

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

MEDIATEK INC. AND NXP USA, INC.
Petitioners,

v.

Bell Northern Research, LLC,
Patent Owner.

IPR2023-01414
U.S. Patent 8,416,862
Filing Date: September 28, 2005
Issue Date: April 9, 2013

DECLARATION OF JONATHAN WELLS, Ph.D.

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I, Jonathan Wells, Ph.D. of Pleasanton, California, declare that:

I. ASSIGNMENT

1. I have been retained as a technical expert by counsel on behalf of MediaTek USA INC. (“MediaTek”) and NXP USA, Inc. (“NXP”). I refer to MediaTek and NXP collectively as “Petitioners” herein. I understand that Petitioners are requesting that the Patent Trial and Appeal Board (“PTAB” or “the Board”) institute an *inter partes* review (“IPR”) proceeding of U.S. Patent No. 8,416,862 (“the ’862 patent”) (EX1001).

2. I have been asked to provide my independent analysis of the ’862 patent in light of the prior art publications cited below. I previously submitted an opinion in support of LG’s petition for *inter partes* review in IPR2020-00108 on the identical grounds presented herein, which was instituted by the Patent Trials and Board.

3. I am not, and never have been, an employee of MediaTek or NXP. I received no compensation for this declaration beyond my normal hourly compensation based on my time actually spent analyzing the ’862 patent, the prior art publications cited below, and the issues related thereto, and I will not receive any added compensation based on the outcome of any IPR or other proceeding involving the ’862 patent.

II. QUALIFICATIONS

4. I received a B.Sc. in Physics with Physical Electronics, awarded with first class honors, from the University of Bath in Bath, United Kingdom, in 1987. In 1991, I earned my Ph.D., also from the University of Bath. I earned my M.B.A., awarded with distinction, from Massey University in New Zealand, in 1998.

5. I have over 35 years of wireless communications experience in areas including cellular technologies, wireless devices, network infrastructure, and wireless rules and regulations. I have written a textbook and multiple industry reports and journal/conference papers which focus on wireless communications systems. For example, I am the author of “*Multi-Gigabit Microwave and Millimeter-Wave Wireless Communications*,” published by Artech House in 2010. I have also authored four comprehensive industry reports on cellular connectivity for Mobile Experts. I have lectured as part of undergraduate programs at University of California, Berkeley, Carnegie Mellon University, and University of Bath, and have given over two dozen lectures and conference presentations on topics germane to wireless communications. I am also a listed inventor of several patents, and am an author of over 40 academic and commercial publications and presentations.

6. I began my career in 1985, as an Engineer for Plessey Research, Caswell, United Kingdom, developing high-speed fiber optic transmitter/receiver devices. In 1987, I worked at British Aerospace, Filton, Bristol, United Kingdom, designing and fabricating novel mixer devices, to support my Ph.D. research.

Later in 1990, as a Post-Doctoral Research Officer for University of Bath, I designed and fabricated novel quantum amplifiers in a clean room environment and developed computer models to predict semiconductor device performance.

7. In 1983, I joined Matra Marconi Space, Portsmouth, United Kingdom, as a Senior Design Engineer and developed a GaAs MMIC mixer and MIC transmitter board for two satellite payloads and performed theoretical analysis and modeling of low noise VCOs.

8. From 1994 to 1998, I worked for MAS Technology (now Aviat Networks), Wellington, New Zealand, first as Senior RF Design Engineer and later as RF Group Manager. I was responsible for RF hardware development for cellular and telecommunications applications; developed three generations of wireless transmission, switching, and multiplexing products; designed and sustained responsibility for satellite ground station terminals; and was responsible for company's European regulatory approvals.

9. In 1998, I joined Adaptive Broadband (now GE Digital Energy), Rochester, New York, first as Engineering Group Leader and later as Director Wideband Products. I was responsible for the Terrestrial Infrastructure Group, providing telecommunications products for cellular and private network applications; managed P&L responsibility for \$4M wireless division; and was

responsible for the development of a family of digital radios and associated switching/multiplexing equipment.

10. From 2000 to 2004, I worked for Stratex Networks (now Aviat Networks), San Jose, California, as Director Product Development. I was responsible for global product development of high-end digital microwave radios primarily for cellular backhaul applications; led RF/microwave development team of 35 engineers based in two continents; performed technical leadership of flagship Eclipse product, shipping over 250,000 units; and was responsible for technical management of overseas manufacturing subcontractors.

11. In 2005, I joined GigaBeam Corporation, Herndon, Virginia, as Director Product Management and Global Regulatory Affairs. I was responsible for product strategy for industry-transforming high data rate wireless product; initiated market development in over 40 countries including in Europe, Canada, Caribbean, Latin America, the Middle East, and Asia; and participated and drove standard development in FCC, CEPT, and ETSI technical meetings.

12. Since 2007, I have been an independent consultant with AJIS Consulting, where I provide independent technical consulting on wireless communications and emerging wireless fields. The services I provide include: acting as a technical expert support of 2G, 3G, 4G, and 5G cellular and wireless patent litigation; providing analysis of cellular and mobile wireless patents and

infringing equipment; providing cellular and wireless technology technical and industry analysis for companies, analysts, and investment institutions, and researching and publication of analyst reports; providing wireless product development and marketing strategies; providing specialized technical workshops on various wireless technologies, including cellular networks, mm-wave radios, security sensors, and short range radios; and providing specialized global regulatory tasks and product approvals.

13. I have been a member of the Institute of Electrical and Electronic Engineers (IEEE) since 1995 and was elected as a Senior Member in 1999. In 2019, I was recognized by the IEEE Santa Clara Valley Section, one of the largest IEEE Sections in the world, as their 2019 “Outstanding Engineer.” This was awarded “For acknowledged expertise in the field of wireless communications and wireless technology, for his willingness to mentor others in the field, and for his work in the development of the next generation of creative and innovative technical products.”

14. My curriculum vitae, attached to this declaration as Appendix A, sets forth details of my background and relevant experience. My CV includes a listing of cases for which I have provided expert testimony over the last four years and a complete list of publications I have authored. Based on my experience and education, I believe that I am qualified to opine as to the knowledge and level of

skill of one of ordinary skill in the art at the time of the alleged invention of the '862 patent (which I further describe below) and what such a person would have understood at that time, and the state of the art during that time. Based on my experiences, I understand and know of the capabilities of persons of ordinary skill in this field during the early-to-mid 2000s and specifically during the time before the time of the alleged invention of the '862 patent. Indeed, I taught, participated in organizations, and worked closely with many such persons in the field during that time frame.

III. LEGAL PRINCIPLES

15. In forming my analysis and conclusions expressed in this declaration, I have applied the legal principles described in the following paragraphs, which were provided to me by counsel for the Petitioners.

A. Anticipation

16. I have been informed that a patent claim is invalid as anticipated if each and every element of a claim, as properly construed, is found either explicitly or inherently in a single prior art reference. Under the principles of inherency, if the prior art necessarily functions in accordance with, or includes the claimed limitations, it anticipates.

17. I have been informed that a claim is invalid if the claimed invention was known or used by others in the U.S., or was patented or published anywhere,

before the Applicant's invention. I further have been informed that a claim is invalid if the invention was patented or published anywhere, or was in public use, on sale, or offered for sale in this country, more than one year prior to the filing date of the patent application (critical date). Further, I have been informed that a claim is invalid if an invention described by that claim was described in a U.S. patent granted on an application for a patent (or in a published application for a U.S. patent) that was filed by another in the U.S. before the date of invention for such a claim.

B. Obviousness

18. I have been informed that a patent claim is invalid as "obvious" in light of one or more prior art references if it would have been obvious to a person of ordinary skill in the art at the time of the alleged invention ("POSITA"), taking into account (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any so called "secondary considerations" of non-obviousness, which include: (i) "long felt need" for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) "copying" of the claimed invention by others.

19. While I do not know the exact date that the alleged invention claimed in the '862 patent was made, I do know that the '862 patent claims priority to a

number of other patent applications. In particular, the '862 patent is a continuation-in-part of U.S. App. Serial No. 11/168,793 ("793 application", EX1014), and claims priority to U.S. Provisional App. Serial No. 60/673,451 ("451 provisional", EX1010), filed April 21, 2005, and U.S. Provisional App. Serial No. 60/698,686 ("686 provisional", EX1011), filed July 13, 2005. Based on my analysis of the applications to which the '862 patent claim priority (explained below in Section VI.C), for purposes of my analysis here, I have applied a date of July 13, 2005, as the date of the alleged invention in my obviousness analysis, although in many cases the same analysis would hold true even if the date of the alleged invention occurred earlier than July 13, 2005 (especially given the earlier publication or filing dates of the prior art in Exhibits 1004, 1005, 1006, 1007, 1008, and 1009, as described below). See ¶24 (below).

20. I have been informed that a claim can be obvious in light of a single prior art reference or multiple prior art references. To be obvious in light of a single prior art reference or multiple prior art references, there must be a reason that would have prompted a POSITA to modify the single prior art reference, or combine two or more references, in a manner that provides the elements of the claimed invention. This reason may come from a teaching, suggestion, or motivation to combine, or may come from the reference(s) themselves, the knowledge or "common sense" of a POSITA, or from the nature of the problem to

be solved, and this reason may be explicit or implicit from the prior art as a whole. I have been informed that, under the law, the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. I also understand it is improper to rely on hindsight in making the obviousness determination.

C. Claim Construction

21. I understand that, for purposes of my analysis in this *inter partes* review proceeding, the terms appearing in the patent claims should be interpreted according to their “ordinary and customary meaning,” which is often referred to as the *Phillips* standard. In determining the ordinary and customary meaning, I understand that the words of a claim are first given their plain meaning that those words would have had to a person of ordinary skill in the art at the time of the alleged invention. I also understand that the structure of the claims, the specification and file history also may be used to better construe a claim insofar as the plain meaning of the claims cannot be understood. Moreover, I understand that even treatises and dictionaries may be used, albeit under limited circumstances, to determine the meaning attributed by a person of ordinary skill in the art to a claim term at the time of filing. I have followed this approach in my analysis, and for all of the claim terms considered in this declaration, I have applied the plain and ordinary meaning of those terms. To this end, I was informed that, in the litigation

in which the same claim construction standard was applied, the district court indicated that no formal constructions for the '862 patent claims were required under the *Phillips* standard because the plain and ordinary meaning of the claim language was recognizable without adoption of any formal construction. EX1020, 104:23-107:3-9 and 111:4-114:22. In particular, I was informed that the district court previously explained to the parties that the phrase “baseband processing module operable to...” is not a means-plus-function element under § 112, ¶ 6 because the district court agreed with Patent Owner that “a baseband processing module” was a known and recognizable structure. EX1020, 111:4-114:22; 116:18-118:5 (“THE COURT: ... I don’t see this as a 112, 6 issue. This is a known processing baseband processing module.”). Additionally, I was informed that the district court indicated there was no need for a formal construction of the phrase “decompose the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information” under the *Phillips* standard because the plain and ordinary meaning of the claim language was recognizable without adoption of any formal construction. EX1020, 104:23- 105:2, 106:20-25, 107:3-9 (“Assume the Court will not construe that claim any further, that that language of ‘transmitter beamforming information’ is what it is and that a person of skill in the art would understand that is the result of the decomposition of the estimated transmitter beamforming matrix”). I also understand that in a different proceeding

in the Southern District of Florida, a third party argued that the claim term “a plurality of Radio Frequency (RF) components” (claim 9) is a means-plus-function term under § 112(6) with the function of “receiving an RF signal and converting the RF signal to a baseband signal” but without corresponding structure and therefore indefinite. Ex1023, 8. Patent Owner there contended that the plain and ordinary meaning applied without needing construction, but, alternatively, if § 112(6) applies the structure “includes one or more antennas and includes one or more amplifiers, one or more intermediate frequency, one or more mixers and RF filters.” *Id.* I do not offer an opinion on the proper construction of this claim element. Regardless, my analysis below shows that under both of Patent Owner’s alternative constructions, the prior art discloses or renders obvious claim 9.

22. I also understand that the words of the claims should be interpreted as they would have been interpreted by a POSITA at the time the alleged invention was made (not today). Because I do not know at what date the alleged invention was made, I have used the date of July 13, 2005, for reasons explained in ¶19 (above) and ¶¶47-49 (below). However, the plain meanings/interpretations that I employed in my analysis below would have also been correct if the date of invention was anywhere within the early to mid 2000s.

IV. PERSON OF ORDINARY SKILL IN THE ART

23. Based on my knowledge and experience in the field and my review of the '862 patent and its file history, I believe that would have had Bachelor's degree in Electrical Engineering, Computer Engineering, Computer Science, or a related field, and at least 2 years of experience in the field of wireless communication, or a person with equivalent education, work, or experience in this field. Additional education could substitute for some of the experience, and substantial experience could substitute for some of the educational background. My analysis and conclusions as expressed herein are thus based on the perspective of a person of ordinary skill in the art having this level of knowledge and skill at the time of the alleged invention of the '862 patent.

24. Because I do not know at what date the alleged invention as claimed was made, I have used the filing date of the earliest application to which the '862 patent claims priority that supports each element of the challenged claims 9-12 as the point in time from which my analysis from the perspective of one of ordinary skill in the art is based. Again, as I explain in Section VI.C, that date was July 13, 2005. However, my analysis of the prior art and the conclusion herein would also apply even if the date of the alleged invention as claimed was anywhere within the early to mid 2000s (*e.g.*, refer to the earlier publication or filing dates of Exhibits 1004, 1005, 1006, 1007, 1008, 1009).

V. MATERIALS CONSIDERED

25. My analyses set forth in this declaration are based on my experience in the field of wireless communication devices and associated technologies. Based on my above-described experience in the field of wireless communication devices, I believe that I am considered to be an expert in the field. Also, based on my experiences, I understand and know of the capabilities of persons of ordinary skill in this field during the early to mid 2000s and specifically during the time before the alleged priority date (July 13, 2005) for the '862 patent, and I taught, participated in organizations, and worked closely with many such persons in the field during that time frame.

26. As part of my independent analysis for this declaration, I have considered the following: the background knowledge/technologies that were commonly known to persons of ordinary skill in this field during the time before the alleged priority date for the '862 patent; my own knowledge and experiences gained from my work experience in the fields of electrical engineering and wireless communication devices generally; my experience in teaching and advising others in those subjects; and my experience in working with others involved in those fields. In addition, I have analyzed the following publications and materials:

- U.S. Patent No. 8,416,862 to Aldana et al. ("the '862 patent") (EX1001)
- Prosecution History of the '862 patent (Serial No. 11/237,341) (EX1002)
- U.S. Pat. No. 7,236,748 to Li et al. ("Li '748") (EX1004)

- U.S. Pub. No. 2008/0108310 to Tong et al. (“Tong”) (EX1005)
- U.S. Pat. No. 7,312,750 to Mao et al. (“Mao”) (EX1006)
- U.S. Pub. No. 2006/0092054 to Li et al. (“Li ’054”) (EX1007)
- Yang et al., *Reducing the Computations of the Singular Value Decomposition Array Given by Brent and Luk*, SIAM J. MATRIX ANAL. APPL., Vol. 12, No. 4, pp. 713-725, Oct. 1991 (“Yang”) (EX1008)
- U.S. Pat. No. 7,710,925 to Poon (“Poon”) (EX1009)
- U.S. Provisional Application Serial No. 60/673,451 (“the ’451 provisional”) (EX1010)
- U.S. Provisional Application Serial No. 60/698,686 (“the ’686 provisional”) (EX1011)
- U.S. Provisional Application Serial No. 60/614,621 (“the ’621 provisional”) (EX1012)
- U.S. Provisional Application Serial No. 60/619,461 (“the ’461 provisional”) (EX1013)
- U.S. Patent Application Serial No. 11/168,793 (“the ’793 application”) (EX1014)
- Plaintiff Bell Northern Research, LLC’s Patent Rule 3-1 and 3-2 Disclosure of Asserted Claims and Infringement Contentions Against the Huawei Defendants in Bell Northern Research, LLC, v. Huawei Device (Dongguan) Co., Ltd., Huawei Device (Shenzhen) Co., Ltd., and Huawei Device USA, Inc. (Case No. 3:18-cv-1784) (S.D.Cal.) (EX1015)
- Defendants’ Invalidity Contentions in Bell Northern Research, LLC, v. Huawei Device (Dongguan) Co., Ltd., Huawei Device (Shenzhen) Co., Ltd., and Huawei Device USA, Inc. (Case No. 3:18-cv-1784) (S.D.Cal.) (EX1016)

- Defendants' Joint Opening Claim Construction Brief in Bell Northern Research, LLC, v. Huawei Device (Dongguan) Co., Ltd., Huawei Device (Shenzhen) Co., Ltd., and Huawei Device USA, Inc. (Case No. 3:18-cv-1784) (S.D.Cal.) (EX1017)
- Plaintiff's Opening Claim Construction Brief in Bell Northern Research, LLC, v. Huawei Device (Dongguan) Co., Ltd., Huawei Device (Shenzhen) Co., Ltd., and Huawei Device USA, Inc. (Case No. 3:18-cv-1784) (S.D.Cal.) (EX1018)
- Defendants' Memorandum of Points and Authorities in Support of Their Joint Motion for Summary Judgment on Indefiniteness in Bell Northern Research, LLC, v. Huawei Device (Dongguan) Co., Ltd., Huawei Device (Shenzhen) Co., Ltd., and Huawei Device USA, Inc. (Case No. 3:18-cv-1784) (S.D.Cal.) (EX1019)
- Transcript of Claim Construction Hearing, Day Two, Volume Two, Pages 1-122 in Bell Northern Research, LLC, v. Huawei Technologies CO., LTD., Huawei Device (Hong Kong) CO., LTD., and Huawei Device USA, Inc. (Case No. 3:18-cv-1784) (S.D.Cal.) (EX1020)
- Declaration of Sylvia Hall-Ellis (EX1021)
- Joint Claim Construction and Prehearing Statement, Bell Northern Research LLC v. HMD North America, Inc. et al (Case No. 1:22-cv-22706-RNS) (S.D. Fla) (EX1023).

27. Although this declaration refers to selected portions of the cited references for the sake of brevity, it should be understood that these are examples, and that one of ordinary skill in the art would have viewed the references cited herein in their entirety and in combination with other references cited herein or

cited within the references themselves. The references used in this declaration, therefore, should be viewed as being incorporated herein in their entireties.

VI. BACKGROUND OF THE '862 PATENT

A. Subject Matter Overview

28. The '862 patent is titled "Efficient Feedback of Channel Information in a Closed Loop Beamforming Wireless Communication System," and it is generally directed to a "receiving wireless device" that performs a "method for feeding back transmitter beamforming information ... to a transmitting wireless communication device." EX1001 at Abstract. The '862 patent states that "[i]n order for a transmitter to properly implement beamforming (i.e., determine the beamforming matrix $[V]$), it needs to know properties of the channel over which the wireless communication is conveyed," so "the receiver must provide feedback information for the transmitter to determine the properties of the channel." *Id.* at 3:14-19. In order to send "feedback from the receiver to the transmitter," the receiver may "determine[s] the channel response (h) and [] provides it as the feedback information." *Id.* at 3:19-22. However, "[a]n issue with this approach" was that "the size of the feedback packet [was] so large that, during the time it takes to send it to the transmitter, the response of the channel has changed." *Id.* at 3:22-25. To try to "reduce the size of the feedback," one conventional approach was for the receiver to "decompose the channel using singular value decomposition(SVD)"

using the equation $H=UDV^*$ and to “send information relating only to a calculated value of the transmitter’s beamforming matrix (V) as the feedback information.” *Id.* at 3:26-33. However, feedback size was still a problem for MIMO wireless communication. *Id.* at 3:33-35. The ’862 patent conclude that “[t]herefore, a need exist[ed] ... for reducing beamforming feedback information for wireless communications.” *Id.* at 3:49-51.

29. FIG. 1 (reproduced below) shows “a communication system 10 that includes a plurality of base stations and/or access points 12, 16, a plurality of

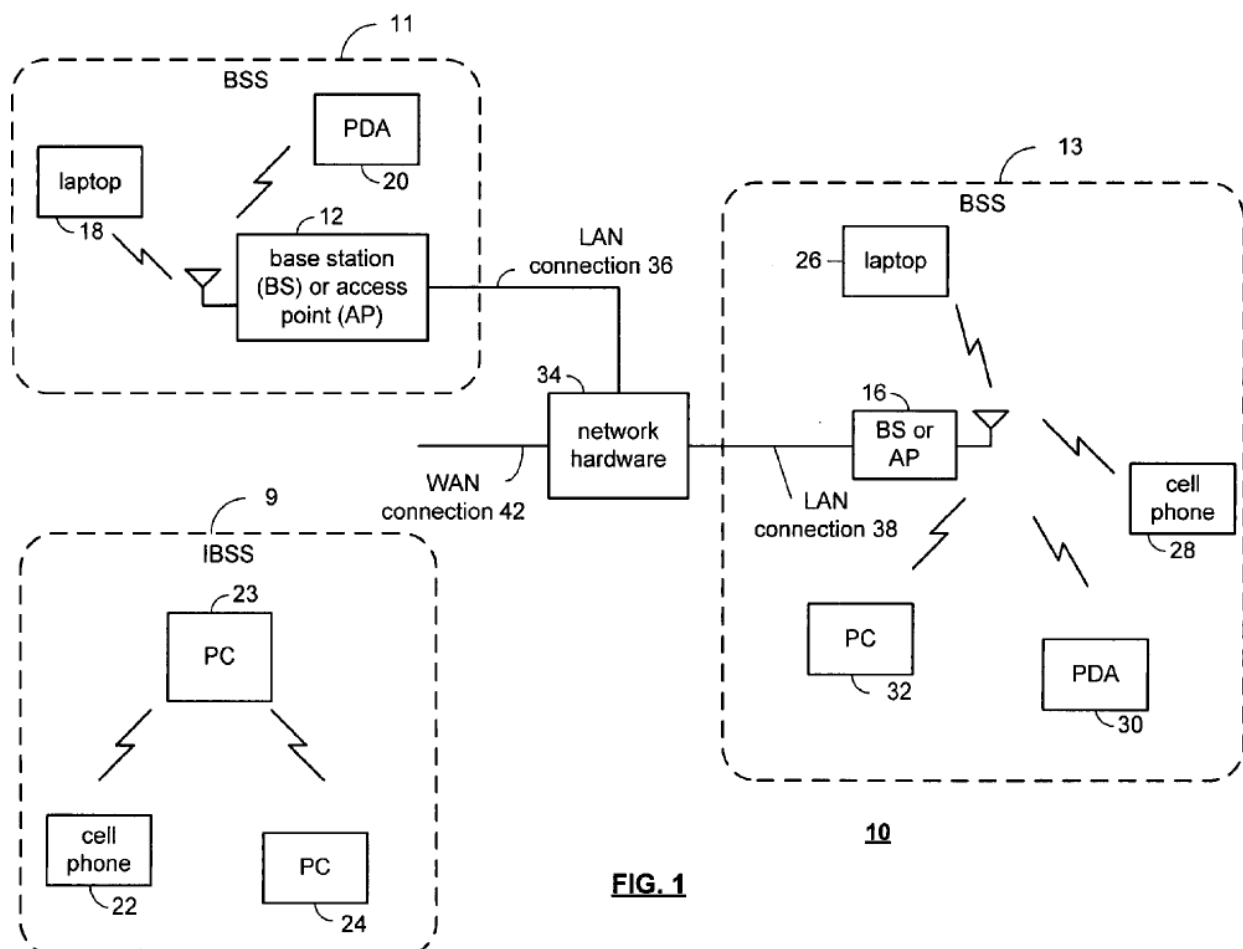


FIG. 1

wireless communication devices 18-32 and a network hardware component 34.”*Id.* at 4:24-27.

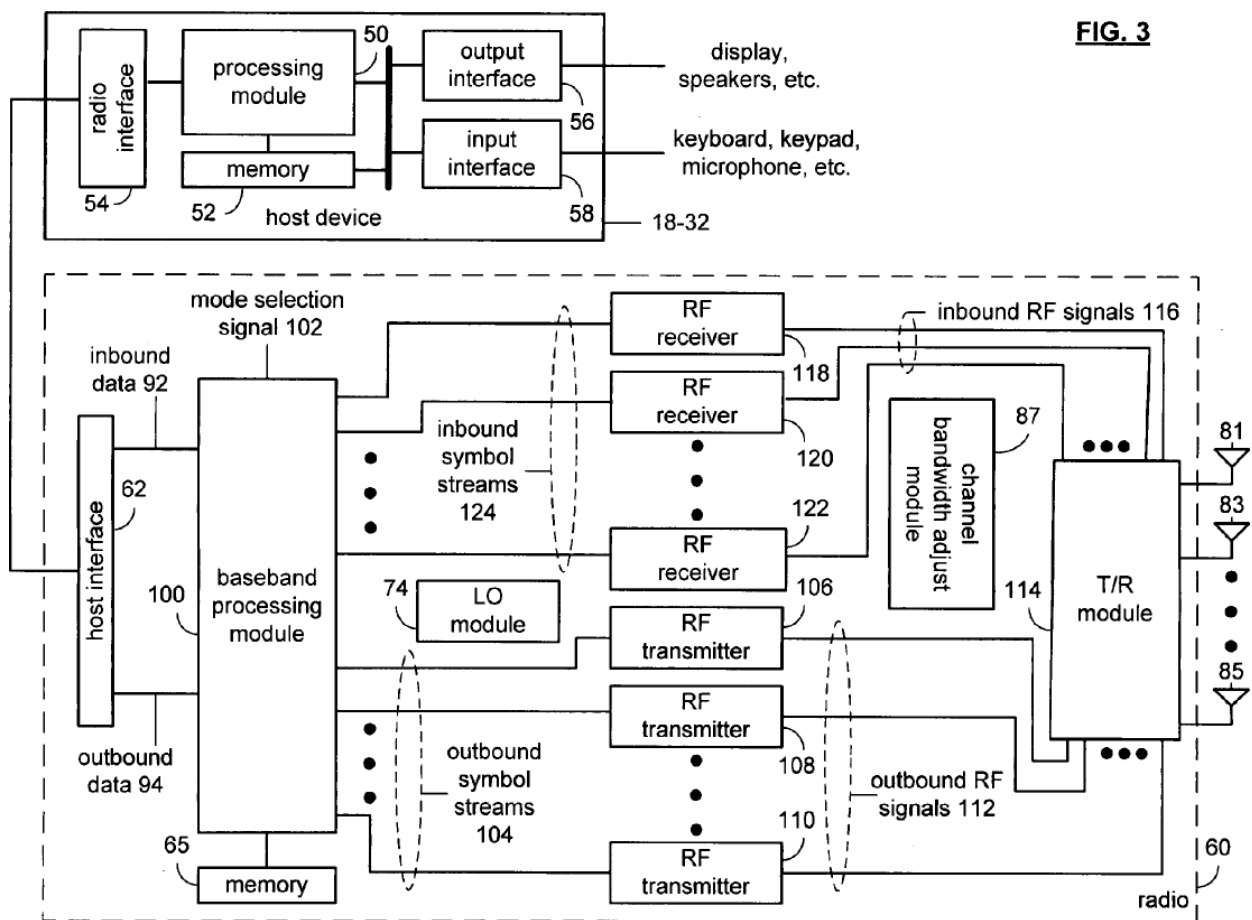
Id. at FIG. 1.

30. FIG. 2 (reproduced below) is a block diagram of “a wireless communication device that includes the host device 18-32 and an associated radio 60.” *Id.* at 5:4-6.

31. The ’862 patent explains that the “[w]ireless communication devices 18-32 may be laptop computers 18 and 26, personal digital assistant hosts 20 and 30, personal computer 24 and 32 and/or cellular telephone 22 and 28.” *Id.* at 4:29-34. In order to communicate with other devices, “each of the base stations or access points 12-16 has an associated antenna or antenna array.” *Id.* at 4:52-55. “Typically, base stations are used for cellular telephone systems and like-type systems, while access points are used for in-home or in-building wireless networks (e.g., IEEE 802.11 and versions thereof, Bluetooth, and/or any other type of radio frequency based network protocol).” *Id.* at 4:63-67. In any case, each device “includes a built-in radio and/or is coupled to a radio.” *Id.* at 5:67-5:3.

32. FIG. 3 (reproduced below) is a block diagram of “a wireless communication device that includes [a] host device 18-32 and an associated radio 60.” *Id.* at 7:21-27. As shown in FIG. 3, “the host device 18-32 includes a processing module 50, memory 52, radio interface 54, input interface 58 and

output interface 56.” *Id.* at 7:28-30. According to the ’862 patent, “[t]he radio interface allows data to be received from and sent to the radio,” and “[f]or data received from the radio 60 (e.g., inbound data), the radio interface 54 provides the data to the processing module 50 for further processing and/or routing to the output interface 56.” *Id.* at 7:36-40. The radio interface 54 then “provides data from the processing module 50 to the radio 60.” *Id.* at 7:43-44.



Id. at FIG. 3.

33. The radio 60 “includes a host interface 62, a baseband processing module 100, memory 65, a plurality of radio frequency (RF) transmitters 106-110,

a transmit/receive (T/R) module 114, a plurality of antennas 81-85, a plurality of RF receivers 118-120, a channel bandwidth adjust module 87, and a local oscillation module 74.” *Id.* at 7:51-56. Using “operational instructions stored in memory 65,” the baseband processing module 100 “executes digital receiver functions and digital transmitter functions, respectively,” which include “but are not limited to, digital intermediate frequency to baseband conversion, demodulation, constellation demapping, decoding, de-interleaving, fast Fourier transform, cyclic prefix removal, space and time decoding, and/or descrambling.” *Id.* at 7:56-64. Digital transmitter functions include “encoding, scrambling, interleaving, constellation mapping, modulation, inverse fast Fourier transform, cyclic prefix addition, space and time encoding, and digital baseband to IF conversion.” *Id.* at 7:64-8:1. The baseband processing module is “implemented using one or more processing devices,” such as “a microprocessor, microcontroller, digital signal processor, microcomputer, central processing unit, field programmable gate array, programmable logic device, state machine, logic circuitry, analog circuitry, digital circuitry, and/or any device that manipulates signals (analog and/or digital) based on operational instructions.” *Id.* at 8:1-9.

34. The “baseband processing module 100, based on the mode selection signal 102 produces one or more outbound symbol streams 104 from the outbound data 94.” *Id.* at 8:46-48. “Depending on the number of outbound streams 104

produced by the baseband module 10, a corresponding number of the RF transmitters 106-110 will be enabled to up convert the output symbol streams 104 into outbound RF signals 112.” *Id.* at 8:56-59. The RF transmitters 106-110 may include “a digital filter and upsampling module, a digital to analog conversion module, a frequency up conversion module, a power amplifier, and a radio frequency bandpass filter. *Id.* at 8:60-64. To transmit an RF signal, the “RF transmitters 106-110 provide the outbound RF signals 112 to the transmit/receive module 114, which provides each outbound RF signal to a corresponding antenna 81-85.” *Id.* at 8:64-67.

35. In a receive mode, “the transmit/receive module 114 receives one or more inbound RF signals 116 via the antennas 81-85 and provides them to one or more RF receivers 118-122.” *Id.* at 9:1-4. Then the RF receiver uses “settings provided by the channel bandwidth adjust module 87” in order to “down convert[] the inbound RF signals 116 into a corresponding number of inbound symbol streams 124.” *Id.* at 9:4-7. Then the baseband processing module 100 “converts the inbound symbol streams 124 into inbound data 92, which is provided to the host device 18-32 via the host interface.” *Id.* at 9:9-12.

36. Figure 5 (reproduced below) is a block diagram of a “baseband receive processing 100-RX that includes a plurality of fast Fourier transform (FFT) modules 140, 142, a beamforming (U) module 144, a plurality of constellation

demapping modules 146, 148, a plurality of interleaving modules 150, 152, a switch, a depuncture module 154, and a decoding module 156 for converting a plurality of inbound symbol streams 124 into inbound data 92.” *Id.* at 11:60-67.

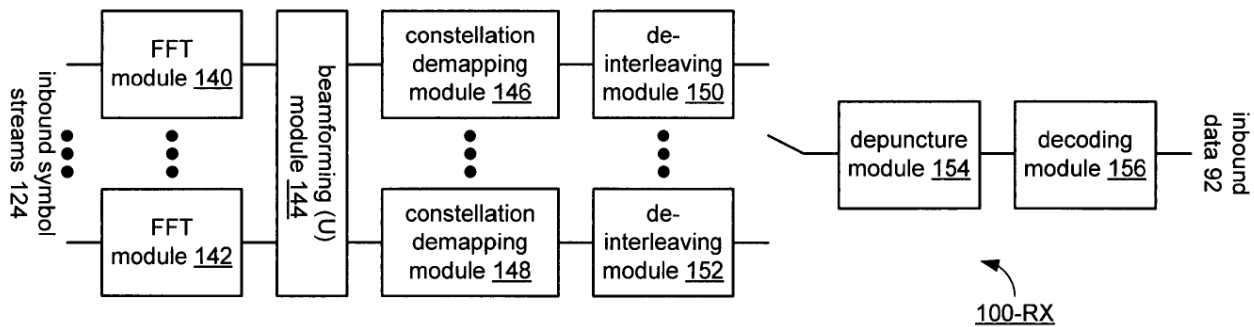
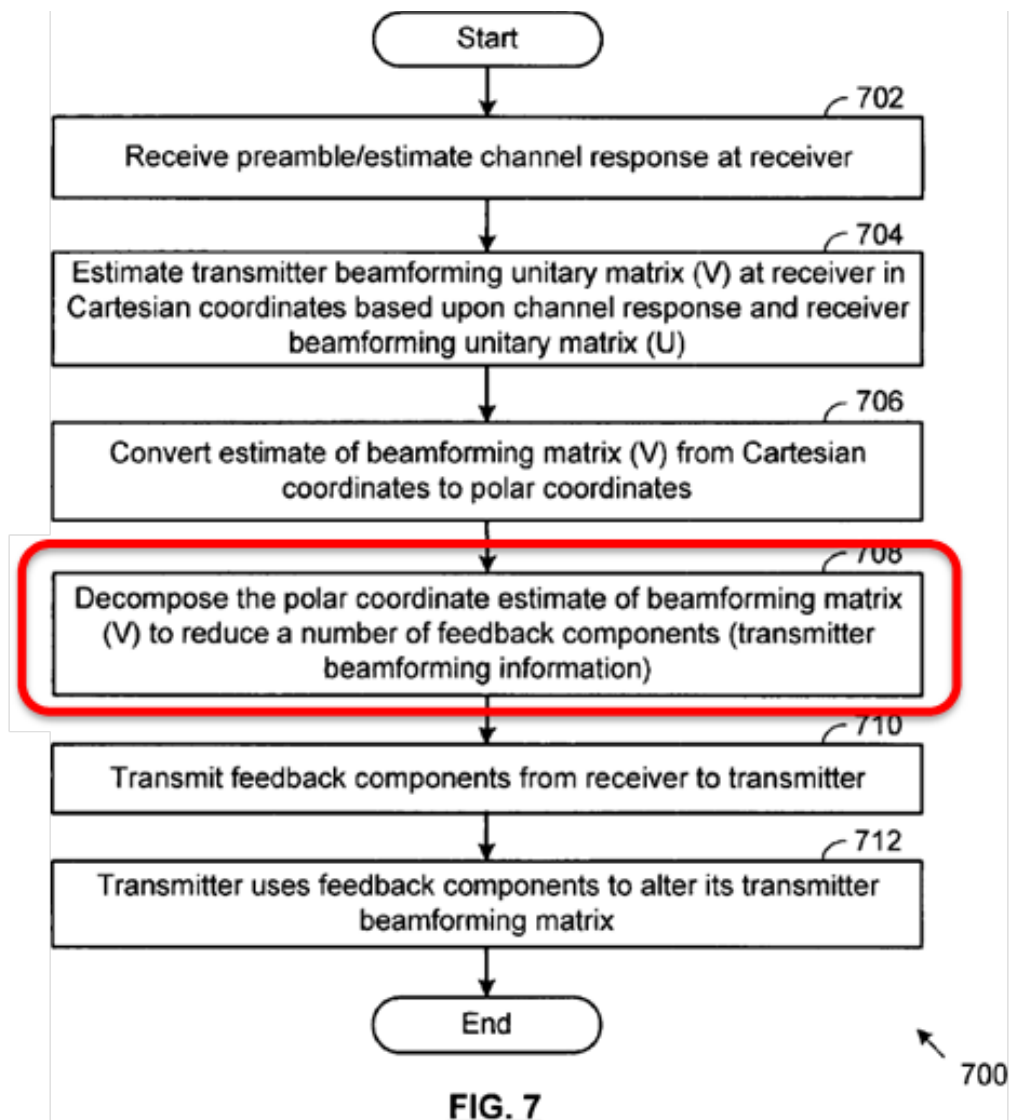


FIG. 5

Id. at FIG. 5.

