case No. 5:17-md-02773-LHK
Matter: Qualcomm antitrust litigation
Project: Expert declaration on standard essential patents, expert report on deemed essential patents, rebuttal expert report, deposition

L122. 2018 **284 Partners**
Case: Federal Trade Commission. v. Qualcomm Incorporated
Northern district of California, Case No. 5:17-cv-00220
Matter: Qualcomm antitrust litigation
Project: Expert report on standard essential patents, expert rebuttal report, deposition

L123. 2018 **Vorys, Sater, Seymour and Pease LLP**
Case: Route1 Inc. v. Airwatch LLC
District of Delaware, Case No. 17-331-RGA
Matter: Patent infringement, remote access
Project: Source code review, declaration regarding claim construction, infringement expert report, validity expert report, reply expert report, deposition, three declarations regarding re-exam

L124. 2018 **Sidley Austin LLP**
Case: Samsung Electronics Co., Ltd v. Huawei Technologies Co., Ltd.
IPR2017-01471, IPR2017-01474, IPR2017-01475
Matter: *Inter Partes* Review, 4G/LTE
Project: Three declarations to support three Patent Owner's responses, supplemental declaration, deposition

L125. 2018 **Fitzpatrick Cella Harper & Scinto**
Case: IPC Systems, Inc. v. Cloud9 Technologies, LLC
District of Delaware, Case No. 16-cv-443-GMS
Matter: Patent infringement, telephone stations and trading turrets
Project: Source code review, declaration regarding claim construction, supplemental declaration regarding claim construction

L126. 2018 **Haynes and Boone, LLP**
Case: LG Electronics Inc., et al. v. Wi-LAN Inc., et al.
IPR2018-00673, IPR2018-00674, IPR2018-00704, IPR2018-00705, IPR2018-00709, IPR2018-00710
Matter: *Inter Partes* Review, bandwidth allocation
Project: Six declarations to support six IPR petitions, two depositions, two reply declarations

L127. 2018 **Pillsbury Winthrop Shaw Pittman LLP**
Case: Cellular Communications Equipment v. ZTE, HTC Corporation, et al.
Eastern district of Texas, Case No. 6:16-cv-475-RWS
Matter: Patent infringement, LTE, power control, emergency notification
Project: Invalidity expert report, deposition

L128. 2018 **Finnegan Henderson Farabow Garrett & Dunner LLP**
Case: FanDuel, Inc. DraftKings, Inc., and Bwin.Party Digital Entertainment PLC. v. CG Technology Development, LLC
IPR2017-00902, IPR2017-01333, IPR2017-01491, IPR2017-01532
Matter: *Inter Partes* Review, location-based gaming
Project: Four declarations to support four Patent Owner's responses, two supplemental declarations, four depositions

L129. 2018 **Calfee, Halter & Griswold LLP**
Case: Hytera Communications Corp. Ltd. v. Motorola Solutions, Inc.
Northern district of Ohio, Case No. 1:17-cv-01794-DNC
Matter: Patent infringement, two-way radios
Project: Source code review, declaration regarding claim construction, rebuttal declaration regarding claim construction, deposition, infringement expert report, validity expert report, two-day depositions

L130. 2017 **Covington & Burling LLP**
Case: Sharp Corporation, et al. v. Hisense Co., Ltd., et al.
In the Matter of Certain Wi-Fi Enabled Electronic Devices and Components Thereof, ITC Investigation No. 337-TA-1072
Matter: Patent infringement, Wi-Fi, OFDMA
Project: Declaration regarding claim construction

L131. 2017 **Vorys, Sater, Seymour and Pease LLP**
Case: Airwatch LLC and VMWare Inc. v. Route1 Inc.
IPR2017-02145
Matter: *Inter Partes* Review, remote access
Project: Declaration to support Patent Owner's response

L132. 2017 **Arnold & Porter Kaye Scholer**
Case: Uniloc USA, Inc. v. Google, Inc.
Eastern district of Texas, Marshall division, Case No. 2:17-cv-0214-JRG, 2:17-cv-0224-JRG, 2:17-cv-0231-JRG, 2:17-cv-0465-JRG, 2:17-cv-0466-JRG, 2:17-cv-0467JRG
Matter: Patent infringement, VoIP messaging
Project: Invalidity consulting

L133. 2017 **Simpson Thacher & Bartlett LLP**
Case: XR Communications, LLC. v. Ubiquiti Networks, Inc.
Central district of California, Case No. 2:17-cv-02968-AG(JCGx)
Matter: Patent infringement, Wi-Fi and adaptive antennas
Project: Declaration regarding claim construction, deposition

L134. 2017 **Covington & Burling LLP**
Case: Huawei Device USA Inc. v. Hitachi Maxell, Ltd.
IPR2018-00209, IPR2018-00210
Matter: *Inter Partes* Review, base station selection, GPS/Cellular location
Project: Two declarations to support two IPR petitions

L135. 2017 **Calfee, Halter & Griswold LLP**
Case: Hytera Communications Corp. Ltd. v. Motorola Solutions, Inc.
IPR2018-00128, IPR2017-02183
Matter: *Inter Partes* Review, two-way radios
Project: Declaration to support IPR petition, deposition, two supplemental declarations, two depositions

L136. 2017 **Finnegan Henderson Farabow Garrett & Dunner LLP**
Case: Hytera Communications Corp. Ltd. v. Motorola Solutions, Inc.
IPR2017-02179, IPR2017-02183
Matter: *Inter Partes* Review, two-way radios
Project: Two declarations to support two IPR petitions, deposition

L137. 2017 **Mayer Brown LLP**
Case: Silver Spring Networks, Inc. v. Sunrise Technologies, Inc.
Silver Spring Networks, Inc. v. Weatherproof Wireless, LLC
IPR2017-*To Be Assigned*, IPR2017-*To Be Assigned*
Matter: *Inter Partes* Review, power meter
Project: Two declarations to support two IPR petitions

L138. 2017 **Covington & Burling LLP**
Case: Hitachi Maxell, Ltd. v. Huawei Device USA Inc. et al.
Eastern district of Texas, Texarkana division, Case No. 5:16-cv-00178-RWS
Matter: Patent infringement, 3G/4G

Project: Source code review, declaration regarding claim construction, invalidity expert report, non-infringement expert report, non-infringing alternatives expert report, two depositions

L139. 2017 **Finnegan Henderson Farabow Garrett & Dunner LLP**
Case: LG Electronics, Inc. et al. v. BLU Products, Inc. and CT Miami, LLC
In the Matter of Certain LTE Wireless Communication Devices and Components Thereof, ITC Investigation No. 337-TA-1051
Matter: Patent infringement, 4G/LTE
Project: Declaration regarding claim construction, second declaration regarding claim construction

L140. 2017 **Sidley Austin LLP**
Case: Huawei Technologies Co., Ltd. v. Samsung Electronics Co., Ltd.
IPR2017-01979, IPR2017-01980, IPR2017-01986
Matter: *Inter Partes* Review, 4G/LTE
Project: Three declarations to support three IPR petitions, deposition

L141. 2017 **Finnegan Henderson Farabow Garrett & Dunner LLP**
Case: Motorola Solutions, Inc. v. Hytera Communications Corp. Ltd. et al.
In the Matter of Certain Two-way Radio Equipment Systems, Related Software and Components Thereof, ITC Investigation No. 337-TA-1053
Matter: Patent infringement, two-way radio
Project: Source code review, declaration regarding claim construction, invalidity expert report, non-infringement expert report, deposition, ITC hearing testimony

L142. 2017 **Haynes and Boone, LLP**
Case: Rackspace US, Inc. v. Realtime Data LLC
IPR2017-01691
Matter: *Inter Partes* Review, data compression
Project: Declaration to support IPR petition

L143. 2017 **Pillsbury Winthrop Shaw Pittman LLP**
Case: ZTE (USA), HTC Corporation, et al. v. Cellular Communications Equipment
IPR2017-01508, IPR2017-01509
Matter: *Inter Partes* Review, LTE, power control, emergency notification
Project: Two declarations to support two IPR petitions, two depositions

L144. 2017 **Alston & Bird LLP; Womble Carlyle Sandridge & Rice LLP**
Case: Itron, Inc. and Duke Energy Corp. v. Smart Meter Technologies
IPR2017-01199
Matter: *Inter Partes* Review, power meter
Project: Declaration to support IPR petition, deposition

L145. 2017 **Haynes and Boone, LLP**
Case: Ericsson Inc. v. Regents of the University of Minnesota
IPR2017-01186, IPR2017-01200, IPR2017-01213
Matter: *Inter Partes* Review, OFDM and MIMO
Project: Three declarations to support three IPR petitions

L146. 2017 **Quinn Emanuel Urquhart & Sullivan, LLP**
Case: GENBAND US, LLC v. Metaswitch Networks Ltd, et al.
Eastern district of Texas, Marshall division, Case No. 2:16-cv-582-JRG-RSP
Matter: Patent infringement, Internet protocols and VoIP, switches and routers
Project: Expert report regarding essentiality

L147. 2017 **Mayer Brown LLP**
Case: Uniloc USA, Inc. et al. v. Avaya Inc., ShoreTel, Inc., et al.
Eastern district of Texas, Tyler division, Case Nos. 6:15-cv-1168-JRG
Matter: Patent infringement, instant messaging and conference calling
Project: Source code review, non-infringement consulting

L148. 2017 **Fish & Richardson P.C.**
Case: Nokia Solutions and Networks US LLC, et al. v. Huawei Technologies Co. Ltd., et al.
Eastern district of Texas, Marshall division, Case Nos. 2:16-cv-753-JRG-RSP, 2:16-cv-754
Matter: Patent infringement, 4G/LTE
Project: Claim construction, two declarations

L149. 2017 **Rothwell Figg Ernst & Manbeck, PC; Pepper Hamilton LLP**
Case: Samsung Electronics, et al. v. Rembrandt Wireless Technologies, LP
IPR2015-00555
Matter: *Ex Parte* Reexamination, Bluetooth
Project: Two declarations to support two Patent Owner's responses, supplemental declaration to support Patent Owner's reply

L150. 2016 **Sidley Austin LLP**
Case: Huawei Technologies Co., et al. v. Samsung Electronics Co, et al. and Samsung Research America v. Hisilicon Technologies Co, LTD
Northern district of California, San Francisco division, Case No. 3:16-cv-2787-WHO
Matter: Patent infringement, 3G/4G/LTE
Project: Source code review, declaration regarding claim construction, declaration opposing summary judgement, infringement expert report, invalidity expert report, non-infringement expert report, validity expert report, two depositions

L151. 2016 **Bragalone Conroy PC**
Case: Securus Technologies, Inc. v. Global Tel*Link Corporation
CBM2017-00034
Matter: Covered Business Method Review, call monitoring and recording
Project: Declaration to support CBM petition, deposition

L152. 2016 **Braxton, Hilton & Perrone PLLC**
Case: Biosonix, LLC. v. Hydrowave, LLC et al.
Eastern district of Texas, Case No. 2:16-cv-139-RC
Matter: Patent infringement, underwater transceivers
Project: Claim construction, Markman hearing and tech tutorial testimony

