IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:	Xuefeng Yin
U.S. Patent No.:	8,891,347
Issue Date:	November 18, 2014
Appl. Serial No.:	13/522,422
Filing Date:	July 16, 2012
Title:	USER-FOCUSING TECHNIQUE FOR WIRELESS COMMUNICATION SYSTEMS

DECLARATION OF EXPERT

I declare that all statements made herein on my own knowledge are true and that all statements made on information and belief are believed to be true, and further, that these statements were made with the knowledge that willful false statements and the like so made are punishable under Section 1001 of Title 18 of the United States Code.

Digitally signed by Zhi Ding
Date: 2025.08.29 09:48:05 -07'00'

Date: August 29, 2025

By: _____
Dr. Zhi Ding

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I. ASSIGNMENT

1. I have been retained on behalf of Apple Inc. ("Apple") to offer technical opinions related to U.S. Patent No. 8,891,347 ("'347 Patent") (APPLE-1001). I understand that Apple is requesting that the Patent Trial and Appeal Board ("PTAB" or "Board") to institute an *inter partes* review ("IPR") proceeding of the '347 Patent.

2. I have been asked to provide my independent analysis of the '347 Patent based on the prior art publications cited in this declaration.

3. I am not and never have been, an employee of Apple. I received no compensation for this declaration beyond my normal hourly compensation based on my time actually spent analyzing the '347 Patent, the prior art publications cited below, and issues related thereto, and I will not receive any added compensation based on the outcome of any IPR or other proceeding involving the '347 Patent.

II. QUALIFICATIONS AND BACKGROUND INFORMATION

4. I am over the age of 18 and am competent to write this declaration. I have personal knowledge, or have developed knowledge of these technologies based upon education, training, or experience, of the matters set forth herein.

5. I presently hold the title of Distinguished Professor in the Department of Electrical and Computer Engineering at the University of California, Davis. Since my appointment on July 1, 2000, I have held the position of professor for the

past 25 years at the present university and have served as a faculty member at several US universities for over 35 years. I am also a private technical consultant on various technologies related to information systems. I have more than three decades of research experience on a wide range of topics related data communications and signal processing.

6. I earned my Bachelor of Science degree in 1982 in wireless engineering from the Nanjing Institute of Technology (later renamed as Southeast University) in Nanjing, China. I earned my Master of Science degree in 1987 in electrical engineering from the University of Toronto in Toronto, Canada. I earned my Ph.D. in 1990 in electrical engineering from Cornell University in Ithaca, New York.

7. My responsibilities as a Professor at University of California, Davis, include classroom instruction on various topics of communication systems and signal analysis, as well as mentoring undergraduate students and supervising graduate students in their research and development efforts on various topics related to digital communications. I have directly supervised such research and development works ranging from signal detection to wireless networking. As the chief academic advisor, I have also directly supervised the completion of over 20 Masters theses and 30 Ph.D. dissertations on various topics related to digital communications. I have served full time as a faculty member at three major

research universities in the United States over the past 30 years, including Auburn University from 1990 to 1998, University of Iowa from 1999 to 2000, and University of California, Davis, from 2000 to present.

8. Since 1990, I have been selected as the principal investigator of multiple highly competitive federal and local research grants, including more than twenty major research projects supported by the National Science Foundation and two research projects funded by the U.S. Army Research Office. These competitive research projects focused on developing more efficient and effective digital communication transceivers, networks, and signal processing tools. I have also participated in several large-scale projects supported by the Defense Advanced Research Projects Agency (DARPA) with teams of researchers. I have applied for, and received support from, other federal, state, and industry sponsors.

9. I have published over 260 peer-reviewed research articles in premier international journals, in addition to over 250 refereed technical articles at top international conferences on communications and information technologies. I also authored two books on communications technologies. My most recent book, coauthored with B.P. Lathi, is entitled, "Modern Digital and Analog Communication Systems," 6th edition, and was published by the Oxford University Press in 2025. The 4th edition of this book (published in 2009) had been widely adopted as an introductory textbook to communication systems.

10. In addition to the over 510 published technical papers that have been cited over 21,000 times by peer scholars or engineers according to Google Scholar[1], I am also co-inventor of 7 issued U.S. patents on communication technologies.