37. Figure 7 (reproduced below) is a flow chart showing a conventional method 700 for providing beamforming feedback information from a receiver to a transmitter. *Id.* at 13:25-27. The method “addresses the feed back of observed transmitter beamforming information from a receiving wireless communication device to a transmitting wireless communication device.” *Id.* at 13:27-32.

The ’862 patent states that the steps of Figure 7 are “typically performed by abaseband processing module” of a receiving wireless device. *Id.* at 13:32-35.



Id. at FIG. 7 (annotated).

38. The method starts at 702 “with the receiving wireless communication device receiving a preamble sequence from the transmitting wireless device and estimating a channel response from the preamble sequence,” where estimating the channel response “includes comparing received training symbols of the preamble to corresponding expected training symbols using any of a number of techniques that are known in the art.” *Id.* at 13:36-44. At step 704, the “receiving wireless

device then determines an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a known receiver beamforming unitary matrix (U).” *Id.* at 13:44-47. “The channel response (H), estimated transmitter beamforming unitary matrix (V), and the known receiver beamforming unitary matrix (U) are related by the equation $H=UDV^*$, where, D is a diagonal matrix. Singular Value Decomposition (SVD) operations may be employed to produce the estimated transmitter beamforming unitary matrix (V) according to this equation.” *Id.* at 13:47-53.

39. At step 706, the “receiving wireless device produces the estimated transmitter beamforming unitary matrix (V) in Cartesian coordinates and then converts the estimated transmitter beamforming unitary matrix (V) to polar coordinates.” *Id.* at 13:54-58. At step 708 (highlighted above in Figure 7), the ’862 patent proposed a solution that was already known in the art—“the receiving wireless device then decomposes the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information.” *Id.* at 13:58-62. The ’862 patent stated that the decomposition operation of step 708 may employ, for example, a Givens Rotation, which was a well-known mathematical operation. *Id.* at 13:63-67. As the ’862 patent explained, a “Givens Rotation relies upon the observation that, with the condition of $V^*V=VV^*=I$, some of the angles of the Givens Rotation are redundant.” *Id.* at 13:65-66; *see also id.* at 14:48-15:58. If a

Givens Rotation is used, “the coefficients of the Givens Rotation and the phase matrix coefficients serve as the transmitter beamforming information that is sent from” the receiver to the transmitter. *Id.* at 15:34-38. Specifically, if a Givens Rotation is used for the decomposition, the transmitter beamforming information are the products of the Givens Rotation. *Id.* at 14:34-36. The ’862 patent explains that the decomposed form of the estimated transmitter beamforming matrix V is a reduced set of angles, which are then fed back to the transmitting wireless device. *Id.* at 13:63-14:3. Using these techniques, “the feedback of transmitter beamforming information” requires less data. *Id.* at 15:59-61. Notably, however, this type of decomposition of matrix V —and use of a Givens Rotation—was already known, as explained in more detail in my analysis below.

40. Finally, at step 710, “the receiving wireless device wirelessly send[s] the transmitter beamforming information to the transmitting wireless device,” and at step 712, the “transmitting wireless device then uses the feedback components to generate a new beamforming matrix (V), which it uses for subsequent transmissions.” *Id.* at 14:4-13.

41. Based on my review of the record, it appears that none of the prior publications I listed above (and which I analyze below) were ever relied upon in any Office Action by the examiner during prosecution. Furthermore, as I explain in detail below, based upon my knowledge and experience in this field and my review

of the publications cited here, I do not agree that claims 9-12 of the '862 patent are patentable over the prior art. The Li '748 (EX1004), Tong (EX1005), Li '054 (EX1007), and Poon (EX1008) references, for example, do in fact describe conventional wireless receiving devices that estimate channel responses from signals received from a transmitter, determine an estimated transmitter beamforming matrix, and decompose the estimated transmitter beamforming matrix before transmitting the information back to the transmitter. As I also explain in greater detail below, the '862 patent describes features that were well-known in similar devices before the Critical Date of the '862 patent, as exemplified by at least the Li '748, Tong, Mao, Li '054, Yang, and Poon references.

B. File History of the '862 Patent

42. As part of my preparation of this declaration, I reviewed the file history of the '862 patent (EX1002). I understand that the application that led to the '862 patent was filed on September 28, 2005, as a continuation-in-part of patent application No. 11/168,793 filed on June 28, 2005, and claimed priority to the '451 provisional filed on April 21, 2005, and the '686 provisional filed on July 13, 2005. *See* EX1001 at Cover Page. The '862 patent eventually issued on August 9, 2013. *Id.*

43. The USPTO issued an office action on August 5, 2008. EX1002 at 153-164. In that office action, the examiner rejected all of the claims as obvious in view of at least U.S. Publication No. 2002/0187753 A1 to Kim et al. (“Kim”) and U.S. Publication No. 2004/0042558 A1 to Hwang et al. (“Hwang”). *Id.* at 155-163. In response, the applicant filed a response with no amendments and arguments only. *Id.* at 148-150.

44. The USPTO issued a final office action on January 23, 2009. *Id.* At 133-145. In that office action, the examiner disagreed with the applicant’s arguments and maintained the rejection. *Id.* at 135-143. In an after-final response dated March 18, 2009, the applicant argued that the cited passages of Kim “merely refer to a method of determining the ‘transmission power’ to be allocated to each of the transmit antennas in order to cancel the interference between the signals produced by the antennas.” *Id.* at 125-129. The examiner maintained his rejection in an Advisory Action mailed April 2, 2009, and the applicant filed a notice of appeal on April 23, 2009. *Id.* at 120-121, 122-124.

45. In its Appeal Brief dated July 20, 2009, the applicant again argued that Kim “only teaches systems and methods for a receiver to calculate transmit power information (e.g., the transmission power to be allocated by a transmitter to transmitting antennae) and for feeding back the calculated transmit power information to the transmitter,” while “the present invention is directed to systems

and method for ‘feeding back transmitter beamforming information.’” *Id.* at 92 (emphasis in original). After the parties submitted their respective arguments, the Patent Board issued a decision that reversed the examiner’s argument. *Id.* at 37-46.

46. The examiner subsequently issued a Notice of Allowance on December 28, 2012. *Id.* at 22-30. Based on my review of the record, none of the Challenged Claims (claims 9-12) were amended during prosecution. Additionally, based on my review of the record, it appears that none of the prior publications I listed above (and which I analyze below) were ever analyzed in any Office Action by the examiner during prosecution.

47. As explained in detail below, based upon my knowledge and experience in this field and my review of the publications cited here, I do not agree that at least claims 9-12 of the ’862 patent are patentable over the prior art. The Li ’748 reference (EX1004), in one example, does in fact provide a teaching of a wireless communication system that estimates a channel response based on received signals, determines an estimated transmitter beamforming unitary matrix, decomposes the estimated transmitter beamforming unitary matrix to produce transmitter beamforming information, and sends the transmitter beamforming information back to a transmitter. EX1004 at 2:63-67, 3:19-39, 8:4-7, 8:60-64, 9:32-46, FIGs. 1, 4. The Tong reference (EX1005) also teaches these elements,

including the use of a Givens Rotation for the decomposition of the estimated transmitter beamforming unitary matrix. EX1005 at [0066], [0073], [0077], [0079], [0087], [0211], [0223], [0227], FIG. 1, FIG. 43. Additional prior art examples that are pertinent to these claims of the '862 patent are described below.

C. Priority Date of the '862 Patent

48. As I noted in the previous section, the '862 patent was filed as a “continuation-in-part” of patent application No. 11/168,793 filed on June 28, 2005, and claimed priority to the '451 provisional filed on April 21, 2005, and the '686 provisional filed on July 13, 2005. *See* EX1001 at Cover Page. Based on my review of these applications to which the '862 patent claims priority, the earliest possible priority date to which claims 9-12 of the '862 patent can claim priority is the July 13, 2005 filing date of the '686 provisional.

49. In particular, claim 9, to which each of claims 10-12 claim priority, recites “a baseband processing module operable to: ... decompose the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information.” Notably, neither the '451 provisional nor the '793 application discloses “decompos[ing] the estimated transmitter beamforming unitary matrix (V).” See, generally, EX1010, EX1014. To the extent that either the '451 or the '793 application discuss any “decomposition,” the discussion pertains to a singular value decomposition (SVD) of matrix H in order to determine matrix

V, but not a decomposition of matrix V itself. E.g., EX1010 at 5:12-15; EX1014 at 5:4-8, 20:7-14

50. Rather, the first time any application to which the '862 patent claims priority discussed decomposing matrix V was the '686 provisional filed on July 13, 2005. EX1011 at 22:3-5 (“With a decomposed matrix form for the V matrix, the set of angles fed back to the transmitter are reduced.”). As such, the earliest possible priority date for claims 9-12 of the '862 patent is July 13, 2005.

D. Background Knowledge of Matrices and their Singular Value Decomposition (SVD)

51. In mathematics, a matrix is a rectangular array of numbers. A matrix is characterized by the number of rows and columns. An $m \times n$ matrix has m rows and n columns. In the example below, the matrix A is a 2×3 matrix.

$$A = \begin{bmatrix} 3 & 9 & -1 \\ 0 & 5 & 4 \end{bmatrix}$$

52. In matrix algebra, the singular value decomposition (SVD) operation refers to the factoring of a matrix into the product of three matrices, each with specific properties. As was commonly known in the prior art, using SVD, an $m \times n$ matrix A can be factored as $A = U \Sigma V^T$ where U is an $m \times m$ matrix, V is an $n \times n$ matrix, and Σ is an $m \times n$ “diagonal” matrix. A diagonal matrix is a matrix where all the entries are zero, except for the elements on the diagonal. A matrix with the

superscript T (e.g. V^T) represents the transpose of the matrix, whereby the rows and columns of the matrix have been interchanged.

53. The '862 patent and most of the prior art references I analyze below reference the use of a singular value decomposition ("SVD") operation, which was a widely known operation in the art, and would have been understood by a POSITA. See, e.g., EX1001 at 13:47-53; EX1004 at 3:19-32; EX1005 at [0223], FIG. 43; EX1007 at [0093], [0018]; EX1009 at 3:53-58. Although the SVD operation in these prior publications is essentially the same, some of the references use slightly different nomenclature for describing the SVD operation. For example, the '862 patent describes the SVD equation $H=UDV^*$. EX1001 at 13:47-53. Similarly, Li '748 describes the SVD equation $H=UDV'$. EX1004 at 3:19-32. Also similarly, Tong describes the SVD equation generally $H=UDV$. EX1005 at FIG. 43 (element 328). Li '054 describes the SVD equation $H_{m \times m} = U_{m \times m} D_{m \times n} V_{n \times n}'$, where the subscripts signify the dimensions of the matrices. EX1007 at [0018]. Poon describes the SVD equation $H=U\Sigma V^y$. EX1009 at 3:53-58. While there are minor differences in the notations used, a POSITA would have understood that all of the equations are, in effect, the same for purposes of describing the commonly known SVD operation.

54. First, with respect to the matrices H, U, D, V, and Σ , a POSITA would have recognized each of these matrices. In particular, a POSITA would have

recognized H as a channel response (or a channel matrix, or channel state matrix), U as a receiver beamforming unitary matrix, V as a transmitter beamforming unitary matrix (or simply a beamforming matrix), and both D and Σ as the same diagonal matrix.

55. Second, with respect to the superscripts that are present above matrix V in some of the references, a POSITA would have understood them all to refer to the well-known operation of transposing the matrix.

56. In other words, a POSITA would have understood the SVD operation described in each of the above prior art documents to be the same, commonly known SVD operation that was also subsequently described in the '862 patent.

VII. OVERVIEW OF CONCLUSIONS FORMED AND PRIOR ART REFERENCES

57. This declaration explains the conclusions that I have formed based on my independent analysis. To summarize those conclusions:

- Based upon my knowledge and experience, and my review of the prior art publications listed above, I believe that claims 1-4 and 9-12 of the '862 patent are obvious in light of U.S. Patent No. 7,236,748 to Li et al. ("Li '748") in view of U.S. Pub. No. 2008/0108310 to Tong et al. ("Tong") and U.S. Pat. No. 7,312,750 to Mao et al. ("Mao").
- Based upon my knowledge and experience, and my review of the prior art publications listed above, I believe that claims 1-4 and 9-12

of the '862 patent are obvious in light of Tong in view of Mao.

- Based upon my knowledge and experience, and my review of the prior art publications listed above, I believe that claims 1, 3-4, 9 and 11-12 of the '862 patent are obvious in light of U.S. Pub. No. 2006/0092054 to Li et al. ("Li '054") in view of Mao.
- Based upon my knowledge and experience, and my review of the prior art publications listed above, I believe that claims 2 and 10 of the '862 patent is obvious in light of Li '054, Mao, and Yang et al., Reducing the Computations of the Singular Value Decomposition Array Given by Brent and Luk, SIAM J. MATRIX ANAL. APPL., Vol. 12, No. 4, pp. 713-725, Oct. 1991 ("Yang").
- Based upon my knowledge and experience, and my review of the prior art publications listed above, I believe that claims 1, 3-4, 9 and 11-12 of the '862 patent are obvious in light of U.S. Pat. No. 7,710,925 to Poon ("Poon") in view of Mao.

VIII. ANALYSIS OF LI '748 IN VIEW OF TONG AND MAO

58. For the reasons articulated in detail below and based on my review of the '862 patent, file history, and the prior art references cited here, it is my opinion that a POSITA would have readily understood that the predictable combination of

Li '748 in view of Tong and Mao provides all the elements of claims 9-12. Li-748's "electronic system 400" is a receiving wireless communication device. EX1004, 9:32-46, FIGs. 1, 4. It performs disclosed methods for feeding back transmitter beamforming information to a transmitting wireless device. *Id.*, 8:4-9:46, 10:16-24, Figs. 2-3. Method claims 1-4 correspond to device claims 9-12, addressed below. Accordingly, the elements of claims 1-4 are rendered obvious for the same reasons as presented below in reference to claims 9-12.

59. Li '748, titled "Closed Loop Feedback in MIMO Systems," was filed September 30, 2004 (EX1004 at cover page), prior to the earliest possible priority date (July 13, 2005) of the '862 patent. As Li '748 explains, "[c]losed loop multiple-input-multiple output (MIMO) systems typically transmit channel state information from a receiver to a transmitter," but doing so "consumes bandwidth that might otherwise be available for data traffic." EX1004 at 1:12-17. As such, Li '748 teaches a "closed loop MIMO system" for reducing feedback bandwidth "by representing a beamforming matrix using orthogonal generator matrices." *Id.* at Abstract.

60. Figure 1 (reproduced below) of Li '748 shows two stations, "station 102, and station 104" that are "part of a wireless local area network (WLAN)." *Id.* at 1:50-52. Each of the stations could be "a mobile station such as a laptop

computer, personal digital assistant (PDA), or the like.” *Id.* at 1:54-57. Each of stations 102 and 104 includes multiple antennas. *Id.* at 2:6.

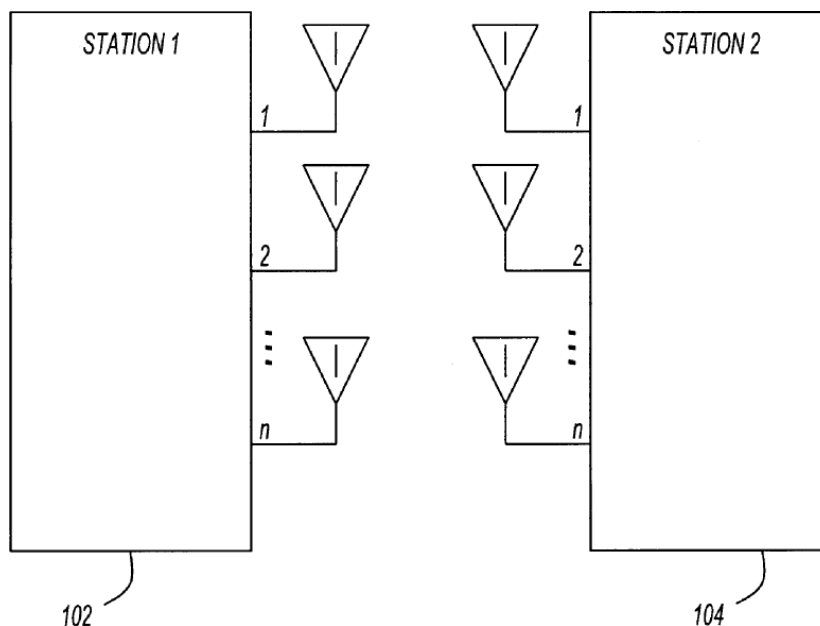


FIG. 1

EX1004 at FIG. 1.

61. Figure 4 (reproduced below) discloses a system 400 that “may be a station capable of representing beamforming matrices.” *Id.* at 9:36-40. In operation, “the system 400 “sends and receives signals using antennas 410, and the signals are processed by the various elements shown in FIG. 4.” *Id.* at 9:55-57. As shown in Figure 4, the system 400 includes a physical layer (430) that “is coupled to antennas 410 to interact with a wireless network” and includes “circuitry to support the transmission and reception of radio frequency (RF) signals,” such as “an RF receiver to receive signals and perform ‘front end’ processing.” *Id.* at 9:55-10:1. As shown in Figure 4, the system 400 also includes a media access control

(MAC) layer 440 and a processor 460 that “reads instructions and data from memory 470 and performs actions in response thereto.” *Id.* at 10:7-17.

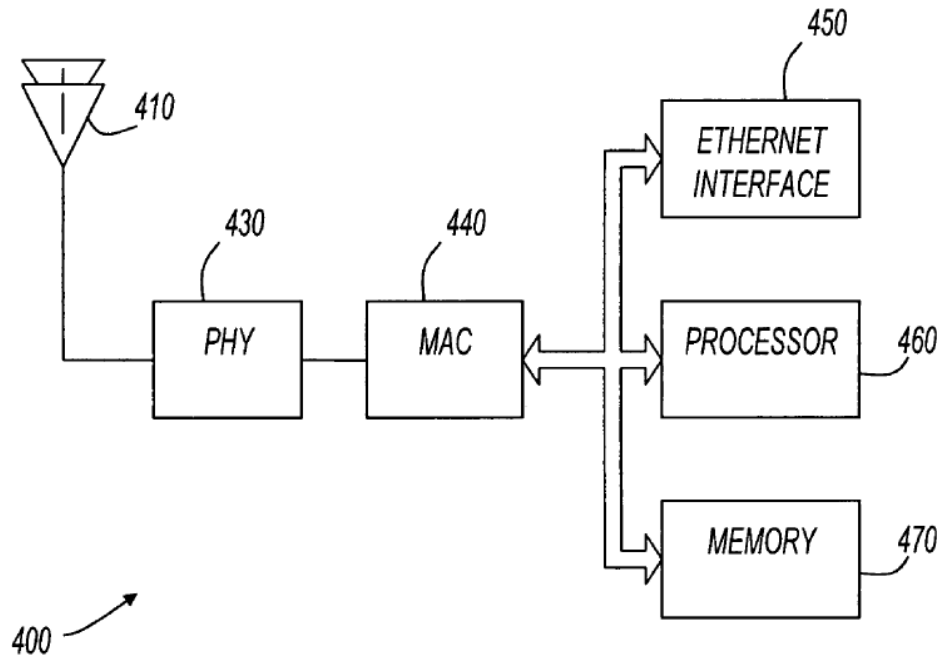


FIG. 4

Id. at FIG. 4.

62. Li '748 explains that MIMO systems, such as the ones disclosed in Li '748, “may operate either ‘open loop’ or ‘closed loop.’” *Id.* at 2:39-40. In open loop systems, “a station estimates the state of the channel without receiving channel state information directly from another station,” and instead usually “employ[s] exponential decoding complexity to estimate the channel.” *Id.* at 2:40-44. In contrast, in closed loop systems, “communications bandwidth is utilized to transmit current channel state information between stations.” *Id.* at 2:44-47. This

bandwidth is known as “feedback bandwidth.” *Id.* at 47-49. In this way, a closed loop MIMO system “reduc[es] the necessary decoding complexity” that is otherwise required in open loop systems. *Id.* at 2:44-47. “The current channel state information may be represented by an n by n unitary beamforming matrix V determined using a singular value decomposition (SVD) algorithm.” *Id.* at 2:52-54. In some implementations, after the beamforming matrix V is determined, the “receiver sends each element of the unitary matrix V back to the transmitter.” *Id.* at 2:57-59.

63. Li '748 discloses that a “transmit beamforming matrix may be found using SVD,” per the equations $H=UDV'$ and $x=Vd$, “where d is the n -vector of code bits for n data streams; x is the transmitted signal vector on the antennas; H is the channel matrix; H 's singular value decomposition is $H=UDV'$; U and V are unitary; D is a diagonal matrix with H 's eigenvalues; V is n by n , and n is the number of spatial channels.” *Id.* at 3:19-32. Specifically, Li '748 states that for the receiver to “obtain V at the transmitter, the transmitter may send training symbols to the receiver; the receiver may evaluate H , compute the matrix V' ; and the receiver may feedback parameters representing V to the transmitter.” *Id.* at 3:32-35.

64. Li '748 further teaches that “the beamforming matrix V is represented by n^2-1 real numbers instead of $2n^2$ real numbers,” so that “the feedback bandwidth [is] reduced.” *Id.* at 2:63-67.

65. Tong, titled “Closed Loop MIMO Systems and Methods,” was filed June 22, 2005 (EX1005 at cover page), prior to the earliest possible priority date (July 13, 2005) of the '862 patent. Additionally, as I explain further in Section XIII, *infra*, I understand that Tong also qualifies as prior art because it is entitled to an earlier filing date in 2004 based on its earlier-filed provisional applications. In other words, not only was Tong’s application filing date of June 22, 2005 before the '862 patent’s Critical Date of July 13, 2005, but I understand that Tong additionally qualifies as prior art on the basis of its supported priority claim to provisional applications filed in 2004.

66. Similar to Li '748, Tong is directed to “[s]ystems and methods for closed loop MIMO (multiple input and multiple output) wireless communication.” EX1005 at Abstract. As shown in Figure 1 (reproduced below), Tong discloses “a base station controller (BSC) 10 which controls wireless communications within multiple cells 12, which cells are served by corresponding base stations (BS) 14.” *Id.* at [0073]. Each “base station 14 facilitates communication using OFDM with mobile terminals 16, which are within the cell 12 associated with the corresponding base station 14.” *Id.* at [0073]. The “base station 14 generally

includes a control system 20, a baseband processor 22, a transmit circuitry 24, receive circuitry 26, multiple antennas 28, and a network interface 30,” where the “receive circuitry 26 receives radio frequency signals bearing information from one or more remote transmitters.” *Id.* at [0074]. The receive circuitry 26 of the base station 14 “receives radio frequency signals bearing information from one or more remote transmitters provided by mobile terminals 16.” *Id.* at [0074].

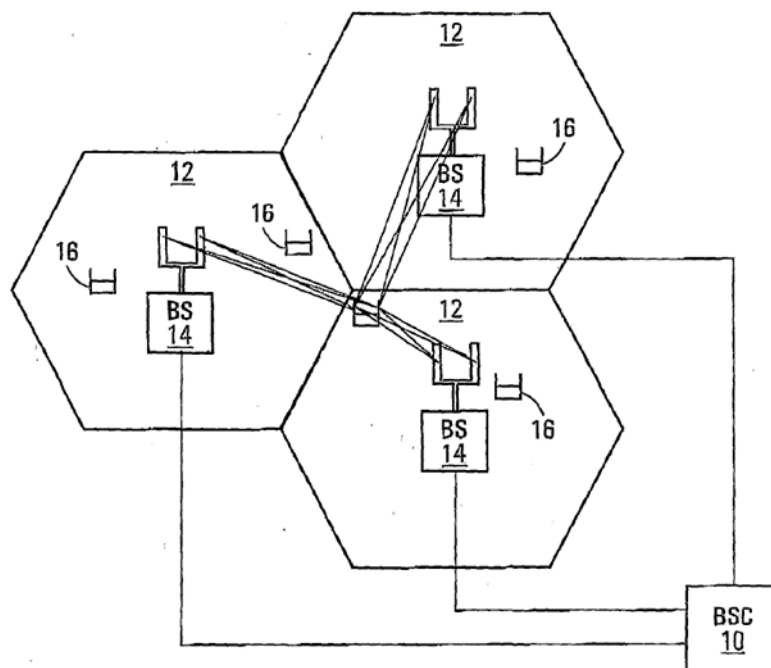


FIG. 1

Id. at FIG. 1.

67. In Figure 3 (reproduced below), “mobile terminal 16” is shown, which includes “a control system 32, a baseband processor 34, transmit circuitry 36, receive circuitry 38, multiple antennas 40, and a network interface 42.” *Id.* at [0077]. The receive circuitry 38 of the mobile terminal 16 “receives radio

frequency signals bearing information from one or more base stations 14.” *Id.* at [0077]. “Downconversion and digitization circuitry” are used to “downconvert the filtered, received signal to an intermediate or baseband frequency signal.” *Id.* at [0077].

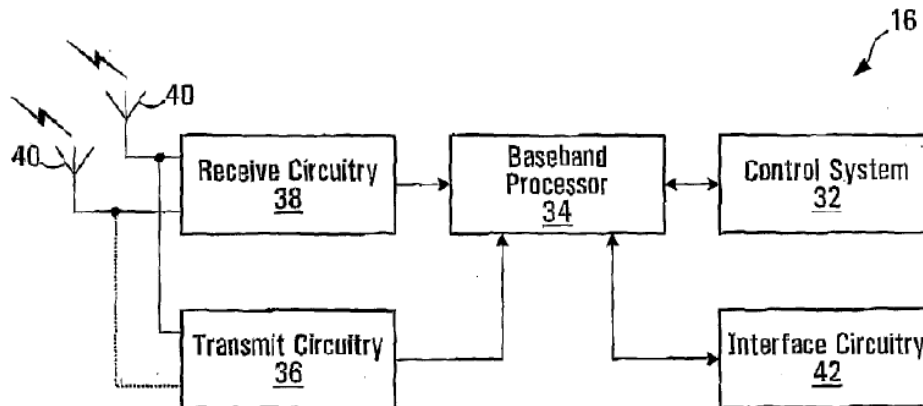


FIG. 3

Id. at FIG. 3.

68. With reference to Figure 43 (reproduced below), Tong discloses a system that includes a transmitter system with “transmit beam-former 320 with transmit antennas 322” (at left) and a receiver system (at right) that “employ[s] an SVD based Givens transform feedback.” *Id.* at [0066], FIG. 43. The receiver includes “receive antennas 324 [that] receive signals” and performs a “channel measurement” at 326, which “produces the channel matrix,” *H*. *Id.* at [0223]. An SVD operation is performed on the channel matrix *H* at 328 in order to obtain the matrix *V*. *Id.* at [0223]. After that, “the *V* matrix is decomposed by the Givens transform 330 to produce a series of matrices $G_1, G_2, \dots$.” *Id.* at [0223]. Each of

these matrices can be “uniquely represented by two parameters Θ and C .” *Id.* This data is then “fed back [to a transmitter] over the MIMO feedback channel 336.” *Id.*, [0224].

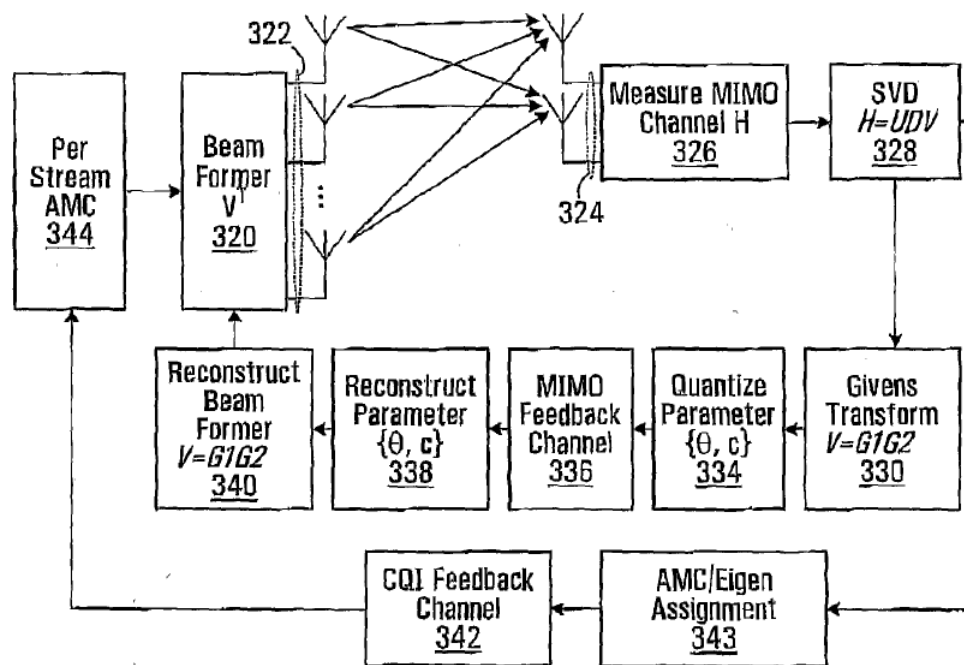


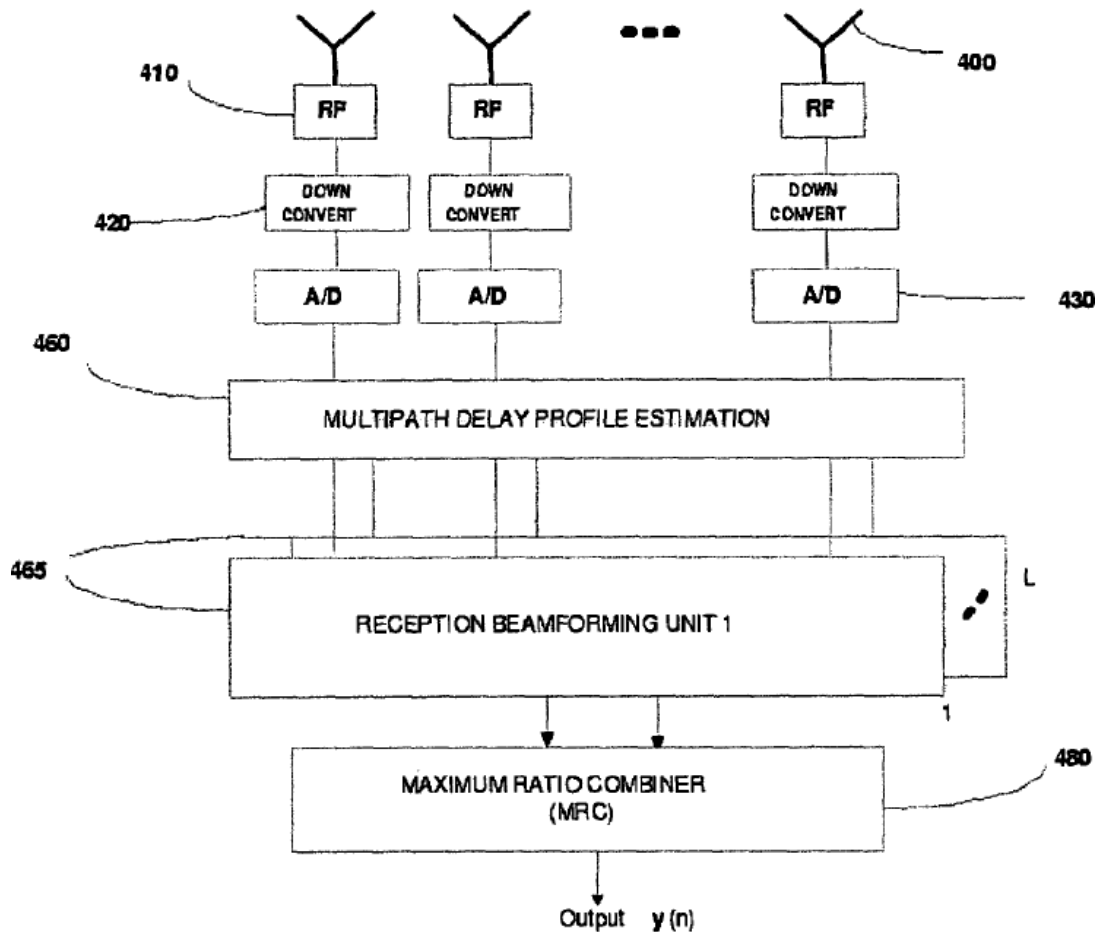
FIG. 43

Id. at FIG. 43.

69. Tong teaches that, “[a]dvantageously, for V matrix feedback, the base station is able to verify the integrity of the received matrix V by exploiting the orthogonality of the matrix.” *Id.* at [0226]. Moreover, Tong teaches that, advantageously, “[b]y decomposing the SVD-based unitary V matrix into Givens matrices, the V matrix can be represented by n^2-n independent complex parameters.” *Id.* at [0227].

70. Mao, titled “Adaptive Beam-forming System Using Hierarchical Weight Banks for Antenna Array in Wireless Communication System,” was filed March 4, 2005 (EX1006 at cover page), prior to the earliest possible priority date (July 13, 2005) of the ’862 patent. Mao is similarly directed to “adaptive beam-forming system” that uses “hierarchical weight banks for antenna arrays in wireless communication systems.” EX1006 at Abstract. In Figure 1 (reproduced below), Mao shows “a receiver beam-forming system” with “antenna elements 400” that “feed[] into a plurality of RF units 410 and down converters 420.” *Id.* at 7:34-42. The receiver beam-forming system of Mao includes A/D units 430, a multipath delay profile estimation unit 460, and beam-forming units 465. *Id.* at 7:42-57.

FIG. 1



Id. at FIG. 1.

71. Mao additionally discloses a “wireless communication system,” which may be a receiver-beamforming system, includes “a plurality of antenna elements that receive and transmit radio-frequency signals, one or more radio-frequency units and frequency converters configured to transform received RF signals to receive analog base-band signals and transform analog transmit base-band signals

into a transmit RF signals, one or more analog-to-digital converters configured to convert the receive analog baseband signals into receive digital base-band signals and one or more digital-to-analog converters configured to convert transmit digital base-band signals into transmit analog base-band signals” *Id.* at 3:28-41.

72. Based on my review of the intrinsic record of the ’862 patent, Li ’748, Tong, Mao, and my knowledge and experience in the field, it is my opinion that all the elements of claims 1-4 and 9-12 are obvious in light of the predictable combination of Li ’748, Tong, and Mao. As part of my analysis, I will address each of the elements of claims 9-12 as follows.

[1.P] and [9.P]

Claim	Claim Language
1.P	A method for feeding back transmitter beamforming information from a receiving wireless communication device to a transmitting wireless communication device, the method comprising:
9.P	A wireless communication device, comprising:

73. Li ’748 discloses a wireless communications device and method for feeding back transmitter beamforming information from the wireless communication device to a transmitting device. For example, Li ’748 discloses a wireless communication device and further discloses the methods of Figures 2-3 are “performed by a ***wireless communications device***,” as follows:

In some embodiments, method 300 may be used in, or for,
a wireless system that utilizes MIMO technology. In some

embodiments, method 300, or portions thereof, is performed by a *wireless communications device*, embodiments of which are shown in the various figures.

EX1004 at 8:60-62.