L153. 2016 **Gray Reed & McGraw**
Case: Optis Cellular Technology, LLC and PanOptis Patent Management, LLC. v. Blackberry Corporation, et al.
Eastern district of Texas, Marshall division, Case No. 2:16-cv-59-JRG-RSP, Case No. 2:16-cv-61-JRG-RSP, Case No. 2:16-cv-62-JRG-RSP
Matter: Patent infringement, LTE
Project: Claim construction, three declarations regarding claim construction, deposition

L154. 2016 **Ropes & Gray LLP; Davidson Berquist Jackson & Gowdey**
Case: SIPCO, LLC et al v. Emerson Electric Co. et al
Eastern district of Texas, Tyler division, Case No. 6:15-cv-907
Emerson Electric Co. et al v. SIPCO, LLC et al.
Northern district of Georgia, Atlanta division, Case No. 1:15-cv-00319-AT
Matter: Patent infringement, links in wireless networks and remote monitoring
Project: Source code review, invalidity consulting

L155. 2016 **McKool Smith**
Case: Regents of University of Minnesota v. AT&T Mobility LLC, et al.
District of Minnesota, Case No. 0:14-cv-04666-JRT-TNL
Matter: Patent infringement, LTE and MIMO
Project: Invalidity consulting

L156. 2016 **EIP US LLP**
Case: GENBAND US, LLC et al. v. Metaswitch Networks Ltd
IPR2015-01456, IPR2015-01457
Matter: *Inter Partes* Review, media gateways, switches and routers
Project: Two declarations to support Patent Owner’s responses, two depositions

L157. 2016 **Haynes and Boone, LLP**
Case: Cox Communications, Inc. v. AT&T Intellectual Property I, II, LP
IPR2015-01187, IPR2015-01227, IPR2015-01273, IPR2015-01536
Matter: *Inter Partes* Review, cable networks
Project: Four declarations to support Patent Owner's responses, four depositions

L158. 2016 **Mayer Brown LLP**
Case: Odyssey Wireless v. Motorola Mobility LLC
Eastern district of North Carolina, Western division, Case No. 5:14-cv-491-D
Southern district of California, Case No. 3:15-cv-01741-H-RBB
Matter: Patent infringement, LTE
Project: Source code review, non-infringement consulting

L159. 2016 **Cooley LLP; Finnegan LLP**
Case: Saint Lawrence Comm. LLC v. Motorola Mobility LLC, ZTE (USA) Inc., et al.
Eastern district of Texas, Marshall division, Case No. 2:15-cv-000351-JRG, Case No. 2:15-cv-000349-JRG
Matter: Patent infringement, speech compression, coding and decoding
Project: Invalidity expert report, expert report regarding AMR-WB standard, expert report regarding Opus and Silk, supplemental expert report regarding invalidity, two-day depositions, jury trial testimony for Motorola

L160. 2015 **Sidley Austin LLP**
Case: Evolved Wireless, LLC v. Microsoft Corp, et al.
District of Delaware, Case No. 15-cv-546
Matter: Patent infringement, LTE
Project: Prior art and invalidity consulting

L161. 2015 **McKool Smith**
Case: Optis Wireless Technology, LLC and PanOptis Patent Management, LLC. v. ZTE Corporation and ZTE (USA) Inc.
Eastern district of Texas, Marshall division, Case No. 2:15-cv-300-JRG-RSP
Matter: Patent infringement, cellular messages and multimedia attachments
Project: Source code review, claim construction, declaration

L162. 2015 **Fish & Richardson, P.C.**
Case: Saint Lawrence Comm. LLC v. LG Elec., Inc. et al.
Eastern district of Texas, Marshall division, Case No. 2:14-cv-1055-JRG
Matter: Patent infringement, speech compression, coding and decoding
Project: Invalidity expert report

L163. 2015 **Finnegan Henderson Farabow Garrett & Dunner LLP**
Case: LG Electronics, Inc. v. Cellular Communications Equipment LLC
IPR2016-00178
Matter: *Inter Partes* Review, LTE
Project: Declaration to support IPR petition

L164. 2015 **McKool Smith**
Case: AT&T, et al. v. Cox Communication, Inc., et al.
District of Delaware, Case No. 14-1106-GMS
Matter: Patent infringement, cable networks
Project: Claim construction, declaration

L165. 2015 **McKool Smith**
Case: Ericsson Inc., et al. v. TCL Communication, et al.
Eastern district of Texas, Marshall division, Case No. 2:15-cv-00011-RSP
Matter: Patent infringement, wireless devices and systems
Project: Source code review, claim construction, declaration, infringement expert report, validity expert report, two-day depositions

L166. 2015 **Foley & Lardner LLP**
Case: Kyocera Communications, Inc. v. Cellular Communications Equipment LLC
IPR2015-01559, IPR2015-01564
Matter: *Inter Partes* Review, LTE, power control, emergency notification
Project: Two declarations to support two IPR petitions

L167. 2015 **Fish & Richardson, P.C.**
Case: Fairfield Industries Inc. v. Wireless Seismic, Inc.
Southern district of Texas, Case No. 4:14-cv-02972-KPE
Matter: Patent infringement, wireless sensor networks
Project: Non-infringement expert report

L168. 2015 **Quinn Emanuel Urquhart & Sullivan, LLP**
Case: GENBAND US, LLC v. Metaswitch Networks Ltd, et al.
Eastern district of Texas, Marshall division, Case No. 2:14-cv-33-JRG-RSP
Matter: Patent infringement, Internet protocols and VoIP, switches and routers
Project: Expert report regarding essentiality, non-infringement expert report, rebuttal expert report regarding non-practice, supplemental rebuttal expert report, three-day depositions, jury trial testimony

L169. 2015 **Duane Morris LLP; Foley & Lardner LLP**
Case: Mobile Telecommunications Technologies, LLC v. Leap Wireless International, Cricket Communications, Inc.
Eastern district of Texas, Marshall division, Case No. 2:13-cv-00885-RSP
Matter: Patent infringement, OFDM and MIMO
Project: Non-infringement expert report, deposition

L170. 2015 **Hogan Lovells US LLP; Kenyon & Kenyon LLP**
Case: One-E-Way v. Beats Electronics, LLC, Sony Corporation, et al.
In the Matter of Certain Wireless Headsets, ITC Investigation No. 337-TA-943
Matter: Patent infringement, wireless communication
Project: Claim construction, declaration

L171. 2015 **McKool Smith**
Case: Solocron Media, LLC v. AT&T Inc., et al.
Eastern district of Texas, Marshall division, Case No. 2:13-cv-1059-JRG
Matter: Patent infringement, ringtone download
Project: Claim construction, invalidity expert report

L172. 2015 **EIP US LLP**
Case: Good Technology Software, Inc. v. Mobile Iron, Inc.
IPR2015-00833, IPR2015-00836, IPR2015-01090
Matter: *Inter Partes* Review, software management in wireless devices
Project: Three declarations to support three IPR petitions

L173. 2015 **McKool Smith**
Case: AirWatch LLC v. Good Technology Corp
Northern district of Georgia, Case No. 1:14-cv-02281-SCJ
Matter: Patent infringement, software management in wireless devices
Project: Claim construction, declaration

L174. 2015 **Simpson Thacher & Bartlett LLP**
Case: IXI Mobile (R&D) Ltd. et al. v. Apple Inc.
Southern district of New York, Case No. 14-cv-7594-RJS
Matter: Patent infringement, PDA and Bluetooth
Project: Invalidity consulting

L175. 2014 **Bragalone Conroy PC**
Case: Global Tel*Link Corporation v. Securus Technologies, Inc.
IPR2014-00785, IPR2014-00810, IPR2014-00824, IPR2014-00825, IPR2014-01278, IPR2014-01282, IPR2014-01283
Matter: *Inter Partes* Review, VoIP call monitoring and recording, allocating telecommunication resources and information systems

Project: Seven declarations to support seven Patent Owner's responses, five depositions

L176. 2014 **Orrick, Herrington & Sutcliffe LLP**
Case: Shopkick, Inc. v. Novitaz, Inc.
IPR2015-00277, IPR2015-00278
Matter: *Inter Partes* Review, wireless customer service management
Project: Two declarations to support two IPR petitions

L177. 2014 **Paul Hastings LLP**
Case: Cellular Communications Equipment LLC v. AT&T, et al.
Eastern district of Texas, Tyler division, Case No. 6:13-cv-507-LED (Lead Case for Consolidation)
Matter: Patent infringement, 3G cellular communication
Project: Claim construction, declaration

L178. 2014 **Baker Botts LLP**
Case: Orlando Communications LLC v. AT&T, et al.
M.D. Florida, Case No. 6:14-cv-01021
Matter: Patent infringement, 3G/4G cellular communication
Project: Non-infringement and claim construction consulting

L179. 2014 **EIP US LLP**
Case: Good Technology Software, Inc. v. AirWatch, LLC
IPR2015-00248, IPR2015-00875
Matter: *Inter Partes* Review, software management in wireless devices
Project: Two declarations to support two IPR petitions

L180. 2014 **Bragalone Conroy PC**
Case: Securus Technologies, Inc. v. Global Tel*Link Corporation
IPR2015-00153, IPR2015-00155, IPR2015-00156
Matter: *Inter Partes* Review, VoIP call monitoring and recording
Project: Three declarations to support three IPR petitions, two depositions

L181. 2014 **Andrews Kurth LLP**
Case: Sony Mobile Communications (USA) v. Adaptix Inc.
IPR2014-01524, IPR2014-01525
Matter: *Inter Partes* Review, subcarrier selection in LTE
Project: Two declarations to support two IPR petitions, deposition

L182. 2014 **Steptoe & Johnson LLP; Baker & McKenzie LLP**
Case: VTech Communications, Inc. and Uniden America Corporations v. Spherix Incorporated
IPR2014-01432
Matter: *Inter Partes* Review, IP telephony

Project: Declaration to support IPR petition, deposition, reply declaration, deposition

L183. 2014 **Steptoe & Johnson LLP; Baker & McKenzie LLP**
Case: Spherix Inc. v. VTech Telecommunications Ltd., et al.
Spherix Inc. v. Uniden Corp, et al.
Northern district of Texas, Dallas division, Case No. 3:13-cv-3494 and 3:13-cv-3496
Matter: Patent infringement, IP telephony
Project: Claim construction, declaration, deposition

L184. 2014 **McKool Smith**
Case: Good Technology Corp. v. MobileIron, Inc.
Northern district of California, Case No. 5:12-cv-05826-PSG
Matter: Patent infringement, software management in wireless devices
Project: Claim construction, three declarations, claim invalidity expert report, non-infringement expert report, deposition, jury trial testimony

L185. 2014 **Lee & Hayes**
Case: Broadcom Corp. v. Ericsson, Inc.
IPR2013-00601, IPR2013-00602, and IPR2013-00636
Matter: *Inter Partes* Review, ARQ protocols
Project: Three declarations to support Patent Owner's responses, two declarations to support Patent Owner's Motion to Amend, deposition, two reply declarations

L186. 2014 **Sidley Austin LLP**
Case: Adaptix, Inc. v. Huawei Technologies Co., et al.
Eastern district of Texas, Case No. 6:13-cv-00438, 439, 440 and 441
Matter: Patent infringement, subcarrier selection in LTE
Project: Source code review, non-infringement consulting

L187. 2014 **Finnegan Henderson Farabow Garrett & Dunner LLP**
Case: Cell and Network Selection LLC v. Huawei Technologies Co., et al.
Eastern district of Texas, Case No. 6:13-cv-00404-LED-JDL
Matter: Patent infringement, base station selection in LTE
Project: Non-infringement consulting

L188. 2014 **Feinberg Day Alberti & Thompson LLP**
Case: DSS Technology Management, Inc. v. Apple Inc.
Eastern district of Texas, Tyler division, Case No. 6:13-cv-00919-JDL
Matter: Patent infringement, PDA and Bluetooth
Project: Claim construction and invalidity consulting

L189. 2014 **Sheppard Mullin Richter & Hampton LLP**
Case: Digcom Inc. v. ZTE (USA), Inc.