11. I am a member of the Institute of Electrical and Electronics Engineers (IEEE) and was elevated to the grade of Fellow in January 2003 for contributions made in signal processing for communication. The IEEE is the world's largest professional society of engineers, with over 400,000 members in more than 160 countries. The IEEE has led the development of many standards for modern digital communications and networking, most notably, the IEEE 802 series of network standards. The IEEE Grade of Fellow is conferred by the Boards of Directors upon a person with an extraordinary record of accomplishments in any of the IEEE fields of interest. The total number selected in any one year does not exceed one-tenth of one percent of the total voting Institute membership.

12. I have served the IEEE in the following capacities:

- Chief Information Officer of the IEEE Communications Society from Jan. 2018 to present.
- Chief Marketing Officer of the IEEE Communications Society

[1] https://scholar.google.com, as of June 17, 2024.

from Jan. 2020 to present.

- General Chair of the 2016 IEEE International Conference on Acoustics, Speech, and Signal Processing, the flagship conference of the IEEE Signal Processing Society.
- Chair of the Steering Committee for the IEEE Transactions on Wireless Communications from 2008 to 2010.
- Distinguished Lecturer of the IEEE Communications Society from January 2008 to December 2009.
- Technical Program Chair of the 2006 IEEE Globecom, one of two flagship annual IEEE Communication Society conferences.
- Distinguished Lecturer of the IEEE Circuits and Systems Society from 2004 to 2005.
- Associate Editor of the IEEE Transactions on Signal Processing from 1994 to 1997 and from 2001 to 2004.
- Member of the IEEE Statistical Signal and Array Processing for Communications Technical Committee from 1993 to 1998.
- Member of the IEEE Signal Processing for Communications Technical Committee from 1998 to 2004.

13. In 2012, I received the Wireless Communications Technical Committee Recognition Award from the IEEE Communications Society, an award

given to a person with a high degree of visibility and contribution in the field of "Wireless and Mobile Communications Theory, Systems, and Networks." I received the 2020 Education Award from the IEEE Communications Society. According to the Society, this award "recognizes distinguished and significant contributions to education within the Society's technical scope."

14. I have also served as a technical consultant for the telecommunication industry. For example, in 1995 I consulted for Analog Devices, Inc., on the development of the first generation DOCSIS cable modem systems. I have also consulted for other companies, including Nortel Networks and NEC US Laboratories. I worked as a visiting faculty research fellow at NASA Glenn Research Center in 1992 and at U.S. Air Force Wright Laboratory in 1993. I have served on multiple review panels of the National Science Foundation to evaluate competitive research proposals in the field of communication. I have also reviewed a large number of research proposals at the request of the National Science and Engineering Research Council (NSERC) of Canada as an expert panelist from 2010 to 2013, and also at the request of the Research Grant Council (RGC) of Hong Kong as an external reviewer.

15. I have served as an expert witness or consulting expert on a number of matters related to intellectual property, mostly in the arena of telecommunications, including cellular communications, Wi-Fi technologies, Bluetooth, and optical

communications. For example, since 2007, I have been engaged to work on various litigations involving cellular, WiFi, Bluetooth, cable modems, RFID, and optical communication networks.

16. Based on my above-described near three decades of experience in communications technologies, and the acceptance of my publications and professional recognition by societies in my field, I believe that I am qualified to be an expert in wireless communication systems, communication networks, and signal processing.

17. My curriculum vitae, attached as Exhibit A, includes a list of publications on which I am a named author. It contains further details regarding my experience, education, publications, and other qualifications provide to an expert opinion in connection with this proceeding.

III. SUMMARY OF CONCLUSIONS FORMED

18. My opinions, as explained below, are based on my education, experience, and expertise in the fields relating to the '347 Patent. Unless otherwise stated, my testimony below refers to the knowledge of one of ordinary skill in the art as of the earliest possible priority date. Any figures that appear within this document have been prepared with the assistance of Counsel and reflect my understanding of the '347 Patent and the prior art discussed below.

19. This declaration explains the conclusions that I have formed based on

my analysis of all of the considered materials and my personal experience. To summarize those conclusions, based upon my knowledge and experience and my review of the prior art references listed above, I believe that:

- Ground 1: claims 19, 1, 6, 8, and 14-15 of the '347 Patent are made obvious by Hardacker.
- Ground 2: claims 20-23, 2-4, 6, 9-12, and 16 of the '347 Patent are made obvious by Hardacker-Medbo.
- Ground 3: claims 19-20, 23, 1-2, 8, 12 and 15-17 of the '347 Patent are made obvious by Wallace.
- Ground 4: claims 20-22, 2-4, and 16 of the '347 Patent are made obvious by Wallace-Medbo.