FIG. 4 shows a system diagram in accordance with various embodiments of the present invention. Electronic system 400 includes antennas 410, physical layer (PHY) 430, media access control (MAC) layer 440, Ethernet interface 450, processor 460, and memory 470. In some embodiments, electronic system 400 may be a station capable of representing beamforming matrices using generator matrices as described with reference to the previous figures. In other embodiments, *electronic system 400 may be a station that receives quantized parameters, and performs beamforming in a MIMO system.* For example, *electronic system 400 may be utilized in a wireless network as a station 102 or station 104* (FIG. 1). Also, for example, electronic system 400 may be a station capable of performing the calculations shown in any of the equations (1)-(35), above.

Id. at 9:32-46.

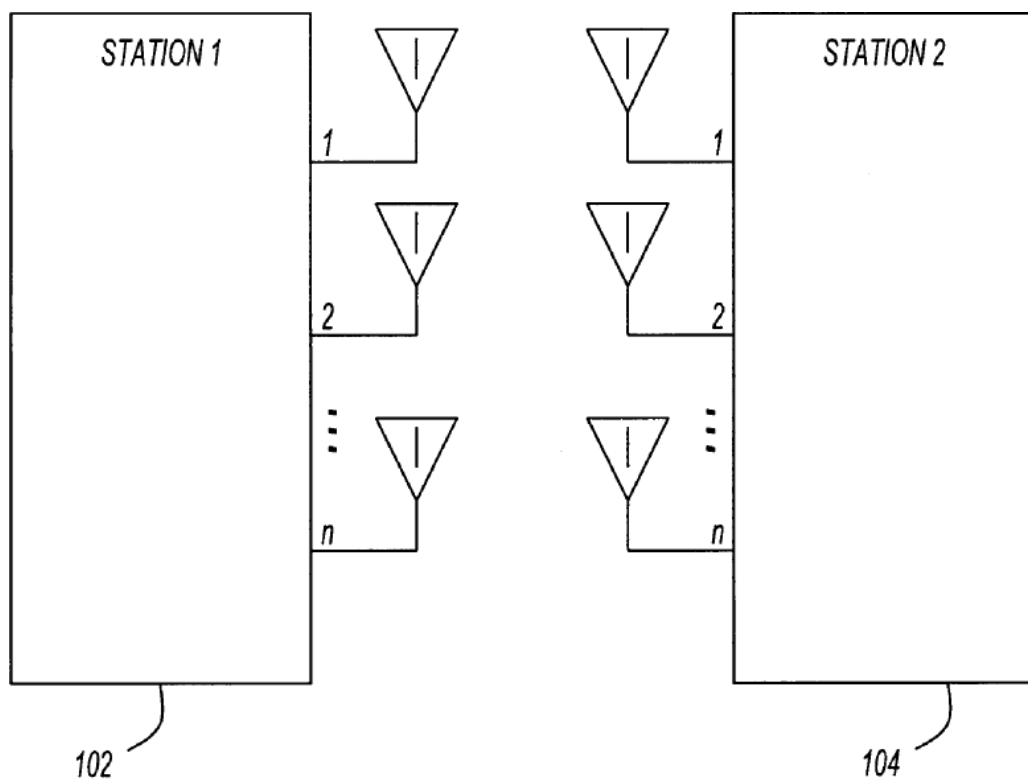


FIG. 1

Id. at FIG. 1.

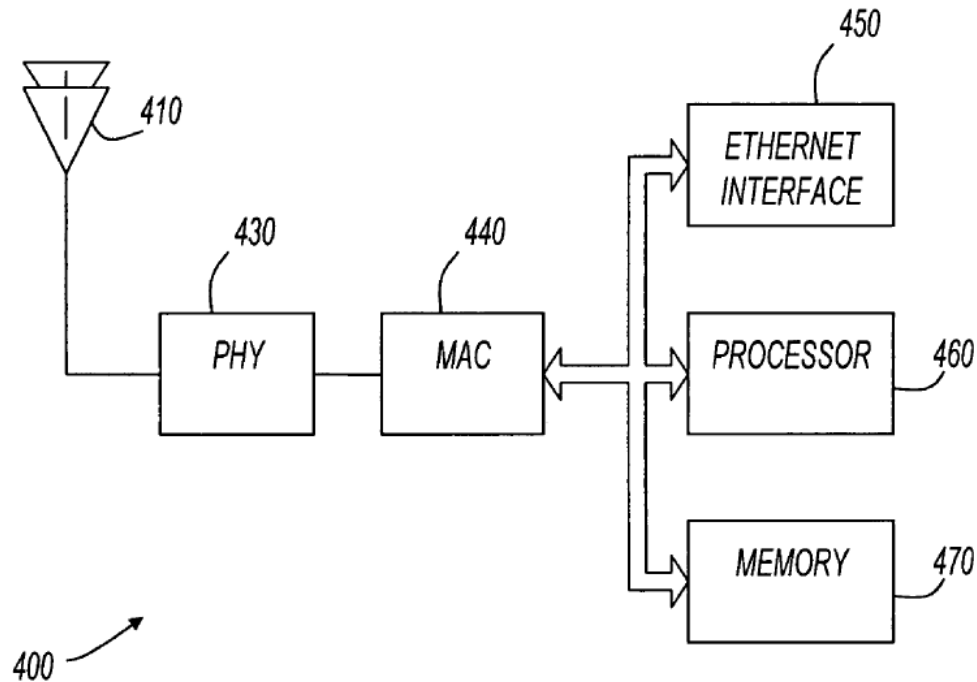


FIG. 4

Id. at FIG. 4.

[9.a]

Claim	Claim Language
9.a	a plurality of Radio Frequency (RF) components operable to receive an RF signal and to convert the RF signal to a baseband signal; and

74. Li '748 in view of Tong discloses a plurality of Radio Frequency (RF) components operable to receive an RF signal and to convert the RF signal to a baseband signal.

75. First, based upon my analysis of Li '748's device, it is my opinion that Li '748 alone teaches, or at least suggests, this element. Li '748 discloses that its

device includes an RF receiver that receives RF signals and performs processing on those signals:

In operation, system 400 sends and *receives signals using antennas 410*, and the signals are processed by the various elements shown in FIG. 4. Antennas 410 may be an antenna array or any type of antenna structure that supports MIMO processing. System 400 may operate in partial compliance with, or in complete compliance with, a wireless network standard such as an 802.11 standard.

Id. at 9:55-61.

Physical layer (PHY) 430 is coupled to *antennas 410* to interact with a wireless network. *PHY 430 may include circuitry to support the transmission and reception of radio frequency (RF) signals*. For example, in some embodiments, PHY 430 includes an *RF receiver to receive signals and perform “front end” processing* such as low noise amplification (LNA), filtering, *frequency conversion* or the like. Further, in some embodiments, PHY 430 includes transform mechanisms and beamforming circuitry to support MIMO signal processing. Also for example, in some embodiments, PHY 430 includes circuits to support frequency up-conversion, and an RF transmitter.

Id. at 9:62-10:6.

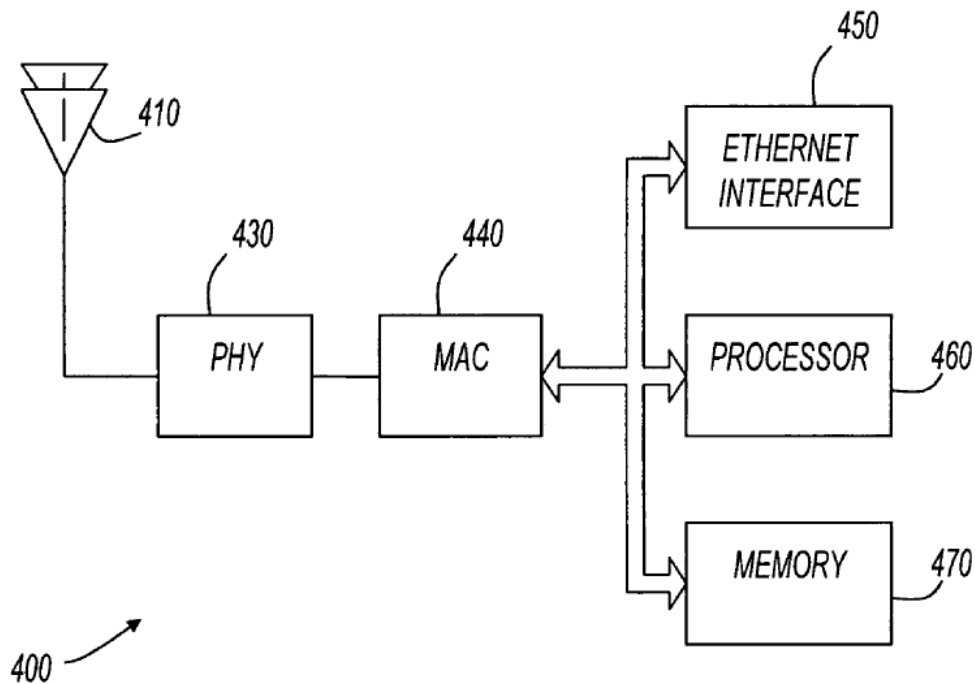


FIG. 4

Id. at FIG. 4.

76. Based upon these teachings in Li '748, a POSITA would have recognized that Li '748's antennas and RF receiver (and its conventional circuits) provided "a plurality of radio frequency (RF) components are operable to receive an RF signal," as was conventional at the time. Moreover, Li '748's teaching here confirms that the "front end" processing performed by Li '748's RF receiver would have included conventional RF-to-baseband conversion. Indeed, a POSITA would have understood that such conversion was necessary, or at least the most ubiquitous and predictable manner, for these conventional receiving devices to be

able to take the analog radio frequency (RF) signals incident on the antennas, downconvert them to a lower frequency where they can be more easily managed and digitized, and then further process the received signals as a digital baseband signal. Based upon my knowledge and experience in this field and my review of Li '748, a POSITA would have understood that such conversion from RF to baseband was necessary in Li '748's device in order for the digital baseband circuitry to perform signal processing on the received signal, such as, for example, to estimate a channel matrix. For at least these reasons, Li '748 teaches or suggests this element [9.a].

77. Next, to the extent Li '748 does not explicitly describe that its RF components operate "to receive an RF signal and to convert the RF signal to a baseband signal," this functionality was commonplace in such wireless devices, as demonstrated by Tong's teaching. Tong discloses a wireless communications device that includes receive circuitry that receives RF signals and converts those signals to baseband signals:

For purposes of providing context for the embodiments described below, an example OFDM system will now be described with reference to FIGS. 1 to 5. FIG. 1 shows a base station controller (BSC) 10 which controls *wireless communications* within multiple cells 12, which cells are served by corresponding base stations (BS) 14. In general, each base station 14 facilitates *communications using OFDM* with

mobile terminals 16, which are within the cell 12 associated with the corresponding base station 14. The movement of the mobile terminals 16 in relation to the base stations 14 results in significant fluctuation in channel conditions. As illustrated, *the base stations 14 and mobile terminals 16 may include multiple antennas to provide spatial diversity for communications.*

EX1005 at [0073].

With reference to FIG. 3, a mobile terminal 16 configured according to one embodiment of the present invention is illustrated. Similar to the base station 14, the mobile terminal 16 will include a control system 32, a baseband processor 34, transmit circuitry 36, *receive circuitry 38*, multiple antennas 40, and user interface circuitry 42. The *receive circuitry 38 receives radio frequency signals* bearing information from one or more base stations 14. Preferably, a low noise amplifier and a filter (not shown) cooperate to amplify and remove broadband interference from the signal for processing. *Downconversion* and digitization *circuitry* (not shown) will then *downconvert the filtered, received signal to* an intermediate or *baseband frequency signal*, which is then digitized into one or more digital streams.

Id. at [0077].

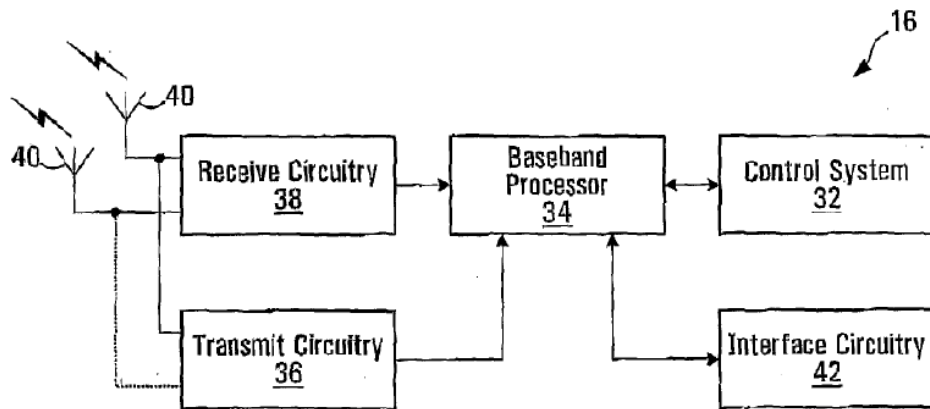


FIG. 3

Id. at FIG. 3.

78. Based on my knowledge and experience in this field and my review of Li '748 and Tong, it would have been obvious to a POSITA to implement the wireless device of Li '748 in a manner suggested by Tong so as to be operable to receive an RF signal and then convert the RF signal into a baseband signal. In context, a POSITA would have recognized Li '748's conventional wireless device included an RF receiver that received RF signals and performed frequency conversions. EX1004 at 9:55-10:6. Also, Tong confirmed what a POSITA would have already known—namely, that such a conventional wireless device (having receiver circuitry to receive RF signals) predictably used downconversion circuitry to convert the RF signals to baseband signals. EX1005 at [0073], [0077]. Indeed, based upon my knowledge and experience in this field, Tong corroborates the known fact that this type of RF-to-baseband conversion circuitry was ubiquitous in wireless communications devices at the time. Here, a POSITA would have

recognized that the predictable implementation of Li '748 (in a manner suggested by Tong) would have predictably provided a wireless device that would convert the received RF signals to baseband signals to efficiently and properly prepare for a digital conversion (to a digital signal) for processing by the digital electronics of Li '748's device. Additionally, for the reasons explained above, my analysis of Li '748 confirms that such circuitry was in fact necessary in order for Li '748's device to perform further processing using its digital electronics/processing.

79. Thus, Tong teaches implementing wireless communications devices, such as the device in Li '748, to include circuitry that receives RF signals and circuitry that converts the received RF signals to baseband signals. Moreover, based upon the overwhelming similarities of Li '748 and Tong and the ordinary knowledge of a POSITA at the time, the typical application of Tong's suggestion (receiving an RF signal and subsequently converting the RF signal to a baseband signal) to Li '748's wireless device would have led to predictable results without significantly altering or hindering the functions of Li '748's wireless device. In addition, a person of ordinary skill would have found Tong's conversion techniques obvious to try in the context of Li-748 because Tong's approach was just one of a finite number of solutions for receiving and processing Li-748's signals. A POSITA would have found this solution predictable and likely to

succeed at least because Tong's RF conversion techniques were long used in wireless device like those of Li-748.

[9.b]

Claim	Claim Language
9.b	a baseband processing module operable to:

80. Li '748 discloses and/or renders obvious a baseband processing module, as follows:

FIG. 4 shows a system diagram in accordance with various embodiments of the present invention. Electronic system 400 includes antennas 410, physical layer (PHY) 430, media access control (MAC) layer 440, Ethernet interface 450, ***processor 460, and memory 470***. In some embodiments, electronic system 400 may be a station capable of representing beamforming matrices using generator matrices as described above with reference to the previous figures. In other embodiments, electronic system 400 may be a station that receives quantized parameters, and performs beamforming in a MIMO system. For example, electronic system 400 may be utilized in a wireless network as station 102 or station 104 (FIG. 1). Also for example, electronicsystem 400 may be a station capable of performing the calculations shown in any of the equations (1)-(35), above.

EX1004 at 9:33-46.

In operation, ***processor 460 reads instructions and data***

from memory 470 and performs actions in response thereto. For example, processor 460 may access instructions from memory 470 and perform method embodiments of the present invention, such as method 200 (FIG. 2) or method 300 (FIG. 3) or methods described with reference to other figures. Processor 460 represents any type of processor, including but not limited to, a microprocessor, a digital signal processor, a microcontroller, or the like.

Id. at 10:16-22.

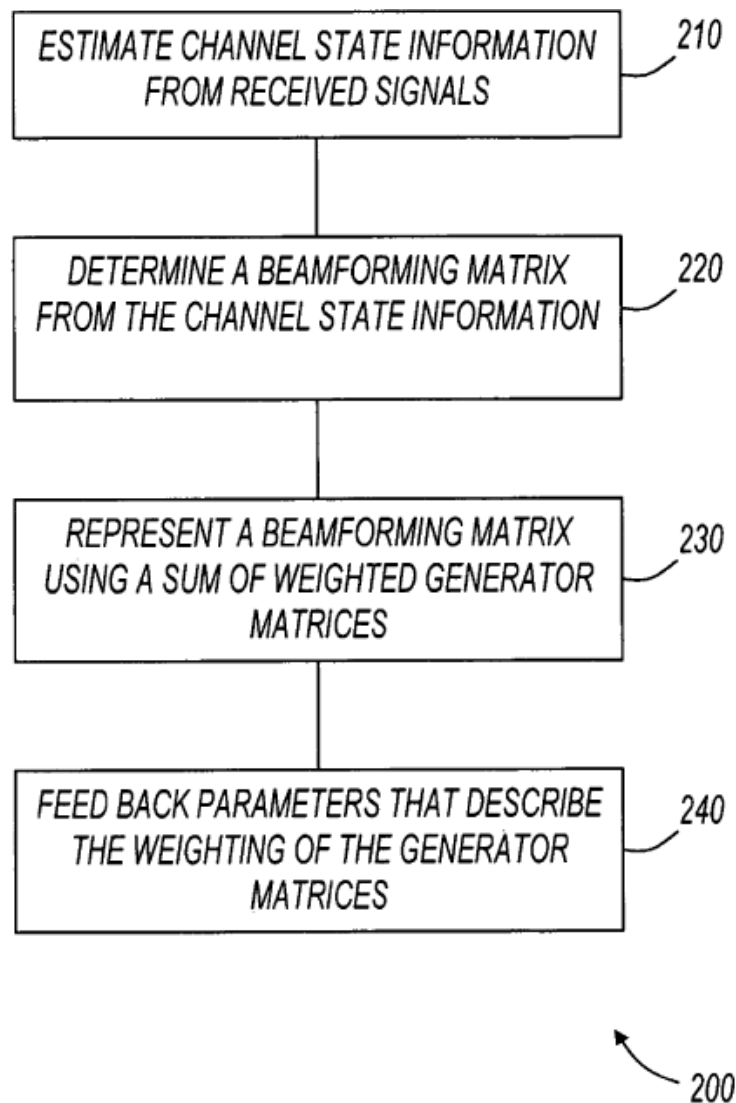


FIG. 2

Id. at FIG. 2.

81. Based upon this teaching in Li '748, a POSITA would have recognized that Li '748's processor and memory provided a baseband processing module, which was widely common in such wireless communication devices at the time. Indeed, Li '748 specifically states that its "processor 460 reads instructions and data from memory 470" and "perform[s] method embodiments of the present invention, such as method 200 (FIG. 2)." *Id.* at 16-20. Indeed, as further explained below, I note that the steps in Figure 2 of Li '748 (reproduced above) are essentially the same the steps performed by the baseband processing module of the '862 patent.

[1.a.] and [9.c]

Claim	Claim Language
1.a	the receiving wireless communication device receiving a preamble sequence from the transmitting wireless device;
9.c	receive a preamble sequence carried by the baseband signal

82. Li '748 discloses that its baseband processing module is operable to receive a preamble sequence carried by the baseband signal, as follows:

To obtain V at the transmitter, the transmitter may send ***training symbols to the receiver***; the receiver may evaluate H , compute the matrix V' ; and the receiver may feedback parameters representing V to the transmitter.

Id. at 3:31-34.

... the feedback angles are computed by the *receiver that received channel training symbols*. After the angles are computed, the *receiver feeds back the angles to the transmitter of training symbols*.

Id. at 4:20-24. Li-748 explains that “channel state information is estimated from *received signals*.” *Id.* at 8:4-7 (emphasis added), Fig. 2.

83. Based upon Li '748's teaching here, a POSITA would have recognized that the “training symbols” of Li '748 are signals that the receiver uses to determine a channel response (e.g., matrix H) and beamforming matrix V. Similarly, the “preamble” of the '862 patent is received by a “receiving wireless communication device,” which then estimates the channel response and “determines an estimated transmitter beamforming unitary matrix (V).” EX1001 at 13:37-47. Indeed, the '862 patent specifically states that “[e]stimating the channel response includes comparing *received training symbols of the preamble* to corresponding expected training symbols using any of a number of techniques that are known in the art.” *Id.* at 13:40-44. That is, the “preamble” disclosed in the '862 patent includes essentially the same type of traditional “training symbols” (as disclosed in Li '748) to estimate the channel response and determine the beamforming matrix, and a POSITA would have recognized this similarity because it was a customary practice at the time in such wireless

devices. Thus, Li '748 discloses receiving a preamble sequence carried by the baseband signal.

[1.b] and [9.d]

Claim	Claim Language
1.b	the receiving wireless device estimating a channel response based upon the preamble sequence;
9.d	estimate a channel response based upon the preamble sequence

84. Li '748 discloses Li-748's baseband processing module is operable to estimate a channel response based upon the preamble sequence. For example:

Method 200 is shown beginning at block 210 in which *channel state information is estimated from received signals.*

The *channel state information may include the channel state matrix H* described above.

EX1004 at 8:4-7. This is also depicted in Figure 2 (below) of Li '748:

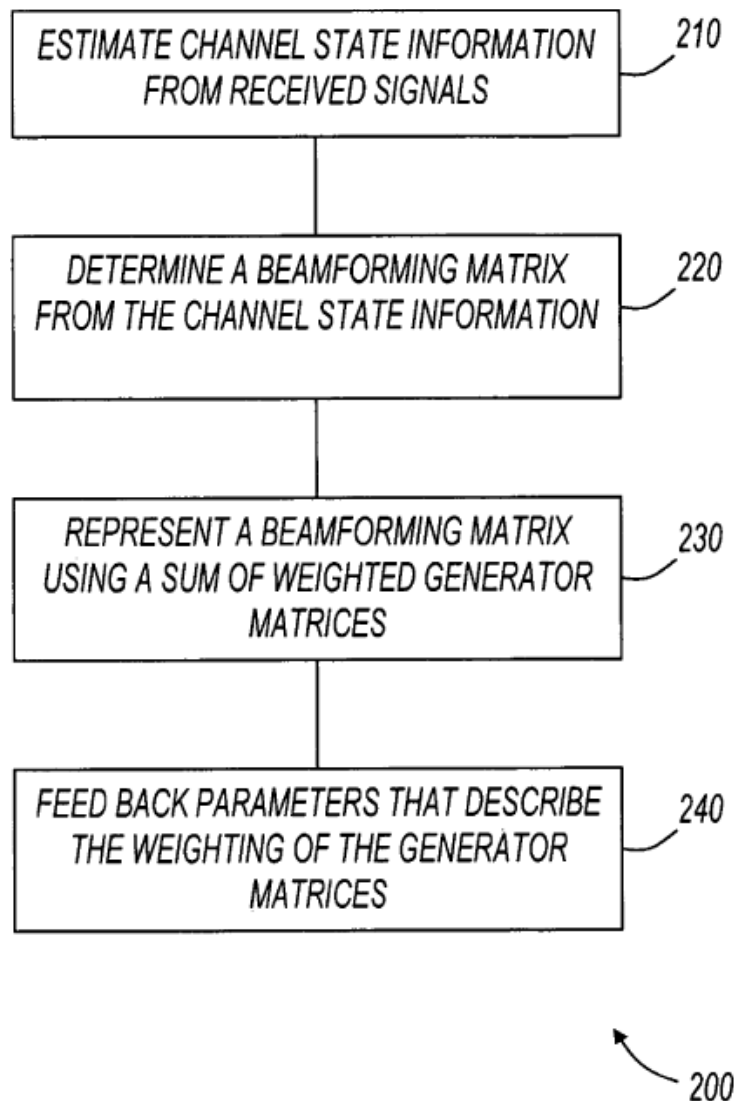
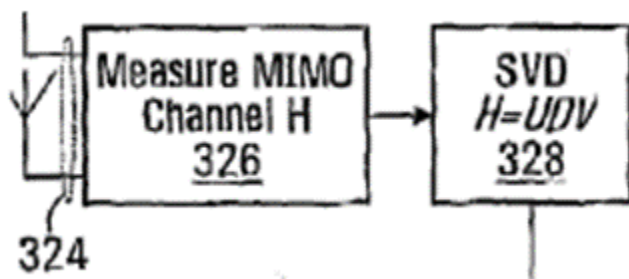


FIG. 2

Id. at FIG. 2.

85. As explained, *supra*, in Section VI.D, a POSITA would have understood that “the channel state matrix H ” (col. 8:4-7) was a conventional “channel response.” In addition, it would have been obvious to implement Tong’s approach into Li-748’s device. For example, as I explain below, ¶¶115-116. Tong’s “*pilot symbols*” are received by a receiver from a transmitter, and the

“MIMO channel H is measured,” or estimated, by the receiver based on the pilot symbols. EX1005, [0211], [0087], [0090] (“actual and interpolated channel responses are used to estimate an overall channel response”). Tong states that “[a]t the receiver, receive antennas 324 receive signals, and the channel measurement is performed at 326,” which “*produces the channel matrix,*” matrix H that is then “SVD decomposed at 328,” when discussing Figure 43. *Id.*, [0223]



Ex1005, Fig. 43 (excerpted),

[1.c] and [9.e]

Claim	Claim Language
1.c	the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U);
9.e	determine an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U)

86. Li '748 discloses that its baseband processing module is operable to determine an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U). For example, Li '048 confirms this conventional determination as follows:

A *transmit beamforming matrix* may be found using SVD as follows:

$$H=UDV' \quad (1)$$

$$X=Vd \quad (2)$$

where d is the n -vector of code bits for n data streams; x is the transmitted signal vector on the antennas; ***H is the channel matrix***; H 's singular value decomposition is $H=UDV'$; ***U and V are unitary***; D is a diagonal matrix with H 's eigenvalues; V is n by n , and n is the number of spatial channels. ***To obtain V at the transmitter***, the transmitter may send training symbols to the receiver; ***the receiver may evaluate H, compute the matrix V'***; and the receiver may feedback parameters representing V to the transmitter. As described more fully below, the number of feedback parameters used to represent V may be reduced by representing the beamforming matrix using a weighted sum of orthogonal generator matrices.

Id. at 3:19-39.

87. As explained, *supra*, in Section VI.D, a POSITA would have recognized from Li '048's teaching and conventional notation that the "U" in the equation " $H=UDV$ " was a receiver beamforming unitary matrix.

[1.d.] and [9.f]

Claim	Claim Language
1.d	the receiving wireless device decomposing the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information; and
9.f	decompose the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information; and

88. Li '748 alone or in view of Tong provided a baseband processing module operable to decompose the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information. First, Li '748 teaches or suggests this element by explaining:

the *beamforming matrix V is represented by n^2-1 real numbers instead of $2n^2$ real numbers*. By sending n^2-1 real numbers instead of $2n^2$ real numbers to represent the beamforming matrix, the *feedback bandwidth may be reduced*.

Id. at 2:63-67.

As described more fully below, the number of feedback parameters used to represent V *may be reduced* by representing the beamforming matrix using a weighted sum of orthogonal generator matrices.

Id. at 3:35-39.

89. Based upon the teachings of Li '748, a POSITA would have understood Li '748 described a reduction (i.e., decomposition) of the transmit beamforming matrix V , and indeed, my analysis of Li '748 confirms that it describes such a reduction (i.e., decomposition) just like the '862 patent. *See* EX1001 at 13:67-14:3. In this way, Li '748 confirms this element of the '862 patent merely recites the then-common practice of decomposing the transmit beamforming matrix V .

90. Next, to the extent Li '748 does not explicitly describe that its RF components that the RF components “decompose” the estimated transmitter beamforming unitary matrix (V) as recited in this element [9.f], a POSITA would have recognized that this operation was normally implemented in such wireless devices, as demonstrated by Tong’s teaching. Tong clearly teaches the traditional operation of “decomposing” the transmit beamforming matrix V , as follows:

An example of a system employing Givens feedback is shown FIG. 43. Shown is a transmit beam-former 320 with transmit antennas 322. At the receiver, receive antennas 324 receive signals, and the channel measurement is performed at 326. This produces the channel matrix which is then SVD decomposed at 328. Next, *the V matrix is decomposed by the Givens transform 330 to produce a series of matrices $G_1, G_2, \dots$, the number of matrices being required being a function of the size of the channel matrix. Each such Givens matrix can then be uniquely represented by two parameters θ and C .* These parameters are selected at 332 and differentially quantized at 334.

EX1005 at [0223].

By *decomposing the SVD-based unitary V matrix* into Givens matrices, *the V matrix can be represented by $n^2 - n$ independent complex parameters.*

Id. at [0227].

FIG. 43 is a block diagram of a system employing an SVD

based Givens transform feedback in accordance with an embodiment of the invention[.]

Id. at [0066].

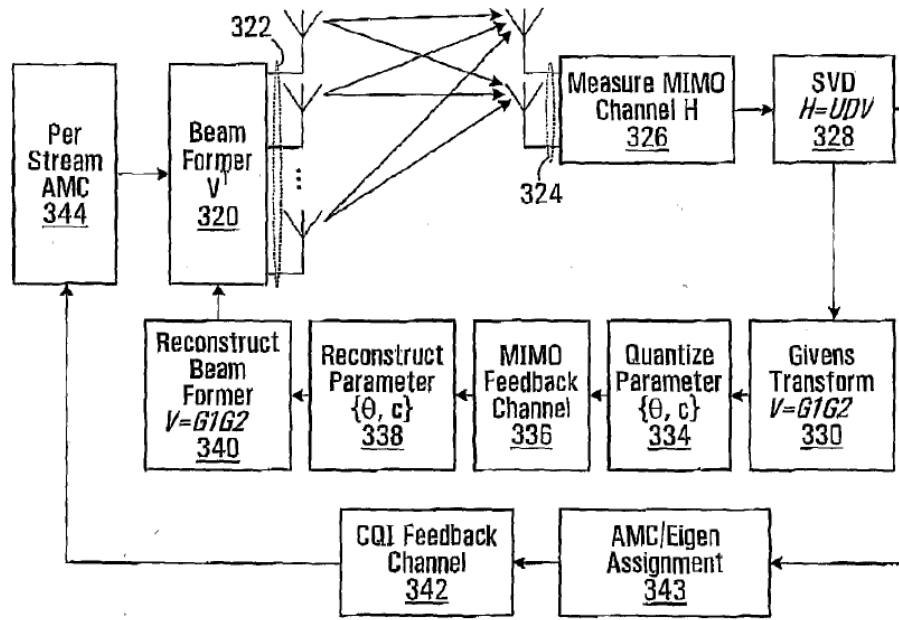


FIG. 43

Id. at FIG. 43. Based upon my knowledge and experience in this field and my analysis of the Tong reference, it is my opinion that a POSITA in possession of Li-748 would have recognized that Tong’s suggestion for using a Givens rotation to decompose matrix V was a common practice at the time—and Tong described known benefits for doing so. *Id.* at [0222] (“reduce the amount of feedback required”). I note that Tong’s suggestion for using a “Givens transform” is the same as the alleged solution set forth in the example of the ’862 patent. *See* EX1001, 13:58-67 (“Givens Rotation”).

91. Based on my knowledge and experience in this field and my review of Li '748 and Tong, it would have been obvious to a POSITA to implement the wireless device of Li '748 in a manner that uses Tong's suggestion for a Givens-rotation based decomposition. First, a POSITA would have been prompted to do so to beneficially achieve a wireless device that reduces feedback bandwidth by decomposing matrix V . This known benefit was expressly described in Tong, which explained that the " V matrix can be decomposed" in parameters that "can be fed back directly, or differentially and/or quantized to potentially *reduce the amount of feedback required*." EX1005 at [0222]. As such, a POSITA would have been motivated to implement Li '748's wireless device to perform a Givens rotation as taught by Tong to decompose the beamforming matrix V to reduce feedback as Li-748 discloses. Second, a POSITA would have been motivated to implement the wireless device of Li '748 based on Tong's suggestion (for performing a Givens rotation to decompose matrix V) in order to advantageously allow the received data to be "verified." *Id.* at [0226]. In particular, Tong suggests this benefit by explaining that "[a]dvantageously, for V matrix feedback, the base station is able to verify the integrity of the received matrix V by exploiting the orthogonality of the matrix." *Id.* at [0226]. Thus, the combination of Li '748 and Tong would have advantageously and predictably allowed a base station (e.g., transmitter) that receives the transmitter beamforming information from the

wireless device of Li '748 to “verify the integrity of the received matrix V.” *Id.*

Finally, given the overlapping similarities in the teachings of Li '048 and Tong (and Tong's suggested improvement), a POSITA would have recognized that applying Tong's suggestion (decomposition matrix V using a conventional Givens rotation) to the wireless device of Li '748 would have led to predictable results without significantly altering or hindering the functions performed by Li '748's wireless device. As such, it would have been obvious to a POSITA to implement Li '748's wireless device in light of Tong's suggestion of decomposing the beamforming matrix V using a conventional Givens rotation.

[1.e] and [9.g]

Claim	Claim Language
1.e	the receiving wireless device wirelessly sending the transmitter beamforming information to the transmitting wireless device.
9.g	form a baseband signal employed by the plurality of RF components to wirelessly send the transmitter beamforming information to the transmitting wireless device

92. Li '748 in view of Tong and Mao renders obvious that its baseband processing module is operable to form a baseband signal employed by the plurality of RF components to wirelessly send the transmitter beamforming information to the transmitting wireless device. First, based upon Li '748's teachings regarding the receiver providing feedback to the transmitter, a POSITA would have recognized that Li '748's device “formed a baseband signal employed by the plurality of RF components to wirelessly send . . . beamforming information”—a

ubiquitous operation in such wireless devices at the time (as I explained above). For example, Li '748 discloses:

To obtain V at the transmitter, the transmitter may send training symbols to the receiver; the receiver may evaluate H , compute the matrix V' ; and *the receiver may feedback parameters representing V to the transmitter*. As described more fully below, the number of feedback parameters used to represent V may be reduced by representing the beamforming matrix using a weighted sum of orthogonal generator matrices.

EX1004 at 3:31-39. Also, step 240 of Figure 2 (below) shows such parameters that are fed back:

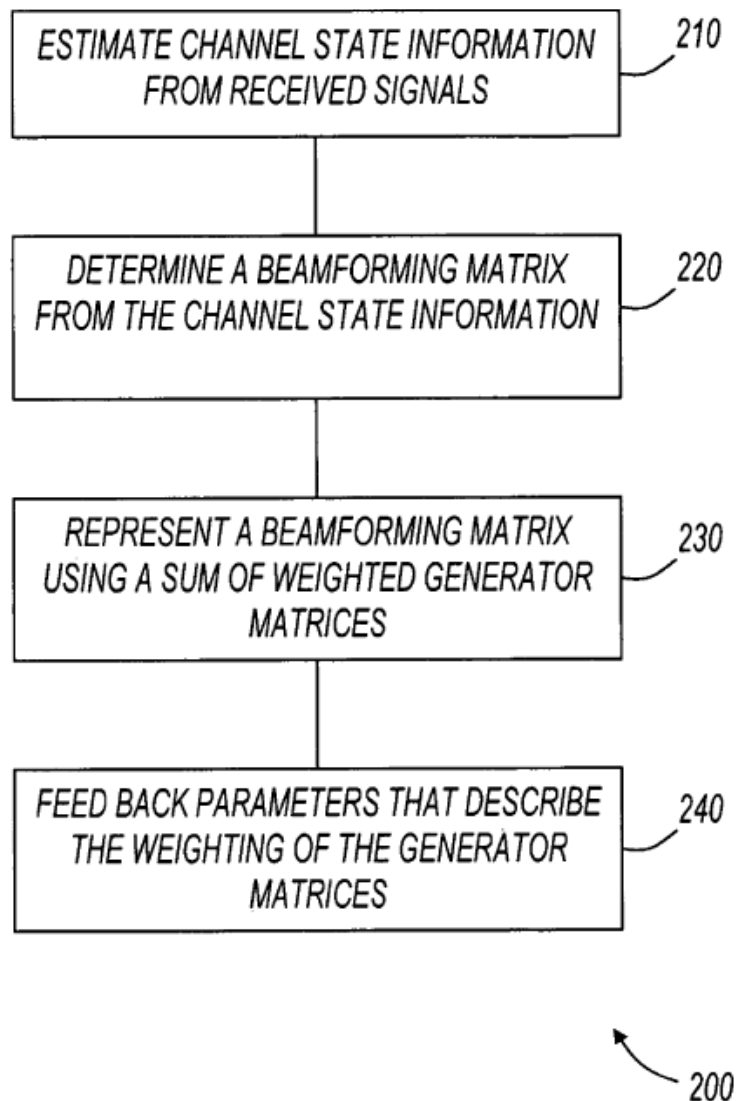


FIG. 2

Id. at FIG. 2.