District of Nevada, Case No. 3:13-cv-00178-RCJ-WGC
Matter: Patent infringement, cellular communication
Project: Claim construction consulting

L190. 2014 **Lott & Fischer**
Case: Zenith Electronics, LLC, et al. v. Craig Electronics, Inc.
Southern district of Florida, Case No. 9:13-cv-80567-DMM/DLB
Matter: Patent infringement, HDTV transmission and reception
Project: Opening expert report regarding nonessentiality

L191. 2013 **McKool Smith**
Case: Zenith Electronics, LLC, et al. v. Curtis International Ltd.
Southern district of Florida, Case No. 9:13-cv-80568-DMM/DLB
Matter: Patent infringement, HDTV transmission and reception
Project: Claim construction, declaration, deposition

L192. 2013 **Gibson Dunn**
Case: Straight Path IP Group v. Sharp Corp. and Sharp Electronics Corp.
In the Matter of Certain Point-to-Point Network Communication Devices and Products Containing Same, ITC Investigation No. 337-TA-892
Matter: Patent infringement, point-to-point network communication
Project: Non-infringement consulting

L193. 2013 **Kilpatrick Townsend & Stockton LLP; Cooley LLP**
Case: Monec Holding AG v. Motorola Mobility LLC, HTC, et al.
District of Delaware, Case No. 1:11-cv-798-LPS-SRF
Matter: Patent infringement, displaying books on tablets
Project: Non-infringement expert report for Motorola, non-infringement expert report for HTC, deposition

L194. 2013 **Gartman Law Group**
Case: Lone Star WiFi LLC v. Legacy Stonebriar Hotel, Ltd; et al.
Eastern district Of Texas, Tyler, Case No. 6:12-cv-957
Matter: Patent infringement, levels of access in Wi-Fi networks
Project: Claim validity consulting

L195. 2013 **White & Case, LLP**
Case: Nokia Corp and Nokia, Inc. v. HTC Corp and HTC America, Inc. and Google, Inc.
In the Matter of Certain Portable Electronic Communication Devices, Including Mobile Phones and Components Thereof, ITC Investigation No. 337-TA-885
Matter: Patent infringement, App download and installation
Project: Non-infringement consulting

L196. 2013 **Heim, Payne & Chorush, LLP**
Case: Rembrandt Wireless v. Samsung Electronics Co., et al.
Eastern district of Texas, Marshall, Case No. 2:13-cv-213-JRG-RSP
Matter: Patent infringement, Bluetooth
Project: Expert report regarding validity, deposition, jury trial testimony

L197. 2013 **Baker Hostetler; Davis Polk & Wardwell LLP**
Case: Comcast v. Sprint; and Nextel Inc.
Eastern district of Pennsylvania, Case No. 2:12-cv-00859-JD
Matter: Patent infringement, SMS/MMS in Cellular Networks
Project: Infringement expert report, validity expert report, reply expert report, declaration, two-day depositions, jury trial testimony

L198. 2013 **McKool Smith**
Case: Samsung Electronics America v. Ericsson Inc.
In the Matter of Certain Wireless Communications Equipment and Articles Therein, ITC Investigation No. 337-TA-866
Matter: Patent infringement, LTE uplink and downlink
Project: Source code review, prior art research, claim construction, claim invalidity expert report, non-infringement expert report, ITC hearing testimony

L199. 2012 **DLA Piper US LLP**
Case: CSR Technology Inc. v. Freescale Semiconductor, Inc.
USDC-San Francisco, Case No. 3:12-cv-02619-RS
Matter: Patent infringement, radio transceivers
Project: Claim construction, declaration

L200. 2012 **Fish & Richardson P.C.**
Case: GPNE Corp. v. Apple, Inc.; et al.
USDC-ND California, Case No. 5:12-cv-02885-LHK
Matter: Patent infringement, resource allocation in wireless networks
Project: Prior art research consulting

L201. 2012 **Polsinelli Shughart PC**
Case: Single Touch Interactive, Inc. v. Zoove Corporation
Northern district of California, Case No. 3:12-cv-00831-JSC
Matter: Patent infringement, abbreviated dialing, information delivery
Project: Claim construction, Markman hearing and tech tutorial testimony, two declarations

L202. 2012 **K & L Gates**
Case: EON Corp. IP Holdings, LLC v. Novatel Wireless, Inc.; et al.
DC-Tyler, Texas, Case No. 6:11-cv-00015-LED-JDL
Matter: Patent infringement, wireless modem and 3G services
Project: Non-infringement expert report, deposition

L203. 2012 **Simpson Thacher & Bartlett LLP**
Case: CSR Technology, Inc. v. Bandspeed, Inc.
Western district of Texas, Case No. 1:12-cv-297-LY
Matter: Patent infringement, packet identification in 2.4 GHz and 5 GHz
Project: Source code review, Markman hearing and tech tutorial testimony, infringement expert report

L204. 2012 **Sheppard Mullin Richter & Hampton LLP**
Case: Wi-LAN v. HTC America, Inc., et al.
Eastern district of Texas, Case No. 6:10-cv-521-LED
Matter: Patent infringement, CDMA, Orthogonal Codes
Project: Source code review, non-infringement expert report, deposition, jury trial testimony

L205. 2012 **Dechert LLP**
Case: Hitachi v. TPV and Vizio, Inc.; and Vizio v. Hitachi, LTD.
Eastern district of Texas, Case No. 2:10-cv-260
Matter: Patent infringement, HD television transmission and reception
Project: Prior art research, claim invalidity consulting

L206. 2012 **Fish & Richardson P.C.; Covington & Burling; Alston & Bird; Brinks Hofer Gilson & Lione**
Case: InterDigital Commc'n, LLC v. Huawei Tech. Co. LTD; LG Electronics, Inc.; Nokia, Inc.; and ZTE (USA) Inc.
Certain Wireless Devices With 3G Capabilities and Components Thereof, ITC Investigation No. 337-TA-800
Matter: Patent infringement, channel coding in UMTS, HSDPA
Project: Non-infringement consulting

L207. 2012 **Fish & Richardson P.C.; Covington & Burling; Alston & Bird; Brinks Hofer Gilson & Lione**
Case: InterDigital Commc'n, LLC v. Huawei Tech. Co. LTD; LG Electronics, Inc.; Nokia, Inc.; and ZTE (USA) Inc.
District of Delaware, Case No. 1:11-cv-00654-UNA
Matter: Patent infringement, channel coding in UMTS, HSDPA
Project: Non-infringement consulting

L208. 2011 **O'Melveny & Myers LLP**
Case: MobileMedia Ideas, LLC v. Apple, Inc.
District of Delaware, Case No. 1:10-cv-00258-SLR-MPT
Matter: Patent infringement, voice control, call rejection in mobile phones
Project: Source code review, prior art research, declaration, claim invalidity expert report, non-infringement expert report, deposition, jury trial testimony

L209. 2011 **Wilmer Cutler Pickering Hale and Dorr**
Case: Apple, Inc. v. Samsung Electronics Co.
Northern district of California, Case No. 5:11-cv-01846-LHK
Matter: Patent infringement, channel coding in CDMA, E-AGCH, TFCI
Project: Prior art research, claim construction consulting

L210. 2011 **Weil, Gotshal & Manges LLP**
Case: Vizio, Inc. v. Renesas Electronics America, Inc.
ITC Investigation No. 337-TA-789
Matter: Patent infringement, HD television transmission and reception
Project: Claim invalidity consulting

L211. 2011 **Shapiro Cohen**
Case: TenXc Wireless Inc. v. Andrew LLC
TenXc Wireless Inc. v. Mobi Antenna Technologies Ltd.
Matter: Patent infringement, antenna design, sectorized cellular network
Project: Claim validity consulting

L212. 2010 **Fish & Richardson P.C.**
Case: Vizio, Inc., v. LG Electronics, Inc.
ITC Investigation No. 337-TA-733
Matter: Patent infringement, HD television transmission and reception
Project: Claim charts, claim construction expert report, deposition

L213. 2010 **Fish & Richardson P.C.**
Case: Vizio, Inc., v. LG Electronics, Inc.
District of Maryland, Case No. 1:09-cv-1481-BEL
Matter: Patent infringement, HD television transmission and reception
Project: Claim charts, claim construction expert report, deposition

L214. 2008 **Kaye Scholer LLP**
Case: eBay Inc. v. IDT.
Western district of Arkansas, Case No. 4:08-cv-4015-HFB
Matter: Patent infringement, long distance communication using Internet
Project: Prior art research, claim construction consulting

L215. 2008 **Simpson Thacher & Bartlett LLP**
Case: Commil USA, LLC v. Cisco Systems, Inc.
Eastern district of Texas, Case No. 2:07-cv-00341-DF-CE
Matter: Patent infringement, two-level wireless protocol
Project: Prior art research

L216. 2006 **Woodfill and Pressler**
Case: Charles Russell v. Interinsurance Exchange of the Auto Club
Harris County, Texas, Case No. 2005-19706
Matter: House fire and insurance claim

Project: Determining user location using cellular phone records, expert report, deposition, jury trial testimony

Consulting History

From: 11/2022 **Abe, Ikubo & Katayama (Client: ASUS Japan K.K.)**
To: 12/2022 Japan
Duties: Analyze 3GPP standards contribution.

From: 8/2022 **JLP Enterprise Holdings LLC**
To: 8/2022 Dallas, TX
Duties: Analyze patents for essentiality to 5G standards.

From: 5/2022 **Washington Utilities and Transportation Commission DOCKET UT-181051**
To: 12/2022 Olympia, WA
Duties: Analyze cause(s) of network failure, provide testimony on behalf of Staff, deposition, hearing testimony

From: 8/2021 **Carter Arnett (Client: G+ Communications)**
To: 5/2022 Dallas, TX
Duties: Analyze patents for essentiality to 4G and 5G standards.

From: 2/2021 **ExpertsDirect Pty Ltd**
To: 3/2021 Australia
Duties: Analyze antenna arrays.

From: 11/2020 **Licks Attorneys**
To: 1/2021 Brazil
Duties: Analyze patents for essentiality to 4G standards.