IV. LEVEL OF ORDINARY SKILL IN THE ART

20. I have been informed that a person of ordinary skill in the art ("POSITA") is a hypothetical person who is presumed to have the skill and experience of an ordinary worker in the field at the time of the alleged invention. The '347 Patent was filed July 16, 2012, and claims priority to PCT Application No. PCT/CN2011/077718 filed July 28, 2011 ("Critical Date"). Because I do not know at what date the invention as claimed was made, if ever, I have used the Critical Date of the '347 Patent as the point in time for claim interpretation purposes. My opinion does not change if the invention date is earlier.

21. In my opinion, a POSITA would have had a bachelor's degree in electrical engineering, computer engineering, computer science, or a related field, and two to three years of experience in the design or development of wireless telecommunication systems, or the equivalent. Additional graduate education could substitute for professional experience, or significant experience in the field could substitute for formal education.

22. Based on my experiences, I have a good understanding of the capabilities of a POSITA. Indeed, I have taught, participated in organizations, and worked closely with many such persons over the course of my career. Based on my knowledge, skill, and experience, I have an understanding of the capabilities of a POSITA. For example, from my industry experience, I am familiar with what a POSITA would have known and found predictable in the art. From teaching and supervising my post-graduate students, I also have an understanding of the knowledge that a person with this academic experience possesses. Furthermore, I possess those capabilities myself.

V. LEGAL STANDARDS

A. Terminology

23. I have been informed by Counsel and understand that the best indicator of claim meaning is its usage in the context of the patent specification as understood by one of ordinary skill. I further understand that the words of the

claims should be given their plain meaning unless that meaning is inconsistent with the patent specification or the patent's history of examination before the Patent Office. Counsel has also informed me, and I understand that, the words of the claims should be interpreted as they would have been interpreted by one of ordinary skill at the time of the invention was made (not today). Because I do not know at what date the invention as claimed was made, if ever, I have used the Critical Date of the '347 Patent as the point in time for claim interpretation purposes. My opinion does not change if the invention date is earlier.

B. Legal Standards

24. I have been informed by Counsel and understand that documents and materials that qualify as prior art can render a patent claim unpatentable as being anticipated or obvious.

25. I am informed by Counsel and understand that all prior art references are to be looked at from the viewpoint of a person of ordinary skill in the art at the time of the invention, and that this viewpoint prevents one from using his or her own insight or hindsight in deciding whether a claim is anticipated or rendered obvious.

C. Anticipation

26. I understand that patents or printed publications that qualify as prior art can be used to invalidate a patent claim as anticipated or as obvious.

27. I understand that, once the claims of a patent have been properly construed, the second step in determining anticipation of a patent claim requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

28. I understand that a prior art reference "anticipates" an asserted claim, and thus renders the claim invalid, if all limitations of the claim are disclosed in that prior art reference, either explicitly or inherently (i.e., necessarily present).

D. Obviousness

29. I understand that even if a patent is not anticipated, it is still invalid if the differences between the claimed subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a POSITA.

30. I have been informed by Counsel and understand that a claim is unpatentable for obviousness and that obviousness may be based upon a combination of references. I am informed by Counsel and understand that the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. However, I am informed by Counsel and understand that a patent claim composed of several elements is not proved obvious merely by demonstrating that each of its elements was, independently, known in the prior art.

31. I am informed by Counsel and understand that when a patented invention is a combination of known elements, a court determines whether there was an apparent reason to combine the known elements in the fashion claimed by the patent at issue by considering the teachings of prior art references, the effects of demands known to people working in the field or present in the marketplace, and the background knowledge possessed by a person having ordinary skill in the art.

32. I am informed by Counsel and understand that a patent claim composed of several limitations is not proved obvious merely by demonstrating that each of its limitations was independently known in the prior art. I am informed by Counsel and understand that identifying a reason those elements would be combined can be important because inventions in many instances rely upon building blocks long since uncovered, and claimed discoveries almost of necessity will be combinations of what, in some sense, is already known. I am informed by Counsel and understand that it is improper to use hindsight in an obviousness analysis, and that a patent's claims should not be used as a "roadmap."