93. A POSITA would have recognized from Li '748's teachings (relating to the receiver providing feedback parameters representing V to the transmitter) that Li '748's wireless device "formed a baseband signal" as recited in this element [9.g], for purposes of communicating to the RF transmitter. Indeed, a POSITA

would have known that such a step was ubiquitously performed in wireless phones having RF transmitters at that time.

94. Next, to the extent Li '748 alone does not explicitly describe that the wireless device would “form a baseband signal” as recited in this Element [9.g], such a step of “form[ing] a baseband signal employed by the plurality of RF components to wirelessly send” the data to the transmitter was normally used by similar wireless devices, as demonstrated by both Tong and Mao. For example, Tong discloses converting data for transmission as follows:

For *transmissions* the baseband processor 34 receives digitized data, which may represent voice, data, or control information, from the control system 32, which it encodes for transmission. The encoded data is output to the transmit circuitry 36, where it is used by a *modulator to modulate a carrier signal that is at a desired transmit frequency or frequencies*

EX1005 at [0079].

Each of the resultant signals is up-converted in the digital domain to an intermediate frequency and converted to an analog signal via the corresponding digital up-conversion (DUC) and digital-to-analog (D/A) conversion circuitry 66. *The resultant (analog) signals are then simultaneously modulated at the desired RF frequency, amplified, and transmitted via the RF circuitry 68 and antennas 28.*

Id. at [0087].

95. Based on Tong’s disclosure, a POSITA would have recognized that the “resultant (analog) signals” (which were upconverted, converted to analog signals, and modulated to a desired RF frequency) were ordinary “baseband signals” generated by the baseband processor in Tong’s wireless device. Tong discloses that these baseband signals are employed by a plurality of RF components (RF circuitry including up-conversion and digital-to-analog conversion circuitry, amplifiers, antennas, etc.) to wirelessly send the transmitter beamforming information to the transmitting wireless device. For the same reasons I previously articulated in connection with Element [9.a], a POSITA would have been prompted to implement the wireless device of Li ’748 to form baseband signals, as suggested by Tong, to achieve known benefits at the time, including advantageously and customarily converting between baseband, digital, analog, and RF signals (and vice versa). *Supra*, ¶¶76-78.

96. A POSITA would also have found it obvious to implement Mao’s teachings into the combination of Li-748 and Tong. Mao confirms that such wireless devices would ordinarily form baseband signals that are converted to RF signals for sending databack to the transmitter, as follows:

In one embodiment, the present invention provides a wirelesscommunication system, comprising an antenna array structure having a plurality of antenna elements that receive and *transmit radio-frequency signals*, one or more *radio-*

frequency units and frequency converters configured to transform received RF signals to receive analog base-band signals and transform analog transmit base-band signals into a transmit RF signals, one or more analog-to-digital converters configured to convert the receive analog base-band signals into a receive digital base-band signals and one or more digital-to-analog converters configured to convert transmit digital base-band signals into transmit analog base-band signals.

EX1006 at 3:28-41.

The transmission beam-forming system includes an antenna array system and a *plurality of RF units which may be shared with the receiver beam-forming system, a plurality of up-converters which transform base-band signals into RF signals*, a plurality of digital-to-analog (D/A) conversion units which convert the digital signals to analog signals, and a transmit beam-forming unit.

Id. at 6:31-38. Here, Mao describes the traditional and ubiquitous practice of forming “base-band signals” for conversion into RF signals. Accordingly, even if Tong does not expressly use the phrase “form a baseband signal,” a POSITA would have been motivated to modify Li-748’s device with Mao’s clear teaching of the conventional practice of forming “base-band signals” as recited in element [9.g] and as related to [9.a].

97. Based on my knowledge and experience in this field and my review of Li '748, Tong, and Mao, it would have been obvious to a POSITA to implement the wireless device of Li '748 in a manner suggested by Mao (to form a baseband signal employed by the plurality of RF components) in order to properly send data to the transmitter for wireless transmission. Indeed, this predictable implementation of Li '748 would have provided a wireless device that would advantageously convert a digital signal (processed by the wireless device's circuitry) into a baseband signal for purposes of properly preparing the signal for transmission back to the transmitter—a practice that was conventional at the time. Indeed, Mao confirms the customary usage of “a plurality of up-converters which transform base-band signals into RF signals.” *Id.* at 6:34-35. Moreover, given the noticeable overlap and similarities in the teachings of Li '048, Tong, and Mao for converting the digital signal to an RF signal usable by the RF transmitter, a POSITA would have recognized that applying Mao's suggestion (forming “base-band signals” for purposes of sending data to the transmitter for wireless RF transmission) to Li '748's device would have led to predictable results without significantly altering or hindering the functions performed by Li '748's wireless device.

[2] and [10]

Claim	Claim Language
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2	The method of claim 1 wherein the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U) comprises: the receiving wireless device producing the estimated transmitter beamforming unitary matrix (V) in Cartesian coordinates; and the receiving wireless device converting the estimated transmitter beamforming unitary matrix (V) to polar coordinates.
10	The wireless communication device of claim 9, wherein in determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U), the baseband processing module is operable to: produce the estimated transmitter beamforming unitary matrix (V) in Cartesian coordinates; and convert the estimated transmitter beamforming unitary matrix (V) to polar coordinates.

98. Li '748 in view of Tong teaches wherein in determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U), the baseband processing module is operable to: produce the estimated transmitter beamforming unitary matrix (V) in Cartesian coordinates; and convert the estimated transmitter beamforming unitary matrix (V) to polar coordinates. For example, Li '748 discloses:

In some embodiments of the present invention, the beamforming matrix V is represented by n^2-1 real numbers instead of $2n^2$ real numbers. By sending n^2-1 real numbers instead of $2n^2$ real numbers to represent the beamforming matrix, the feedback bandwidth may be reduced.

EX1004 at 2:63-67.

A *transmit beamforming matrix* may be found using SVD

as follows:

$$H=UDV' \quad (1)$$

Id. at 3:19-23. Li-748 also describes “hermitian generator matrices . . . utilized to represent the beamforming matrix” where the numbers are “angles from $-\pi$ to π of an (n^2-1) -dimension polar coordinate . . .”) *Id.* at 3:5-11. A POSITA would have understood that Li-748 here referred to producing a beamforming matrix V in cartesian coordinates before converting it to polar coordinates.

99. Moreover, to the extent Li-748 alone or in view of the knowledge of a POSITA does not disclose this limitation, it would have been obvious to implement the teachings of Tong into the device of Li-748. Such a feature of producing the transmitter beamforming unitary matrix (V) in Cartesian coordinates and then converting them into polar coordinates was common and well known, as confirmed by Tong. For example, with reference to Figure 43, Tong discloses, “employing an SVD based Givens transform feedback.” EX1005 at [0066]. Specifically, Tong discloses that “the V matrix is decomposed by the Givens transform 330 to produce a series of matrices $G_1, G_2, \dots$,” and “[e]ach such Givens matrix can then be uniquely represented by two parameters θ and C .” *Id.* at [0223]. Tong explains that because “an $n \times n$ V matrix can be decomposed into Givens matrices containing n^2-n complex parameters,” the “amount of feedback required” can advantageously be reduced. *Id.* at [0222]. A POSITA would have recognized

from Tong's teaching that "series of matrices $G_1, G_2, \dots$ " are matrices which have been converted from their original Cartesian coordinates to polar coordinates for at least two reasons. First, Tong teaches that "each such Givens matrix" can be "represented by two parameters θ and C "—a POSITA would have recognized that these two parameters are the traditional polar coordinate representations of the angle and distance, respectively. Second, a POSITA would have recognized that Tong's teaching that the "Givens matrices contain n^2-2 complex parameters" further indicates that the Givens matrices were produced in polar coordinates, which was normal practice at the time. Moreover, a POSITA would have understood that to perform the Givens rotation decomposition on the beamforming matrix V and "produce a series of matrices represented by "two parameters θ and C ," as Tong suggests, one would necessarily need to convert matrix V from Cartesian coordinates to polar coordinates.

100. POSITA would have understood these Li-748 and Tong disclose producing a beamforming matrix V in cartesian coordinates before converting it to polar coordinates. For example, Yang (EX1008) demonstrates the well-known technique of converting Cartesian coordinates to polar coordinates. A POSITA would have understood these concepts and their application to same technology and field of use described by Li-748 and Tong. Yang relates to a "method for computing two-sided rotations involved in singular value decomposition (SVD)"

that “leads to significantly reduced computations.” EX1008, Abstract. Yang explains that there was “massive interest in parallel architectures for computing SVD,” and discloses the use of “coordinate rotation digital computer (CORDIC) processors” in order to avoid the “computational overhead” of previous computational methods. EX1008, 1, Abstract. Yang discloses a “CORDIC algorithm” for computing “Cartesian-to-polar coordinates conversions.” *Id.*, 4. Yang explains that SVD, which arises in beam-forming, has a “high computational complexity,” but that the CORDIC algorithm reduces the complexity, including the step of Cartesian-to-polar coordinates conversions *Id.*, 1, 5, Abstract. Using this algorithm, Yang explains “the Cartesian coordinate (x0, y0) of a plane vector is converted to its polar representation.” *Id.*, 6. Thus, as evidenced by Yang, a POSITA would have understood the uses and applications for first producing beamforming matrix V in Cartesian coordinates and then converting V to polar coordinates and would have understood that Li-748 and Tong discloses these claimed uses. Additionally, as I explained in Section VIII (Element [9.f]), there are multiple reasons that would have prompted a POSITA to implement the wireless device of Li ’748 to employ Tong’s suggestion of a Givens rotation-based decomposition of matrix V, resulting in a device that further reduces feedback bandwidth. This combination of Li ’748 and Tong would have included a baseband module that converts the beamforming matrix V from Cartesian coordinates to

polar coordinates so that matrix V could then be decomposed using the Givens rotation, as was well known and common at the time (and suggested by Tong).

101. As such, the predictable combination of Li '748, Tong, and Mao teaches claim 10.

[3] and [11]

Claim	Claim Language
3	The method of claim 1 wherein the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix.
11	The wireless communication device of claim 9, wherein the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix

102. Li '748 discloses that the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix, as follows:

A transmit beamforming matrix may be found using SVD as follows:

$$H=UDV' \quad (1)$$

$$X=Vd \quad (2)$$

where d is the n-vector of code bits for n data streams; x is the transmitted signal vector on the antennas; H is the channel matrix; *H's singular value decomposition is $H=UDV'$* ; U and V are unitary; *D is a diagonal matrix* with H's eigenvalues; V

is n by n , and n is the number of spatial channels. To obtain V at the transmitter, the transmitter may send training symbols to the receiver; the receiver may evaluate H , compute the matrix V' ; and the receiver may feedback parameters representing V to the transmitter. As described more fully below, the number of feedback parameters used to represent V may be reduced by representing the beamforming matrix using a weighted sum of orthogonal generator matrices.

EX1004 at 3:19-39; *supra*, Analysis of Elements [9.e]-[9.f]; *supra*, Section VI.D(discussion of SVD).

103. Moreover, Li '748's baseband module (i.e., processor 460 that accesses instructions from memory 470) "perform[s] method embodiments of the present invention, such as method 200 (FIG. 2)." EX1004 at 10:16-20. Step 220 of Figure 2 recites "determine a beamforming matrix from the channel state information," which Li '748 states "corresponds to *performing a singular value decomposition (SVD)*" according to the equation $H=UDV'$. *Id.* at 8:7-11, 3:22, FIG. 2.

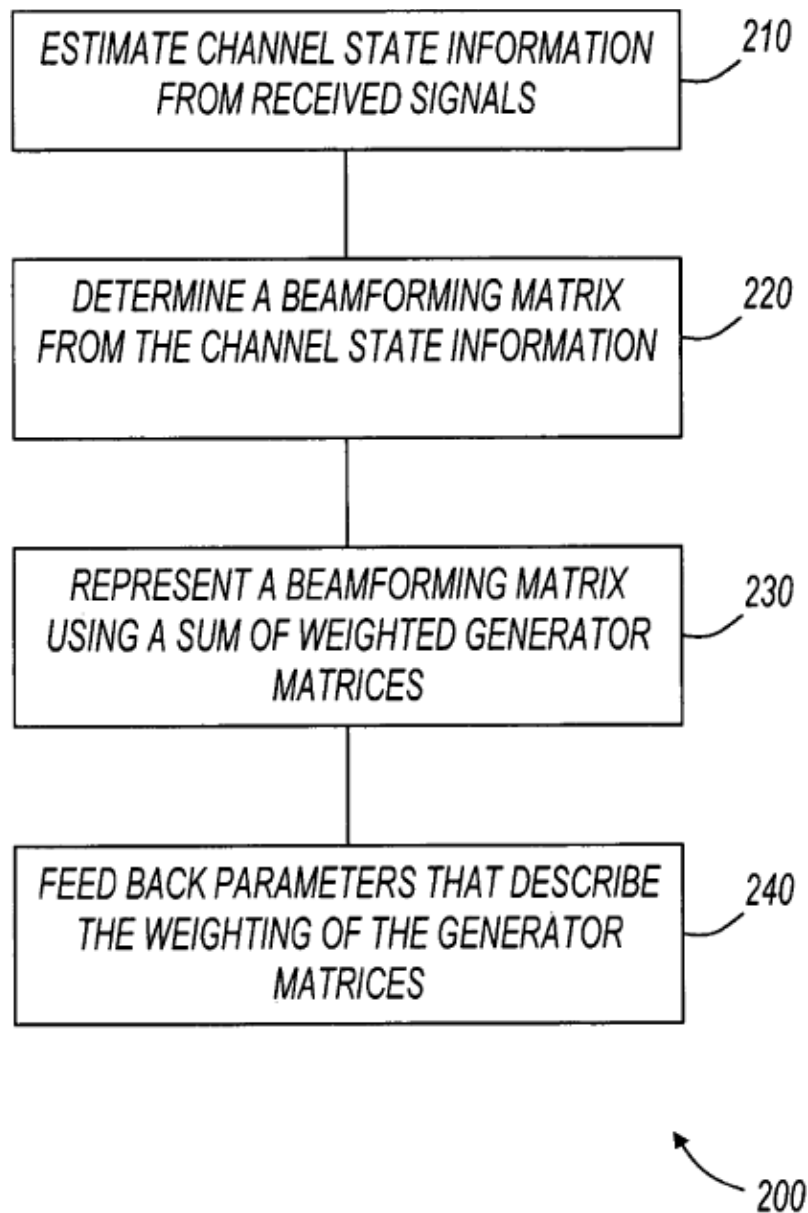


FIG. 2

Id. at FIG. 2.

104. As such, the predictable combination of Li '748, Tong, and Mao teaches claim 11.

[4] and [12]

Claim	Claim Language
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4	The method of claim 3, wherein the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U) comprises performing a Singular Value Decomposition (SVD) operation
12	The wireless communication device of claim 9, wherein in determining the estimated transmitter beamforming unitary matrix (V) based upon the channel response and the receiver beamforming unitary matrix (U), the baseband processing module performs Singular Value Decomposition (SVD) operations.

105. As previously explained with respect to claim 11 in Section VIII and incorporated here, Li '748 discloses that in determining the estimated transmitter beamforming unitary matrix (V) based upon the channel response and the receiver beamforming unitary matrix (U), the baseband processing module performs Singular Value Decomposition (SVD) operations. EX1004 at 3:19-39; *supra*, Analysis of Elements [9.b], [9.e]-[9.f]; *supra*, Section VI.D (discussion of SVD); *supra* ¶¶101-103.

106. For at least these reasons, it is clear that the predictable combination of Li '748, Tong, and Mao renders obvious all elements of claims 9-12 of the '862 patent.

IX. ANALYSIS OF TONG IN VIEW OF MAO

107. For the reasons articulated in detail below, and based on my review of the '862 patent, file history, and the prior art references cited here, it is my opinion that a POSITA would have readily understood that the predictable combination of Tong in view of Mao provide all the elements of claims 9-12. As previously

explained in ¶¶64-68 (above), like the preferred embodiment of the '862 patent, Tong describes a wireless communications device (e.g., a mobile terminal) that receives signals, produces a channel matrix, performs an SVD operation on the channel matrix to obtain beamforming matrix V, and decomposes matrix V using a Givens transform. *Compare* EX1005 at [0223] (“Givens transform”), *with* EX1001, 13:58-67 (“Givens Rotation”). As previously explained in ¶¶69-70 (above), Mao describes a receiver beamforming system in a wireless communications system that includes radio frequency units and frequency converts from transforming received RF signals into baseband signals, and vice versa. Claims 1-4 are method claims that correspond to device claims 9-12 addressed below. Tong’s mobile device (mobile terminal 16) is a receiving wireless communication device. Ex1005, ¶ [0073], FIGs. 1-3. It performs disclosed methods for feeding back transmitter beamforming information to a transmitting wireless. Ex1005, ¶¶ [0073]-[0077], FIGs. 1-3. Accordingly, the elements of claims 1-4 are rendered obvious for the same reasons as the corresponding portions of claims 9-12.

108. Tong and Mao both describe receiver devices in wireless communications systems that use beamforming, and there were a number of reasons that would have prompted a POSITA to predictably apply the teachings of Mao to the wireless device of Tong for purposes of achieving known benefits (as

described in detail below). Based on the multiple reasons articulated below, a POSITA would have been prompted to implement the Tong's wireless device (based on features suggested by Mao) to achieve such known benefits and as a matter of predictable and ordinary engineering design. In particular, it would have been obvious to a POSITA to combine Tong's wireless device with Mao's suggestion of forming a baseband signal in order to generate a signal for conversion and later transmission back to a transmitter. As part of my analysis, I will address each of the elements of claims 9-12 as follows.

[1.P] and [9.P]

Claim	Claim Language
1.P	A method for feeding back transmitter beamforming information from a receiving wireless communication device to a transmitting wireless communication device, the method comprising:
9.P	A wireless communication device, comprising:

109. Tong discloses a wireless communications device. For example, Tong discloses a wireless communication device, as follows:

For purposes of providing context for the embodiments described below, an example OFDM system will now be described with reference to FIGS. 1 to 5. FIG. 1 shows a base station controller (BSC) 10 which controls *wireless communications* within multiple cells 12, which cells are served by corresponding base stations (BS) 14. In general, each base station 14 facilitates communications using OFDM with

mobileterminals 16, which are within the cell 12 associated with the corresponding base station 14. The movement of the mobile terminals 16 in relation to the base stations 14 results in significant fluctuation in channel conditions. As illustrated, the base stations 14 and mobile terminals 16 may include multiple antennas to provide spatial diversity for communications.

EX1005 at [0073].

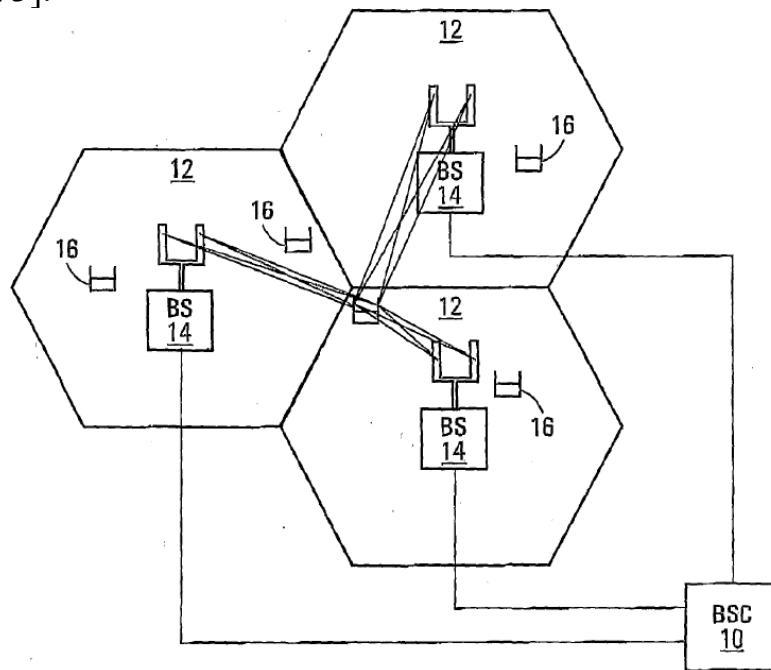


FIG. 1

Id. at FIG. 1 (elements 16).

[9.a]

Claim	Claim Language
9.a	a plurality of Radio Frequency (RF) components operable to receive an RF signal and to convert the RF signal to a baseband signal; and

110. Tong discloses a plurality of Radio Frequency (RF) components operable to receive an RF signal and to convert the RF signal to a baseband signal.

111. Tong discloses that its device includes receive circuitry that receives RF signals and converts those signals to baseband signals:

With reference to FIG. 3, a mobile terminal 16 configured according to one embodiment of the present invention is illustrated. Similar to the base station 14, the mobile terminal 16 will include a control system 32, a baseband processor 34, transmit circuitry 36, *receive circuitry 38*, multiple antennas 40, and user interface circuitry 42. The *receive circuitry 38 receives radio frequency signals* bearing information from one or more base stations 14. Preferably, a low noise amplifier and a filter (not shown) cooperate to amplify and remove broadband interference from the signal for processing. *Downconversion* and digitization *circuitry* (not shown) will then *downconvert the filtered, received signal to* an intermediate or *baseband frequency signal*, which is then digitized into one or more digital streams.

Id. at [0077].

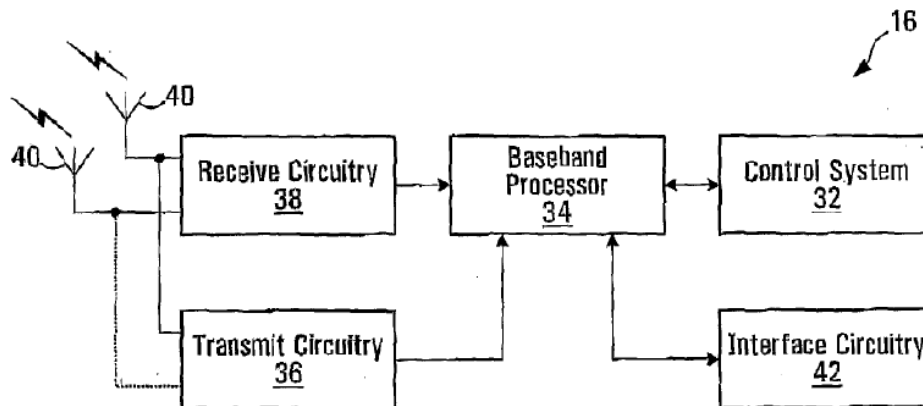


FIG. 3

Id. at FIG. 3.

[9.b]

Claim	Claim Language
9.b	a baseband processing module operable to:

112. Tong discloses a baseband processing module, as follows:

With reference to FIG. 3, a mobile terminal 16 configured according to one embodiment of the present invention is illustrated. Similar to the base station 14, the mobile terminal 16 will include a control system 32, **a baseband processor 34**, transmit circuitry 36, receive circuitry 38, multiple antennas 40, and user interface circuitry 42. The receive circuitry 38 receives radio frequency signals bearing information from one or more base stations 14. Preferably, a low noise amplifier and a filter (not shown) cooperate to amplify and remove broadband interference from the signal for processing. Downconversion and digitization circuitry (not shown) will then downconvert the filtered, received signal to an

intermediate or baseband frequency signal, which is then digitized into one or more digital streams.

Id. at [0077].

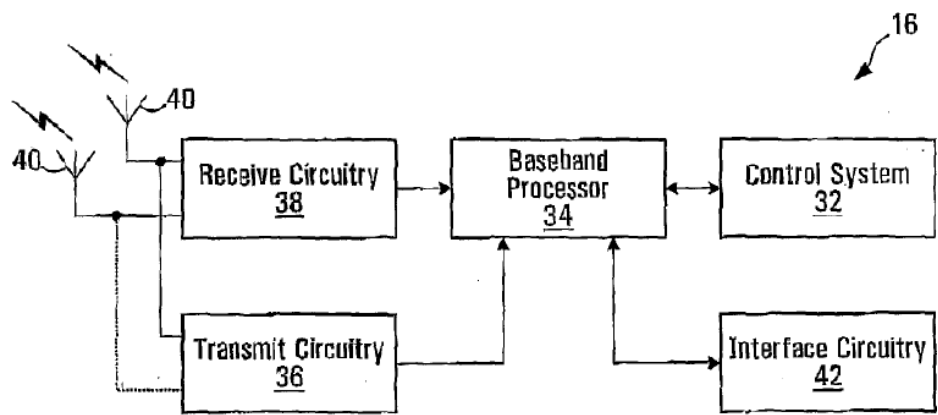


FIG. 3

Id. at FIG. 3 (element 34).

The *baseband processor 34 processes the digitized received signal to extract the information or data bits conveyed in the received signal.* This processing typically comprises demodulation, decoding, and error correction operations, as will be discussed on greater detail below. The baseband processor 34 is generally implemented in one or more digital signal processors (DSPs) and application specific integrated circuits (ASICs).

Id. at [0078].

[1.a] and [9.c]

Claim	Claim Language
1.a	the receiving wireless communication device receiving a preamble sequence from the transmitting wireless device;
9.c	receive a preamble sequence carried by the baseband signal

113. Tong discloses receiving a preamble sequence carried by the baseband signal. For example, Tong discloses receiving signals and measuring the channel H using pilot symbols that were received, as follows:

The mobile terminal 16, which is discussed in detail, will use the *pilot signals* for channel estimation.

Id. at [0087].

At the transmitter, there is a transmit beam-former 202 that uses matrix V^T this being the transpose of the matrix v in the singular value decomposition of the channel H . The output of the beam-former is transmitted on M transmit antennas 204. This is received at the receiver by N receive antennas 206, and the *MIMO channel H is measured* as indicated at 208. There are many existing methods of measuring the channel. *This may for example be done using pilot symbols transmitted at known locations in time and/or frequency*, possibly using one of the formats introduced previously and performing interpolation if necessary. This may include receiver specific pilots and or generic pilots. Next, block 212 performs a singular value decomposition of the channel matrix H into the matrix product UDV where U and V are unitary matrices and D is a diagonal matrix containing the eigenvalues.

Id. at [0211].

An example of a system employing Givens feedback is shown FIG. 43. Shown is a transmit beam-former 320 with transmit

antennas 322. At the receiver, receive antennas 324 receive signals, and the channel measurement is performed at 326. This produces the channel matrix which is then SVD decomposed at 328. Next, the V matrix is decomposed by the Givens transform³³⁰ to produce a series of matrices G1, G2, . . . , the number of matrices being required being a function of the size of the channel matrix. Each such Givens matrix can then be uniquely represented by two parameters θ and C. These parameters are selected at 332 and differentially quantized at 334.

Id. at [0223].

114. Based upon Tong's teaching here, a POSITA would have recognized that the "pilot symbols" of Tong are signals that the receiver uses to determine a channel response (e.g., matrix H) and beamforming matrix V. Similarly, the "preamble" of the '862 patent is received by a "receiving wireless communication device," which then estimates the channel response and "determines an estimated transmitter beamforming unitary matrix (V)." EX1001 at 13:37-47. Indeed, the '862 patent specifically states that "[e]stimating the channel response includes comparing received training symbols of the preamble to corresponding expected training symbols using any of a number of techniques that are known in the art." *Id.* at 13:40-44. Similarly, Tong discloses that the receiver "compares the received pilot symbols with the pilot symbols that are expected in certain sub-carriers at

certain times to determine a channel response for the sub-carriers in which pilot symbols were transmitted.” EX1005 at [0090]. As such, the “preamble” disclosed in the ’862 patent include essentially the same type of traditional “pilot symbols” (as disclosed in Tong) to estimate the channel response and determine the beamforming matrix, and a POSITA would have recognized this similarity because it was a customary practice at the time in such wireless devices. Thus, Tong discloses receiving a preamble sequence carried by the baseband signal.

[1.b] and [9.d]

Claim	Claim Language
1.b	the receiving wireless device estimating a channel response based upon the preamble sequence;
9.d	estimate a channel response based upon the preamble sequence

115. Tong discloses that its baseband processing module is operable to estimate a channel response, H , based upon the preamble sequence (*e.g.*, pilot signals or pilot symbols), as follows:

The mobile terminal 16, which is discussed in detail, will use the ***pilot signals*** for channel estimation.

Id. at [0087].

At this point, the OFDM symbols in the time domain are ready for conversion to the frequency domain using FFT processing logic 90. The results are frequency domain symbols, which are sent to processing logic 92. The processing logic 92 extracts the scattered pilot signal using

scattered pilot extraction logic 94, determines a channel estimate based on the extracted pilot signal using channel estimation logic 96, and provides channel responses for all sub-carriers using channel reconstruction logic 98. *In order to determine a channel response for each of the sub-carriers, the pilot signal is multiple pilot symbols that are scattered among the data symbols throughout the OFDM sub-carriers in a known pattern in both time and frequency.* Continuing with FIG. 5, the *processing logic compares the received pilot symbols with the pilot symbols that are expected in certain sub-carriers at certain times to determine a channel response for the sub-carriers in which pilot symbols were transmitted.* The results are interpolated to estimate a channel response for most, if not all, of the remaining sub-carriers for which pilot symbols were not provided. The *actual and interpolated channel responses are used to estimate an overall channel response*, which includes the channel responses for most, if not all, of the sub-carriers in the OFDM channel.

Id. at [0090].

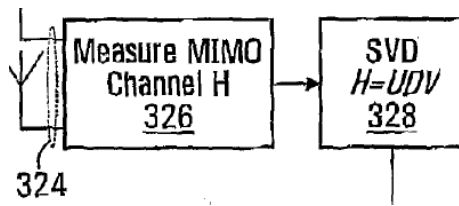
At the transmitter, there is a transmit beam-former 202 that uses matrix V^T this being the transpose of the matrix v in the singular value decomposition of the channel H . The output of the beam-former is transmitted on M transmit antennas 204. This is received at the receiver by N receive antennas 206, and the *MIMO channel H is measured* as indicated at 208. There are many existing methods of measuring the channel. *This may*

for example be done using pilot symbols transmitted at known locations in time and/or frequency, possibly using one of the formats introduced previously and performing interpolation if necessary. This may include receiver specific pilots and or generic pilots. Next, block 212 performs a singular value decomposition of the channel matrix H into the matrix product UDV where U and V are unitary matrices and D is a diagonal matrix containing the eigenvalues.

Id. at [0211].

An example of a system employing Givens feedback is shown FIG. 43. Shown is a transmit beam-former 320 with transmit antennas 322. At the receiver, *receive antennas 324 receive signals, and the channel measurement is performed at 326. This produces the channel matrix* which is then SVD decomposed at 328. Next, the V matrix is decomposed by the Givens transform 330 to produce a series of matrices $G_1, G_2, \dots$, the number of matrices being required being a function of the size of the channel matrix. Each such Givens matrix can then be uniquely represented by two parameters θ and C . These parameters are selected at 332 and differentially quantized at 334.

Id. at [0223].



Id. at FIG. 43 (excerpted).

116. As explained, *supra*, in Section VI.D., a POSITA would have understood that the “channel matrix H” ([0211], [0223]) was a conventional “channel response.”

[1.c] and [9.e]

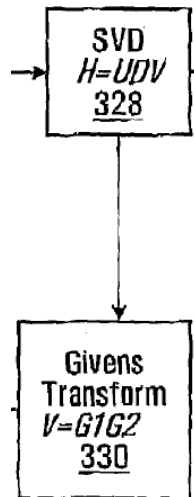
Claim	Claim Language
1.c	the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U);
9.e	determine an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U)

117. Tong discloses determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U). In particular, Tong discloses performing a conventional SVD on the channel matrix H in order to determine the transmit beamforming matrix V, using the well-known SVD equation $H=UDV$, as follows:

An example of a system employing Givens feedback is shown FIG. 43. Shown is a transmit beam-former 320 with transmit antennas 322. At the receiver, receive antennas 324 receive signals, and the channel measurement is performed at 326.

This produces *the channel matrix which is then SVD decomposed at 328*. Next, the *V matrix* is decomposed by the Givens transform³³⁰ to produce a series of matrices $G_1, G_2, \dots$, the number of matrices being required being a function of the size of the channel matrix. Each such Givens matrix can then be uniquely represented by two parameters θ and C . These parameters are selected at 332 and differentially quantized at 334.

Id. at [0223].



Id. at FIG. 43 (excerpted).

118. As explained, *supra*, in Section VI.D, a POSITA would have recognized from Tong’s teaching and conventional notation that the SVD equation “ $H=UDV$ ” shown in Figure 43 is used to determine the transmitter beamforming unitary matrix V (which is then decomposed using a Givens Transform in step 330). As clearly shown in the equation, the transmitter beamforming unitary

matrix V is determined based on the values of H and U , as was customary and well-known at the time. Moreover, based on the disclosure of Tong, a POSITA would have recognized that in the well-known SVD equation $H=UDV'$, channel matrix “ H ” was the ordinary symbol for the channel response, “ V ” was the ordinary symbol for the transmit beamforming matrix, and “ U ” was the ordinary symbol for the receiver beamforming unitary matrix, as I explained, *supra*, in Section VI.D.

[1.d] and [9.f]

Claim	Claim Language
1.d	the receiving wireless device decomposing the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information; and
9.f	decompose the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information; and

119. Tong discloses decomposing the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information. For example, Tong teaches decomposing the transmit beamforming matrix V , as follows:

An example of a system employing Givens feedback is shown FIG. 43. Shown is a transmit beam-former 320 with transmit antennas 322. At the receiver, receive antennas 324 receive signals, and the channel measurement is performed at 326. This produces the channel matrix which is then SVD decomposed at 328. Next, *the V matrix is decomposed by the*

Givens transform 330 to produce a series of matrices $G_1, G_2, \dots$, the number of matrices being required being a function of the size of the channel matrix. Each such Givens matrix can then be uniquely represented by two parameters θ and C . These parameters are selected at 332 and differentially quantized at 334.

Id. at [0223].

By *decomposing the SVD-based unitary V matrix into Givens matrices*, the V matrix can be represented by $n^2 - n$ independent complex parameters.

Id. at [0227].

FIG. 43 is a block diagram of a system employing an SVD based Givens transform feedback in accordance with an embodiment of the invention[.]

Id. at [0066].