From: 6/2019 **Fish & Richardson, P.C. (Client: Huawei)**
To: 5/2022 Dallas, TX
Duties: Analyze patents for essentiality to 3G, 4G, and 5G standards.

From: 1/2013 **Heim, Payne & Chorush, LLP**
To: 3/2013 Houston, TX
Duties: Analyze patents on wireless technologies.

From: 4/2007 **Collin County Sheriff's Office**
To: 5/2007 McKinney, TX
Duties: Analyzed cellular record data and determined user location in a double-homicide investigation.

From: 4/2004 **Allegiant Integrated Solutions**
To: 5/2004 Fort Worth, TX

	Duties:	Designed and developed an integrated set of tools for fast deployment of wireless networks. The tools optimize the placement of Access Points and determine their respective channel allocations to minimize interference and maximize capacity.
From:	3/2002	**Input/Output Incorporated**
To:	4/2002	New Orleans, LA
	Duties:	Designed and implemented an algorithm in MATLAB for optimizing the frequency selection process used by sonar for scanning the bottom of the ocean.
From:	6/1998	**Teleware Corporation**
To:	7/1998	Seoul, South Korea
	Duties:	Designed and developed a software package for analyzing the capacity in a CDMA network to maximize the number of subscribers.

Employment History

From:	5/2023	**University of North Texas**
To:	Present	Denton, TX
	Position:	*Tenured Professor Department of Computer Science and Engineering* Conducting research on MIMO and 5G cellular networks. Teaching telecommunication courses. Advising graduate and undergraduate students.
From:	1/2015	**University of North Texas**
To:	8/2021	Denton, TX
	Position:	*Associate Chair of Graduate Studies Department of Computer Science and Engineering* In charge of all administrative duties related to the Master's and Ph.D. programs in the department.
From:	5/2008	**University of North Texas**
To:	5/2023	Denton, TX
	Position:	*Tenured Associate Professor Department of Computer Science and Engineering* Conducting research on cellular networks and wireless sensor networks. Teaching wireless communication courses. Advising graduate and undergraduate students.
From:	9/2002	**University of North Texas**
To:	5/2008	Denton, TX
	Position:	*Assistant Professor Department of Computer Science and Engineering* Conducting research on WCDMA/UMTS wireless networks. Teaching wireless communication and computer architecture courses. Advising graduate and undergraduate students.

From: 1/2002 **University of New Orleans**
To: 8/2002 New Orleans, LA
Position: *Assistant Professor Department of Electrical Engineering*
Designed and taught two new courses "Computer Systems Design I and II". Developed a Computer Engineering Curriculum with strong hardware-design emphasis. Formed a wireless research group. Advised graduate and undergraduate students.

From: 10/2000 **Comspace Corporation**
To: 12/2001 Coppell, TX
Position: *Senior Systems Engineer*
Designed, coded (in MATLAB), and simulated Viterbi decoding, Turbo coding, trellis coded modulation (TCM), and Reed-Muller codes. Optimized soft decision parameters and interleavers for additive white Gaussian and Rayleigh faded channels. Extended the control and trunking of push-to-talk Logic Trunked Radio (LTR) to include one-to-one and one-to-many voice and data messaging.

From: 8/1997 **MinMax Corporation**
To: 5/1999 Saint Louis, MO
Position: *Research Associate*
Designed software packages that provide the tools to flexibly allocate capacity in a CDMA network and maximize the number of subscribers. Analyzed and simulated different audio compression schemes. Validated, simulated (logical and timing), and developed the hardware architecture for an ATM switch capable of channel group switching.

From: 8/1994 **Washington University**
To: 8/2000 Saint Louis, MO
Position: *Research and Teaching Assistant*
Taught, consulted, and graded Circuit Analysis at the undergraduate level and Network Design at the graduate level.

Publications

Conference Proceedings

C1. R. Chataut, **R. Akl**, "An Adaptive User Scheduling Algorithm for 6G Massive MIMO Systems," *26th IEEE International Conference on Advanced Communications Technology (IEEE ICACT 2024)*, February 2024, pp. 1475-1482.

C2. R. Chataut, **R. Akl**, U.K. Dey, "An Adaptive User Scheduling Algorithm for 6G Massive MIMO Systems," *25th IEEE International Conference on Advanced Communications Technology (IEEE ICACT 2023)*, February 2023, pp. 158-163.

C3. U.K. Dey, **R. Akl**, R. Chataut, "Performance Improvement in Cellular V2X (CV2X) by Using Massive MIMO Jacobi Detector," *2022 IEEE 19th International Conference on Smart Communities: Improving Quality of Life Using ICT, IoT and AI (HONET)*, December 2022, pp. 122-127.

C4. U.K. Dey, **R. Akl**, R. Chataut, "Performance Improvement in Cellular V2X (CV2X) by Using Low Density Parity Check (LDPC) Code," *2022 IEEE 13th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*, October 2022, pp. 296-302.

C5. M. Robaei, **R. Akl**, "Distributed Compressed Sensing Karhunen-Loéve Expansion - Application to Millimeter-Wave Resource Allocation Through Group Beamforming," *2022 IEEE International Workshop Technical Committee on Communications Quality and Reliability (CQR)*, September 2022, pp. 7-12.

C6. R. Chataut, **R. Akl**, U.K. Dey, "Massive MIMO Uplink Signal Detector for 5G and Beyond Networks," *2022 IEEE Texas Symposium on Wireless and Microwave Circuits and Systems (WMCS)*, April 2022, 7 pgs.

C7. M. Robaei, **R. Akl**, R. Chataut, U.K. Dey, "Adaptive Millimeter-Wave Channel Estimation and Tracking," *2022 24th International Conference on Advanced Communication Technology (ICACT)*, February 2022, pp. 23-28.

C8. U.K. Dey, **R. Akl**, R. Chataut, "Throughput Improvement in Vehicular Communication by Using Low Density Parity Check (LDPC) Code," *IEEE CCWC 2022 The 12th Annual Computing and Communication Workshop and Conference*, January 2022, pp. 836-843.

C9. U.K. Dey, **R. Akl**, R. Chataut, M. Robaei, "Selective MIMO in Vehicular Communication for Reliable Safety Services and High Speed Non-Safety Services," *2021 IEEE 12th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*, 2021, pp. 785-790, 6 pgs.

C10. R. Chataut, **R. Akl**, U.K. Dey, "An Efficient and Fast-convergent Detector for 5G and Beyond Massive MIMO Systems," *2021 IEEE 12th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)*, 2021, pp. 866-872, 7 pgs.

C11. M. Robaei, **R. Akl**, "Millimeter-Wave Blockage Modeling And Mitigation," *2021 IEEE International Workshop Technical Committee on Communications Quality and Reliability (CQR 2021)*, 2021, 6 pgs.

C12. M. Robaei, **R. Akl**, "Characterizing Non-Stationary Millimeter-Wave Communication Using Fuzzy Entropy," *2021 55th Annual Conference on Information Sciences and Systems (CISS)*, 2021, 6 pgs.

C13. M. Robaei, **R. Akl**, R. Chataut, U.K. Dey, "Adaptive Millimeter-Wave Channel Estimation and Tracking," *2021 23rd International Conference on Advanced Communication Technology (ICACT)*, February 2021, pp. 23-28, 6 pgs.

C14. U.K. Dey, **R. Akl**, R. Chataut, M. Robaei, "Modified PHY Layer for High Performance V2X Communication using 5G NR," *IEEE UEMCON 11th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference*, October 2020, pp. 137-142, 6 pgs.

C15. R. Chataut, **R. Akl**, "An Efficient and Fair Scheduling for Downlink 5G Massive MIMO Systems," *IEEE Texas Symposium on Wireless and Microwave Circuits and Systems*, June 2020, paper no.TSWMCS2020-39, 8 pgs.

C16. R. Chataut, **R. Akl**, "Efficient and Low-Complexity Iterative Detectors for 5G Massive MIMO Systems," *IEEE DCOSS 2020 International Conference on Distributed Computing in Sensor Systems*, May 2020, pp. 442-449, 8 pgs.

C17. U.K. Dey, **R. Akl**, R. Chataut, "High Throughput Vehicular Communication Using Spatial Multiplexing MIMO," *IEEE CCWC 2020 The 10th Annual Computing and Communication Workshop and Conference*, January 2020, paper no. 1570613408, 6 pgs.

C18. R. Chataut, **R. Akl**, M. Robaei, "Accelerated and Preconditioned Refinement of Gauss-Seidel Method for Uplink Signal Detection in 5G Massive MIMO Systems," *IEEE CCWC 2020 The 10th Annual Computing and Communication Workshop and Conference*, January 2020, paper no. 1570605343, 7 pgs.

C19. M. Robaei, **R. Akl**, "Examining Spatial Consistency for Millimeter-Wave Massive MIMO Channel Estimation in 5G-NR," *IEEE ICCE 2020 The 38th International Conference on Consumer Electronics*, January 2020, paper no. 1570596880, 6 pages.

C20. R. Chataut, **R. Akl**, "Channel Gain Based User Scheduling for 5G Massive MIMO Systems," *IEEE HONET-ICT 2019 The 16th International Conference on Smart Cities: Improving Quality of Life Using ICT & IoT and AI*, October 2019, paper no. 1570565594, 5 pgs.

C21. M. Robaei, **R. Akl**, "Time-Variant Broadband mmWave Channel Estimation Based on Compressed Sensing," *IEEE UEMCON 2019 The 10th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference*, October 2019, paper no. 1570577430, 7 pages.

C22. R. Chataut, **R. Akl**, U. Dey, "Least Square Regressor Selection Based Detection for Uplink 5G Massive MIMO Systems," *IEEE WAMICON 2019 The 20th Annual IEEE Wireless and Microwave Technology Conference*, April 2019, paper no. 1570524727, 6 pgs.

C23. R. Chataut, **R. Akl**, "Huber Fitting Based ADMM Detection for Uplink 5G Massive MIMO Systems," *IEEE UEMCON 2018 The 9th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference*, November 2018, paper no. 1570492416, 5 pgs.

C24. R. Chataut, **R. Akl**, "Efficient and Low Complex Uplink Detection for 5G Massive MIMO Systems," *IEEE WAMICON 2018 The 19th Annual Wireless and Microwave Technology Conference*, April 2018, paper no. 1570431593, 6 pgs.

C25. R. Chataut, **R. Akl**, "Optimal Pilot Reuse Factor Based on User Environments in 5G Massive MIMO," *IEEE CCWC 2018 The 8th Annual Computing and Communication Workshop Conference*, January 2018, paper no. 1570413394, 6 pgs.

C26. S. Alotaibi, **R. Akl**, "Radio Resource Management in LTE Femtocell Networks," *IEEE NCA '17 International Symposium on Network Computing and Applications*, November 2017, paper no. 117, 5 pgs.

C27. U. Sawant, **R. Akl**, "Subcarrier Allocation in LTE Network Deployment with Mobility," *IEEE UEMCON 2017 8th Annual Ubiquitous Computing, Electronics and Mobile Communication Conference*, October 2017, paper no. 1570349184, 8 pgs.