33. I am informed by Counsel and understand that an obviousness inquiry requires consideration of the following factors: (1) the scope and content of the prior art, (2) the differences between the prior art and the claims, (3) the level of ordinary skill in the art, and (4) any so called "secondary considerations" of non-

obviousness, which include: (i) "long felt need" for the claimed invention, (ii) commercial success attributable to the claimed invention, (iii) unexpected results of the claimed invention, and (iv) "copying" of the claimed invention by others.

34. I have been informed by Counsel and understand that an obviousness evaluation can be based on a single reference or a combination of multiple prior art references. I understand that the prior art references themselves may provide a suggestion, motivation, or reason to combine, but that the nexus linking two or more prior art references is sometimes simple common sense. I have been informed by Counsel and understand that obviousness analysis recognizes that market demand, rather than scientific literature, often drives innovation, and that a motivation to combine references may be supplied by the direction of the marketplace.

35. I have been informed by Counsel and understand that if a technique has been used to improve one device, and a person of ordinary skill at the time of invention would have recognized that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill.

36. I have been informed by Counsel and understand that practical and common-sense considerations should guide a proper obviousness analysis, because familiar items may have obvious uses beyond their primary purposes. I have been

informed by Counsel and understand that a person of ordinary skill looking to overcome a problem will often be able to fit together the teachings of multiple prior art references. I have been informed by Counsel and understand that obviousness analysis therefore takes into account the inferences and creative steps that a person of ordinary skill would have employed at the time of invention.

37. I have been informed by Counsel and understand that a proper obviousness analysis focuses on what was known or obvious to a person of ordinary skill at the time of invention, not just the patentee. Accordingly, I understand that any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed.

38. I have been informed by Counsel and understand that a claim can be obvious in light of a single reference, without the need to combine references, if the elements of the claim that are not found explicitly or inherently in the reference can be supplied by the common sense of one of skill in the art.

39. In sum, my understanding is that prior art teachings are properly combined where one of ordinary skill having the understanding and knowledge reflected in the prior art and motivated by the general problem facing the inventor, would have been led to make the combination of elements recited in the claims. Under this analysis, the prior art references themselves, or any need or problem

known in the field of endeavor at the time of the invention, can provide a reason for combining the elements of multiple prior art references in the claimed manner.

40. I have been informed by Counsel and understand that in an *inter partes* review, "the petitioner shall have the burden of proving a proposition of unpatentability," including a proposition of obviousness, "by a preponderance of the evidence." 35 U.S.C. §316(e).

VI. MATERIALS CONSIDERED

41. My analysis and conclusions set forth in this declaration are based on my educational background and experiences in the field (*see* Section II). Based on my knowledge and experience, I believe that I am considered to be an expert in the field. Also, based on my knowledge and experience, I understand and know of the capabilities of persons of ordinary skill in the field around the Critical Date, and I taught, participated in professional organizations of, or worked closely with many such persons in the field during that time frame.

42. 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 art during the time before the Critical Date; my own knowledge and experiences gained from my work experience in the field of the '347 Patent and related disciplines; and my experience in working with others involved in this field and related disciplines.

43. In addition, I have analyzed the publications and materials listed below:

- APPLE-1001 U.S. Patent No. 8,891,347 ("'347 Patent")
- APPLE-1002 Excerpts from the Prosecution History of the '347 Patent
- APPLE-1004 U.S. Patent Pub. 2010/0159855A1 ("Hardacker")
- APPLE-1005 U.S. Patent Pub. 2014/0010274Al ("Medbo")
- APPLE-1006 U.S. Patent No. 6,473.467 ("Wallace")
- APPLE-1007 Stefania Sesia, et al., *LTE: The UMTS Long Term Evolution from Theory to Practice Second Edition*, 2011 ("Sesia").
- APPLE-1008 Rudolf F. Graf, *Modern Dictionary of Electronics Seventh Edition*, 1999.

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

VII. THE '347 PATENT

A. Overview of the '347 Patent

45. The '347 Patent describes a pre-distortion technique for transmitting signals wirelessly from a transmitter (e.g., a base station or eNodeB) to a receiver (e.g., UE) in a wireless communication system. *See* APPLE-1001, 12:54-58, Abstract.

46. The ’347 Patent describes a “user-focusing” technique designed to enhance wireless communication system performance by leveraging precise channel knowledge, primarily by shifting compensation from the receiver to the transmitter through pre-distortion. APPLE-1001, 3:20-54. The method begins with a wireless device receiving a first signal transmitted from a base station (transmitter) over one or more radio propagation paths. *Id*. This first signal is distorted by the propagation environment (e.g., propagation loss). *Id*. The received, distorted first signal allows the receiver to accurately perceive and characterize the propagation path’s influence on the signal e.g., the effect of propagation loss on received/transmitted signals. *Id*.