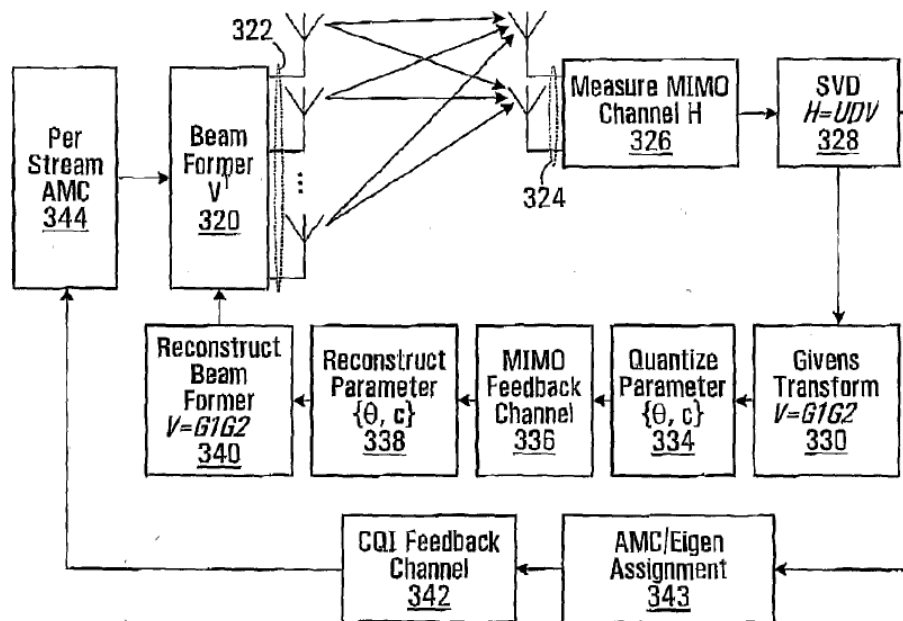


FIG. 43

Id. at FIG. 43.

120. Based on my knowledge and experience in this field and my analysis of the Tong reference, it is my opinion that a POSITA would have recognized that Tong's disclosure for using a "Givens transform" was the same as the "Givens Rotation" example in the '862 patent. EX1001 at 13:58-67. In particular, the '862 patent states in one example of a decomposition of the estimated transmitter beamforming unitary matrix (V), "the decomposition operations of step 708 employ a Givens Rotation operation." *Id.* at 13:58-65. Moreover, the '862 patent states that with "a decomposed matrix form for the estimated transmitter beamforming matrix (V), the set of angles fed back to the transmitting wireless device are reduced." *Id.* at 13:67-14:3. Similarly, Tong teaches that "the amount of

feedback required” can be reduced by decomposing the V matrix “into Givens matrices” using a conventional Givens operation. EX1005 at [0222].

[1.e] and [9.g]

Claim	Claim Language
1.e	the receiving wireless device wirelessly sending the transmitter beamforming information to the transmitting wireless device.
9.g	form a baseband signal employed by the plurality of RF components to wirelessly send the transmitter beamforming information to the transmitting wireless device

121. Tong in combination with Mao renders obvious forming a baseband signal employed by the plurality of RF components to wirelessly send the transmitter beamforming information to the transmitting wireless device. First, based upon Tong’s teachings regarding its wireless device transmitting data back to a transmitter, a POSITA would have recognized that Tong’s device “formed a baseband signal”—a ubiquitous operation in such wireless devices at the time (as I explained above). For example, Tong discloses:

For *transmissions* the baseband processor 34 receives digitized data, which may represent voice, data, or control information, from the control system 32, which it encodes for transmission. The encoded data is output to the transmit circuitry36, where it is used by a *modulator to modulate a carrier signal that is at a desired transmit frequency or frequencies*

Id. at [0079].

Each of the resultant signals is up-converted in the digital domain to an intermediate frequency and converted to an analog signal via the corresponding digital up-conversion (DUC) and digital-to-analog (D/A) conversion circuitry 66. *The resultant (analog) signals are then simultaneously modulated at the desired RF frequency*, amplified, and *transmitted via the RF circuitry 68 and antennas 28*.

Id. at [0087].

122. A POSITA would have recognized that the “resultant signals” that are upconverted, converted to analog signals, and modulated to a desired RF frequency, are conventional baseband signals generated by the baseband processor in Tong’s wireless device that were employed by the RF components to wireless send beamforming information. As such, Tong discloses forming a baseband signal employed by the plurality of RF components to wirelessly send the transmitter beamforming information to the transmitting wireless device, just as it disclosed converting the received RF signal to a baseband signal in element [9.a].

123. Next, to the extent that Tong does not explicitly describe that the wireless device would “form a baseband signal” as recited in this element [9.g], it would have been obvious to implement Mao’s teachings in Tong’s device. Mao confirms that it was widely known to form baseband signals that are converted to RF signals for sending data back to the transmitter, as follows:

In one embodiment, the present invention provides a wireless

communication system, comprising an antenna array structure having a plurality of antenna elements that receive and *transmit radio-frequency signals*, one or more *radio-frequency units and frequency converters configured to* transform received RF signals to receive analog base-band signals and *transform analog transmit base-band signals into a transmit RF signals*, one or more analog-to-digital converters configured to convert the receive analog base-band signals into a receive digital base-band signals and one or more digital-to-analog converters configured to convert transmit digital base-band signals into transmit analog base-band signals.

EX1006 at 3:28-41.

The transmission beam-forming system includes an antenna array system and a *plurality of RF units which may be shared with the receiver beam-forming system, a plurality of up-converters which transform base-band signals into RF signals*, a plurality of digital-to-analog (D/A) conversion units which convert the digital signals to analog signals, and a transmit beam-forming unit.

Id. at 6:31-38.

124. Here, Mao describes the traditional and ubiquitous practice of forming “base-band signals” for conversion into RF signals. Accordingly, even if Tong does not expressly use the phrase “form a baseband signal,” Mao clearly teaches the conventional practice of forming “base-band signals” as recited in this element [9.g].

125. Based on my knowledge and experience in this field and my review of Tong and Mao, a POSITA would have been motivated to implement the wireless device of Tong in a manner suggested by Mao (to form a baseband signal employed by the plurality of RF components) for many reasons. A POSITA would have done so to properly send data to the transmitter for wireless transmissions. Indeed, this predictable implementation of Tong would have provided a wireless device that would advantageously convert a digital signal (processed by the wireless device’s circuitry) into a baseband signal for purposes of properly preparing the signal for transmission back to the transmitter—a practice that was conventional at the time. Mao confirms the customary usage of “a plurality of up-converters which transform base-band signals into RF signals.” *Id.* at 6:34-35. Moreover, given the noticeable overlap and similarities in the teachings of Tong and Mao for converting the digital signal to an RF signal usable by the RF transmitter, a POSITA would have recognized that applying Mao’s suggestion (forming “baseband signals” for transmission) to Tong’s device would have led to predictable results without significantly altering or hindering the functions performed by Tong’s wireless device.

[2] and [10]

Claim	Claim Language
2	The method of claim 1 wherein the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary

	matrix (U) comprises: the receiving wireless device producing the estimated transmitter beamforming unitary matrix (V) in Cartesian coordinates; and the receiving wireless device converting the estimated transmitter beamforming unitary matrix (V) to polar coordinates.
10	The wireless communication device of claim 9, wherein in determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U), the baseband processing module is operable to: produce the estimated transmitter beamforming unitary matrix (V) in Cartesian coordinates; and convert the estimated transmitter beamforming unitary matrix (V) to polar coordinates.

126. Tong teaches wherein in determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U), the baseband processing module is operable to: produce the estimated transmitter beamforming unitary matrix (V) in Cartesian coordinates; and convert the estimated transmitter beamforming unitary matrix (V) to polar coordinates. Indeed, such a feature of producing the transmitter beamforming unitary matrix (V) in Cartesian coordinates and then converting them into polar coordinates was common and well known, as Tong discloses the following:

FIG. 43 is a block diagram of a system *employing an SVD based Givens transform feedback* in accordance with an embodiment of the invention

EX1005 at [0066].

In another embodiment of the invention, the V matrix determined through singular value decomposition is fed back from

the receiver to the transmitter using Givens feedback. Unitary matrices have the property that they can be decomposed into a product of Givens matrices. In particular, *an $n \times n$ V matrix can be decomposed into Givens matrices containing $n^2 - n$ complex parameters*. The parameters can be fed back directly, or differentially and/or quantized to potentially *reduce the amount of feedback required*. Then, at the transmitter, the Givens matrices can be reconstructed, and then the V matrix reconstructed as the product of the reconstructed Givens matrices.

Id. at [0222].

An example of a system employing Givens feedback is shown FIG. 43. Shown is a transmit beam-former 320 with transmit antennas 322. At the receiver, receive antennas 324 receive signals, and the channel measurement is performed at 326. This produces the channel matrix which is then SVD decomposed at 328. Next, the *V matrix is decomposed by the Givens transform 330 to produce a series of matrices $G_1, G_2, \dots$, the number of matrices being required being a function of the size of the channel matrix. Each such Givens matrix can then be uniquely represented by two parameters θ and C* . These parameters are selected at 332 and differentially quantized at 334.

Id. at [0223].

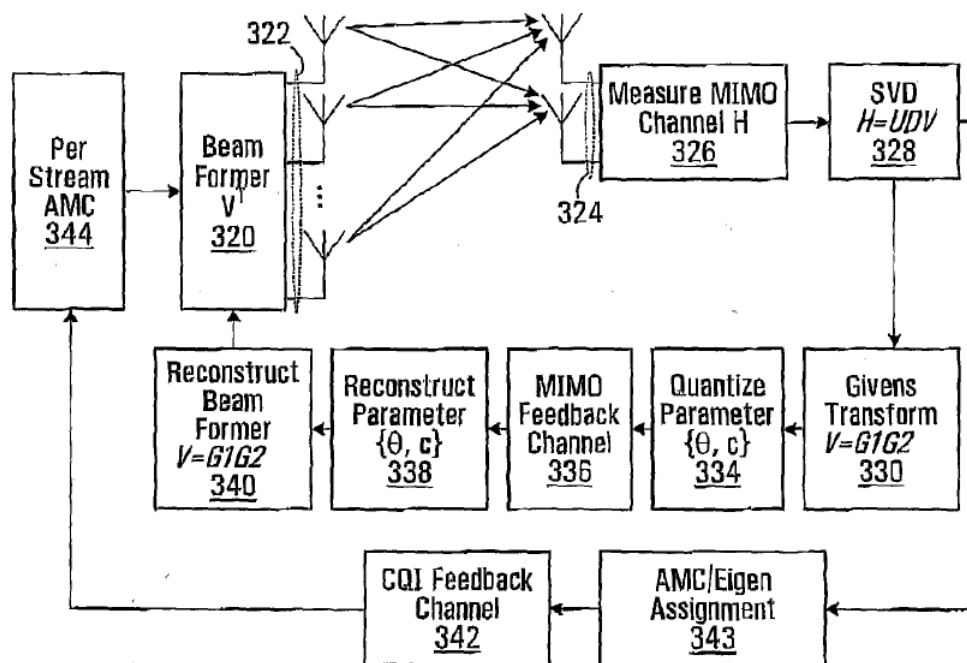


FIG. 43

Id. at FIG. 43.

127. A POSITA would have recognized from Tong’s teaching that “series of matrices $G_1, G_2, \dots$ ” are matrices which have been converted from their original Cartesian coordinates to polar coordinates for at least two reasons. First, Tong teaches that “each such Givens matrix” can be “represented by two parameters θ and C ”—a POSITA would have recognized that these two parameters are the traditional polar coordinate representations of the angle and distance, respectively. Second, a POSITA would have recognized that Tong’s teaching that the “Givens matrices contain[] n^2-2 complex parameters” further indicates that the Givens matrices were produced in polar coordinates, which was normal practice at the time. Moreover, a POSITA would have understood that to perform the Givens

rotation decomposition on the beamforming matrix V and “produce a series of matrices represented by “two parameters θ and C ,” as Tong suggests, one would necessarily need to convert matrix V from Cartesian coordinates to polar coordinates.

128. For example, Yang (EX1008) demonstrates that it was well-known to convert Cartesian coordinates to polar coordinates and this approach was used in similar beam-forming systems. A POSITA would have understood these concepts and their application to the same technology and field of use described by Tong. Yang describes a “method for computing two-sided rotations involved in singular value decomposition (SVD)” that “leads to significantly reduced computations.” EX1008, Abstract. Yang explains that there was “massive interest in parallel architectures for computing SVD” and discloses the use of “coordinate rotation digital computer (CORDIC) processors” to avoid the “computational overhead” of previous computational methods. EX1008, 1, Abstract. Yang discloses a “CORDIC algorithm” for computing “Cartesian-to-polar coordinates conversions.” *Id.*, 4. Yang explains that SVD, which arises in beam-forming, has a “high computational complexity,” but that the CORDIC algorithm reduces the complexity in part because of its Cartesian-to-polar coordinates conversions *Id.*, 1, 5, Abstract. Using this algorithm, Yang explains “the Cartesian coordinate (x_0, y_0) of a plane vector is converted to its polar representation.” *Id.*, 6. Thus, Yang shows

that a POSITA would have understood the uses and applications for first producing beamforming matrix V in Cartesian coordinates and then converting V to polar coordinates and would have understood that Tong discloses these claimed uses.

[3] and [11]

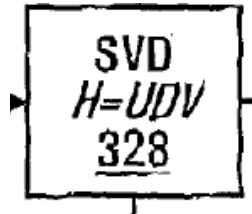
Claim	Claim Language
3	The method of claim 1 wherein the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix.
11	The wireless communication device of claim 9, wherein the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix

129. Tong discloses claims 3 and 11. Tong discloses that the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix, as follows:

An example of a system employing Givens feedback is shown FIG. 43. Shown is a transmit beam-former 320 with transmit antennas 322. At the receiver, receive antennas 324 receive signals, and the channel measurement is performed at 326. ***This produces the channel matrix which is then SVD decomposed at 328.*** Next, the V matrix is decomposed by the Givens transform 330 to produce a series of matrices $G_1, G_2, \dots$, the number of matrices being required being a function of the size of the channel matrix. Each such Givens matrix can

then be uniquely represented by two parameters θ and C . These parameters are selected at 332 and differentially quantized at 334.

Id. at [0223].



Id. at FIG. 43 (excerpted); *supra*, Analysis of Elements [9.e]-[9.f]; *supra*, Section VI.D (discussion of SVD); *see also* EX1005 at [0187].

130. Thus, the predictable combination of Tong and Mao teaches claim 11.

[4] and [12]

Claim	Claim Language
4	The method of claim 3, wherein the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U) comprises performing a Singular Value Decomposition (SVD) operation
12	The wireless communication device of claim 9, wherein in determining the estimated transmitter beamforming unitary matrix (V) based upon the channel response and the receiver beamforming unitary matrix (U), the baseband processing module performs Singular Value Decomposition (SVD) operations.

131. As previously explained with respect to claim 11 in Section IX and incorporated here, Tong discloses that in determining the estimated transmitter beamforming unitary matrix (V) based upon the channel response and the receiver beamforming unitary matrix (U), the baseband processing module performs

Singular Value Decomposition (SVD) operations. EX1005 at [0223] (“produces the channel matrix which is then SVD decomposed”), FIG. 43 (excerpted) (“SVD $H=UDV$ ”); *supra*, Analysis of Elements [9.e]-[9.f]; *supra*, Section VI.D (discussion of SVD); *see also* EX1005 at [0187]; *supra* ¶¶128-129.

132. For at least these reasons, it is clear that the predictable combination of Tong and Mao renders obvious all elements of claims 9-12 of the '862 patent.

X. ANALYSIS OF LI '054 IN VIEW OF MAO

133. For the reasons articulated in detail below, and based on my review of the '862 patent, file history, and the prior art references cited here, it is my opinion that a POSITA would have readily understood that the predictable combination of Li '054 in view of Mao render obvious all the elements of claims 9-12 of the '862 patent. Claims 1 and 3-4 are method claims that correspond to device claims 9 and 11-12 addressed below. Li-054's “wireless stations” are receiving wireless communication devices that perform methods for feeding back transmitter beamforming information to transmitting wireless devices. Ex1007, ¶¶ [0011]-[0014], Fig. 1. Accordingly, the elements of claims 1 and 3-4 are rendered obvious for the same reasons as the corresponding portions of claims 9 and 11-12.

134. Li '054, titled “Recursive Reduction of Channel State Feedback,” was filed September 8, 2004 (EX1007 at cover page), prior to the earliest possible priority date (July 13, 2005) of the '862 patent. As Li '054 explains, “[c]losed

loop multiple-input-multiple output (MIMO) systems typically transmit channel state information from a receiver to a transmitter,” but doing so “consumes bandwidth that might otherwise be available for data traffic.” EX1007 at [0002]. As such, Li ’054 teaches reducing feedback bandwidth “in a closed loop MIMO system by Householder transformer and vector quantization using codebooks.” *Id.* at Abstract.

135. Li ’054 discloses wireless stations 102 and 104 that are part of a wireless local area network (WLAN), as shown in Figure 1 (reproduced below). *Id.* at [0011]. The stations may be “an access point in a WLAN” or “a laptop computer, personal digital assistant (PDA), or the like.” *Id.* at [0011]. The stations include “any number of antennas” for communication. *Id.* at [0013]. “The channel between stations 102 and 104 is described by the channel state matrix, H , that includes entries describing the complex channel gains between each transmit and receive antenna pair.” *Id.* at [0013].

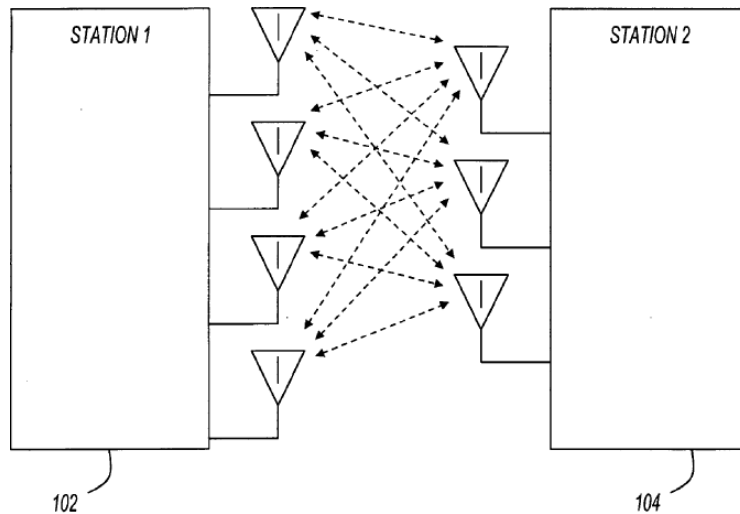


FIG. 1

Id. at FIG. 1.

136. Figure 5 (reproduced below) shows a more detailed system diagram of a system that could be, for example, one of the stations 102, 104 of Figure 1, where the system “includes antennas 510, physical layer (PHY) 530, media access control (MAC) layer 540, Ethernet interface 550, processor 560, and memory 570,” and can perform various operation *Id.* at [0101]. As an example of an operation performed by the system, Li ’054 discloses that a “receiver receives training symbols and computes the beamforming matrix, V .” *Id.* at [0022]. The “beamforming matrix V is fed back from the receiver to the transmitter.” *Id.* at [0019].

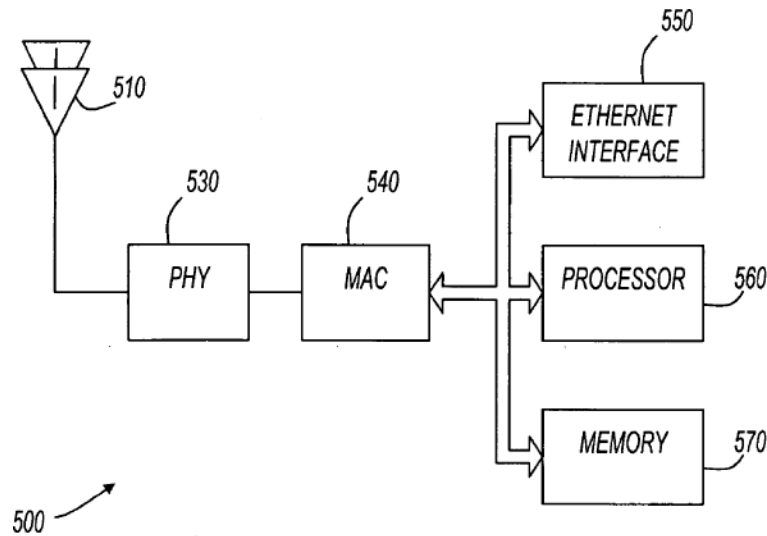


FIG. 5

Id. at FIG. 5.

137. Li '054 describes these operations in more detail with reference to Figure 3 (reproduced below). *Id.* at [0092]. At 310, “channel state information is estimated from received signals,” where the “channel state information may include the channel state matrix H .” *Id.* at [0093]. At 320, “a beamforming matrix is determined from the channel state information,” which, may “correspond[] to performing singular value decomposition (SVD)” using the equation $H_{m \times n} = U_{m \times m} D_{m \times n} V'_{n \times n}$. *Id.* at [0093], [0018]. At 330, “a column of a beamforming matrix is quantized using a codebook,” and at 340, “a householder reflection is performed on the beamforming matrix to reduce the dimensionality of the beamforming matrix.” *Id.* at [0094]-[0095]. At 360, “the quantized column vectors are transmitted.” *Id.* at [0096].

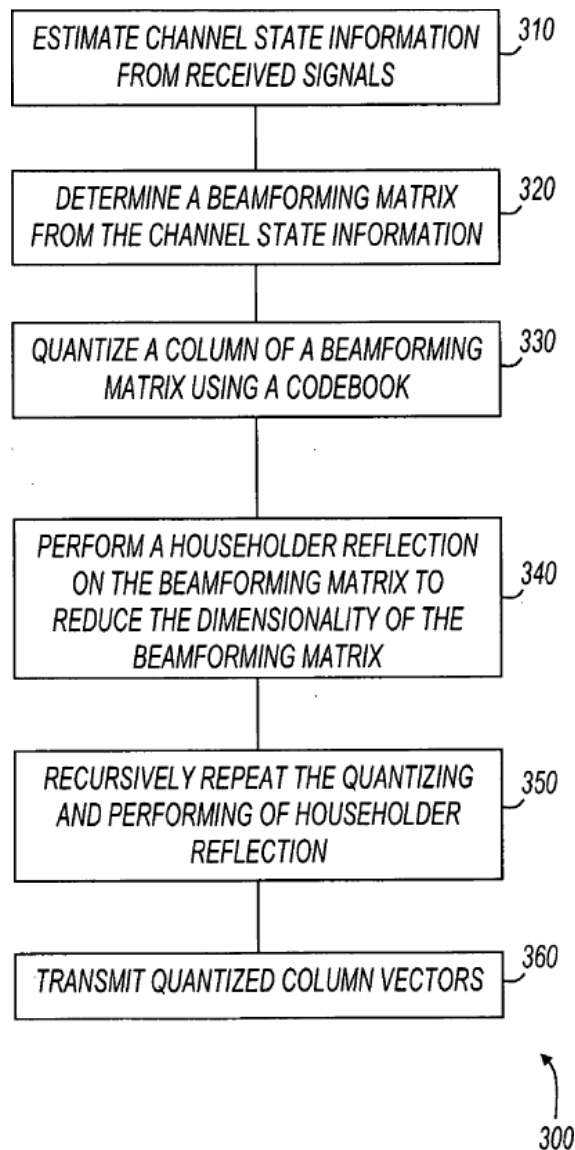


FIG. 3

Id. at FIG. 3.

138. As previously explained above, Mao describes a receiver beamforming system in a wireless communications system that includes radio frequency units and frequency converts from transforming received RF signals into baseband signals, and vice versa. *Supra* ¶¶69-70.

139. Li '054 and Mao both describe receiver devices in wireless communications systems that use beamforming, and there were a number of reasons that would have prompted a POSITA to predictably apply the suggestions of Mao to the wireless device of Li '054 for purposes of achieving known benefits (as described in detail below). Based on the multiple reasons articulated below, a POSITA would have been prompted to implement Li '054's wireless device (based on features suggested by Mao) to achieve such known benefits and as a matter of predictable and ordinary engineering design. In particular, it would have been obvious to a POSITA to combine Li '054's wireless device with Mao's suggestion of forming a baseband signal in order to generate a signal for conversion and later transmission back to a transmitter. As part of my analysis, I will address each of the elements of claims 9 and 11-12 as follows.

[1.P] and [9.P]

Claim	Claim Language
1.P	A method for feeding back transmitter beamforming information from a receiving wireless communication device to a transmitting wireless communication device, the method comprising:
9.P	A wireless communication device, comprising:

140. Li '054 discloses a wireless communications device. For example, Li '054 discloses a wireless communication device, as follows:

FIG. 1 shows a diagram of ***two wireless stations: station 102, and station 104***. In some embodiments, stations 102 and

104 are part of a wireless local area network (WLAN). For example, one or more of stations 102 and 104 may be an access point in a WLAN. Also for example, one or more of stations 102 and 104 may be a mobile station such as a laptop computer, personal digital assistant (PDA), or the like. Further, in some embodiments, ***stations 102 and 104 are part of a wireless wide area network (WWAN)***. For example, one or more of stations 102 and 104 may be a base station or a subscriber unit. Although only two stations are shown in FIG. 1, any number of stations may be present without departing from the scope of the present invention.

EX1007 at [0011].

Stations 102 and 104 may include any number of antennas. In the example of FIG. 1, station 102 includes four antennas, and station 104 includes three antennas. The “channel” through which ***stations 102 and 104 communicate*** may include many possible signal paths. For example, when stations 102 and 104 are in an environment with many “reflectors” (e.g. walls, doors, or other obstructions), many signals may arrive from different paths. This condition is known as “multipath.” In some embodiments, ***stations 102 and 104 utilize multiple antennas to take advantage of the multipath and to increase the communications bandwidth***. For example, in some embodiments, ***stations 102 and 104 may communicate using Multiple-Input-Multiple-Output (MIMO) techniques***. In general, MIMO systems offer higher capacities by utilizing multiple spatial channels made possible by multipath. The

channel between stations 102 and 104 is described by the channelstate matrix, H , that includes entries describing the complex channel gains between each transmit and receive antenna pair.

Id. at [0013].

FIG. 5 shows a system diagram in accordance with various embodiments of the present invention. Electronic system 500 includes antennas 510, physical layer (PHY) 530, media access control (MAC) layer 540, Ethernet interface 550, processor 560, and memory 570. In some embodiments, electronic system 500 may be a station capable of quantizing column vectors and performing Householder transformations as described above with reference to the previous figures. In other embodiments, electronic system 500 may be a station that receives quantized column vectors, and performs beamforming in a MIMO system. For example, electronic system 500 may be utilized in a *wireless network as station 102 or station 104* (FIG. 1). Also for example, electronic system 500 may be a station capable of performing the calculations shown in any of the equations above.

Id. at [0101].

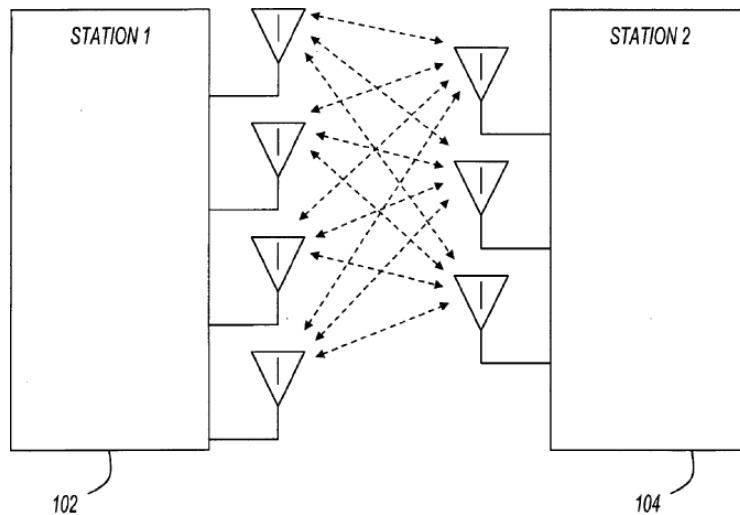


FIG. 1

Id. at FIG. 1 (elements 102, 104).

[9.a]

Claim	Claim Language
9.a	a plurality of Radio Frequency (RF) components operable to receive an RF signal and to convert the RF signal to a baseband signal; and

141. Li '054 discloses a plurality of Radio Frequency (RF) components operable to receive an RF signal and to convert the RF signal to a baseband signal.

142. First, based upon my analysis of Li '054's device, it is my opinion that Li '054 alone teaches, or at least suggests, this element. Li '054 discloses that its device includes circuitry for receiving RF signals and converting those signals:

In operation, system 500 sends and *receives signals using antennas 510*, and the signals are processed by the various elements shown in FIG. 5. Antennas 510 may be an antenna array or any type of antenna structure that supports MIMO processing. System 500 may operate in partial compliance

with, or in complete compliance with, a wireless network standard such as an 802.11 standard.

Id. at [0103].

Physical layer (PHY) 530 is coupled to antennas 510 to interact with a wireless network. PHY 530 may include *circuitry to support the transmission and reception of radio frequency (RF) signals*. For example, in some embodiments, PHY 530 includes an *RF receiver to receive signals and perform “front end” processing* such as low noise amplification (LNA), filtering, *frequency conversion* or the like. Further, in some embodiments, PHY 530 includes transform mechanisms and beamforming circuitry to support MIMO signal processing. Also for example, in some embodiments, PHY 530 includes circuits to support frequency up-conversion, and an RF transmitter.

Id. at [0104].

143. Based upon these teachings in Li '054, a POSITA would have recognized that the conventional components that Li '054 disclosed (e.g., antennas, circuitry to support the reception of RF signals, and RF receiver) provided “a plurality of radio frequency (RF) components are operable to receive an RF signal,” as was conventional at the time. Additionally, a POSITA would have understood that Li '054's description of its “RF receiver to ... perform ‘front end’ processing such as ... frequency conversion” disclosed or at least suggested

frequency conversion circuitry that converts RF signals to baseband signals for processing. Indeed, a POSITA would have understood that such frequency conversion circuitry was ubiquitous and customary in these types of conventional wireless devices at the time to be able to take the analog radio frequency (RF) signals incident on the antennas, downconvert them to a lower frequency where they can be more easily managed and digitized, and then further process the received signals as a digital baseband signal. Based upon my knowledge and experience in this field and my review of Li '054, a POSITA would have understood that such conversion from RF to baseband was necessary in Li '054's device in order for the digital baseband circuitry to perform signal processing on the received signal, such as, for example, to estimate a channel matrix. For at least these reasons, Li '054 teaches or suggests this element [9.a].

144. Next, to the extent Li '054 does not explicitly describe that its RF components operate “to receive an RF signal and to convert the RF signal to a baseband signal,” this functionality was certainly commonplace in such mobile devices, as demonstrated by Mao. Mao discloses a wireless communication system with a plurality of RF components operable to receive an RF signal and convert the RF signal to a baseband signal as follows:

In one embodiment, the present invention provides a *wireless communication system*, comprising an antenna array structure having a plurality of *antenna elements that receive*

and transmit *radio-frequency signals*, one or more radio-frequency units and *frequency converters configured to transform received RF signals to receive analog base-band signals* and transform analog transmit base-band signals into a transmit RF signals, one or more analog-to-digital converters configured to convert the receive analog base-band signals into a receive digital base-band signals and one or more digital-to-analog converters configured to convert transmit digital base-band signals into transmit analog base-band signals.

EX1006 at 3:28-41.

145. Based on my knowledge and experience in this field and my review of Li '054 and Mao, it would have been obvious to a POSITA to implement the wireless device of Li '054 in a manner suggested by Mao so as to be operable to receive an RF signal and then convert the RF signal into a baseband signal for several reasons. In context, a POSITA would have recognized Li '054's conventional wireless device included an RF receiver that received RF signals and performed frequency conversions. EX1007 at [0103]-[0104]. Also, Mao confirmed what a POSITA would have already known—namely, that such a conventional wireless device predictably included antennas that receives RF signals and frequency converters that converted the RF signals to baseband signals. EX1006 at 3:28-41. Indeed, based upon my knowledge and experience in this field, Mao corroborates the known fact that this type of RF-to-baseband conversion circuitry

was ubiquitous in wireless communications devices at the time. Here, a POSITA would have recognized that the predictable implementation of Li '054 (in a manner suggested by Mao) would have predictably provided a wireless device that would convert the received RF signals to baseband signals to efficiently and properly prepare for a digital conversion (to a digital signal) for processing by the digital electronics of Li '054's device. Additionally, for the reasons explained above, my analysis of Li '054 confirms that such circuitry was in fact necessary in order for Li '054's device to perform further processing using its digital electronics/processing.

146. Thus, Mao teaches implementing wireless communications devices, such as the device in Li '054, to include circuitry that receives RF signals and circuitry that converts the received RF signals to baseband signals. Moreover, based upon the many similarities between Li '054 and Mao and the ordinary knowledge of a POSITA at the time, the typically application of Mao's suggestion (receiving an RF signal and subsequently converting the RF signal to a baseband signal) to Li '054's wireless device would have led to predictable results without significantly altering or hindering the functions of Li '054's wireless device.

[9.b]

Claim	Claim Language
9.b	a baseband processing module operable to:

147. Li '054 discloses a baseband processing module, as follows:

FIG. 5 shows a system diagram in accordance with various embodiments of the present invention. Electronic system 500 includes antennas 510, physical layer (PHY) 530, media access control (MAC) layer 540, Ethernet interface 550, **processor 560**, and **memory 570**. In some embodiments, electronic system 500 may be a station capable of quantizing column vectors and performing Householder transformations as described above with reference to the previous figures. In other embodiments, electronic system 500 may be a station that receives quantized column vectors, and performs beamforming in a MIMO system. For example, electronic system 500 may be utilized in a wireless network as station 102 or station 104 (FIG. 1). Also for example, electronic system 500 may be a station capable of performing the calculations shown in any of the equations above.

EX1007 at [0101].

In operation, **processor 560 reads instructions and data from memory 570 and performs actions in response thereto.** For example, **processor 560 may access instructions from memory 570 and perform method embodiments of the present invention, such as method 300 (FIG. 3) or method 400 (FIG. 4) or methods described with reference to other figures.** Processor 560 represents any type of processor, including but not limited to, a microprocessor, a digital signal processor, a microcontroller, or the like.

Id. at [0106].

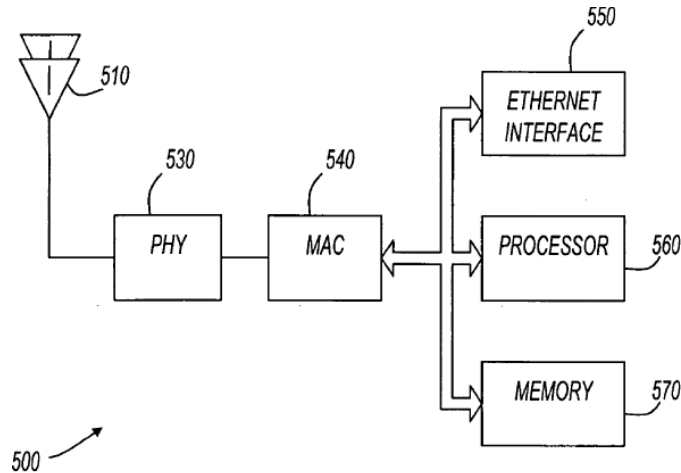


FIG. 5

Id. at FIG. 5.

148. As indicated above, Li '054 states that the “processor 560 may access instructions from memory 570 and perform method embodiments of the present invention, such as method 300 (FIG. 3) or method 400 (FIG. 4).” *Id.* at [0106]. In addition, as further explained below, the steps in Figure 3 of Li '054 (reproduced below) includes steps performed by the baseband processing module of the '862 patent.