C28. S. Alotaibi, **R. Akl**, "Packet Scheduling Bandwidth Type-Based Mechanism for LTE," *IEEE UEMCON 2017 8th Annual Ubiquitous Computing, Electronics and Mobile Communication Conference*, October 2017, paper no. 1570394639, 6 pgs.

C29. S. Alotaibi, **R. Akl**, "Dynamic Fractional Frequency Reuse (FFR) Scheme for Two-Tier Network in LTE," *IEEE UEMCON 2017 8th Annual Ubiquitous Computing, Electronics and Mobile Communication Conference*, October 2017, paper no. 1570394969, 6 pgs.

C30. U. Sawant, **R. Akl**, "Evaluation of Adaptive and Non Adaptive LTE Fractional Frequency Reuse Mechanisms," *IEEE WOCC 2017 The 26th Annual Wireless and Optical Communications Conference*, April 2017, paper no. 1570341174, 6 pgs.

C31. S. Alotaibi, **R. Akl**, "Range-Based Scheme for Adjusting Transmission Power for Femtocells in Co-Channel Deployment," *IEEE WTS 2017 The 16th Annual Wireless Telecommunications Symposium*, April 2017, paper no. 1570334744, 5 pgs.

C32. U. Sawant, **R. Akl**, "A Novel Metric to Study the Performance of Sectorized Fractional Frequency Reuse Techniques in LTE," *IEEE WTS 2017 The 16th Annual Wireless Telecommunications Symposium*, April 2017, paper no. 1570338498, 7 pgs.

C33. S. Alotaibi, **R. Akl**, "Dynamic Frequency Partitioning Scheme for LTE HetNet Networks Using Fractional Frequency Reuse," *IEEE WCNC '17 Wireless Communications and Networking Conference*, March 2017, paper no. 1570332420, 5 pgs., demo and poster.

C34. U. Sawant, **R. Akl**, "Performance Evaluation of Network Productivity for LTE Heterogenous Networks with Reward-Penalty Weights Assessment," *IEEE CCWC 2017 The 7th Annual Computing and Communication Workshop Conference*, January 2017, paper no. 1570328396, 6 pgs.

C35. S. Alotaibi, **R. Akl**, "Self-Adjustment Downlink Transmission Power for Femtocells in Co-Channel Deployment in Heterogeneous Networks," *IEEE CCWC 2017 The 7th Annual Computing and Communication Workshop Conference*, January 2017, paper no. 1570326815, 6 pgs.

C36. U. Sawant, **R. Akl**, "Performance Evaluation of Sectorized Fractional Frequency Reuse Techniques Using Novel Metric," *IEEE ISCC 2016 The Twenty-First IEEE Symposium on Computers and Communications*, June 2016, paper no. 1570275270, 7 pgs.

C37. R. Tidwell, S. Akumalla, S. Karlaputi, **R. Akl**, K. Kavi, and D. Struble, "Evaluating the Feasibility of EMG and Bend Sensors for Classifying Hand Gestures," *1st International Conference on Multimedia and Human Computer Interaction*, July 2013, paper no. 63, 8 pgs.

C38. **R. Akl**, K. Pasupathy, and M. Haidar, "Anchor Nodes Placement for Effective Passive Localization," *2011 IEEE International Conference on Selected Topics in Mobile and Wireless Networks (iCOST)*, October 2011, paper no. 1569490799, pp. 127 - 132.

C39. **R. Akl**, P. Kadiyala, and M. Haidar, "Non-Uniform Grid-Based Routing in Sensor Networks," *9th IEEE Malaysia International Conference on Communications*, December 2009, paper no. 1569243649, pp. 536 - 540.

C40. M. Haidar, M. Al-Rizzo, Y. Chan, **R. Akl**, M. Bouharras, "Throughput Validation of an Advanced Channel Assignment Algorithm in IEEE 802.11 WLAN," *ICCSN 2009 – International Conference on Communication Software and Networks*, February 2009, paper no. P385, pp. 801 - 806.

C41. **R. Akl** and D. Keathly, "Robocamp: Encouraging Young Women to Embrace STEM," 4th Annual TETC Best Practices Conference, February 2009, 13 pgs.

C42. M. Haidar, R. Ghimire, M. Al-Rizzo, **R. Akl**, Y. Chan, "Channel Assignment in an IEEE 802.11 WLAN Based on Signal-to-interference Ratio," *IEEE CCECE –*

Canadian Conference on Electrical and Computer Engineering: Communications and Networking, May 2008, paper no. 1569092894, pp. 1169 - 1174.

C43. H. Al-Rizzo, M. Haidar, **R. Akl**, and Y. Chan, "Enhanced Channel Assignment and Load Distribution in IEEE 802.11 WLANs," *IEEE International Conference on Signal Processing and Communication*, November 2007, paper no. 1569042132, pp. 768 - 771.

C44. **R. Akl** and Y. Saravanos, "Hybrid Energy-Aware Synchronization Algorithm in Wireless Sensor Networks," *18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, September 2007, paper no 692, 5 pgs.

C45. M. Haidar, **R. Akl**, and H. Al-Rizzo, "Channel Assignment and Load Distribution in a Power-Managed WLAN," *18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, September 2007, paper no. 463, 5 pgs.

C46. D. Keathly and **R. Akl,** "Attracting and Retaining Women in Computer Science and Engineering: Evaluating the Results," *Proceedings of American Society for Engineering Education: ASEE Annual Conference*, June 2007, paper no. AC 2007-1229, 10 pgs.

C47. M. Haidar, **R. Akl**, H. Al-Rizzo, Y. Chan, R. Adada, "Optimal Load Distribution in Large Scale WLAN Networks Utilizing a Power Management Algorithm," *Proceedings of IEEE Sarnoff Symposium*, May 2007, 5 pgs.

C48. R. Dantu, P. Kolan, **R. Akl,** and K. Loper, "Classification of Attributes and Behavior in Risk Management Using Bayesian Networks," *Proceedings of IEEE Intelligence and Security Informatics Conference*, May 2007, pp. 71-74.

C49. **R. Akl** and A. Arepally, "Dynamic Channel Assignment in IEEE 802.11 Networks," *Proceedings of IEEE Portable 2007: International Conference on Portable Information Devices*, March 2007, pp 309-313.

C50. **R. Akl** and U. Sawant, "Grid-based Coordinated Routing in Wireless Sensor Networks," *Proceedings of IEEE CCNC 2007: Consumer Communications and Networking Conference*, January 2007, pp. 860-864.

C51. **R. Akl** and A. Arepally, "Simulation of Throughput in UMTS Networks with Different Spreading Factors," *Proceedings of IEEE VTC Fall 2006: Vehicular Technology Conference,* September 2006, pp. C1-5.

C52. A. Alhabsi, H. Al-Rizzo, and **R. Akl,** "Parity Assisted Decision Making for QAM Modulation," *International Conference on Mobile Computing and Wireless Communications*, September 2006, paper no. 1568988776, 5 pgs.

C53. **R. Akl** and R. Garlick**,** "Retention and Recruitment of Women in Computer Engineering," *ICEE 2006: International Conference on Engineering Education,* July 2006, paper no. 3318, 5 pgs.

C54. R. Garlick and **R. Akl,** "Intra-Class Competitive Assignments in CS2: A One-Year Study," *ICEE 2006: International Conference on Engineering Education,* July 2006, paper no. 3325, 5 pgs.

C55. **R. Akl**, D. Tummala, and X. Li, "Indoor Propagation Modeling at 2.4 GHz for IEEE 802.11 Networks," *WNET 2006: Wireless Networks and Emerging Technologies,* July 2006, paper no. 510-014, 6 pgs.

C56. P. Chen, K. Kavi, and **R. Akl,** "Performance Enhancement by Eliminating Redundant Function Execution," *Proceedings of IEEE: 39th Annual Simulation Symposium*, April 2006, pp. 143-150.

C57. **R. Akl** and S. Nguyen, "Capacity Allocation in Multi-cell UMTS Networks for Different Spreading Factors with Perfect and Imperfect Power Control," *Proceedings of IEEE CCNC 2006: Consumer Communications and Networking Conference*, January 2006, vol. 2, pp. 928-932.

C58. W. Li, K. Kavi, and **R. Akl**, "An Efficient Non-Preemptive Real-Time Scheduling," *18th International Conference on Parallel and Distributed Computing Systems*, Las Vegas, NV, September 2005, pp. 154-160.

C59. S. Nguyen and **R. Akl**, "Approximating User Distributions in WCDMA Networks Using 2-D Gaussian," *CCCC20T 05: International Conference on Computing, Communications, and Control Technologies*, July 2005, 5 pgs.

C60. **R. Akl** and S. Park, "Optimal Access Point Selection and Traffic Allocation in IEEE 802.11 Networks," *Proceedings of 9th World Multiconference on Systemics, Cybernetics and Informatics (WMSCI 2005): Communication and Network Systems, Technologies and Applications*, July 2005, vol. 8, pp. 75-79.

C61. **R. Akl**, M. Naraghi-Pour, M. Hegde, "Throughput Optimization in Multi-Cell CDMA Networks," *IEEE WCNC 2005 - Wireless Communications, and Networking Conference*, March 2005, vol. 3, pp. 1292-1297.

C62. **R. Akl**, "Subscriber Maximization in CDMA Cellular Networks," *Proceedings of CCCT 04: International Conference on Computing, Communications, and Control Technologies*, August 2004, vol. 3, pp. 234-239.

C63. **R. Akl** and A. Parvez, "Global versus Local Call Admission Control in CDMA Cellular Networks," *Proceedings of CITSA 04: Communications, Information and Control Systems, Technologies and Applications*, July 2004, vol. 2, pp. 283-288.

C64. **R. Akl** and A. Parvez, "Impact of Interference Model on Capacity in CDMA Cellular Networks," *Proceedings of SCI 04: Communication and Network Systems, Technologies and Applications*, July 2004, vol. 3, pp. 404-408. Selected as **best paper** of those presented in the session: Tele-Communication Systems, Technologies and Application II.

C65. **R.G. Akl**, M.V. Hegde, M. Naraghi-Pour, P.S. Min, "Call Admission Control Scheme for Arbitrary Traffic Distribution in CDMA Cellular Systems," *IEEE Wireless Communications and Networking Conference*, September 2000, vol. 1, pp. 465-470.

C66. **R.G. Akl**, M.V. Hegde, M. Naraghi-Pour, P.S. Min, "Cell Placement in a CDMA Network," *IEEE Wireless Communications and Networking Conference*, September 1999, vol. 2, pp. 903-907.

C67. **R.G. Akl**, M.V. Hegde, P.S. Min, "Effects of Call Arrival Rate and Mobility on Network Throughput in Multi-Cell CDMA," *IEEE International Conference on Communications*, June 1999, vol. 3, pp. 1763-1767.

C68. **R.G. Akl**, M.V. Hegde, M. Naraghi-Pour, P.S. Min, "Flexible Allocation of Capacity in Multi-Cell CDMA Networks," *IEEE Vehicular Technology Conference*, May 1999, vol. 2, pp. 1643-1647.