47. Based on the reception of this first signal, the wireless device is configured to perform a channel estimation to obtain detailed channel estimation including “path parameter information.” APPLE-1001, 8: 4-16. The ’347 Patent lists some common channel characteristics that are measurable via different methods: they include precise estimations of propagation delay, Doppler frequency, direction of arrival (DOA), direction of departure (DOD), and complex amplitude for the propagation path. APPLE-1001, 3:39-54, 8:4-16. The ’347 Patent also notes the potential for estimating polarization status for more advanced focusing. APPLE-1001, 10:14-19, 12: 22-31. The estimation can employ a wide array of sophisticated algorithms, including but not limited to Maximum

Likelihood (ML) estimation (e.g., SAGE, RiIMAX), spectral-based methods (e.g., Bartlett, Capon, MUSIC), subspace-based techniques (e.g., ESPRIT), Bayesian approaches, and various tracking algorithms such as Kalman filtering. APPLE-1001, 8:17-57, Claim 4.

48. Once the channel parameters are estimated by the wireless receiving device during channel estimation, the receiving device then sends this channel estimate, including the "path parameter information," back to the transmitter. APPLE-1001, 1: 45-2:32. This feedback channel information enables the transmitter to execute its "user-focusing" function. *Id*. The transmitter then pre-distorts and transmits a subsequent (second) signal using this received channel information. *Id*. This predistortion is applied across the time, frequency, and spatial domains and compensates for the channel's distortions during propagation, ensuring a constructive and coherent arrival at the receiver. APPLE-1001, 7:50-55. The wireless device ultimately receives this pre-distorted second signal. APPLE-1001, 1: 45-2:32.

B. Prosecution History of the '347 Patent

49. The '347 Patent issued on November 18, 2014 from U.S. Patent Application No. 13/522,422 filed July 16, 2012. APPLE-1002, 77-78. This application was a National Stage Entry of W.I.P.O International Application No. PCT/CN11/77718, filed July 28, 2011. APPLE-1002, 295.

50. During prosecution claims were rejected under §102 as being anticipated by U.S. 2007/0177551 A1 ("Joham") and §103 as being unpatentable over Joham in view of U.S. 2010/0177746 A10 ("Gorokhov"). APPLE-1002, 150-165.

51. Applicant argued that Joham "only discloses compensating for the spatial components and not . . . the time domain, the frequency domain, and the spatial domain." APPLE-1002, 139. The notice of allowance agreed that Joham did not teach the combination of all three types of pre-distortion. APPLE-1002, 109.

VIII. OVERVIEW AND COMBINATIONS OF PRIOR ART REFERENCES

A. Hardacker (APPLE-1004)

52. Hardacker is titled "TECHNIQUES FOR PRE-DISTORTING TRANSMITTED SIGNALS FOR A TRANSMITTER DEVICE." APPLE-1004, Title (emphasis added). The method addresses a fundamental challenge in communication systems: the inherent asymmetry and complexity between transmitters and receivers, particularly in broadcast scenarios where receivers are often constrained by cost and power, thus the receivers having limited capabilities for compensation of the channel distortions. APPLE-1004, [0001]-[0002]. The core teaching of Hardacker revolves around shifting the burden of distortion compensation from the receiver to the transmitter through intelligent pre-distortion techniques. APPLE-1004, [0004]-[0005]. Hardacker is analogous to the '347

Patent because Hardacker is in the same field of endeavor and addresses problems reasonably pertinent to those discussed in the '347 Patent.

53. Traditionally, a transmitter simply broadcasts a signal, and a receiver, equipped with an equalizer, attempts to recover the transmitted original signal from the channel-distorted reception. APPLE-1004, [0002]. However, if the channel distortion exceeds the equalizer's recovery capability, the transmitted signal cannot be accurately reconstructed at the receiver. *Id*. Hardacker proposes a solution where the transmitter has measured channel information about the distortion characteristics (e.g., propagation loss) of the communication medium, i.e., channel, and uses this prior knowledge to pre-distort the transmitted signal. APPLE-1004, [0003]-[0006]. This ensures that by the time the signal traverses the communication/propagation path, the overall channel distortion to a signal accounting for the predistortion and actual channel distortion is manageable by a less complex receiver. APPLE-1004, [0005].