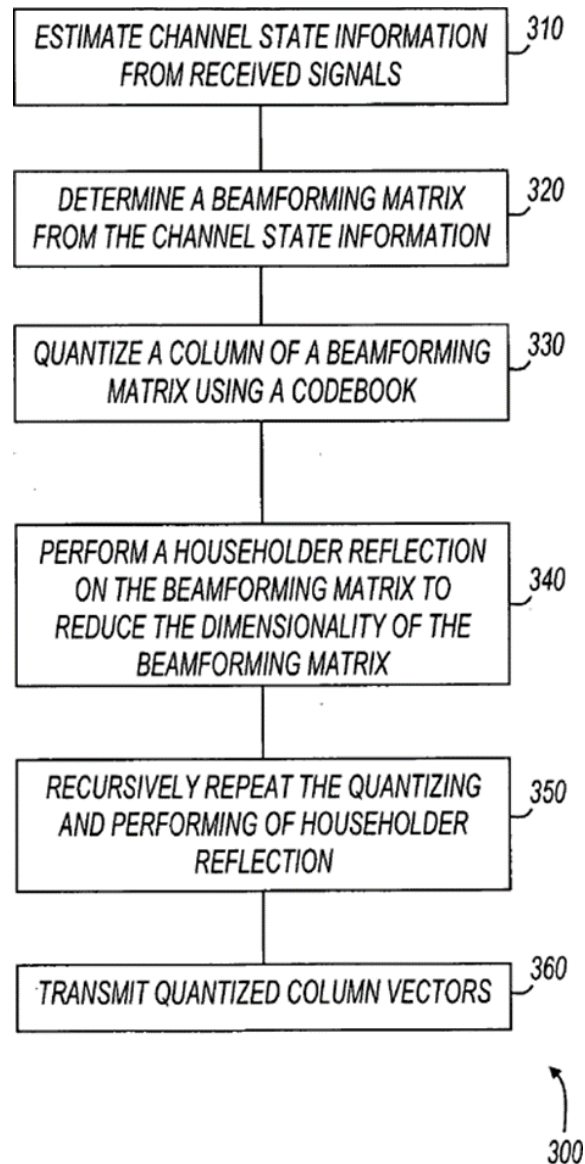


FIG. 3

Id. at FIG. 3.

149. Based upon this teaching in Li '054, a POSITA would have recognized that Li '054's processor and memory structure provided a baseband processing module, which was widely common in such wireless communication devices at the time. Indeed, Li '054 specifically states that its processor accesses instructions from memory and "perform[s] method embodiments of the present

invention, such as method 300 (FIG. 3) or method 400 (FIG. 4).” *Id.* at [0106].

Indeed, as further explained below, I note that the steps in Figure 3 of Li ’054 (reproduced above) includes steps performed by the baseband processing module of the ’862 patent.

[1.a] and [9.c]

Claim	Claim Language
1.a	the receiving wireless communication device receiving a preamble sequence from the transmitting wireless device;
9.c	receive a preamble sequence carried by the baseband signal

150. Li ’054 discloses receiving a preamble sequence carried by the baseband signal. For example, Li ’054 discloses receiving signals and measuring the channel H using pilot symbols that were received, as follows:

Quantization of the beamforming matrix V is illustrated below by an example, in which 4 transmit antennas exist and 3 receive antennas exist. Although the example employs a 4×3 system, the various embodiments of the invention are not so limited. The ***receiver receives training symbols and computes the beamforming matrix, V as shown above in equation (1).*** Next, the receiver only needs to quantize the first 3 columns of V since the channel supports at most three modes. If the receiver knows the transmitter only employs two spatial channels, the receiver may only quantize the first two columns of V in the scheme depicted next.

Id. at [0022].

A transmit beamforming matrix may be found using

singular value decomposition (SVD) of the channel state matrix H as follows:

$$H_{m \times n} = U_{m \times m} D_{m \times n} V'_{n \times n} \quad (1)$$

$$x_{n \times 1} = V_{n \times n} d_{n \times 1} \quad (2)$$

where d is the n-vector of data symbols containing k non-zero elements, where k is the number of active spatial channels (see next paragraph); x is the beamformed, transmitted signal vector on n transmit antennas; H is the channel matrix; H's singular value decomposition is $H=UDV'$; U and V are unitary; D is a diagonal matrix with H's eigenvalues; V is n by n and only the first k columns are needed to be fed back. Equation (2) is the beamforming act at the transmitter after the beamforming matrix V is fed back from the receiver to the transmitter.

Id. at [0018]-[0019].

151. Based upon Li '054's teachings, a POSITA would have recognized that the "training symbols" of Li '054 are signals that the receiver uses to determine a channel response (e.g., channel state matrix H) and transmit beamforming matrix V. Similarly, the "preamble" of the '862 patent is received by a "receiving wireless communication device," which then estimates the channel response and "determines an estimated transmitter beamforming unitary matrix (V)." EX1001 at 13:37-47. Indeed, the '862 patent specifically states that "[e]stimating the channel response includes comparing *received training symbols of the preamble* to corresponding expected training symbols using any of a number

of techniques that are known in the art.” *Id.* at 13:40-44. That is, the “preamble” disclosed in the ’862 patent includes essentially the same type of traditional “training symbols” (as disclosed in Li ’054) to estimate the channel response and determine the beamforming matrix, and a POSITA would have recognized this similarity because it was a customary practice at the time in such wireless devices. Thus, Li ’054 discloses receiving a preamble sequence carried by the baseband signal.

[1.b] and [9.d]

Claim	Claim Language
1.b	the receiving wireless device estimating a channel response based upon the preamble sequence;
9.d	estimate a channel response based upon the preamble sequence

152. Li ’054 discloses that its baseband processing module is operable to estimate a channel response (e.g., channel state matrix H) based upon the preamble sequence (e.g., training symbols), as follows:

Method 300 is shown beginning at ***block 310 in which channel state information is estimated from received signals.*** The channel state information may include the ***channel state matrix H*** described above. At 320, a beamforming matrix is determined from the channel state information. In some embodiments, this corresponds to performing singular value decomposition (SVD) as described above with reference to equation (1). The beamforming matrix V is also described above.

EX1007 at [0093].

A transmit beamforming matrix may be found using singularvalue decomposition (SVD) of the channel state matrix H as follows:

$$H_{m \times n} = U_{m \times m} D_{m \times n} V'_{n \times n} \quad (1)$$

$$x_{n \times 1} = V_{n \times n} d_{n \times 1} \quad (2)$$

where d is the n-vector of data symbols containing k non-zero elements, where k is the number of active spatial channels (see next paragraph); x is the beamformed, transmitted signal vector on n transmit antennas; H is the channel matrix; H's singular value decomposition is $H=UDV'$; U and V are unitary; D is a diagonal matrix with H's eigenvalues; V is n by n and only the first k columns are needed to be fed back. Equation (2) is the beamforming act at the transmitter after the beamforming matrix V is fed back from the receiver to the transmitter.

Id. at [0018]-[0019]. This is also depicted in Figure 3 (below) of Li '054:

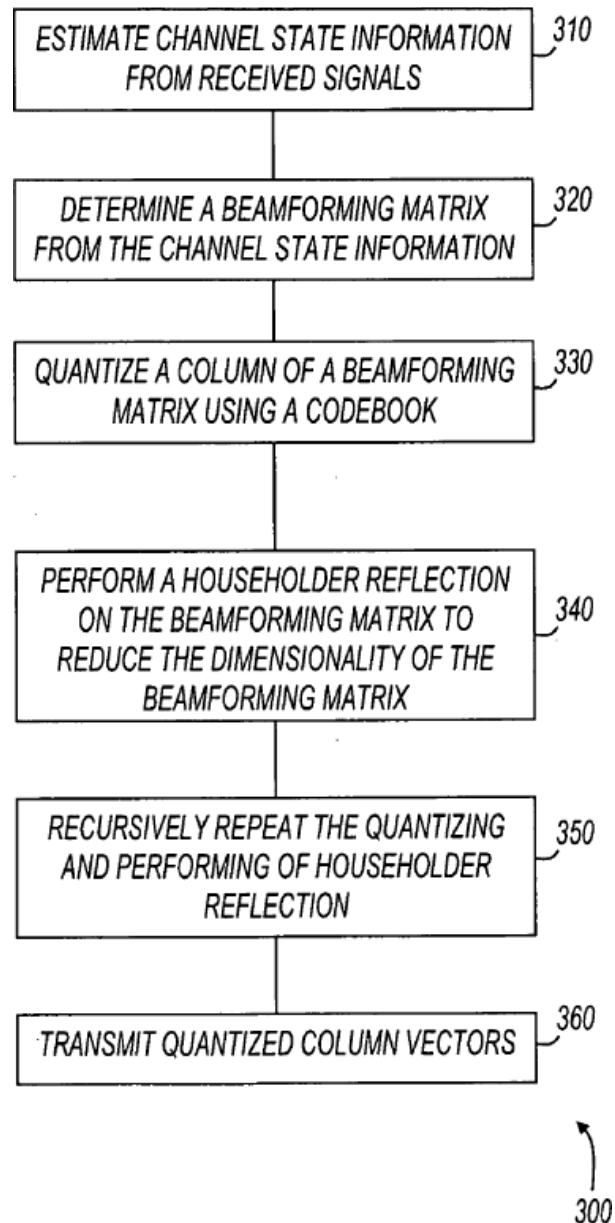


FIG. 3

Id. at FIG. 3.

153. As explained, *supra*, in Section VI.D, a POSITA would have understood that “the channel state matrix H ” ([0018]) was a conventional “channel response.”

[1.c] and [9.e]

Claim	Claim Language
1.c	the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U);
9.e	determine an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U)

154. Li '054 discloses determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U). In particular, Li '054 discloses performing an SVD on the channel state matrix H in order to determine the (transmit) beamforming matrix V, using the well-known SVD equation $H=UDV$, as follows:

Method 300 is shown beginning at block 310 in which channel state information is estimated from received signals. The channel state information may include the channel state matrix H described above. *At 320, a beamforming matrix is determined from the channel state information.* In some embodiments, this corresponds to performing *singular value decomposition (SVD)* as described above with reference to equation (1). The beamforming matrix V is also described above.

Id. at [0093].

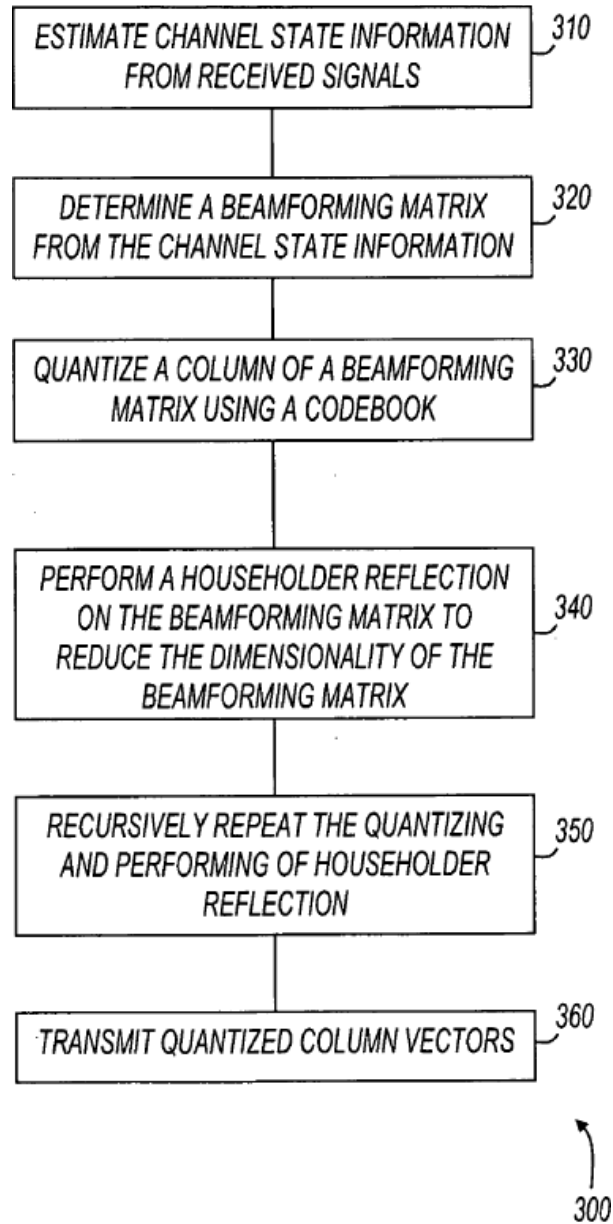


FIG. 3

Id. at FIG. 3 (element 320).

A transmit beamforming matrix may be found using singular value decomposition (SVD) of the channel state matrix H as follows:

$$H_{m \times n} = U_{m \times m} D_{m \times n} V'_{n \times n} \quad (1)$$

$$x_{n \times 1} = V_{n \times n} d_{n \times 1} \quad (2)$$

where d is the n -vector of data symbols containing k non-zero elements, where k is the number of active spatial channels (see next paragraph); x is the beamformed, transmitted signal vector on n transmit antennas; H is the channel matrix; H 's singular value decomposition is $H=UDV'$; U and V are unitary; D is a diagonal matrix with H 's eigenvalues; V is n by n and only the first k columns are needed to be fed back. Equation (2) is the beamforming act at the transmitter after the beamforming matrix V is fed back from the receiver to the transmitter.

Id. at [0018]-[0019].

155. As explained, *supra*, in Section VI.D, a POSITA would have recognized from Li '054's teaching and conventional notation that the equation " $H_{m \times n} = U_{m \times m} D_{m \times n} V'_{n \times n}$ " is the commonly-known SVD equation $H=UDV^*$ used to determine the transmitter beamforming unitary matrix V . The subscripts following each of the variables are included to indicate the dimensions of the respective matrix (e.g., matrix H is an $m \times n$ matrix). As clearly shown in the equation, the transmitter beamforming unitary matrix V is determined based on the values of H and U , as was customary and well-known at the time. Moreover, as explained, *supra*, in Section VI.D, a POSITA would have recognized from Li '054's teaching and conventional notation that in the well-known SVD equation $H=UDV$, channel matrix " H " was the ordinary symbol for the channel response,

“V” was the ordinary symbol for the transmit beamforming matrix, and “U” was the ordinary symbol for the receiver beamforming unitary matrix.

[1.d] and [9.f]

Claim	Claim Language
1.d	the receiving wireless device decomposing the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information; and
9.f	decompose the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information; and

156. Li '054 discloses decomposing the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information. For example, Li '054 teaches decomposing, or reducing, the transmit beamforming matrix V in order to advantageously reduce the feedback bandwidth, as follows:

At 330, a column of a beamforming matrix is quantized using a codebook. In various embodiments of the present invention, the actions of 330 correspond to searching a code block for an entry that most closely matches the column vector. For example, the operations described above with reference to equation (4) may be utilized to search a code book. In various embodiments of the present invention, the size of the codebook, and therefore the number of bits used to represent the quantized vector, may vary. For example, in some embodiments, a large codebook may be used for all column vectors. Also for example, in some embodiments longer column vectors may be quantized using larger codebooks, and a smaller column vectors may be quantized using a smaller code book.

At 340, *a householder reflection is performed on the beamforming matrix to reduce the dimensionality of the beamforming matrix*. In some embodiments, the actions of 340

correspond to the operations described above with reference to the equations (5) and (6). At 350, the quantizing and householder reflection operations of 330 and 340 are recursively repeated. As the operations are recursively repeated, each of the columnvectors may be quantized using the same codebook or different codebooks. For example, as the dimensionality of the beamforming matrix is reduced, smaller codebooks may be usedfor successive column vectors. In some embodiments, where three column vectors are quantized, codebooks of descending size may be utilized such that the column vectors are quantized into eight bits, six bits, three bits, or six bits, five bits, and four bits, or five bits, four bits, and three bits, although this is not a limitation of the present invention.

Id. at [0094]-[0095].

157. Based upon the teachings of Li '054, a POSITA would have understood that Li '054 described a reduction (i.e., a composition) of the transmit beamforming matrix V , and indeed, my analysis of Li '054 confirms thatit describes such a reduction (i.e., decomposition), just like the '862 patent. *See* EX1001 at 13:67-14:3. In this way, Li '054 confirms this element of the '862

patent merely recites the then-common practice of decomposing the transmit beamforming matrix V .

[1.e] and [9.g]

Claim	Claim Language
1.e	the receiving wireless device wirelessly sending the transmitter beamforming information to the transmitting wireless device.
9.g	form a baseband signal employed by the plurality of RF components to wirelessly send the transmitter beamforming information to the transmitting wireless device

158. The combination of Li '054 and Mao renders obvious forming a baseband signal employed by the plurality of RF components to wirelessly send the transmitter beamforming information to the transmitting wireless device. First, based upon Li '054's teachings regarding the receiver providing feedback to the transmitter, a POSITA would have recognized that 'Li '054's device "formed a baseband signal"—a ubiquitous operation in such wireless devices at the time (as I explained above). For example, Li '054 discloses:

Equation (2) is the beam forming act at the transmitter after the beam forming matrix V is fed back from the receiver to the transmitter.

EX1007 at [0019].

In some embodiments of method 300, quantizing and Householder reflection is recursively performed until a small matrix remains, and the small matrix is quantized using a codebook of small matrices. Also in some embodiments, large

column vectors may be quantized by breaking the large column vectors into two or more sub-vectors, and then each of the sub-vectors may be quantized using one or more codebooks. The partition itself may be quantized using one or more codebooks. In still further embodiments, column vectors or sub-vectors may be quantized by normalizing the average power of each element, and quantizing each element using a radial constellation, such as the radial constellation shown in FIG. 2. At 360, the quantized column vectors are transmitted.

Id. at [0096].

Physical layer (PHY) 530 is coupled to antennas 510 to interact with a wireless network. PHY 530 may include circuitry to support the transmission and reception of radio frequency (RF) signals. For example, in some embodiments, PHY 530 includes an RF receiver to receive signals and perform “front end” processing such as low noise amplification (LNA), filtering, frequency conversion or the like. Further, in some embodiments, PHY 530 includes transform mechanisms and beamforming circuitry to support MIMO signal processing. Also for example, in some embodiments, ***PHY 530 includes circuits to support frequency up-conversion, and an RF transmitter.***

Id. at [00104].

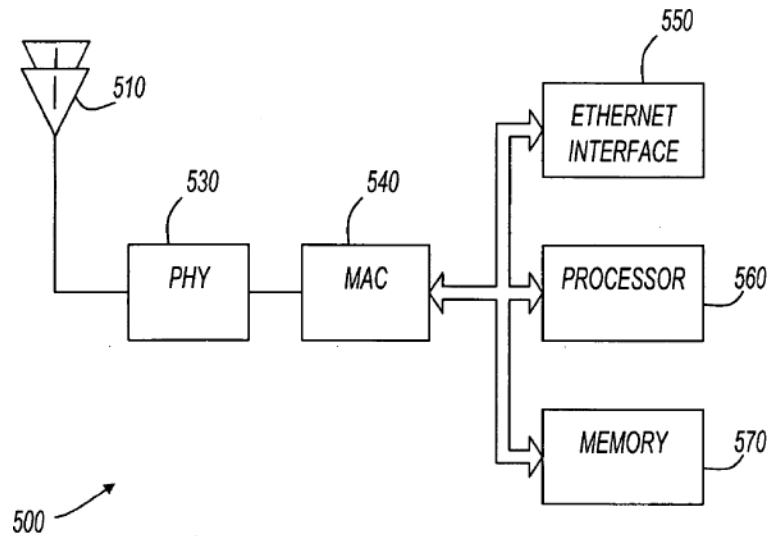


FIG. 5

Id. at FIG. 5.

159. A POSITA would have recognized from Li '054's teaching (relating to the receiver providing feedback in the form of the beamforming matrix V to the transmitter) that Li '054's device "formed a baseband signal," as recited in this element [9.g], for purposes of communicating to the RF transmitter. Li '054 clearly discloses "circuits to support frequency up-conversion" in the physical layer (PHY) 530 that which are used to convert baseband signals into RF signals to be transmitted by the "RF transmitter." *Id.* at [0104]. A POSITA would have known that such components and frequency conversions were ubiquitous in wireless communications devices at the time.

160. Next, to the extent Li '054 does not explicitly describe that the wireless device would "form a baseband signal" as recited in this element [9.g],

such a step of “form[ing] a baseband signal employed by the plurality of RF components to wireless send” the data to the transmitter was normally used in similar wireless devices, as demonstrated by Mao, as follows:

In one embodiment, the present invention provides a wireless communication system, comprising an antenna array structure having a plurality of antenna elements that receive and *transmit radio-frequency signals*, one or more *radio-frequency units and frequency converters configured to* transform received RF signals to receive analog base-band signals and *transform analog transmit base-band signals into a transmit RF signals*, one or more analog-to-digital converters configured to convert the receive analog base-band signals into a receive digital base-band signals and one or more digital-to-analog converters configured to convert transmit digital base-band signals into transmit analog base-band signals.

EX1006 at 3:28-41.

The transmission beam-forming system includes an antenna array system and a *plurality of RF units which may be shared with the receiver beam-forming system, a plurality of up-converters which transform base-band signals into RF signals*, a plurality of digital-to-analog (D/A) conversion units which convert the digital signals to analog signals, and a transmit beam-forming unit.

Id. at 6:31-38. Here, Mao describes the traditional and ubiquitous practice of forming

“base-band signals” for conversion into RF signals. Accordingly, even if Li ’054 does not expressly use the phrase “baseband signals,” Mao clearly teaches the conventional practice of forming “base-band signals” as recited in this Element[9.g].

161. Based on my knowledge and experience in this field and my review of Li ’054 and Mao, it would have been obvious to a POSITA to implement the wireless device of Li ’054 in a manner disclosed by Mao (to form a baseband signal employed by the plurality of RF components) in order to efficiently send data to the transmitter for wireless transmission. Indeed, this predictable implementation of Li ’054 would have provided a wireless device that would advantageously convert a digital signal (processed by the wireless device’s circuitry) into a baseband signal for purposes of properly preparing the signal for transmission back to the transmitter—a practice that was conventional at the time. Indeed, Mao confirms the customary usage of “a plurality of up-converters which transform base-band signals into RF signals.” *Id.* at 6:34-35. Moreover, given the noticeable overlap and similarities in the teachings of Li ’054 and Mao for converting the digital signal to an RF signal usable by the RF transmitter, a POSITA would have recognized that applying Mao’s suggestion (forming “base-band signals” for purposes of sending data to the transmitter for wireless RF transmission) to Li ’054’s device would have led to predictable results without

significantly altering or hindering the functions performed by Li '054's wireless device.

[3] and [11]

Claim	Claim Language
3	The method of claim 1 wherein the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix.
11	The wireless communication device of claim 9, wherein the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix

162. Li '054 discloses these claims. Li '054 discloses that the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix, as follows:

Method 300 is shown beginning at block 310 in which channel state information is estimated from received signals. The channel state information may include the channel state matrix H described above. At 320, a beamforming matrix is determined from the channel state information. In some embodiments, this corresponds to *performing singular value decomposition (SVD) as described above with reference to equation (1)*. The beamforming matrix V is also described above.

EX1007 at [0093].

A transmit beamforming matrix may be found using singular value decomposition (SVD) of the channel state matrix H as follows:

$$H_{m \times n} = U_{m \times m} D_{m \times n} V'_{n \times n} \quad (1)$$

$$x_{n \times 1} = V_{n \times n} d_{n \times 1} \quad (2)$$

where d is the n -vector of data symbols containing k non-zero elements, where k is the number of active spatial channels (see next paragraph); x is the beamformed, transmitted signal vector on n transmit antennas; H is the channel matrix; H 's singular value decomposition is $H=UDV'$; U and V are unitary; ***D is a diagonal matrix*** with H 's eigenvalues; V is n by n and only the first k columns are needed to be fed back. Equation (2) is the beamforming act at the transmitter after the beamforming matrix V is fed back from the receiver to the transmitter.

Id. at [0018]-[0019]; *supra*, Analysis of Elements [9.e]-[9.f]; *supra*, Section VI.D (discussion of SVD).

163. Thus, Li '054 discloses claims 3 and 11.

[4] and [12]

Claim	Claim Language
4	The method of claim 3, wherein the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U) comprises performing a Singular Value Decomposition (SVD) operation
12	The wireless communication device of claim 9, wherein in determining the estimated transmitter beamforming unitary matrix (V) based upon the channel response and the receiver beamforming unitary matrix (U), the baseband processing module performs Singular Value Decomposition (SVD) operations.

164. As previously explained with respect to claim 11 in Section X and incorporated here, Li '054 discloses that in determining the estimated transmitter

beamforming unitary matrix (V) based upon the channel response and the receiver beamforming unitary matrix (U), the baseband processing module performs Singular Value Decomposition (SVD) operations. EX1007 at [0093] (“a beamforming matrix is determined from the channel state information”; “performing singular value decomposition (SVD)”), [0018] (“ $H_{m \times n} = U_{m \times m} D_{m \times n} V'_{n \times n}$ ”); *supra*, Analysis of Elements [9.e]-[9.f]; *supra*, Section VI.D (discussion of SVD); *supra* ¶¶161-162.

165. For at least these reasons, it is clear that the predictable combination of Li '054 and Mao renders obvious all elements of claims 1, 3-4, 9 and 11-12 of the '862 patent.

XI. ANALYSIS OF LI '054 IN VIEW OF MAO AND YANG

166. For the reasons articulated in detail below, and based on my review of the '862 patent, file history, and the prior art references cited here, it is my opinion that a POSITA would have readily understood that the predictable combination of Li '054 in view of Mao and Yang renders obvious all the elements of claims 2 and 10 of the '862 patent. As previously explained, Li '054 discloses wireless devices that estimate channel state information from received signals, determine a beamforming matrix from the channel state information using SVD, reduce the beamforming matrix, and transmit the reduced information back to a transmitter. *Supra* ¶¶133-136. Additionally, as previously explained, Mao discloses a receiver

beamforming system in a wireless communications system that includes radio frequency units and frequency converts from transforming received RF signals into baseband signals, and vice versa. *Supra* ¶¶69-70.

167. Yang, titled “Reducing the Computations of the Singular Value Decomposition Array Given by Brent and Luk,” was published in a scholarly journal in 1991 (EX1008 at 1)—years before the earliest possible priority date (July 13, 2005) of the ’862 patent. Yang is directed to a “method for computing two-sided rotations involved in singular value decomposition (SVD)” that “leads to significantly reduced computations.” EX1008 at Abstract. Yang states an “important problem in linear algebra and digital signal processing is the singular value decomposition (SVD), and that “typical applications [of SVD] arise in beam-forming.” *Id.* at 1. Because of the “high computational complexity of SVD,” there has been “massive interest in parallel architectures for computing SVD.” *Id.* at 1. As such, Yang teaches the traditional use of “coordinate rotation digital computer (CORDIC) processors” in order to reduce the “computational overhead” of previous computational methods. *Id.* at Abstract. Yang explains that the “CORDIC algorithm” is “an iterative procedure for computing plane rotations and Cartesian-to-polar coordinates conversions.” *Id.* at 4. By utilizing the CORDIC algorithm, Yang explains that “the Cartesian coordinate (x_0, y_0) of a plane vector is converted to its polar representation.” *Id.* at 6.

168. As I previously explained (*supra*, Section X), Li '054 and Mao both describe receiver devices in wireless communications systems that use beamforming, and there were a number of reasons that would have prompted a POSITA to predictably apply the teachings of Mao to the wireless device of Li '054 for purposes of achieving known benefits (as described in detail above in Section X). Also, the Yang publication (much like Li '054) describes the traditional use of the SVD operation in beamforming systems. Based on the multiple reasons articulated below, a POSITA would have been prompted to modify Li '054's wireless device (based on features suggested by Yang) to achieve such known benefits and as a matter of predictable and ordinary engineering design. In particular, it would have been obvious to a POSITA to combine Li '054's wireless device with Yang's suggestion of converting Cartesian coordinates to polar coordinates in beamforming. As I explained above in Section X, the predictable combination of Li '054 and Mao renders obvious independent claims 1 and 9, on which claims 2 and 10 depends. I address the additional elements of claims 2 and 10 with respect to the ordinary and predictable result of Li '054 and Mao, in further view of Yang, as follows.

[2] and [10]

Claim	Claim Language
2	The method of claim 1 wherein the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary

	matrix (U) comprises: the receiving wireless device producing the estimated transmitter beamforming unitary matrix (V) in Cartesian coordinates; and the receiving wireless device converting the estimated transmitter beamforming unitary matrix (V) to polar coordinates.
10	The wireless communication device of claim 9, wherein in determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U), the baseband processing module is operable to: produce the estimated transmitter beamforming unitary matrix (V) in Cartesian coordinates; and convert the estimated transmitter beamforming unitary matrix (V) to polar coordinates.

169. The combination of Li '054, Mao, and Yang renders obvious providing a device wherein, in determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U), the baseband processing module is operable to: produce the estimated transmitter beamforming unitary matrix (V) in Cartesian coordinates; and convert the estimated transmitter beamforming unitary matrix (V) to polar coordinates. As a preliminary matter, Li '054 teaches that a “transmit beamforming matrix may be found using singular value decomposition (SVD) of the channel state matrix H.” EX1007 at [0018]-[0019]; *see also* [0093]. Yang additionally discloses the use of SVD in beamforming and converting from Cartesian coordinates to polar coordinates as follows:

One important problem in linear algebra and digital signal processing is the *singular value decomposition (SVD)*. *Typical applications arise in beamforming* and direction finding, spectrum analysis, digital image processing, etc.

EX1008 at 1.

The Cordic algorithm. In the previous section, we have seen that the main operations of the TPR-method are plane rotations and *Cartesian-to-polar coordinates conversions*.

Id. at 5.

The ***CORDIC algorithm*** was originally designed by Volder as an iterative procedure for computing plane rotations and Cartesian-to-polar coordinates conversions.

Id. at 5.

In this way, two different types of CORDIC trigonometric functions can be computed (Table 1). In the mode $y_n \rightarrow 0$, the *Cartesian coordinate (x_0, y_0) of a plane vector is converted to its polar representation*.

Id. at 7.

170. Based on my knowledge and experience in this field and my review of Li '054 and Yang, it would have been obvious to a POSITA to implement the wireless device of Li '054 to convert Cartesian coordinates to polar coordinates (as suggested by Yang) to achieve known benefits at the time. First, a POSITA would have recognized that such an implementation would have predictably provided a wireless device that reduces processor bandwidth in determining matrix V when performing SVD operation, so a POSITA would have been motivated to employ Yang's suggestion (e.g., a CORDIC algorithm) to reduce computational complexity. Additionally, based upon the overlapping similarities between Li '054 and Yang (including the fact that both the traditional use of the SVD operation in beamforming systems), a POSITA would have recognized that applying Yang's suggestion of using the CORDIC algorithm for performing an SVD (including converting the Cartesian coordinates of matrix V to polar coordinates) to the wireless device of Li '054 would have led to predictable results without significantly altering or hindering the functions performed by Li '054's wireless device. As such, it would have been obvious to a POSITA to implement Li '054's wireless device in light of Yang's suggestion of converting the Cartesian coordinates of the V matrix to polar coordinates.

171. For at least these reasons, it is clear that a POSITA would have recognized that the combination of Li '054 in view of Mao and Yang renders obvious claims 2 and 10.

XII. ANALYSIS OF POON IN VIEW OF MAO

172. For the reasons articulated in detail below, and based on my review of the '862 patent, file history, and the prior art references cited here, it is my opinion that a POSITA would have readily understood that the predictable combination of Poon in view of Mao render obvious all the elements of claims 9 and 11-12 of the '862 patent.

173. Poon, titled "Spatial Puncturing Apparatus, Method, and System" was filed June 23, 2004 (EX1009 at cover page), prior to the earliest possible priority date (July 13, 2005) of the '862 patent. Poon is directed to a "receiving station" that "determines channel state information for N spatial channels and feedback to the transmitting station channel information for only N-1 spatial channels," where the "channel state information may include a beamforming matrix." EX1009 at Abstract.

174. Poon shows "wireless stations" 102 and 104 in Figure 1 (reproduced below), where the stations may be part of a wireless local area network. and each include multiple antennas, number 1 to N or 1 to M, respectively. *Id.* at 1:56-58. The stations "each include multiple antennas." *Id.* at 2:5-7.

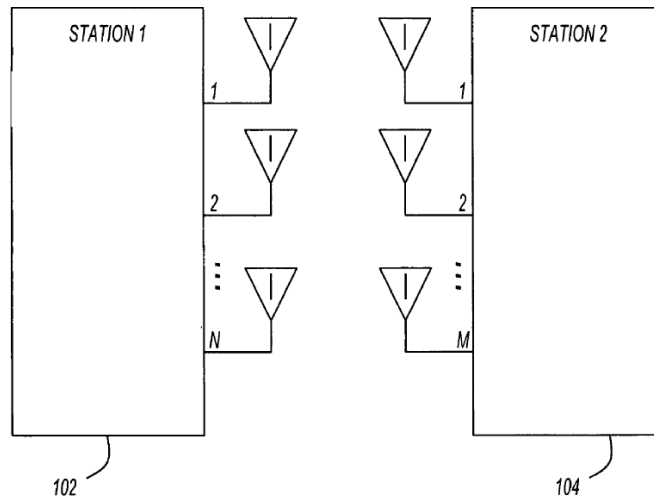


FIG. 1

Id. at FIG. 1

175. Figure 2 (reproduced below) shows a series of steps performed by a receiving device. *Id.* at FIG. 2, 3:7-8, 3:20-22. At step 210, “a receiving station receives a training pattern from a transmitting station,” such as, for example, station 102 transmitting a training pattern and station 104 receiving the training pattern. *Id.* at 3:20-23. At step 220, “the receiving station estimates N spatial channels, where N is equal to the number of receiving antennas,” such as, for example, “station 104 computing a current channel matrix describing the current state of the N spatial channels.” *Id.* at 3:23-28. At 230, “the receiving station determines the weakest of the N spatial channels, and at 240, the receiving stations transmits back the channel state information describing the N-1 spatial channels.” *Id.* at 3:28-31. The channel state information may be “in the form of a transmit beamforming matrix,” where “the receiver computes a transmit beamforming

matrix from the current channel matrix and then sends the beamforming matrix back to the transmitter.” *Id.* at 3:31-36.

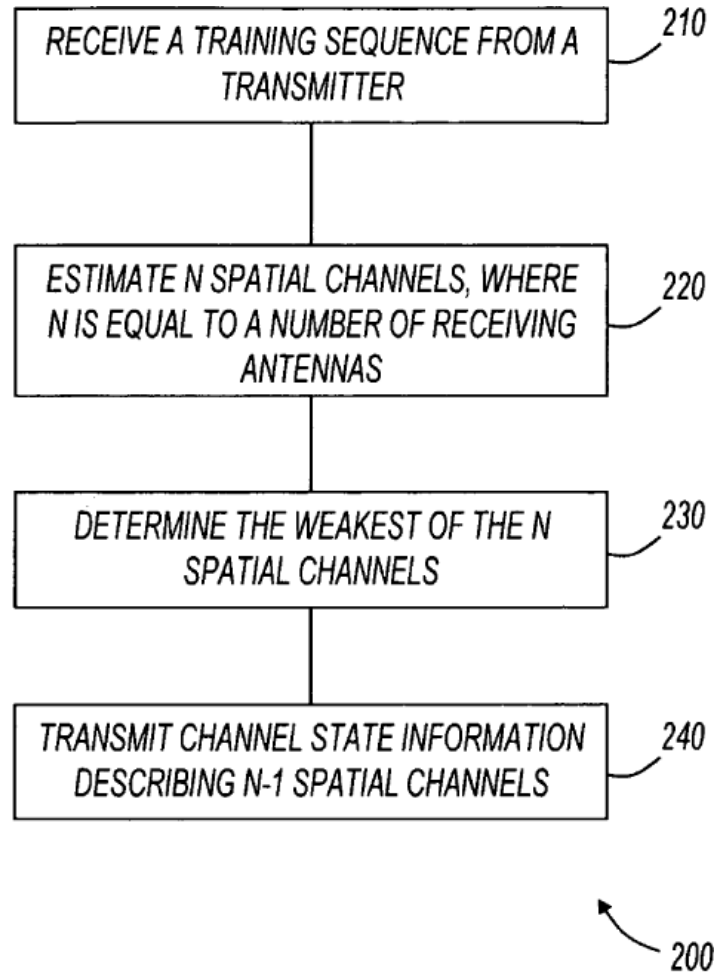


FIG. 2

Id. at FIG. 2.

176. Poon further discloses using “singular value decomposition (SVD)” with the equation $H=U\Sigma V^y$, “where U and V are $N\times N$ unitary matrices, and Σ is a diagonal matrix with positive entries”; and “[m]atrix V is the transmit beamforming matrix.” *Id.* at 3:53-58, FIG. 2.