Journal Publications

J1. R. Chataut, M. Nankya, **R. Akl**, "6G Networks and the AI Revolution – Exploring Technologies, Applications, and Emerging Challenges," *Sensors 2024,* March 2024, 29 pgs.

J2. R. Chataut, **R. Akl**, "An Adaptive User Scheduling Algorithm for 6G Massive MIMO Systems," *IEEE Transactions on Advanced Communications Technology*, November 2023, 8 pgs.

J3. M. Nankya, R. Chataut, **R. Akl**, "Securing Industrial Control Systems: Components, Cyber Threats, and Machine Learning-Driven Defense Strategies," *Sensors 2023,* October 2023, 41 pgs.

J4. R. Chataut, A. Phoummalayvane, **R. Akl**, "Unleashing the Power of IoT: A Comprehensive Review of IoT Applications and Future Prospects in Healthcare, Agriculture, Smart Homes, Smart Cities, and Industry 4.0," *Sensors 2023*, August 2023, 19 pgs.

J5. M. Robaei, **R. Akl**, "Quadratic Displacement Operators—Theory and Application to Millimeter-Wave Channel Tracking," *IEEE Transactions on Wireless Communications,* January 2023, Vol. 22, No. 1, 15 pgs.

J6. M. Robaei, **R. Akl**, "Continuous Compressed Sensing Hilbert-Schmidt Integral Operator," *IEEE Access*, August 2022, pp. 80264-80276.

J7. R. Chataut, **R. Akl**, U.K. Dey, M. Robaei, "SSOR Preconditioned Gauss-Seidel Detection and Its Hardware Architecture for 5G and beyond Massive MIMO Networks," *Electronics 2021 ISSN 2079-9292*, 10(5), 578, *Special Issue MIMO for Next Generation Wireless Systems,* March 2021, 17 pgs.

J8. R. Chataut, **R. Akl**, "Massive MIMO Systems for 5G and Beyond Networks – Overview, Recent Trends, Challenges, and Future Research Direction," *Sensors 2020*, 20(10), 2753, May 2020.

J9. R. Chataut, **R. Akl,** "Massive MIMO Systems for 5G," *Encyclopedia 2020*, doi:10.32545, 2020, (ISSN 2309-3366).

J10. S. Alotaibi, **R. Akl**, "Range-Based Scheme for Adjusting Transmission Power of Femtocell in Co-Channel Deployment," *International Journal of Interdisciplinary Telecommunications and Networking*, IJITN Vol. 10, No. 4, pgs. 14-24, 2018.

J11. U. Sawant, **R. Akl**, "Adaptive and Non Adaptive LTE Fractional Frequency Reuse Mechanisms Mobility Performance," *Advances in Science, Technology and Engineering Systems Journal*, ASTES Vol. 3, No. 3, 02-11, 11 pgs., 2018.

J12. M. Haidar, H.M. Al-Rizzo, **R. Akl**, and Z. Elbazzal, "The Effect of an Enhanced Channel Assignment Algorithm in an IEEE 802.11 WLAN," *World Scientific and Engineering Academy and Society Transactions on Communications*, WSEAS, Vol. 8, Issue 12, December 2009.

J13. **R. Akl**, P. Kadiyala, and M. Haidar, "Non-Uniform Grid-Based Coordinated Routing in Wireless Sensor Networks," *Journal of Sensors*, article ID 491349, volume 2009, 11 pages.

J14. M. Haidar, M. Al-Rizzo, Y. Chan, **R. Akl**, "User-Based Channel Assignment Algorithm in a Load-Balanced IEEE 802.11 WLAN," *International Journal of Interdisciplinary Telecommunications & Networking (IJITN)*, April-June 2009, 1(2), pp. 66-81.

J15. **R. Akl**, D. Keathly, and R. Garlick, "Strategies for Retention and Recruitment of Women and Minorities in Computer Science and Engineering," *iNEER Special Volume: Innovations 2007- World Innovations in Engineering Education and Research*, 9 pgs., 2007.

J16. R. Garlick and **R. Akl**, "Motivating and Retaining CS2 Students with a Competitive Game Programming Project," *iNEER Special Volume: Innovations 2007- World Innovations in Engineering Education and Research*, 9 pgs., 2007.

J17. **R. Akl** and S. Nguyen, “UMTS Capacity and Throughput Maximization for Different Spreading Factors,” *Journal of Networks*, July 2006, vol. 1, issue 3, pp. 40-49. ISSN: 1796-2056

J18. W. Li, K. Kavi, and **R. Akl**, “A Non-preemptive Scheduling Algorithm for Soft Real-time Systems,” *Journal of Computer and Electrical Engineering,* 2006, vol. 32, 18 pgs. ISSN: 0045-7906

J19. **R. Akl**, A. Parvez, and S. Nguyen, “Effects of Interference on Capacity in Multi-Cell CDMA Networks,” *Journal of Systemics, Cybernetics and Informatics*, 2006, vol. 3, no. 1, p825612, 7 pgs. ISSN: 1690-4524

J20. **R.G. Akl**, M. Hegde and M. Naraghi-Pour, “Mobility-based CAC Algorithm for Arbitrary Traffic Distribution in CDMA Cellular Systems,” *IEEE Transactions on Vehicular Technology,* March 2005*,* vol. 54, no. 2, pp. 639-651.

J21. **R.G. Akl**, M.V. Hegde, M. Naraghi-Pour, P.S. Min, “Multi-Cell CDMA Network Design,” *IEEE Transactions on Vehicular Technology*, May 2001, vol. 50, no. 3, pp. 711-722.

Technical Papers

T1. J. Williams, **R. Akl,** et al, “Flight Control Subsystem,” *The Eagle Feather*, Special Section: Undergraduate Research Initiative in Engineering, University of North Texas, Vol. 7, 2010.

T2. **R.G. Akl**, M.V. Hegde, A. Chandra, P.S. Min, “CDMA Capacity Allocation and Planning,” Technical Document, Washington University Department of Electrical Engineering WUEE-98, April 1998.

Book Chapters

B1. R. Akl, Y. Saravanos, and M. Haidar, “Chapter 18: Hybrid Approach for Energy-Aware Synchronization in Sensor Networks,” *Sustainable Wireless Sensor Networks*, December 2010, pgs. 413-429, ISBN: 978-953-307-297-5.

B2. K. Kavi, **R. Akl** and A. Hurson, “Real-Time Systems: An Introduction and the State-of-the-Art,” *Encyclopedia of Computer Science and Engineering*, John Wiley & Sons, Volume 4, January 2009, pgs. 2369-2377.

B3. **R. Akl** and K. Kavi, “Chapter 12: Modeling and Analysis using Computational Tools,” *Introduction to Queuing Theory: Modeling and Analysis*, Birkhauser Boston, December 2008, pgs. 295-320.

Technical Presentations

P1. "Bio-Com Project," Raytheon, Richardson TX, May 2012, (invited).

P2. "Bio-Com Project," Net-Centric Software and Systems I/UCRC Meeting, Denton TX, December 2011, (invited).

P3. "Student Outreach Report: Robocamp," College of Engineering Advisory Board Meeting, Denton TX, May 2011, (invited).

P4. "Robocamp: Encouraging Young Women to Embrace STEM," 4th Annual TETC Best Practices Conference, Austin TX, February 2009, (invited).

P5. "Self-Configuring Wireless MEMS Network (demo)," Southern Methodist University, Dallas TX, January 2008, (invited).

P6. "Energy-aware Routing and Hybrid Synchronization in Sensor Networks," *Southern Methodist University,* Dallas TX, September 2007, (invited).

P7. "Retention and Recruitment of Women in Computer Engineering," *ICEE 2006: International Conference on Engineering Education,* Puerto Rico, July 2006, (refereed).

P8. "Capacity Allocation in Multi-cell UMTS Networks for Different Spreading Factors with Perfect and Imperfect Power Control," *IEEE CCNC 2006: Consumer Communications and Networking Conference*, Las Vegas, NV, January 2006, (refereed).

P9. "Research, Teaching, and Outreach," CSE Advisory Council Meeting, *UNT Research Park*, Denton, TX, December 2005, (invited).

P10. "Wi-Fi and WCDMA Network Design," *University of Arkansas*, Little Rock, AR, April 2005, (invited).

P11. "Wi-Fi and WCDMA Network Design," *Southern Methodist University*, Dallas, TX, March 2005, (invited).

P12. "Current Research in Wireless at UNT," *Nortel Networks*, Richardson, TX, October 2004, (invited).

P13. "Subscriber Maximization in CDMA Cellular Networks," *International Conference on Computing, Communications, and Control Technologies*, Austin, TX, August 2004, (refereed).

P14. "Global versus Local Call Admission Control in CDMA Cellular Networks," *International Conference on Cybernetics and Information Technologies, Systems* *and Applications*, Orlando, FL, July 2004, (refereed).

P15. "Impact of Interference Model on Capacity in CDMA Cellular Networks," *8th World Multi-Conference on Systemics, Cybernetics, and Informatics*, Orlando, FL, July 2004, (refereed).

P16. "CDMA Network Design," IEEE Communications Society – New Orleans Chapter, New Orleans, LA, May 2002, (invited).

P17. "Cell Design to Maximize Capacity in CDMA Networks," Louisiana State University, Baton Rouge, LA, April 2002, (invited).

P18. "Call Admission Control Scheme for Arbitrary Traffic Distribution in CDMA Cellular Systems," *IEEE Wireless Communications and Networking Conference*, Chicago, IL, September 2000, (refereed).

P19. "Cell Placement in a CDMA Network," *IEEE Wireless Communications and Networking Conference*, September 1999, (refereed).

P20. "Effects of Call Arrival Rate and Mobility on Network Throughput in Multi-Cell CDMA," *IEEE International Conference on Communications*, June 1999, (refereed).

P21. "Flexible Allocation of Capacity in Multi-Cell CDMA Networks," *IEEE Vehicular Technology Conference*, May 1999, (refereed).

P22. "CCAP: A Strategic Tool for Managing Capacity of CDMA Networks," Teleware Co. Ltd., Seoul, South Korea, 1998, (invited).

Courses Developed

- CSCE 5933: LTE Physical Layer Using MATLAB.
  Research issues in the design of LTE physical layer and simulate using MATLAB. Topics include modulation and coding, OFDM, channel modeling, MIMO, and link adaption.

- CSCE 6590: Advanced Topics in Wireless Communications & Networks: 4G/LTE.
  Research issues in the design of next generation wireless networks: cellular systems, medium access techniques, signaling, mobility management, control and management for mobile networks, wireless data networks, Internet mobility, quality-of-service for multimedia applications, caching for wireless web access, and ad hoc networks.

- CSCE 5933: Fundamentals of VoIP.

Fundamentals of VoIP, with emphasis on network infrastructure implementation and security. Topics include IP protocol suite, SS7, speech-coding techniques, quality of service, session initiation protocol, and security issues.

- CSCE 5540: Introduction to Sensor Networks.
  Topics include: design implications of energy (hardware and software), and otherwise resource-constrained nodes; network self-configuration; services such as routing under network dynamics, localization, time-synchronization and calibration; distributed data management, in-network aggregation and collaborative signal processing, programming tools and language support.