54. The mechanism for the transmitter to acquire this measured channel information is crucial. APPLE-1004, [0006]. In a bi-directional communication system, a return channel (or "back channel") is leveraged. APPLE-1004, [0005]. For instance, as seen in figure 4, if Device 1 transmits to Device 2, Device 2 can measure the channel distortion experienced by the signal transmitted by Device 1 and then relay this distortion information back to Device 1. APPLE-1004, FIG. 4,

[0022]-[0026]. Hardacker describes accounting for propagation loss using this system in two scenarios, symmetrical and asymmetrical.

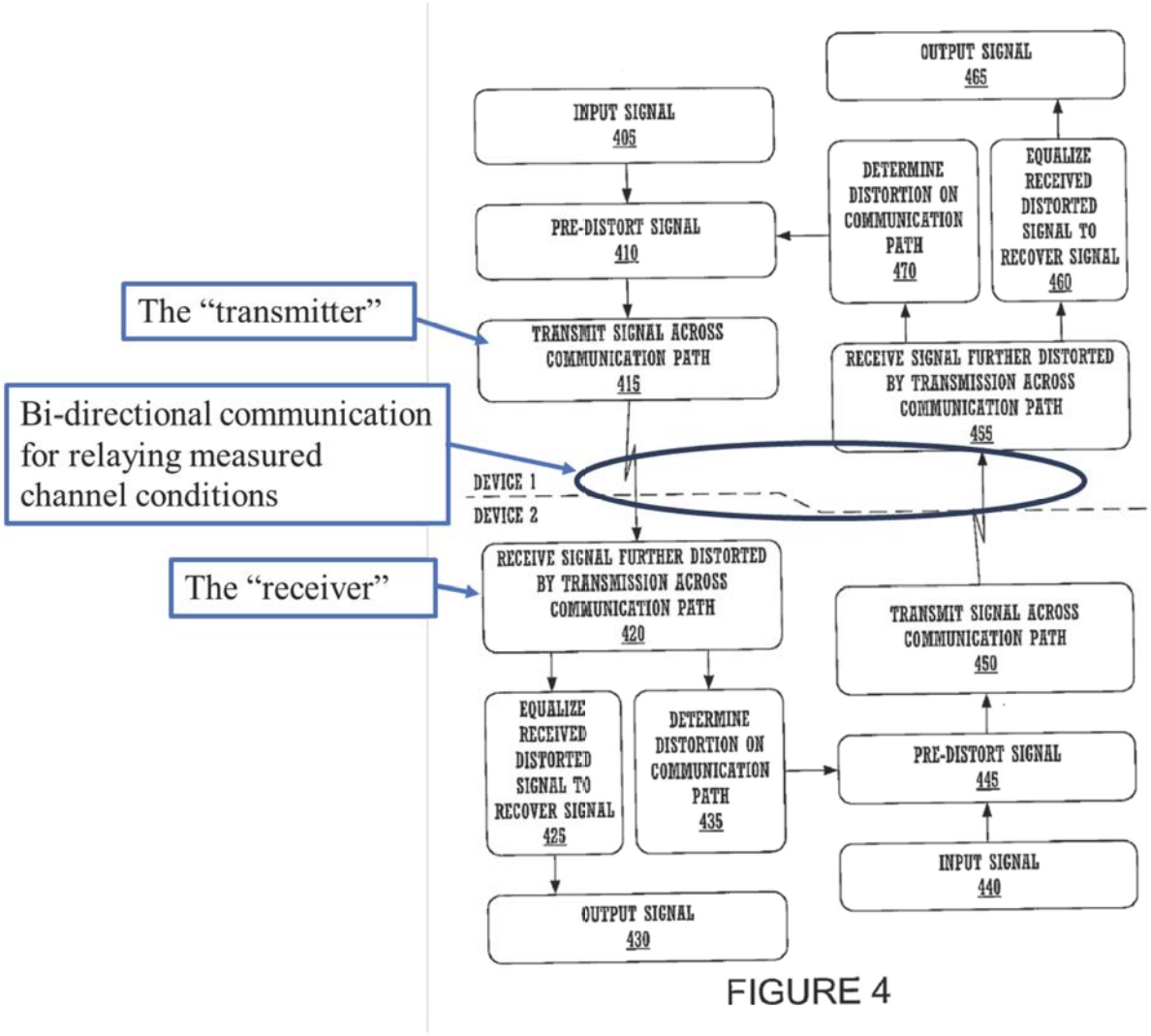


FIGURE 4

APPLE-1004, FIG. 4[2].