177. Figure 7 of Poon shows a system 700 that “may be a receiver capable of performing channel estimation.” *Id.* at FIG. 7, 6:5-17. The receiver system “sends and receives signals using antennas 710, and the signals are processed by the various elements shown in FIG. 7.” *Id.* at 6:26-28. The receiver system includes a physical layer (PHY) 730 that “is coupled to antennas 710 to interact with a wireless network” and “include[s] circuitry to support the transmission and reception of radio frequency (RF) signals,” such as “an RF receiver to receive signals and perform ‘front end’ processing.” *Id.* at 6:33-39. The receiver system further includes a media access control (MAC) layer 740 and a processor 760 that “reads instructions and data from memory 770 and performs actions in response thereto.” *Id.* at 6:45-54, FIG. 7.

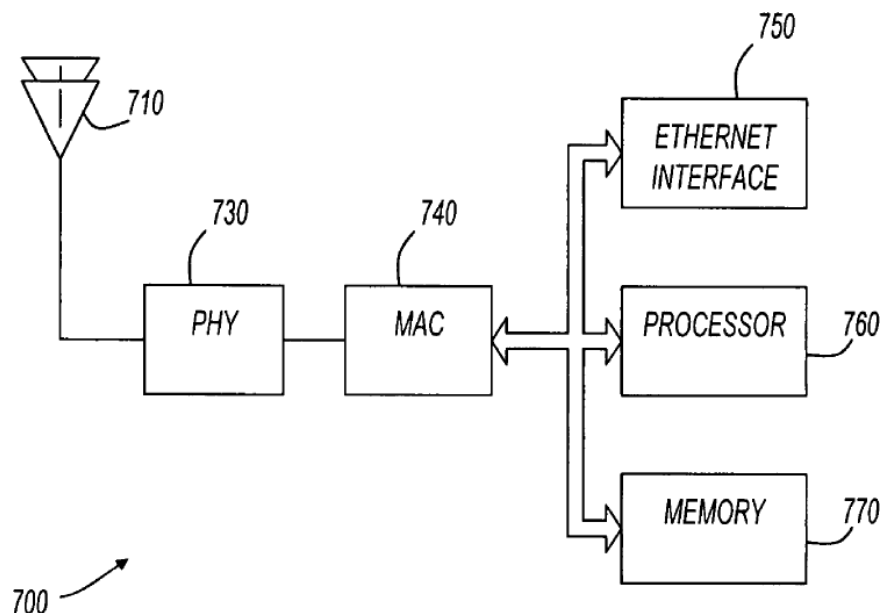


FIG. 7

Id. at FIG. 7.

178. As previously explained above, Mao describes a receiver beamforming system in a wireless communications system that includes radio frequency units and frequency converts from transforming received RF signals into baseband signals, and vice versa. *Supra* ¶¶69-70.

179. Poon and Mao both describe receiver devices in wireless communications systems that use beamforming, and there were a number of reasons that would have prompted a POSITA to predictably apply the teachings of Mao to the wireless device of Poon for purposes of achieving known benefits (as described in detail below). Based on the multiple reasons articulated below, a POSITA would have been prompted to implement Poon's wireless device (based on features suggested by Mao) to achieve such known benefits and as a matter of predictable and ordinary engineering design. In particular, it would have been obvious to a POSITA to combine Poon's wireless device with Mao's suggestion of forming a baseband signal in order to generate a signal for conversion and later transmission back to a transmitter. As part of my analysis, I will address each of the elements of claims 1, 3-4, 9 and 11-12 as follows. Claims 1 and 3-4 are method claims that correspond to device claims 9 and 11-12 addressed below. Figure 1, Poon "wireless station are receiving wireless communication devices that performs methods for feeding back transmitter beamforming information to transmitting

wireless devices. EX1009, 1:56-2:36, 3:7-4:36, FIGs. 1-2. Accordingly, the elements of claims 1 and 3-4 are rendered obvious for the same reasons as the corresponding portions of claims 9 and 11-12.

[1.P] and [9.P]

Claim	Claim Language
1.P	A method for feeding back transmitter beamforming information from a receiving wireless communication device to a transmitting wireless communication device, the method comprising:
9.P	A wireless communication device, comprising:

180. Poon discloses a wireless communications device. For example, Poon discloses a wireless communication device, as follows:

FIG. 1 shows a diagram of ***two wireless stations: station 102, and station 104***. In some embodiments, stations 102 and 104 are part of a ***wireless local area network (WLAN)***.

EX1009 at 1:56-58

Stations 102 and 104 each include multiple antennas. Station 102 includes “N” antennas, and station 104 includes (M)antennas, where N and M may be any number.

Id. at 2:5-7.

FIG. 2 shows a flowchart in accordance with various embodiments of the present invention. In some embodiments, ***method 200 may be used in a wireless system*** that utilizes MIMO technology. In some embodiments, method 200, or portions thereof, is performed by a processor or electronic system, embodiments of which are shown in the various

figures. In other embodiments, *method 200 is performed by a wireless communications device*. Method 200 is not limited by the particular type of apparatus or software element performing the method. The various actions in method 200 may be performed in the order presented, or may be performed in a different order. Further, in some embodiments, some actions listed in FIG. 2 are omitted from method 200..

Id. at 3:7-19, FIG. 2.

[9.a]

Claim	Claim Language
9.a	a plurality of Radio Frequency (RF) components operable to receive an RF signal and to convert the RF signal to a baseband signal; and

181. Poon in view of Mao renders obvious a plurality of Radio Frequency (RF) components operable to receive an RF signal and to convert the RF signal to a baseband signal.

182. First, based upon my analysis of Poon’s device, it is clear that a POSITA would have recognized Poon alone teaches, or at least suggests, this element. Poon discloses that its device includes receiving antennas and baseband data circuits:

Method 200 is shown beginning at block 210 in which a *receiving station receives a training pattern* from a transmitting station. For example, station 102 may transmit a training pattern, and station 104 may receive the training pattern. At 220, the receiving station estimates N spatial

channels, where N is equal to a number of *receiving antennas*.

Id. at 3:20-25.

10. A wireless communications device having N antennas, the *wireless communications device having a combination of hardware and software components* to determine and a weakest of N spatial channels and to always puncture the weakest of N spatial channels, wherein the wireless communications device includes a combination of hardware and software to transmit N-1 beamforming vectors to a transmitter for use in antenna

beamforming into N-1 spatial channels, where N is greater than one.

11. The wireless communications device of claim 10 wherein the wireless communications device includes N-1 *baseband data circuits* to source data to a beamforming network..

Id. at claims 10-11.

183. Based upon these teachings, a POSITA would have recognized that Poon's software, hardware, antennas, and baseband data circuits—all conventional components—are provided “a plurality of Radio Frequency (RF) components operable to receive an RF signal,” as was conventional at the time.

184. A POSITA would have recognized that the conventional hardware and software components disclosed in Poon, including software, hardware, antennas, and baseband data circuits provide a plurality of RF components that are operable

to receive an RF signal and convert it to a baseband signal. Additionally, a POSITA would have understood that components for converting RF signals to baseband signals were nearly universal and customary in these types of wireless receiving devices at the time. Indeed, a POSITA would have understood that such conversion was necessary, or at least the most ubiquitous and predictable manner, for these conventional receiving devices to be able to take the analog radio frequency (RF) signals incident on the antennas, downconvert them to a lower frequency where they can be more easily managed and digitized, and then further process the received signals as a digital baseband signal. Based upon my knowledge and experience in this field and my review of Poon, a POSITA would have understood that such conversion from RF to baseband was necessary in Poon's device in order for the digital baseband circuitry to perform signal processing on the received signal, such as, for example, to estimate a channel matrix. For at least these reasons, Poon discloses this element [9.a].

185. Next, to the extent Poon does not explicitly state that its RF components operate "to receive an RF signal and to convert the RF signal to a baseband signal," it would have been obvious to combine Poon with the teachings of Mao. This functionality was certainly commonplace in such mobile devices, as demonstrated by Mao's teaching. Mao discloses a wireless communication system

with a plurality of RF components operable to receive an RF signal and convert the RF signal to a baseband signal as follows:

In one embodiment, the present invention provides a *wireless communication system*, comprising an antenna array structure having a plurality of *antenna elements that receive and transmit radio-frequency signals*, one or more radio-frequency units and *frequency converters configured to transform received RF signals to receive analog base-band signals* and transform analog transmit base-band signals into a transmit RF signals, one or more analog-to-digital converters configured to convert the receive analog base-band signals into a receive digital base-band signals and one or more digital-to-analog converters configured to convert transmit digital base-band signals into transmit analog base-band signals.

EX1006 at 3:28-41.

186. Based on my knowledge and experience in this field and my review of Poon and Mao, it would have been obvious to a POSITA to implement the wireless device of Poon in a manner suggested by Mao so as to be operable to receive an RF signal and then convert the RF signal into a baseband signal. In context, a POSITA would have recognized Poon's conventional wireless device included an RF receiver that received signals with its receiving antennas and baseband data circuits to source data. EX1009 at 3:20-25, claim 11. A POSITA would further have recognized Mao's conventional wireless device included receive circuitry that

received RF signals and conversion circuitry that converted the RF signals to baseband signals. EX1006 at 3:28-41. Indeed, based upon my knowledge and experience in this field, Mao corroborates the known that that this type of RF-to-baseband conversion circuitry was ubiquitous in wireless communications devices at the time. Here, a POSITA would have recognized that the predictable implementation of Poon (in a manner suggested by Mao) would have predictably provided a wireless device that would convert the received RF signals to baseband signals to efficiently and properly prepare for a digital conversion (to a digital signal) for processing by the digital electronics of Poon's device. Additionally, for the reasons explained above, my analysis of Poon confirms that, such circuitry was in fact necessary in order for the wireless communications devices to perform further processing.

187. Thus, Mao teaches implementing wireless communications devices, such as the device in Poon, to include circuitry that receives RF signals and circuitry that converts the received RF signals to baseband signals. Moreover, based upon the similarities of Poon and Mao and the ordinary knowledge of a POSITA at the time, the typical application of Mao's suggestion (receiving an RF signal and subsequently converting the RF signal to a baseband signal) to Poon wireless device would have led to predictable results without significantly altering or hindering the functions of Poon's wireless device.

[9.b]

Claim	Claim Language
9.b	a baseband processing module operable to:

188. Poon discloses or at least renders obvious this limitation. Poon discloses a baseband processing module, as follows:

FIG. 7 shows a system diagram in accordance with various embodiments of the present invention. Electronic system 700 includes antennas 710, physical layer (PHY) 730, media access control (MAC) layer 740, Ethernet interface 750, **processor 760, and memory 770**. In some embodiments, electronic system 700 may be a station capable of puncturing one spatial channel. For example, electronic system 700 may be utilized in a wireless network as station 102 or station 104 (FIG. 1).

EX1009 at 654-13.

In operation, processor 760 reads instructions and data from memory 770 and performs actions in response thereto. For example, ***processor 760 may access instructions from memory 770 and perform method embodiments of the present invention, such as method 200 (FIG. 2) or methods described with reference to other figures.*** Processor 760 represents any type of processor, including but not limited to, a microprocessor, a digital signal processor, a microcontroller, or the like.

Id. at 6:53-61.

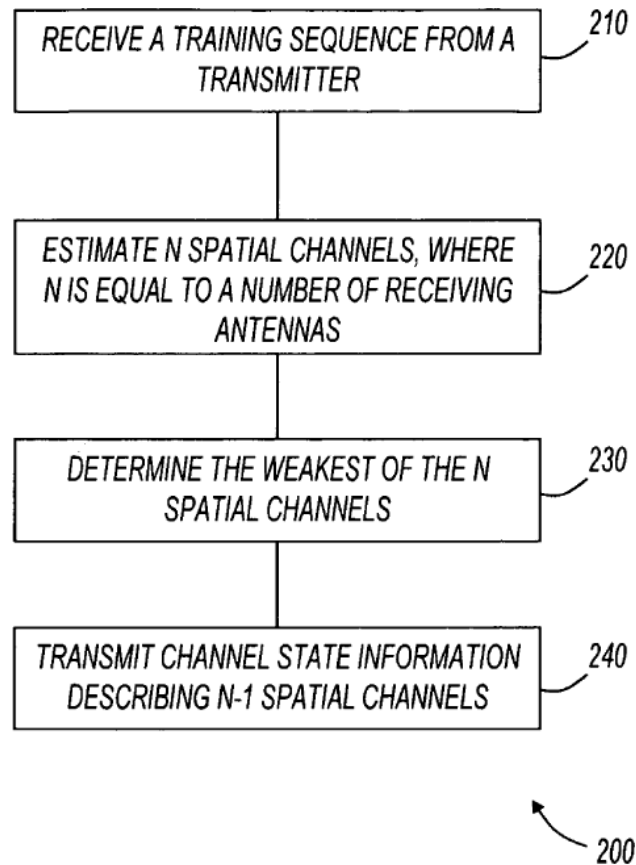


FIG. 2

Id. at FIG. 2.

189. Based upon this teaching in Poon, a POSITA would have recognized that Poon’s processor and memory provided a baseband processing module, which was widely common in such wireless communication devices at the time. Indeed, Poon specifically states that the “processor 760 may access instructions from memory 770 and perform method embodiments of the present invention, such as method 200 (FIG. 2) or methods described with reference to other figures.” *Id.* at 6:53-58. Indeed, as further explained below, I note that the steps in Figure 2 of Poon (reproduced above) includes steps performed by the baseband processing

module of the '862 patent. As such, a POSITA would have recognized that Poon's processor and memory structure provided a baseband processing module.

[1.a] and [9.c]

Claim	Claim Language
1.a	the receiving wireless communication device receiving a preamble sequence from the transmitting wireless device;
9.c	receive a preamble sequence carried by the baseband signal

190. Poon discloses or at least renders obvious receiving a preamble sequence carried by the baseband signal. For example, Poon discloses receiving signals and measuring the channel H using pilot symbols that were received, as follows:

Method 200 is shown beginning at block 210 in which a ***receiving station receives a training pattern*** from a transmitting station. For example, station 102 may transmit a training pattern, and station 104 may receive the training pattern. At 220, the receiving station ***estimates N spatial channels***, where N is equal to a number of receiving antennas. In some embodiments, this may correspond to station 104 computing a current channel matrix describing the current state of the N spatial channels. At 230, the receiving station determines the weakest of the N spatial channels, and at 240, the receiving stations transmits back the channel state information describing the N-1 spatial channels. In some embodiments, the channel state information is in the form of a transmit beamforming matrix. In these embodiments, the ***receiver***

computes a transmit beamforming matrix from the current channel matrix and then sends the beamforming matrix back to the transmitter. In various embodiments of the present invention, one spatial channel is always punctured, and the transmit beamforming matrix is reduced in size, thereby reducing the feedback bandwidth. Mathematical descriptions of various acts shown in FIG. 2 are provided below.

Let the input/output (I/O) model be

$$y = Hx + z$$

where x_i is the signal on the i th transmit antenna, y_i is the signal received at the i th receive antenna, H_{ij} is the channel gain from the j th transmit antenna to the i th receive antenna, and z_i is the noise on the i th receive antenna. In closed-loop MIMO, the receiver may send a pre-coding matrix P back to the transmitter and the I/O model becomes

$$y = HPx + z$$

Upon singular value decomposition (SVD), we have

$$H = U\Sigma V^H$$

where U and V are $N \times N$ unitary matrices, and Σ is a diagonal matrix with positive entries. Matrix V is the transmit beamforming matrix. When V represents N spatial channels, V includes $2N^2$ real numbers, and when V represents $N-1$ channels, V includes $2N(N-1)$ real numbers.

Id. at 3:20-60.

191. A POSITA would have recognized that the “training pattern” of Poon are signals that the receiving station uses to determine a channel response (e.g.,

“estimates N spatial channels”; channel matrix H) and transmit beamforming matrix V. Similarly, the “preamble” of the ’862 patent is received by a “receiving wireless communication device,” which then estimates the channel response and “determines an estimated transmitter beamforming unitary matrix (V).” EX1001 at 13:37-47. Indeed, the ’862 patent specifically states that “[e]stimating the channel response includes comparing *received training symbols of the preamble* to corresponding expected training symbols using any of a number of techniques that are known in the art.” *Id.* at 13:40-44. That is, the “preamble” disclosed in the ’862 patent includes traditional “training symbols,” or a training pattern (as disclosed in Poon), to estimate the channel response (e.g., estimate the spatial channel) and determine the transmit beamforming matrix V, and a POSITA would have recognized this similarity because it was a customary practice at the time in such wireless devices. Thus, Poon discloses receiving a preamble sequence carried by the baseband signal.

[1.b] and [9.d]

Claim	Claim Language
1.b	the receiving wireless device estimating a channel response based upon the preamble sequence;
9.d	estimate a channel response based upon the preamble sequence

192. Poon discloses or at least renders obvious that its baseband processing module is operable to estimate a channel response (e.g., channel matrix H) based upon the preamble sequence (e.g., training pattern). Poon teaches that the

“receiving station receives a *training pattern*” used to determine a channel response H and beamforming matrix V. Ex1009 at 3:20-60. For example:

Method 200 is shown beginning at block 210 in which a receiving station receives a training pattern from a transmitting station. For example, station 102 may transmit a training pattern, and station 104 may receive the training pattern. At 220, the receiving station *estimates N spatial channels*, where N is equal to a number of receiving antennas. In some embodiments, this may correspond to station 104 *computing a current channel matrix* describing the current state of the N spatial channels.

Id., 3:20-28. This is also depicted in Figure 2 (below) of Poon:

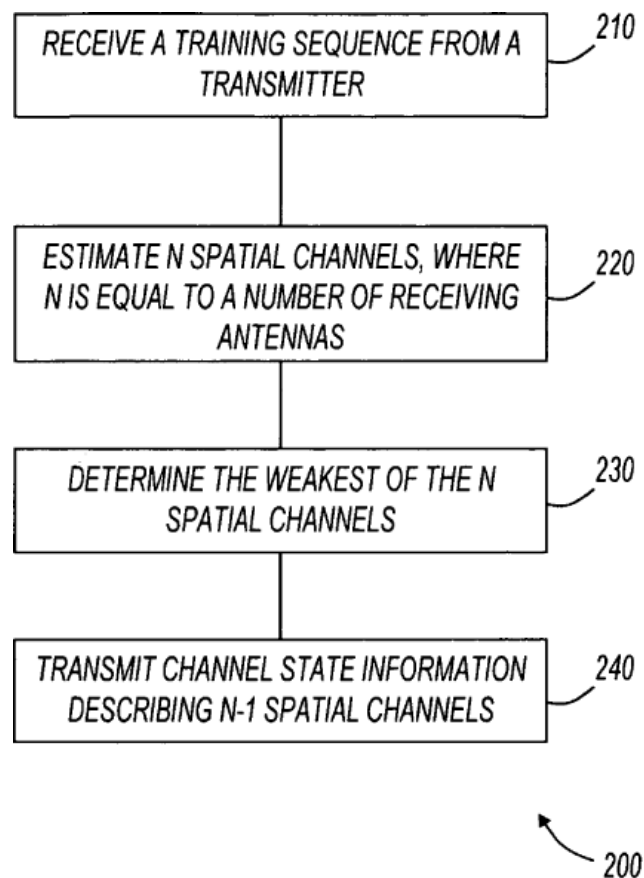


FIG. 2

Id. at FIG. 2 (elements 210, 220).

193. As explained, *supra*, in Section VI.D, a POSITA would have understood that the estimates of the spatial channels or channel matrices of Poon are conventional estimated channel responses.

[1.c] and [9.e]

Claim	Claim Language
1.c	the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U);
9.e	determine an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U)

194. Poon discloses determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U). For example, Poon confirms this conventional determination, as follows:

In some embodiments, the channel state information is in the form of a transmit beamforming matrix. In these embodiments, the receiver computes a ***transmit beamforming matrix from the current channel matrix*** and then sends the beamforming matrix back to the transmitter.

Id. at 3:31-36.

Upon ***singular value decomposition (SVD)***, we have

$$H=U\Sigma V^*$$

where U and V are N×N unitary matrices, and Σ is a diagonal

matrix with positive entries. Matrix V is the transmit beamforming matrix.

Id. at 3:53-58.

195. As explained, *supra*, in Section VI.D, a POSITA would have recognized from Poon's teaching and conventional notation that the equation " $H=U\Sigma V^y$ " is the commonly-known SVD $H=UDV^*$ equation (where the diagonal matrix D is instead represented by Σ) used to determine the transmitter beamforming unitary matrix V . As clearly shown in the equation, the transmitter beamforming unitary matrix V is determined based on the values of H and U , as was customary and well-known at the time. Moreover, based on the disclosure of Poon, a POSITA would have recognized that in the well-known SVD equation $H=UDV^*$ (or $H=U\Sigma V^y$), channel matrix " H " was the ordinary symbol for the channel response, " V " was the ordinary symbol for the transmit beamforming matrix, " U " was the ordinary symbol for the receiver beamforming unitary matrix, and the superscript " y " represents the transpose of the matrix, as I explained, *supra*, in Section VI.D.

[1.d] and [9.f]

Claim	Claim Language
1.d	the receiving wireless device decomposing the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information; and
9.f	decompose the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information; and

196. Poon discloses or at least renders obvious decomposing the estimated transmitter beamforming unitary matrix (V) to produce the transmitter beamforming information. For example, Poon teaches decomposing, or reducing, the transmit beamforming matrix V in order to advantageously reduce the feedback bandwidth, as follows:

In various embodiments of the present invention, one spatial channel is always punctured, and the transmit beamforming matrix is reduced in size, thereby reducing the feedback bandwidth.

Id. at 3:36-39.

197. Based upon the teachings of Poon, a POSITA would have understood that Poon discloses a reduction (*i.e.*, a decomposition) of the transmit beamforming matrix V , and indeed, my analysis of Poon confirms that it describes such a reduction (*i.e.*, decomposition) just like the '862 patent. *See* EX1001 at 13:67-14:3. The teachings of Poon match the '862 patent's explanation that "[w]ith a decomposed matrix form for the estimated transmitter beamforming matrix (V), the set of angles fed back to the transmitting wireless device are reduced." EX1001, 13:67-14:3. In this way, Poon confirms this element of the '862 patent merely recites the then-common practice of decomposing the transmit beamforming matrix V .

[1.e] and [9.g]

Claim	Claim Language
1.e	the receiving wireless device wirelessly sending the transmitter beamforming information to the transmitting wireless device.
9.g	form a baseband signal employed by the plurality of RF components to wirelessly send the transmitter beamforming information to the transmitting wireless device

198. Poon in view of Mao renders obvious forming a baseband signal employed by the plurality of RF components to wirelessly send the transmitter beamforming information to the transmitting wireless device. First, based on Poon's teachings regarding the receiving station transmitting information back to the transmitter, a POSITA would have recognized that Poon's device "formed a baseband signal—a ubiquitous operation in such wireless devices at the time (as I explained above). For example, Poon discloses:

At 230, the receiving station determines the weakest of the N spatial channels, and at 240, the *receiving stations transmits back the channel state information describing the $N-1$ spatial channels*. In some embodiments, the channel state information is in the form of a transmit beamforming matrix.

Id. at 3:28-33.

199. From Poon's teachings (relating to the receiving station sending formation back to a transmitter), a POSITA would have recognized that the baseband module (e.g., processor 760) of Poon's device "formed a baseband signals," as recited in this element [9.g] and the receiving stations then converted those baseband signals into RF signals for purposes of communicating to the RF

transmitter Indeed, a POSITA would have known that such components and frequency conversions were ubiquitous at the time in wireless communication devices having RF transmitters.

200. Next, to the extent Poon does not explicitly state that the wireless device would “form a baseband signal” as recited in this element [9.g], it would have been obvious to combine Poon with Mao. Such a step of “form[ing] a baseband signal employed by the plurality of RF components to wirelessly send” the data to the transmitter was normally used by similar wireless devices, as demonstrated by Mao. For example, Mao also discloses forming baseband signals that are converted to RF signals for sending data back to the transmitter, as follows:

In one embodiment, the present invention provides a wirelesscommunication system, comprising an antenna array structure having a plurality of antenna elements that receive and *transmit radio-frequency signals*, one or more *radio-frequency units and frequency converters configured to* transform received RF signals to receive analog base-band signals and *transform analog transmit base-band signals into a transmit RF signals*, one or more analog-to-digital converters configured to convert the receive analog base-band signals into a receive digital base- band signals and one or more digital-to-analog converters configured to convert transmit digital base-band signals into transmit analog base-

band signals.

EX1006 at 3:28-41.

The transmission beam-forming system includes an antenna array system and a *plurality of RF units which may be shared with the receiver beam-forming system, a plurality of up-converters which transform base-band signals into RF signals*, a plurality of digital-to-analog (D/A) conversion units which convert the digital signals to analog signals, and a transmit beam-forming unit.

Id. at 6:31-38. Here, Mao describes the traditional and ubiquitous practice of forming “base-band signals” for conversion into RF signals. Accordingly, even if Poon does not expressly use the phrase “form baseband signals,” Mao clearly teaches the conventional practice of forming “base-band signals” as recited in this Element [9.g].

201. Based on my knowledge and experience in this field and my review of Poon and Mao, it would have been obvious to a POSITA to implement the wireless device of Poon in a manner suggested by Mao (to form a baseband signal employed by the plurality of RF components) in order to properly send data to the transmitter for wireless transmission. Indeed, this predictable implementation of Poon would have provided a wireless device that would advantageously convert a digital signal (processed by the wireless device’s circuitry) into a baseband signal for purposes of properly preparing the signal for transmission back to the

transmitter—a practice that was conventional at the time. Indeed, Mao confirms the customary usage of “a plurality of up-converters which transform base-band signals into RF signals.” *Id.* at 6:34-35. Moreover, a POSITA would have recognized that applying Mao’s suggestion (forming “base-band signals” for purposes of sending data to the transmitter for wireless RF transmission) to Poon’s device would have led to predictable results without significantly altering or hindering the functions performed by Poon’s wireless device.

[3] and [11]

Claim	Claim Language
3	The method of claim 1 wherein the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix.
11	The wireless communication device of claim 9, wherein the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix

202. Poon discloses that the channel response (H), estimated transmitter beamforming unitary matrix (V), and the receiver beamforming unitary matrix (U) are related by the equation: $H=UDV^*$ where, D is a diagonal matrix, as follows—where the diagonal matrix is represented by the letter Σ instead of the letter D, and the transpose of the matrix is indicated by the superscript “y” instead of “*”:

Upon singular value decomposition (SVD), we have

$$H=U\Sigma V^y$$

where U and V are $N \times N$ unitary matrices, and Σ is a diagonal matrix with positive entries. Matrix V is the transmit beamforming matrix.

EX1009 at 3:53-58.

203. Thus, the combination of Poon and Mao renders obvious claims 3 and 11.

[4] and [12]

Claim	Claim Language
4	The method of claim 3, wherein the receiving wireless device determining an estimated transmitter beamforming unitary matrix (V) based upon the channel response and a receiver beamforming unitary matrix (U) comprises performing a Singular Value Decomposition (SVD) operation
12	The wireless communication device of claim 9, wherein in determining the estimated transmitter beamforming unitary matrix (V) based upon the channel response and the receiver beamforming unitary matrix (U), the baseband processing module performs Singular Value Decomposition (SVD) operations.

204. As previously explained with respect to claim 11 in Section XII and incorporated here, Poon discloses that in determining the estimated transmitter beamforming unitary matrix (V) based upon the channel response and the receiver beamforming unitary matrix (U), the baseband processing module performs Singular Value Decomposition (SVD) operations. *Id.* at 3:53-58 (“Upon singular value decomposition (SVD), we have $H=U\Sigma V^y$ ”); *supra*, Analysis of Elements [9.e]-[9.f]; *supra*, Section VI.D (discussion of SVD); *supra* ¶¶201-202.

205. For at least these reasons, it is my opinion that the predictable combination of Poon and Mao renders obvious all elements of claims 9 and 11-12 of the '862 patent.

XIII. SUPPORT FOR TONG IN EARLIER-FILED PROVISIONAL APPLICATION

206. I have been asked to review U.S. Provisional Application Serial No. 60/614,621 (“Tong ’621 Provisional Application” filed in 2004; EX1012) and U.S. Provisional Application Serial No. 60/619,461 (“Tong ’461 Provisional Application” also filed in 2004; EX1013) (collectively, the “Tong Provisional Applications”) to determine if: (1) one or more of the Tong Provisional Applications provides support for all elements of at least one claim of Tong (EX1005); and (2) the Tong Provisional Applications provide support for the portions of Tong cited within my declaration. As demonstrated below, the Tong ’621 Provisional Application provides full support at least claim 1 of Tong, and the Tong Provisional Applications provide full support for all portions of Tong cited in this Declaration here. For example, the following chart illustrates how the Tong ’621 Provisional Application (filed September 30, 2004) supports each element of claim 1 of Tong, with the citations below to the Tong ’621 Provisional Application confirming why a POSITA would have recognized that the inventors fully contemplated and possessed the knowledge of the “MIMO system” set forth in

claim 1 of Tong. Citations in the chart provide examples of support and should not be considered exhaustive:

	<u>Claim Language (EX1005)</u>	<u>Provisional Support (EX1012)</u>
1.P	1. A MIMO system comprising:	Page 4, FIGs. 1-2, 7, 8, 12, 16, 29
1.a	a transmitter having multiple transmit antennas;	Page 15, FIGs. 7, 8, 12, 16, 29
1.b	at least one receiver, each receiver having at least one receiver antenna;	Page 15, FIGs. 7-8, 12, 16, 29
1.c	each receiver being adapted to transmit at least one type of feedback information selected from a group consisting of: information for use in performing beam-forming; antenna selection/grouping information	Page 15, FIGs. 16, 29

207. Similarly, my analysis confirms that the Tong Provisional Applications from 2004 provide full support for all portions of Tong that I have cited in my Declaration here. For instance, the following chart demonstrates that the teachings in the Tong publication were likewise described in the earlier Tong

Provisional Applications from 2004 (citations in the chart provide examples of support and should not be considered exhaustive):

<u>Tong (EX1005)</u>	<u>Support in Tong '621 Provisional Application (EX1012) and/or Tong '461 Provisional Application (EX1013)</u>
Abstract	EX1013: 72
FIG. 1	EX1013: 20 (FIG. 2)
FIG. 3	EX1012: 22 (FIG. 4)
FIG. 43	EX1012: 39 (FIG. 16)

[0066]	EX1012: 39 (FIG. 16)
[0073]	EX1013: 31
[0074]	EX1013: 31-32
[0077]	EX1013: 32-33
[0078]	EX1013: 33
[0079]	EX1013: 33
[0087]	EX1013: 35
[0090]	EX1013: 36-37
[0187]	EX1012: 21 (FIG. 2), 39 (FIG. 16), 74 (FIG. 51)
[0211]	EX1013: 15-16 EX1012: 30 (FIG. 7), 31 (FIG. 8)
[0222]	EX1012: 37 (FIG. 14), 38 (FIG. 38)
[0223]	EX1012: 39 (FIG. 16), 19
[0226]	EX1012: 39 (FIG. 16)
[0227]	EX1012: 37 (FIG. 14)

XIV. ADDITIONAL REMARKS

208. 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.

[0223]	EX1012: 39 (FIG. 16), 19
[0226]	EX1012: 39 (FIG. 16)
[0227]	EX1012: 37 (FIG. 14)

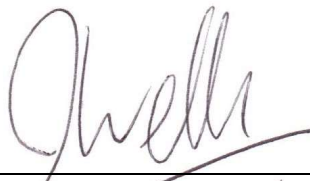
XIV. ADDITIONAL REMARKS

209. 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.

210. 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.

Dated: Sept 25, 2023

By:



 Jonathan Wells, Ph.D.
 Scottsdale, Arizona

APPENDIX A

Jonathan Wells, Ph.D., M.B.A.

Scottsdale, AZ, USA

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Wireless Communications Expertise

- Cellular Networks (5G, 4G, 3G, 2G / NR, LTE, LTE-Advanced, HSPA, WCDMA, UMTS, CDMA, EDGE, GSM, IS-95)
 - Cellular Infrastructure (Handsets, Base Stations, Backhaul and RANs)
 - Wireless LANs (Wi-Fi and Bluetooth)
 - Wireless Standards, Rules and Regulations (3GPP, 3GPP2, IEEE, FCC, ETSI, CEPT)
 - Radio Frequency (RF), Microwave and MM-Wave Devices, Systems and Networks
 - RF Design, including RF Assemblies, Components and Integrated Circuits (ICs, MMICs)
 - Intellectual Property, Patent Analysis and Litigation Support
-

Professional Summary

Dr. Wells has 35 years of wireless communications experience gained from working in three continents. He is currently an independent consultant providing expertise on cellular technologies, wireless devices, network infrastructure and wireless rules and regulations to a client base of attorneys, intellectual property organizations, investment and research institutions, public listed and private companies. Dr. Wells has over 40 academic and commercial publications and presentations, and is lead inventor on several patents. He is Senior Member of the IEEE and is author of “*Multi-Gigabit Microwave and Millimeter-Wave Wireless Communications*,” Artech House, 2010.

Employment History

2007 to present **AJIS Consulting, Pleasanton, CA** *Independent Consultant*

Provide independent technical consulting on wireless communications and emerging wireless fields.

- Technical expert support of 2G, 3G, 4G and 5G cellular and wireless patent litigation.
- Analysis of cellular and mobile wireless patents and infringing equipment.
- Cellular and wireless technology technical and industry analysis for companies, analysts and investment institutions. Research and publication of analyst reports.
- Wireless product development and marketing strategies.
- Specialized technical workshops on various wireless technologies; including cellular networks, mm-wave radios, security sensors and short range radios.
- Specialized global regulatory tasks and product approvals.

2005 to 2007 **GigaBeam Corporation, Herndon, VA**
Director Product Management and Global Regulatory Affairs

Responsible for product strategy for industry-transforming high data rate wireless product.

- Initiated market development in over 40 countries including in Europe, Canada, Caribbean, Latin America, Middle East and Asia.
- Participated and drove standard development in FCC, CEPT and ETSI technical meetings.

2000 to 2004 **Stratex Networks (now Aviat Networks), San Jose, CA**
Director Product Development

Responsible for global product development of high-end digital microwave radios primarily for cellular backhaul applications.

- Led RF/microwave development team of 35 engineers based in two continents.
- Technical leadership of flagship Eclipse product, shipping over 250,000 units.
- Technical management of overseas manufacturing subcontractors.

1998 to 2000 **Adaptive Broadband (now GE Digital Energy), Rochester, NY**
1999-2000: Director Wideband Products, 1998-9: Engineering Group Leader

Full responsibility for the Terrestrial Infrastructure Group, providing telecommunications products for cellular and private network applications.

- P&L responsibility for \$4M wireless division.
- Responsible for the development of a family of digital radios and associated switching / multiplexing equipment.

1994 to 1998 **MAS Technology (now Aviat Networks), Wellington, New Zealand**
1995-98: RF Group Manager, 1994-95: Senior RF Design Engineer

Responsible for RF hardware development for cellular and telecommunications applications.

- Developed three generations of wireless transmission, switching and multiplexing products.
- Design and sustaining responsibility for satellite ground station terminals.
- Responsible for company's European regulatory approvals.

1993 to 1994 **Matra Marconi Space, Portsmouth, UK** *Senior Design Engineer*

- Developed GaAs MMIC mixer and MIC transmitter board for two satellite payloads.
- Theoretical analysis and modeling of low noise VCOs.

1990 to 1992 **University of Bath, Bath, UK** *Post Doctoral Research Officer*

- Fabricated novel quantum amplifiers in clean room environment.
- Developed computer models to predict semiconductor device performance.

1987 to 1990 **British Aerospace, Filton, Bristol, UK** *Engineer (part time)*

- Designed and fabricated novel mixer devices, to support PhD research.

1985 to 1986 **Plessey Research, Caswell, UK** *Engineer (1 year placement)*

- Developed high speed fiber optic transmitter / receiver devices.