- CSCE 5510. Wireless Communication.
  Point-to-point signal transmission through a wireless channel, channel capacity, channel encoding, and multi-user transmissions. First, second, and third generation cellular systems, and mobility management.

- CSCE 3510. Introduction to Wireless Communication.
  Fundamentals of wireless communications and networking, with emphasis on first, second, and third generation cellular systems. Topics include point-to-point signal transmission through a wireless channel, cellular capacity, multi-user transmissions, and mobility management.

- CSCE 3020. Communications Systems.
  Introduction to the concepts of transmission of information via communication channels. Amplitude and angle modulation for the transmission of continuous-time signals. Analog-to-digital conversion and pulse code modulation. Transmission of digital data. Introduction to random signals and noise and their effects on communication. Optimum detection systems in the presence of noise.

- ENEE 3583. Computer Systems Design I (UNO).
  The design process of digital computer systems is studied from the instruction set level, system architecture level, and digital logic level. Topics include machine organization, register transfer notation, processor design, memory design, and input/output considerations. Includes semester project.

- ENEE 3584. Computer Systems Design II (UNO).
  The design and evaluation of contemporary computer systems are analyzed to compare the performance of different architectures. Topics include performance metrics, computer arithmetic, pipelining, memory hierarchies, and multiprocessor systems.

- ENEE 3514. Computer Architecture Laboratory (UNO).
  Selected experiments examining programmable logic, VHDL and logic synthesis, and including a final design project, to accompany and complement the lecture course ENEE 3584. Three hours of laboratory.

Courses Taught

Spring 2025
- CSCE 3020.1: Communication Systems (no evaluation yet)

Spring 2024
- CSCE 3020.1: Communication Systems (4.0 / 5.0)

Fall 2023
- CSCE 3010.1: Signals and Systems (3.6 / 5.0)

Spring 2023
- CSCE 3020.1: Communication Systems (4.5 / 5.0)

Fall 2022
- CSCE 3010.1: Signals and Systems (4.4 / 5.0)
- CSCE 6950.743: Dissertation (no evaluation done)

Spring 2022
- CSCE 3020.1: Communication Systems (4.2 / 5.0)
- CSCE 6950.743: Dissertation (no evaluation done)

Fall 2021
- CSCE 3010.1: Signals and Systems (4.2 / 5.0)
- CSCE 5933.1: LTE Physical Layer Using MATLAB (5.0 / 5.0)
- CSCE 6950.743: Dissertation (no evaluation done)

Spring 2021
- CSCE 2610.2: Computer Organization (4.0 / 5.0)
- CSCE 3020.1: Communication Systems (4.2 / 5.0)
- CSCE 6950.743: Dissertation (no evaluation done)

Fall 2020
- CSCE 3010.1: Signals and Systems (4.1 / 5.0)
- CSCE 6940.743: 5G MIMO Systems (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Spring 2020
- CSCE 6940.743: 5G MIMO Systems (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Fall 2019
- CSCE 5933.3: LTE Physical Layer Using MATLAB (4.3 / 5.0)
- CSCE 6940.743: 5G MIMO Systems (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Spring 2019
- CSCE 6940.743: 5G MIMO Systems (no evaluation done)
- CSCE 6940.743: Software Defined Radios (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Fall 2018
- CSCE 5933.3: LTE Physical Layer Using MATLAB (4.8 / 5.0)
- CSCE 6940.743: 5G MIMO Systems (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Spring 2018

- CSCE 6940.743: 5G MIMO Systems (no evaluation done)
- CSCE 6940.743: Jitter-buffer Management and Interference in VoIP (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Fall 2017

- CSCE 5933.3: LTE Physical Layer Using MATLAB (4.9 / 5.0)
- CSCE 6940.743: 5G MIMO Systems (no evaluation done)
- CSCE 6940.743: VoLTE and VoWiFi (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Spring 2017

- CSCE 6950.743: Dissertation (no evaluation done)

Fall 2016

- CSCE 5933.3: LTE Physical Layer Using MATLAB (4.7 / 5.0)
- CSCE 6950.743: Dissertation (no evaluation done)

Spring 2016

- CSCE 5950.743: Thesis (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Fall 2015

- CSCE 3010.1: Signals and Systems (5.7 / 7.0)
- CSCE 5950.743: Thesis (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Spring 2015

- CSCE 5934.743: Directed Study (no evaluation done)
- CSCE 5950.743: Thesis (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Fall 2014

- CSCE 3010.1: Signals and Systems (3.32 / 4.00)
- CSCE 5950.743: Thesis (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)
- CSCE 6590.1: Advanced Topics in Wireless Communications & Networks: 4G/LTE (3.79 / 4.00)

Spring 2014

- CSCE 3510.1: Intro to Wireless Communication (808 – Highly Effective)
- CSCE 5510.1: Wireless Communications (808 – Highly Effective)
- CSCE 5950.743: Thesis (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Fall 2013

- CSCE 5950.743: Thesis (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)
- CSCE 6590.1: Advanced Topics in Wireless Communications & Networks: 4G/LTE (804 – Highly Effective)

Spring 2013

- CSCE 4890.743: Directed Study (no evaluation done)
- CSCE 5950.743: Thesis (no evaluation done)

- CSCE 6940.743: Individual Research (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Fall 2012

- CSCE 3010.1: Signals and Systems (793 – Highly Effective)
- CSCE 5540.1: Intro to Sensor Networks (814 – Highly Effective)
- CSCE 5950.743: Thesis (no evaluation done)
- CSCE 6950.743: Dissertation (no evaluation done)

Spring 2012

- CSCE 3020.1: Communication Systems (809 – Highly Effective)
- CSCE 3510.1: Intro to Wireless Communication (811 – Highly Effective)
- CSCE 5510.1: Wireless Communications (817 – Highly Effective)
- EENG 3810.1: Communication Systems (801 – Highly Effective)

Fall 2011

- CSCE 3010.1: Signals and Systems (793 – Highly Effective)
- CSCE 5540.1: Intro to Sensor Networks (824 – Highly Effective)

Spring 2011

- CSCE 3020.1: Communication Systems (820 – Highly Effective)
- CSCE 3510.1: Intro to Wireless Communication (812 – Highly Effective)
- CSCE 5510.1: Wireless Communications (812 – Highly Effective)
- EENG 3810.1: Communication Systems (826 – Highly Effective)

Fall 2010

- CSCE 3010.1: Signals and Systems (857 – Highly Effective)
- CSCE 5540.1: Intro to Sensor Networks (831 – Highly Effective)

Spring 2010

- CSCE 3020.1: Communication Systems (792 – Highly Effective)
- CSCE 3510.1: Intro to Wireless Communication (793 – Highly Effective)
- CSCE 5510.1: Wireless Communications (834 – Highly Effective)
- EENG 3810.1: Communication Systems (854 – Highly Effective)

Fall 2009

- CSCE 3010.1: Signals and Systems (4.40 / 5.00)
- CSCE 5540.1: Intro to Sensor Networks (4.70 / 5.00)
- EENG 2620.1: Signals and Systems (4.40 / 5.00)

Spring 2009

- CSCE 3020.1: Communication Systems (4.87 / 5.00)
- CSCE 3510.1: Intro to Wireless Communication (4.65 / 5.00)
- CSCE 5510.1: Wireless Communications (4.79 / 5.00)

Fall 2008

- CSCE 3010.1: Signals and Systems (4.91 / 5.00)
- CSCE 5540.2: Intro to Sensor Networks (4.10 / 5.00)
- EENG 2620.3: Signals and Systems (4.91 / 5.00)

Spring 2008

- CSCE 3020.1: Communication Systems (4.68 / 5.00)
- CSCE 3510.1: Intro to Wireless Communication (3.96 / 5.00)
- CSCE 5510.1: Wireless Communications (4.75 / 5.00)

Fall 2007

- CSCE 3010.1: Signals and Systems (4.57 / 5.00)
- CSCE 5540.2: Intro to Sensor Networks (4.01 /5.00)

Summer 2007

- CSCE 3020.1: Fund. of Communication Theory (no evaluation done)
- EENG 3810.1: Communication Systems (no evaluation done)

Spring 2007

- CSCE 5510.2: Wireless Communications (4.75 / 5.00)
- CSCE 5933.6: Fundamentals of VoIP (4.70 / 5.00)

Fall 2006

- CSCE 3010.1: Signals and Systems (4.58 / 5.00)
- CSCE 5540.1: Intro to Sensor Networks (4.70 / 5.00)
- EENG 2620.1: Signals and Systems (4.58 / 5.00)

Summer 2006

- CSCE 3020.1: Fund. of Communication Theory (no evaluation done)
- CSCE 3510.21: Intro to Wireless Communications (no evaluation done)
- CSCE 5510.21: Intro to Wireless Communications (no evaluation done)
- EENG 3810.1: Communication Systems (no evaluation done)

Spring 2006

- CSCE 2610.2: Computer Organization (3.69 / 5.00)
- CSCE 3010.1: Signals and Systems (4.41 / 5.00)
- EENG 2620.1: Signals and Systems (4.41 / 5.00)

Fall 2005

- CSCE 3510.1: Intro to Wireless Communications (4.52 / 5.00)
- CSCE 5510.1: Wireless Communications (4.46 / 5.00)
- CSCE 5933.6: Intro to Sensor Networks (4.60 / 5.00)

Summer 2005

- CSCE 3010.21: Signals and Systems (no evaluation done)
- CSCE 3510.21: Intro to Wireless Communications (no evaluation done)

Spring 2005

- CSCE 3510.02: Intro to Wireless Communications (4.46 / 5.00)
- CSCI 3100.02: Computer Organization (4.14 / 5.00)

Fall 2004

- CSCE 3510.01: Intro to Wireless Communications (4.15 / 5.00)
- CSCI 4510.01: Machine Structures (4.55 / 5.00)
- CSCI 5330.02: Intro to Wireless Communications (4.05 / 5.00)

Summer 2004

- CSCI 4330.22: Intro to Wireless Communications (no evaluation done)
- CSCI 4330.23: Intro to Wireless Communications (no evaluation done)
- CSCI 5330.22: Intro to Wireless Communications (no evaluation done)

Spring 2004

- CSCI 3100: Computer Organization (4.64 / 5.00)
- CSCI 4330: Intro to Wireless Communications (4.22 / 5.00)

Fall 2003

- CSCI 4510: Machine Structures (4.49 / 5.00)
- CSCI 5330: Intro to Wireless Communications (4.83 / 5.00)

Summer 2003

- CSCI 3100: Computer Organization (no evaluation done)

Spring 2003

- CSCI 3100: Computer Organization (3.84 / 5.00)

Fall 2002

- CSCI 4510: Machine Structures (4.38 / 5.00)

Funded Proposals

R1. "I/UCRC Industrial Membership - Ashum Corp," 2020. Krishna Kavi (PI), Robert Akl (co-PI), **$52,000.**

R2. "I/UCRC Industrial Membership - Ashum Corp," 2019. Krishna Kavi (PI), Robert Akl (co-PI), **$60,900.**

R3. "I/UCRC Industrial Membership - Ashum Corp," 2018. Krishna Kavi (PI), Robert Akl (co-PI), **$57,700.**

R4. "Robotics and App Design Summer Camp" under Texas Higher Education Coordinating Board: Engineering Summer Program. Requested amount is $11,727. Submitted 5/5/17. Robert Akl (PI), **$11,727.**

R5. "I/UCRC Industrial Membership - Ashum Corp," 2017. Krishna Kavi (PI), Robert Akl (co-PI), **$50,000.**

R6. "UNT GenCyber Summer Program: Inspiring the Next Generation of Cyber Stars in North Texas," National Security Agency (NSA). Requested amount is $85,000. Submitted 11/4/2016. Robert Akl (co-PI), **$85,000**.