55. Specifically, for the symmetrical scenario Hardacker teaches in figure 4, a bi-directional communication scheme where both devices actively engage in

[2] All figures are annotated in color unless otherwise noted.

pre-distortion to manage propagation path losses, predicated on the assumption that channel distortion—measured using the received signals—is substantially consistent and steady in time between the communicating entities. APPLE-1004, [0023]-[0027]. In this example, Device 1 initiates transmission of a first input signal which is pre-distorted by its pre-distortion circuit using an estimate of the channel's distortion. *Id*. This pre-distortion factor is determined from prior channel measurements made by Device 1's distortion determination circuit upon receiving a previous signal from Device 2. *Id*. When this pre-distorted signal traverses the channel and is further distorted by the channel conditions, it arrives at Device 2's receiver. *Id*. Device 2 then calculates/determines the channel distortion based on this received signal. *Id*. Subsequently, when Device 2 prepares to transmit a second input signal back to Device 1, it uses this newly determined channel distortion to determine and apply a corresponding pre-distortion on its own outgoing signal. *Id*. This pre-distorted signal is then transmitted, passes through the channel, and is received by Device 1, which then determines its channel distortion estimate for future transmissions, based on the newly received signal. *Id*. This adaptive pre-compensation strategy means that each transmitting device continuously refines its understanding of the channel characteristics and applies the inverse distortion to its transmitted signals, thereby reducing the complexity requirements for the respective receivers and improving overall link performance. The channel

distortion parameters representing the path parameter information, which can include various types including multi-path, amplitude, or phase distortion, are determined during setup, periodically, or when performance metrics, such as bit error rate (BER), degrade. *Id*., [0003], [0006], [0019].

56. In the asymmetrical scenario, Hardacker discloses conditions in which the channel distortion may be different in the two transmission directions. APPLE-1004, [0027]. In these circumstances, the receiver of Device 2 transmits the data indicating the channel distortion in the direction from Device 1 to Device 2, determined at Device 2, back to Device 1 for use by the transmitter of Device 1 in preconditioning signals sent from Device 1 to Device 2. *Id*; cl. 9 ("wherein the first device further comprises: a second receiver communicatively coupled to the communication path for receiving the data indicating the distortion on the communication path from the first device to the second device.").

B. Medbo (APPLE-1005)

57. Medbo is analogous to the '347 Patent because it is in the same field of endeavor as the '347 Patent and contains teachings reasonably pertinent to the field by addressing an advanced approach for channel estimation based on channel modeling, a technique crucial for modern and future wireless radio communication technologies that demand high bandwidth efficiency and flexibility. APPLE-1005, [0002]-[0003]. This method involves characterizing radio channels from channel

measurements, particularly for channel modeling in radio link and system simulations. *Id*. Medbo emphasizes that a key application of this high resolution channel estimation is for improved channel prediction, which in turn facilitates enhanced link adaptation, including the control of coding and/or transmit power. APPLE-1005, [0002]-[0003], [0043]. Essentially, by precisely understanding the channel's behavior, the transmission parameters can be optimally adjusted to match the channel conditions. *Id*..

58. For example, Medbo's channel estimation can rely on Maximum Likelihood (ML) parameter estimation in conjunction with discrete wave channel models. APPLE-1005, [0004], [0044]-[0046]. Medbo also mentions use of other commonly known methods of channel estimation including Space Alternating Generalized Expectation (SAGE) and Richter's Maximum (RIMAX) Likelihood method. APPLE-1005, [0004]. This approach involves determining a windowed likelihood function based on measured and modeled channel responses. APPLE-1005, [0010]-[0012]. The objective is to maximize this likelihood function to estimate wave parameters such as wave propagation delays, wave propagation directions, and complex amplitudes of the discrete waves that constitute the channel. APPLE-1005, [0076], [0081]. These precise parameters, unlike simplified channel state information, allow for more accurate channel prediction. APPLE-1005, [0040]. For instance, the channel estimator can provide an updated channel

prediction that the transmitter control unit uses for link adaptation, specifically by controlling the coding/modulation and/or transmit power in response to the predicted channel conditions. APPLE-1005, [0043].