Education

- 1998 M.B.A., Massey University, New Zealand
- Awarded with Distinction (top 10% of class)
 - Thesis: “Venture Capital: Does It Exist In New Zealand?”
- 1991 Ph.D., University of Bath, United Kingdom
- Thesis: “Design and optimisation of a millimetre-wave balanced mixer”
 - Sponsored by British Aerospace PLC, Bristol, UK and Science and Engineering Research Council (SERC), UK
- 1987 B.Sc. Physics with Physical Electronics, University of Bath, United Kingdom
- Awarded with First Class Honours, graduated third in class
 - Final year project: “Fibre optic interferometer for location of disturbances”

University Instruction

- 2014 Intellectual Property: Patent Law, Prof. Mark Lemley, Stanford Law School, Stanford University, CA, USA
- 2004 AeA/Stanford Executive Institute for Management of High-Technology Companies, Stanford Graduate School of Business, Stanford University, CA, USA

Expert Witness Experience

Represented underlined party.

- | | |
|-----------------------|--|
| Oct 2022 to Present | <i>Neo Wireless v. <u>General Motors</u>, <u>Tesla</u></i> , 2:22-cv-11407, 11408, E.D. Mich.
Case: Patent case related to multiple 4G/LTE and 5G/NR patents.
Role: Testifying expert for defendant. |
| June 2022 to Present | <i>G+ <u>Communications</u> v. <u>Samsung</u></i> , 2:22-CV-00078, E.D. Tex
Case: Patent case related to multiple 4G/LTE and 5G/NR patents.
Role: Testifying expert for defendant. |
| Mar 2022 to Dec 2022 | <i>Ericsson v. <u>Apple</u></i> , ITC 337-TA-1299
Case: ITC hearing related to two 4G/LTE and 5G/NR patents.
Role: Testifying expert for respondent. Provided two expert reports and witness statement. Deposed. |
| Oct 2021 to Jan 2022 | <i><u>OnePlus</u> v. <u>Bell Northern Research</u></i> , IPR2022-00046, 00047, 00048
Case: <i>Inter Partes</i> Reviews of three cellular and general wireless patents.
Role: Testifying expert for petitioner. Provided multiple declarations. |
| Sept 2021 to Dec 2021 | <i><u>Apple</u> v. <u>Bell Northern Research</u></i> , IPR2021-01588, 01589, 01590, 01591
Case: <i>Inter Partes</i> Reviews of four cellular and general wireless patents.
Role: Testifying expert for petitioner. Provided multiple declarations. |

July 2021 to Dec 2022	<u>Apple v. Ericsson</u> , IPR2021-00446, IPR2021-00450, IPR2022-00338, IPR2022-00340, IPR2022-00456, IPR2022-00462, IPR2022-00468 and IPR2022-00626 Case: <i>Inter Partes</i> Reviews of multiple 4G/LTE, 5G/NR and Wi-Fi patents. Role: Testifying expert for petitioner. Provided multiple declarations, deposed twice.
Mar 2021 to Nov 2022	<u>IP Bridge v. Ericsson, Nokia</u> , 2:21-cv-00213, 00215, E.D. Tex Case: Patent case related to multiple 4G/LTE and 5G patents. Role: Testifying expert for plaintiff. Provided two expert reports. Deposed.
Jan 2021 to Oct 2021	<u>Philips v. Quectel et al.</u> , ITC Inv. No. 337-TA-1240 Case: ITC hearing related to two 4G/LTE patents. Role: Testifying expert for respondent. Provided expert report and witness statement. Deposed. Testified at hearing.
Jan 2021 to Sept 2022	<u>Quectel v. Philips</u> , IPR2021-00562 Case: <i>Inter Partes</i> Review of one 3G patent. Role: Testifying expert for petitioner. Provided declaration. Deposed twice.
Jan 2021 to May 2021	<u>Samsung v. Ericsson</u> , IPR2021-00446, 00450 Case: Two <i>Inter Partes</i> Reviews of two 4G/LTE patents. Role: Testifying expert for petitioner. Provided two declarations.
Dec 2020 to Jan 2023	<u>Finesse Wireless v. AT&T and Verizon</u> , 2:21-cv-00063, E.D. Tex Case: Patent case related to two wireless communication patents. Role: Testifying expert for plaintiff. Provided declaration and two expert reports. Deposed. Testified at trial.
Dec 2020 to May 2021	<u>Ericsson v. Samsung</u> , ITC Inv. No. 337-TA-1425 Case: ITC hearing related to multiple 4G/LTE and 5G patents. Role: Testifying expert for respondent.
Dec 2020 to May 2021	<u>Ericsson v. Samsung</u> , 2:21-cv-10, E.D. Tex Case: Patent case related to multiple 4G/LTE and 5G patents. Role: Testifying expert for defendant.
Dec 2020 to May 2021	<u>Samsung v. Ericsson</u> , IPR2021-00487, 00508, 00568, 00569 Case: Four <i>Inter Partes</i> Reviews of four 4G/LTE and 5G patents. Role: Testifying expert for petitioner. Provided four declarations.
Nov 2020 to Nov 2020	<u>Huawei v. WSOU</u> , IPR2021-00226, 00227 Case: Two <i>Inter Partes</i> Reviews of two cellular patents. Role: Testifying expert for petitioner. Provided two declarations.
Nov 2020 to Apr 2021	<u>Sol IP v. Qualcomm</u> , 6:21-cv-00270, W.D. Tex Case: Patent case related to multiple 4G/LTE, 5G and Wi-Fi patents. Role: Consulting expert for plaintiff.

May 2020 to Aug 2020	<i>AT&T v. KAIFI</i> , IPR2020-00889 Case: <i>Inter Partes</i> Review of one cellular patent. Role: Consulting expert for patent holder.
Mar 2020 to Sept 2020	<i>Samsung v. Bell Northern Research</i> , IPR2020-00675, 00676, 00697, 00698 Case: Four <i>Inter Partes</i> Reviews of three cellular patents. Role: Testifying expert for petitioner. Provided multiple declarations.
Mar 2020 to Dec 2022	<i>Pinn v. Apple, Google, and Samsung</i> , 8:19-cv-1805, 1840, and 1856, C.D. Cal Case: Patent case related to three Bluetooth patents. Role: Testifying expert for defendants. Provided multiple declarations, two expert reports. Deposed. Testified at trial.
Feb 2020 to April 2020	<i>Uniloc v. Samsung</i> , 2:19-cv-00259, E.D. Tex Case: Patent case related to Bluetooth patent. Role: Testifying expert for defendant. Provided declaration.
Jan 2020 to Sept 2020	<i>Apple v. Optis</i> , IPR2020-00465 Case: <i>Inter Partes</i> Review of one 4G/LTE patent. Role: Testifying expert for petitioner. Provided declaration.
Dec 2019 to Nov 2021	<i>Sanyo v. Intel</i> , C.A. No. 2018-0723-MTZ, Court of Chancery, Del Case: Contract dispute related to wireless devices. Role: Testifying expert for defendant. Provided two expert reports. Deposed.
Nov 2019 to Feb 2023	<i>Overhead Door v. Chamberlain Group</i> , ITC Inv. No. 337-TA-1209 Case: ITC hearing related to two wireless transmission and reception patents. Role: Testifying expert for complainant. Provided two expert reports, two witness statements, and multiple post-trial declarations. Deposed twice. Testified at initial hearing and enforcement hearing.
Nov 2019 to Dec 2019	<i>LG Electronics v. Bell Northern Research</i> , IPR2020-00318 Case: <i>Inter Partes</i> Review of Wi-Fi patent. Role: Testifying expert for petitioner. Provided declaration.
Nov 2019 to Dec 2019	<i>Bell Northern Research v. LG Electronics</i> , 3:18-cv-02864, S.D. Cal Case: Patent case related to two Wi-Fi patents. Role: Testifying expert for defendant.
Sept 2019 to Aug 2020	<i>ZTE, Coolpad v. Bell Northern Research</i> , IPR2019-01319, 01320, 01365 Case: Three <i>Inter Partes</i> Reviews of three cellular patent. Role: Testifying expert for petitioner. Provided three declarations.
Sept 2019 to Aug 2020	<i>Bell Northern Research v. Coolpad, ZTE</i> , 3:18-cv-01783, 01786, S.D. Cal Case: Patent case related to three cellular patents. Role: Testifying expert for defendant. Provided expert report. Deposed.
July 2019 to Sept 2019	<i>Harris v. Huawei</i> , 2:18-cv-004390JRG, 2:19-cv-00222, E.D. Tex Case: Patent case related to 4G/LTE patents. Role: Testifying expert for defendant. Provided declaration.

June 2019 to Aug 2021	<i>Optis v. Apple</i> , 2:19-cv-00066, E.D. Tex Case: Patent case related to six 4G/LTE patents. Role: Testifying expert for defendant. Provided declaration and three expert reports. Deposed. Testified at trial.
June 2019 to June 2019	<i>TC Tech v. Sprint</i> , 1:16-cv-00153, D. Del Case: One cellular patents. Role: Consulting expert for plaintiff.
April 2019 to July 2019	<i>Samsung v. Sharp</i> , no case numbers Case: Three <i>Inter Partes</i> Reviews of cellular patents. Role: Consulting expert for petitioner.
April 2019 to Oct 2019	<i>Huawei v. Bell Northern Research</i> , IPR2019-01172, 01174, 01175, 01185, 01186, and 01439 Case: Six <i>Inter Partes</i> Reviews of cellular, Wi-Fi and general wireless patents. Role: Testifying expert for petitioner. Provided six declarations.
April 2019 to Oct 2019	<i>Bell Northern Research v. Huawei</i> , 3:18-cv-01785, S.D. Cal Case: Patent case related to eight cellular, Wi-Fi and general wireless patents. Role: Testifying expert for defendant. Provided two declarations.
Mar 2019 to Mar 2019	<i>Cell Trans v. LG Electronics</i> , 3:18-cv-01955, S.D. Cal Case: Patent case related to one cellular / Wi-Fi patent. Role: Testifying expert for defendant.
Jan 2019 to Aug 2019	<i>Uniloc v. Microsoft</i> , 8:18-cv-2053, 2054, 2224, C.D. Cal Case: Patent cases related to multiple wireless patents. Role: Testifying expert for defendant. Provided declaration.
Dec 2018 to Mar 2019	<i>DSS v. Apple</i> , 4:14-cv-05330, N.D. Cal Case: Patent case related to one Bluetooth patent. Role: Consulting expert for defendant.
Nov 2018 to April 2019	<i>Qualcomm v. Apple</i> , 37-2017-00041389, Sup. Ct. Cal Case: Case related to trade secret misappropriation. Role: Testifying expert for defendant. Provided two declarations.
Nov 2018 to Dec 2018	<i>Sprint v. Intellectual Ventures</i> , IPR2018-01764, 1765 Case: Two <i>Inter Partes</i> Reviews of two wireless communication patents. Role: Technical expert for patent owner.
Nov 2018 to Feb 2019	<i>Maxell v. Huawei</i> , 5:18-cv-00033, E.D. Tex Case: Patent case related to three cellular and cellular / Wi-Fi patents. Role: Testifying expert for defendant. Provided declaration. Deposed.
Aug 2018 to June 2019	<i>Uniloc v. Samsung</i> , 2:18-cv-00040, 41, 42, 44, E.D. Tex Case: Four patent cases related to four cellular, Wi-Fi and Bluetooth patents. Role: Technical expert for defendant. Provided multiple declarations and two expert reports. Deposed twice.

July 2018 to April 2020	<i>Sol IP v. AT&T, Sprint and Verizon</i> , 2:18-cv-00526, 527 and 528, E.D. Tex Case: Three patent cases related to twenty 4G/LTE cellular and seven Wi-Fi patents. Role: Testifying expert for plaintiff. Provided multiple declarations and three expert reports. Deposed.
July 2018 to June 2019	<i>Ericsson v. Intellectual Ventures</i> , IPR2018-01185, 1289 Case: Two <i>Inter Partes</i> Reviews of two wireless communication patents. Role: Technical expert for patent owner.
July 2018 to June 2019	<i>Ericsson v. Intellectual Ventures</i> , IPR2018-01380 Case: <i>Inter Partes</i> Review of wireless communication patent. Role: Consulting expert for patent owner.
Nov 2017 to Apr 2019	<i>Huawei v. Optis Wireless</i> , IPR2018-00653, 655 Case: Two <i>Inter Partes</i> Reviews related to 4G/LTE patent. Role: Testifying expert for petitioner. Provided multiple declarations. Deposed twice.
Nov 2017 to Nov 2018	<i>Huawei v. Optis Wireless</i> , IPR2018-00807 Case: <i>Inter Partes</i> Reviews related to 4G/LTE patent. Role: Testifying expert for petitioner. Provided declaration.
Nov 2017 to Nov 2018	<i>IP Bridge v. TCL Communications</i> , 1:15-cv-00634, D. Del. Case: Patent case related to two 4G/LTE patents. Role: Testifying expert for plaintiff. Provided expert report. Deposed. Testified at trial.
Oct 2017 to Dec 2017	<i>Sharp v. Hisense</i> , ITC Inv. No. 337-TA-1072 Case: ITC hearing related to two Wi-Fi patents. Role: Consulting expert for respondent.
Aug 2017 to Aug 2018	<i>Optis Wireless v. Huawei</i> , 2:17-cv-00123, E.D. Tex Case: Patent case related to three cellular patents. Role: Testifying expert for defendant. Provided two expert reports and multiple declarations. Deposed. Testified at trial.
Aug 2017 to Aug 2017	<i>Securus v. Global Tel*Link</i> , PGR2017-00005 Case: Post grant review proceeding related to one wireless communication patent. Role: Technical expert for patent owner. Provided declaration.
June 2017 to Jan 2019	<i>Huawei v. Maxell</i> , IPR2018-00251 Case: <i>Inter Partes</i> Review related to wireless communication patent. Role: Testifying expert for petitioner. Provided declaration. Deposed.
June 2017 to Dec 2017	<i>Hitachi Maxell v. Huawei</i> , 5:16-cv-00178, E.D. Tex Case: Patent case related to three cellular and cellular / Wi-Fi patents. Role: Testifying expert for defendant. Provided declaration.

Nov 2016 to April 2019	<u>Apple v. Qualcomm</u> , 3:17-cv-00108, S.D. Cal Case: Case related to licensing of cellular and wireless patents. Role: Testifying expert for plaintiff. Provided expert report and declaration. Deposed twice.
Nov 2016 to Aug 2018	<u>Tektronix v. Rohde & Schwarz</u> , ITC Inv. No. 337-TA-1104 Case: ITC hearing related to two radio frequency test and measurement equipment patents. Role: Testifying expert for respondent. Provided expert report.
Jun 2016 to Jan 2017	<u>Arbitration on behalf of LG Electronics</u> Case: Confidential arbitration regarding patent portfolio license. Role: Testifying expert for respondent. Provided two expert reports. Testified at hearing.
Apr 2016 to Nov 2017	<u>Huawei v. T-Mobile</u> , 2:16-cv-00055, 2:16-cv-00056, E.D. Tex Case: Patent case related to five cellular and cellular / Wi-Fi handover patents. Role: Testifying expert for plaintiff. Provided two expert reports and multiple supplements. Deposed twice.
Feb 2016 to July 2016	<u>Unwired Planet v. Huawei and Samsung</u> , HP-2014-000005, High Court of Justice, England Case: UK patent court case related to four European 2G, 3G and 4G/LTE cellular communication patents. Role: Testifying expert for defendant. Provided two expert reports.
Jan 2016 to April 2017	<u>Apple, Microsoft et al v. Evolved Wireless</u> , IPR2016-00981, IPR2016-01177, IPR2016-01185, IPR2016-01208/01209, IPR2016-01228/01229 Case: <i>Inter Partes</i> Reviews of five wireless communication patents. Role: Technical expert for petitioners. Provided five declarations. Deposed four times.
July 2015 to June 2016	<u>Ericsson v. Intellectual Ventures</u> , IPR2015-01367 Case: <i>Inter Partes</i> Review of a wireless communication patent. Role: Technical expert for patent owner. Provided declaration. Deposed.
July 2015 to Feb 2016	<u>Core Wireless v. LG, Google et al</u> , 2:14-cv-00911 and 00912, E.D. Tex Case: Patent case related to location using cellular devices. Role: Testifying expert for defendants. Provided expert report.
May 2015 to May 2016	<u>Adaptix v. Ericsson et al</u> , 6:14-cv-00501, 502, 503, 6:15-cv-00042. E.D. Tex Case: Patent case related to three 4G/LTE communication patents. Role: Testifying expert for plaintiff. Provided two expert reports and multiple declarations.
May 2015 to Dec 2015	<u>Adaptix v. Alcatel-Lucent et al</u> , 6:15-cv-00041, E.D. Tex Case: Patent case related to three 4G/LTE communication patents. Role: Testifying expert for plaintiff.

April 2015 to Dec 2015	<i>Ericsson v. <u>Apple</u></i> , ITC Inv. No. 337-TA-952 Case: ITC hearing related to Bluetooth and cellular / Wi-Fi device patents. Role: Testifying expert for respondent. Provided two expert reports and two witness statements. Deposed. Testified at hearing.
Dec 2014 to Oct 2015	<i>Arbitration on behalf of <u>Huawei</u></i> Case: Confidential arbitration regarding patent portfolio license. Role: Testifying expert for respondent. Provided two expert reports.
Dec 2014 to Sept 2015	<i>Ericsson v. <u>Intellectual Ventures</u></i> , IPR2014-01471 Case: <i>Inter Partes</i> Review of a wireless communication patent. Role: Technical expert for patent owner. Provided declaration. Deposed.
Dec 2014 to Sept 2015	<i>Ericsson v. <u>Intellectual Ventures</u></i> , IPR2014-01412 Case: <i>Inter Partes</i> Review of a wireless communication patent. Role: Technical expert for patent owner. Provided declaration. Deposed.
Nov 2014 to Present	<i><u>Regents of the University of Minnesota v. AT&T et al</u></i> , 0:14-cv-4666, D. Min Case: Patent case related to five 4G/LTE and 5G/NR communication patents. Role: Testifying expert for plaintiff. Submitted multiple declarations and expert reports. Deposed.
Nov 2014 to May 2015	<i>Arbitration on behalf of <u>Samsung</u></i> Case: Confidential arbitration regarding patent portfolio license. Role: Testifying expert for respondent. Provided two expert reports. Testified at hearing.
Oct 2014 to Aug 2015	<i>Ericsson v. <u>Intellectual Ventures</u></i> , IPR2014-01330 Case: <i>Inter Partes</i> Review of a wireless communication patent. Role: Technical expert for patent owner. Provided declaration. Deposed.
Sept 2014 to May 2015	<i>Ericsson v. <u>Intellectual Ventures</u></i> , IPR2014-00963 Case: <i>Inter Partes</i> Review of a wireless communication patent. Role: Technical expert for patent owner. Provided declaration. Deposed.
Sept 2014 to Oct 2014	<i>Ericsson v. <u>TCL Communications</u></i> , 2:14-cv-00677, E.D. Tex Case: Patent case related to a 4G/LTE communication patent. Role: Consulting expert for defendant.
Sept 2014 to Sept 2014	<i>Ericsson v. <u>Intellectual Ventures</u></i> , IPR2014-00958 Case: <i>Inter Partes</i> Review of a wireless communication patent. Role: Technical expert for patent owner.
Jan 2014 to Mar 2016	<i><u>Adaptix v. Ericsson et al</u></i> , 6:12-cv-00049, 00050 and 00369, E.D. Tex Case: Patent case related to three 4G/LTE communication patents. Role: Testifying expert for plaintiff. Provided two expert reports. Deposed.
Jan 2014 to Dec 2015	<i><u>Adaptix v. Alcatel-Lucent et al</u></i> , 6:12-cv-00022, 00122 and 00123, E.D. Tex Case: Patent case related to three 4G/LTE communication patents. Role: Testifying expert for plaintiff. Provided two expert reports. Deposed. Testified at trial.

Jan 2014 to Jan 2015	<u>Cell and Network Selection v. AT&T et al</u> , 6:13-cv-00403 and 404, E.D. Tex Case: Patent case related to a 4G/LTE communication patent. Role: Testifying expert for plaintiff. Provided two expert reports. Deposed.
Oct 2013 to Jan 2014	<u>Ericsson v. Samsung</u> , 6:12-cv-00894 and 00895, E.D. Tex Case: Patent case related to 24 wireless communication patents. Role: Testifying expert for defendant.
June 2013 to Dec 2013	<u>Adaptix v. Ericsson</u> , ITC Inv. No. 337-TA-871 Case: ITC hearing related to 4G/LTE wireless communication patent. Role: Testifying expert for complainant. Provided expert report and witness statement. Deposed.
Mar 2013 to Sept 2014	<u>Mobile Telecommunication v. BlackBerry</u> , 3:12-cv-01652, E.D. Tex Case: Patent case related to five wireless communications patents. Role: Consulting expert for plaintiff.
Mar 2013 to Dec 2013	<u>Mobile Telecommunication v. Sprint</u> , 2:12-cv-00832, E.D. Tex Case: Patent case related to five wireless communications patents. Role: Consulting expert for plaintiff.
Jan 2013 to May 2014	<u>TracBeam v. Google</u> , 6:13-cv-00093, E.D. Tex Case: Patent case related to two cellphone location patents. Role: Testifying expert for defendant. Provided two expert reports. Deposed.
Jan 2013 to Sept 2013	<u>Ericsson v. Samsung</u> , ITC Inv. No. 337-TA-862 Case: ITC hearing related to seven 2G, 3G, 4G/LTE and Wi-Fi patents. Role: Testifying expert for respondent. Provided two expert reports and two Witness Statements. Deposed. Testified at hearing.
Jan 2013 to June 2013	<u>EON v. AT&T et al</u> , 3:11-cv-01555, E.D. Tex Case: Patent case related to wireless communications patent. Role: Consulting expert for plaintiff.
Nov 2012 to Oct 2013	<u>Cormany et. al. v. Fireman's Fund Insurance Company</u> , CIVDS1100146, Sup. Ct. Cal Case: Breach of contract case involving location via cell phone. Role: Testifying expert for plaintiff. Provided technical analyses. Deposed.
Oct 2012 to Dec 2012	<u>Drivertech v. R+L Carriers</u> , 2:08-cv-00862, S.D. Ohio Case: Patent case related to wireless communications patent. Role: Consulting expert for defendant. Provided technical analyses.
May 2012 to April 2013	<u>Sparkes Cable Company v. Rancho San Antonio Retirement Housing Corp.</u> , 112-cv-225390, Sup. Ct. Cal Case: Breach of contract related to telecommunications network. Role: Consulting expert for defendant. Provided technical analyses.
April 2012 to Sept 2012	<u>EON v. T-Mobile et al</u> , 6:10-cv-00379, E.D. Tex Case: Patent case related to wireless communications patent. Role: Testifying expert for plaintiff. Provided expert report and declarations. Deposed.

March 2012 to April 2012	<i>Baker v. SLG Group</i> , CV-2010-901219 Case: Civil case involving location via cell phone. Role: Consulting expert for plaintiff. Provided technical analyses.
Sept 2011 to July 2012	<i>Samsung v. Apple</i> , 11-cv-01846, N.D. Cal Case: Patent case related to 3G WCDMA patent. Role: Consulting expert for defendant. Provided technical analyses.
Mar 2011 to July 2013	<i>Wi-LAN v. Alcatel-Lucent et al</i> , 6:10-cv-00521, E.D. Tex Case: Patent case related to four 3G HSDPA patents. Role: Testifying expert for plaintiff. Provided two Expert Reports, Supplement to Expert Report and Declarations. Deposed. Testified at trial.
Oct 2010 to Jan 2011	<i>People of the State of California v. Wandrey</i> , CR920809 Case: Criminal murder case involving location via cell phone. Role: Consulting expert for defendant. Provided technical analyses.
Sept 2010 to Oct 2010	<i>People of the State of California v. Tran</i> , CC826024 Case: Criminal murder case involving location via cell phone. Role: Consulting expert for defendant. Provided technical analyses.
May 2010 to Apr 2011	<i>People of the State of California v. Rivas & Carrillo</i> , SS090603A/B, SS110071A/B Case: Criminal murder case involving location via cell phone. Role: Testifying expert for defendant. Provided expert report. Testified at trial.
June 2009 to June 2010	<i>American Traffic Solutions v. Redflex Traffic Systems</i> , CV 08-2051-PHX, D. Arizona Case: Unfair competition related to FCC authorization of speed radars. Role: Testifying expert for plaintiff. Provided expert report and multiple declarations.

Professional Affiliations

2011 – Present	Toastmasters International
2008 – Present	IEEE Consultants' Network of Silicon Valley (CNSV) (Treasurer, 2017-18, Vice-chair, 2015-16, Treasurer, 2013-14; Co-chair, Intellectual Property Special Interest Group, 2010-12)
1995 – Present	Institute of Electrical and Electronic Engineers (IEEE) (Senior Member since 1999; Member, IEEE Communications Society; Member, IEEE Microwave Theory and Techniques Society)

Awards, Achievements and Professional Service

- 2019 Awarded IEEE Santa Clara Valley Section 2019 “Outstanding Engineer.”
Citation: “For his acknowledged expertise in the field of wireless communications and wireless technology, for his willingness to mentor others in the field, and for his work in the development of the next generation of creative and innovative technical products.”
- 2016 Awarded Distinguished Toastmaster (DTM), Toastmasters International.
- 2016 Interviewed as Telecommunications Expert by CNN affiliate on national TV.
- 2013 Guest speaker, UC Berkeley course IEOR 190G: Wireless and Mobile Devices Patents – Patent Engineering
- 2012 Technical Reviewer, IEEE International Microwave Symposium, IMS2012
- 2011 Technical Reviewer, IEEE International Microwave Symposium, IMS2011
- 2010 Guest speaker, Carnegie Mellon University course 96-833: Fundamental Consulting Skills
- 2009 Reviewer, US Government’s Broadband Technology Opportunity Program (BTOP) and Broadband Initiatives Program (BIP), part of American Recovery and Reinvestment Act of 2009
- 2009 Expert Advice columnist, Microwave Journal
- 2009 Organizer and session chair, IEEE International Microwave Symposium, IMS2009
- 2008 Co-chair and organizer, IWPC workshop on Millimeter-Wave Security Sensors
- 2008 Co-chair, IWPC workshop on Extending the Life of GSM & EDGE Networks
- 2008 Co-chair, IWPC workshop on Wireless IP/Ethernet Backhaul for Next Generation Mobile Networks
- 2002 – 2006 Member and deputy chair, Wireless Communications Association (WCA) 40+ GHz Spectrum Development Committee
- 2001 – 2004 Member, Cal Poly Electrical Engineering Industrial Advisory Committee
- 1999 Elected as Senior Member, IEEE
- 1993 – 2002 Member, Institution of Electronic Engineers (MIEE)
- 1995 Registered as Chartered Engineer (CEng)

Patents

- US 7,623,829, “Transceiver power detection and control architecture,” issued Nov 24, 2009
- US 7,236,745, “Transceiver power detection architecture,” issued June 26, 2007
- CN 1,757,186, “Transceiver power detection architecture,” published Apr 5, 2006

EP 1,599,952, “Transceiver power detection architecture,” published Nov 30, 2005

WO 2004/080035, “Transceiver power detection architecture,” published Sept 16, 2004

Publications and Presentations

Books and Theses

J.A. Wells, “*Multi-Gigabit Microwave and Millimeter-Wave Wireless Communications*,” Artech House, Boston, Sept. 2010 (ISBN 1608070824)

J.A. Wells, “*Venture Capital: Does It Exist In New Zealand?*” MBA Thesis, Massey University, 1998

J.A. Wells, “*The Design and Optimisation of a Millimetre-Wave Balanced Mixer*,” PhD Thesis, University of Bath, 1991

Television

Nancy Grace, HLN (formerly CNN Headline News), April 27, 2016 (Interviewed as Telecommunications Expert)

Nancy Grace, HLN, April 26, 2016 (Interviewed as Telecommunications Expert)

Published Research Reports

J. Madden and J.A. Wells, “*Backhaul, Midhaul, and Fronthaul for the HetNet*,” Mobile Experts, USA, Dec. 2015

J.A. Wells, “*Backhaul and Fronthaul for the HetNet*,” Mobile Experts, USA, Nov. 2014

J.A. Wells, “*Backhaul for Small Cells*, 2nd Edition” Mobile Experts, USA, Nov. 2012

J.A. Wells, “*Backhaul for Small Cells*,” Mobile Experts, USA, Oct. 2011

Journal and Magazine Publications

J.A. Wells, “The Seven Rules for Hiring a Wireless Technology Expert,” *New Matter; Official Publication of the Intellectual Property Section of the State Bar of California*, Vol. 35, No. 4, pp. 5-6, Dec. 2010

J.A. Wells, “MM-Waves in the Living Room: The Future of Wireless High Definition Multimedia Connectivity,” *Microwave Journal*, Vol. 52, No.8, pp. 72-84, Aug. 2009

J.A. Wells, “Faster Than Fiber: The Future of Multi-Gb/s Wireless,” *IEEE Microwave Magazine*, Vol. 10, No.3, pp. 104-112, May 2009 (Invited Paper)

J.A. Wells, “Multigigabit Wireless Technology at 70, 80 and 90 GHz,” *RF Design*, pp. 50-58, May 2006

J.A. Wells, “Gigabit per Second Wireless Backhaul at 70 and 80 GHz for WiMAX Networks,” *Focus on Technology* supplement in *Wireless Design and Development*, pp. S6-S8, May 2006

J.A. Wells, “New Multi-Gigabit Wireless Systems Satisfy High Security Rapid Response Applications,” *Military Embedded Systems*, Vol. 2, No. 1, pp. 22-26, Spring 2006

J.A. Wells, “Multi-Gigabit Connectivity at 70, 80 and 90 GHz,” *Microwave Journal*, pp. 128-135, July 2005

J.A. Wells, "Millimeter Wave Point-To-Point Radios," *Applied Microwave and Wireless*, pp. 81-82, Aug. 2002 (Guest Editorial)

J.A. Wells and N.J. Cronin, "Theoretical Analysis of Air Bridging and Back Etching Techniques on the Shunt Capacitance of Planar Subharmonic Mixer Diodes," *IEE Proceedings - Part H*, Vol. 140, No. 6, pp. 474-80, Dec. 1993

J.A. Wells and N.J. Cronin, "Frequency Dependent Simulation of Planar Millimeter-Wave Mixer Diodes," *17th International Conference on Infra-Red and Millimeter Waves Digest*, USA, pp. 214-5, Dec. 1992

J.A. Wells and N.J. Cronin, "Determination and Reduction of the Capacitance Associated with the Bonding Pads of Planar Millimeter-Wave Mixer Diodes," *IEEE Microwave and Guided Wave Letters*, Vol. 2, No. 7, pp. 297-9, July 1992

J.A. Wells and N.J. Cronin, "Planar Schottky-Diode Devices for Millimetre-Wave Balanced Mixer Applications," *21st European Microwave Conference Digest*, Germany, pp. 370-5, Sept. 1991

N.J. Cronin, R. James and J.A. Wells, "Subharmonic Mixers for Short Millimetre Wavelengths," *16th International Conference on Infra-Red and Millimeter Waves Digest*, Switzerland, p. 143, Aug. 1991

J.A. Wells, N.J. Cronin and P.H. Reece, "A Rugged 94GHz Crossbar Balanced Mixer," *IEE Proceedings - Part H*, Vol. 137, No. 4, pp. 235-7, Aug. 1990

J.A. Wells, N.J. Cronin and P.H. Reece, "A Rugged 94GHz Millimetre-Wave Balanced Mixer," *1st International Conference on Millimeter Waves and Far-Infrared Technology Digest*, China, pp. 254-6, June 1989

Online Publications

J.A. Wells, "Backhaul for small cells: A 1.5 billion dollar market opportunity," *EE Times, Design Article*, Nov. 2011

J.A. Wells, "The Gigabit Millimeter-Wave Superhighway," *Microwave Journal, Expert Advice Blog*, Aug. 2009 (Invited Column)

Lectures and Conference Presentations

"The Role of the Expert Witness: A Panel Discussion," *IEEE Consultants' Network of Silicon Valley*, USA, Apr. 2019 (Panel Moderator)

"Taking the Pulse of 5G: The Status of the Next Gen Cellular Network," *IEEE Consultants' Network of Silicon Valley*, USA, Jan. 2019

"5G and the Future of Cellular," *IEEE Consultants' Network of Silicon Valley*, USA, Mar. 2016

"SON [Self-Organizing Networks]: The Enabling Technology in Small Cell Networks," *Wireless Communications Alliance (WCA)*, USA, April 2014 (Panel Moderator)

"Feeding the Beast – The Road to 5G Backhaul," *Wireless Communications Alliance (WCA)*, USA, April 2013 (Invited Panelist)

"The Mobile Patent Wars: An Introduction to the Technology behind the Ongoing Smartphone Litigation," *UC Berkeley course IEOR 190G: Wireless and Mobile Devices Patents – Patent Engineering*, USA, March 2013

- “Mobile Patent Wars,” *IEEE-SCV Communications Society*, USA, May 2012 (Invited Panelist)
- “Building a Successful Consulting Practice,” *Carnegie Mellon University (CMU) course 96-833: Fundamental Consulting Skills*, USA, May 2011
- “Faster Than Fiber: Enabling Multi-Gigabit Wireless Communication Links,” *IEEE International Microwave Symposium IMS 2009*, USA, June 2009
- “The Future of Cellular Infrastructure,” *IEEE Consultants’ Network of Silicon Valley*, USA, Mar. 2009
- “Wireless Backhaul Trends: The Future Role of Wireless, Fiber Optics and Copper Wire,” *IEEE-SCV Communications Society*, USA, Oct. 2008
- “Millimeter-Wave Sensor Systems Benchmarking for Security Applications,” *IWPC Workshop on MM-Wave Sensors for Layered Security of Critical Infrastructure*, USA, April 2008
- “Marketing for Translators and Interpreters,” *Northern California Translators Association Workshop*, USA, Mar. 2007
- “WiFiber: New Spectrum Links for Wireless Gigabit Transmission,” *ACM/IEEE conference on Supercomputing SC06*, USA, Nov. 2006
- “WiFiber Wireless Fiber: Ultra High Data Rate Radios,” *Wireless Fibre Amsterdam*, The Netherlands, Sept. 2006 (Keynote Speaker)
- “Gbps+ Wireless Local Loop: Transforming Last Mile Economics,” *USTA Webinar*, Aug. 2006
- “WiFiber: New Spectrum Links for Wireless Gigabit Local Broadband,” *Internet 2 Spring Meeting*, USA, April 2006
- “Multi-Gigabit Wireless Backhaul at 70 and 80 GHz for WiMAX Networks,” *PTC’06*, USA, Jan. 2006
- “Future Trends in MM-Wave Radios for Wireless Backhaul Applications,” *IWPC Workshop on Millimeter Wave Backhaul and 60 GHz Unlicensed Band Radios*, USA, June 2002
- “Millimeter Wave Point-To-Point Radios for Carrier Class Access and Transport Applications,” *8th WCA Technical Symposium Proceedings*, USA, Feb. 2002
- “Commercial Opportunities at 94 GHz,” *IEEE MTT-S International Microwave Symposium*, USA, May 2001 (Invited Panelist)
- “Research and Development at MAS Technology,” *New Zealand Communications Research Workshop 1997*, New Zealand, May 1997 (Invited Paper)
- “Overcoming RF Technical Difficulties in Moving from QPSK to 16 QAM Modulation,” *New Zealand Communications Research Workshop 1997*, New Zealand, May 1997
- “Modern Microwave Technology,” *VHF Convention 1995*, New Zealand, April 1995
- “100W 2GHz Linear FET Amplifier Design,” *VHF Convention 1995*, New Zealand, April 1995
- “Low Phase Noise Oscillator Design for Wide band Radio Applications,” *4th New Zealand Communications Workshop*, New Zealand, Sept. 1994
- “Numerical Modeling of Millimeter-Wave Schottky Diodes,” *2nd UK-Japan N+N Meeting on Terahertz Technology*, Japan, July 1992

“Planar Schottky-Diode Devices for Millimetre-Wave Balanced Mixer Applications,” *21st European Microwave Conference Digest*, Germany, Sept. 1991

“A Rugged 94GHz Millimetre-Wave Balanced Mixer,” *1st International Conference on Millimeter Waves and Far-Infrared Technology Digest*, China, June 1989