R7. "App Design Summer Camp" under Texas Higher Education Coordinating Board: Engineering Summer Program. Requested amount is $12,900. Submitted 5/6/16. Robert Akl (PI), **$12,900.**

R8. "I/UCRC Industrial Membership - Ashum Corp," 2016. Krishna Kavi (PI), Robert Akl (co-PI), **$65,000.**

R9. "Robotics, Game and App Programming Summer Camps" under Texas Workforce Commission: Summer Merit Program. Requested amount is $63,000. Submitted 11/16/15. Robert Akl (PI), **$63,000**.

R10. "App Design Summer Camp" under Texas Higher Education Coordinating Board: Engineering Summer Program. Requested amount is $13,998. Submitted 5/1/15. Robert Akl (PI), **$13,988**.

R11. "I/UCRC Industrial Membership - Ashum Corp," 2015. Krishna Kavi (PI), Robert Akl (co-PI), **$40,000.**

R12. "App Design Summer Camp" under Texas Higher Education Coordinating Board: Engineering Summer Program. Requested amount is $12,500. Submitted 5/2/14. Robert Akl (PI), **$12,500**.

R13. "I/UCRC Industrial Membership - Ashum Corp," 2014. Krishna Kavi (PI), Robert Akl (co-PI), **$46,000.**

R14. "I/UCRC Industrial Membership - Ashum Corp," 2013. Krishna Kavi (PI), Robert Akl (co-PI), **$38,500.**

R15. "Robotics, Game and App Programming Summer Camps" under Texas Workforce Commission: Summer Merit Program. Requested amount is $63,000. Submitted 12/14/12. Robert Akl (PI), **$63,000**.

R16. "Bio-Com Project," funded by Raytheon under Net-Centric Software and Systems I/UCRC 2nd year. Requested amount is $30,000. Submitted 5/12/12. Krishna Kavi (PI), Robert Akl (co-PI), **$30,000.**

R17. "Bio-Com Project," funded by Raytheon under Net-Centric Software and Systems I/UCRC. Requested amount is $30,000. Submitted 5/12/11. Krishna Kavi (PI), Robert Akl (co-PI), **$30,000.**

R18. "Game Programming for Xbox 360 Summer Camp" under Texas Higher Education Coordinating Board: Engineering Summer Program. Requested amount is $20,000. Submitted 3/21/11. Robert Akl (PI), **$20,000**.

R19. "RoboCamps and Game Programming Summer Camps" under Texas Workforce Commission: Summer Merit Program. Requested amount is $63,000. Submitted 2/17/11. Robert Akl (PI), **$63,000**.

R20. "Game Programming for Xbox 360 Summer Camp" under Texas Higher Education Coordinating Board: Engineering Summer Program. Requested amount is $13,000. Submitted 2/22/10. Robert Akl (PI), **$18,000.**

R21. "Robotics and Game Programming Summer Camps" under Texas Workforce Commission: Summer Merit Program. Requested amount is $63,000. Submitted 10/16/09. Robert Akl (PI), **$63,000**.

R22. "Micro Air Vehicle Design: A Collaborative Undergraduate Project for Electrical Engineering, Computer Engineering, and Computer Science Students," under UNT Undergraduate Research Initiative. Submitted 9/25/2009. Robert Akl (co-PI), **$8,000**.

R23. “Summer Merit Program” under Texas Workforce Commission. Requested amount is $42,000. Submitted 3/20/09. Robert Akl (PI), **$42,000**.

R24. “Robocamp at Stewpot” under Dallas Women's Foundation. Requested amount is $20,000. Submitted 2/23/09. Robert Akl (PI), **$18,600**.

R25. “Robocamp Jump Start” under Motorola Foundation Innovation Generation Grant. Requested amount is $29,852. Submitted 2/12/09. Robert Akl (PI), **$30,700**.

R26. “Engineering Summer Program” under Texas Higher Education Coordinating Board. Requested amount is $7,944. Submitted 2/13/09. Robert Akl (PI), **$11,111**.

R27. “Texas Youth in Technology” under Texas Workforce Commission. Requested amount is $152,393. Submitted 11/10/08. Robert Akl (PI), **$152,393**.

R28. “I/UCRC Center Proposal: Net-Centric Software and Systems,” under NSF-07-537: Industry/University Cooperative Research Centers. Requested amount is $349,482. Submitted 9/26/08. Krishna Kavi (PI), Robert Akl (co-PI), **$60,000 per year for 5 years**.

R29. “Robocamp and Beyond” under Motorola Foundation Innovation Generation Grant. Requested amount is $30,000. Submitted 6/20/08. Robert Akl (PI), **$30,000**.

R30. Texas Youth in Technology” under Texas Workforce Commission. Requested amount is $30,000. Submitted 2/27/08. Robert Akl (PI), **$31,500**.

R31. “Robocamp Program for Young Women” under RGK foundation. Requested amount is $30,000. Submitted 11/5/07. Robert Akl (PI), **$15,000**.

R32. “Texas Youth in Technology” under Texas Workforce Commission. Requested amount is $102,514. Submitted 10/22/07. Robert Akl (PI), **$102,514**.

R33. “Women Art Technology” under Hispanic and Global Studies Initiatives Fund. Requested amount is $14,125. Submitted 9/30/07. Jennifer Way (PI), Robert Akl (co-PI), **$12,785**.

R34. “Robocamp Mobile Unit” under Motorola Foundation Innovation Generation Grant. Requested amount is $35,000. Submitted 6/20/07. Robert Akl (PI), **$30,000**.

R35. “ICER: UNT Engineering Challenge Camps” under NSF 0547299. Requested amount is $35,000. Submitted 4/27/07. Oscar Garcia (PI), Robert Akl (senior personnel), **$32,792**.

R36. "I/UCRC-Planning Proposal: UNT Research Site Proposal to join Embedded Systems I/UCRC," under NSF-01-116: Industry/University Cooperative Research Centers. Requested amount is $10,000. Submitted 3/31/07. Krishna Kavi (PI), Robert Akl (co-PI), **$10,000**.

R37. "High-assurance NCCS: Ultra Dependability Integration Engineering," Department of Defense. Requested amount is $20,000. Submitted 3/12/07. Krishna Kavi (PI), Robert Akl (co-PI), **$20,000**.

R38. "Recruiting and Retention Strategies for Computer Science at UNT" under Texas Technology Workforce Development Grant Program – 2005. Requested amount is $163,322. Submitted 3/17/05. Robert Akl (PI), **$125,322**.

R39. UNT Faculty Research Grant for Fall 2003, Robert Akl (PI), $5,000, **$4,000**.

R40. UNT Junior Faculty Summer Research Fellowship for Summer 2003, Robert Akl (PI), $5,000, **$5,000**.

Professional Associations and Achievements

Membership in Professional Organizations

- Senior Member IEEE
- Member, Federation Council of North Texas Universities
- Member, Eta Kappa Nu Electrical Engineering Honor Society
- Member, Golden Key National Honor Society
- Member, Tau Beta Pi Engineering Honor Society

Offices and Committee Assignments in Professional Organizations

- Technical Program Committee Member, IEEE Wireless Communications and Networking Conference, IEEE WCNC
- Technical Program Committee Member, International Wireless Symposium, IWS
- Technical Program Committee Member, IEEE International Conference on Computational Science, IEEE ICCS
- Technical Program Committee Member, IASTED International Conference on Wireless Communications, WC
- Technical Program Committee Member, WTS Wireless Telecommunications Symposium
- Technical Program Committee Member, Mosharaka International Conference on Computer Science and Engineering, Amman
- Invitation to serve as an NSF reviewer/panelist for Engineering Research Centers (ERC) proposals
- Technical Program Committee Member, 18th IEEE International Symposium on Personal, Indoor and Mobile Radio Communication, Greece

- International Program Committee, IASTED International Conference on Wireless and Optical Communication, Canada
- Program Committee Member, Fifth Annual Wireless Telecommunications Symposium, CA
- Technical Publications Chair, IEEE Vehicular Technology Conference, Dallas TX
- Session Chair, International Conference on Computing, Commun. and Control Tech., Austin TX
- Session Chair, International Conference on Cybernetics and Information Technologies, Orlando FL
- Session Chair, 8th World Multi Conference on Systemics, Cybernetic, and Informatics, Orlando FL

Additional Responsibilities and Activities

- Reviewer, *Wireless Communications and Mobile Computing*, 2012 – present
- Reviewer, *Journal of Sensor and Actuator Networks*, 2012 – present
- Reviewer, *IEEE Transactions on Vehicular Technology*, 2011 – present
- Reviewer, *Elsevier Journal of Computers & Electrical Engineering*, 2008 – present
- Reviewer, *IEEE Globecom*, 2007 – present
- Reviewer, *IEEE International Conference on Advanced Networks and Telecommunication Systems (ANTS)*, 2008 – present
- Reviewer, *The International Wireless Communications and Mobile Computing Conference*, 2007 – present
- Reviewer, *Journal on Wireless Communications and Networking*, 2007 – present
- Reviewer, *IEEE Transactions on Communications*, 2007 - present
- Reviewer, *International Journal of Communication Systems*, 2007 – present
- Reviewer, *IEEE Communications Magazine*, 2005 – present
- Reviewer, *Journal of Wireless Networks*, 2004 – present
- Reviewer, *IEEE Transactions on Mobile Computing*, 2004 – present
- Reviewer, *IEEE Transactions on Wireless Communications*, 2004 – present
- Reviewer, *ACM Crossroads*, 2004 – present

Honors and Awards

- Who's Who in America, 2012 Edition
- Winner of Tech Titan of the Future – University Level Award for UNT Robocamps for Girls, Metroplex Technology Business Council, 2010 with **$15,000 cash prize**.
- IEEE Professionalism Award, Ft Worth Chapter, 2008
- UNT College of Engineering Outstanding Teacher Award, 2008
- Certificate of Appreciation: IEEE Vehicular Technology Conference, Dallas, TX, 2005
- Certificate of Appreciation: Denton County Boosting Engineering, Science and Technology (BEST) Robotics Competition, 2004
- Summa Cum Laude Graduate, Ranked First in Undergraduate Class

- The Computer Science Departmental Award for Academic Excellence, Washington University, 1993
- The Dual Degree Engineering Award for Outstanding Senior, Washington University, 1993
- The 1992 Technical Writing Competition Award, The Society for Technical Communication