C. Wallace (APPLE-1006)

59. Wallace is analogous to the '347 Patent because Wallace operates in the same field of endeavor as the '347 Patent and addresses a reasonably pertinent challenge of enhancing efficiency and performance in modern wireless communication systems, particularly those employing Multiple Input/Multiple Output (MIMO) architectures, by effectively managing dynamic channel conditions. APPLE-1006, 1:57-2:22. A core problem in such environments is the deleterious channel effect of fading and multipath propagation loss, where transmitted signals arrive at a receiver via multiple paths with differing delays, leading to destructive signal effects. APPLE-1006, 1:57-2:22. To counteract such effect, Wallace centers on the measurement and timely reporting of transmission path characteristics reported from receiver back to the transmitter. APPLE-1006, 2:25-49 (an "information signal carries the set of transmission characteristics for at least one of the plurality of sub-channels"). This feedback reporting enables the transmitter to precondition transmissions by optimizing signal parameters before they are sent, thereby improving spectral efficiency, reducing bit-error rates, and enhancing system flexibility in accommodating diverse user requirements. APPLE-

1006, 2:25-49, 3:34-54. The utility of the channel characteristic reports is critically dependent on its rapid determination and transmission, as channel characteristics, influenced by factors like receiver movement, can change quickly. APPLE-1006, 2:9-22.

D. Combination of Hardacker and Medbo (APPLE-1005 and APPLE-1006)

60. The integration of Hardacker's pre-distortion techniques with Medbo's advanced channel estimation methodologies represents a compelling proposition for optimizing wireless communication systems, particularly for the purposes of improving effective signal qualities at reception through active signal adjustments/pre-distortion (taught by Hardacker and Medbo). APPLE-1004, [0004]-[0006]; APPLE-1005, [0003]-[0004]. From a fundamental engineering perspective, this combination is a direct application of the core principles of an adaptive control loop, where precise system state feedback enables a feed-forward control action. The synergy aims to mitigate channel impairments at the source, prior to transmission, thereby enhancing received signal quality, spectral efficiency, and system reliability. APPLE-1004, [0004]-[0006]; APPLE-1005, [0003]-[0004].

61. ***First***, the motivation to combine Hardacker's pre-distortion with Medbo's channel estimation lies in the critical dependency of effective pre-distortion on accurate and detailed determination/estimation of the channel

distortion. APPLE-1004, [0026] ("the distortion [D(l)] on the communication path 255 may be determined for each signal received by the receiver 215 or periodically when the distortion changes over time."); APPLE-1005, [0003] ("Another use of highly resolved channel estimation is improved channel prediction, which in turn can be used for enhanced link adaptation including controlling coding and/or transmit power."). Hardacker's method relies on having measured "information regarding the transmission medium and path" and knowing "the nature of the distortion or interference" to effectively pre-distort the signal. APPLE-1004, [0005]. Medbo's channel estimator is "configured to operate based on a discrete wave channel model and measured channel responses" to "determine so-called wave parameters" such as "wave propagation delay(s) and predetermined wave propagation direction(s)," and a "complex polarimetric amplitude matrix". APPLE-1005, [0012], [0057], [0048] ("Each one of the discrete waves is associated with wave parameters to be determined including at least one of wave propagation direction(s) and wave propagation delay."), [0084] ("configured to extract, for each of the discrete waves, a complex polarimetric amplitude matrix that is included in the wave parameters."). This is likely to be a more comprehensive characterization than aggregated channel quality indicators (CQI) or precoding matrix indicators (PMI) typically fed back in cellular systems. APPLE-1007, 175-187. A POSITA would have understood and found obvious that

such high-resolution channel information is vital for precise pre-distortion of a signal transmission, allowing the transmitter to effectively pre-cancel channel distortions. APPLE-1004, [0028] ("the pre-distortion substantially compensates for the distortion introduced by the communication path"). The ability to identify individual wave parameters of a channel, as provided by at least Medbo's ML estimation, allows for a targeted pre-compensation that would be difficult with less detailed CSI. A POSITA would have understood and found obvious the design need (precise channel knowledge for Hardacker) could have been met by "predictable solutions" from another field (Medbo's detailed channel estimation).

62. ***Second***, the Hardacker-Medbo combination offers a significant advantage in dynamic link adaptation and real-time channel improvement, addressing the time-varying nature of wireless channels. APPLE-1004, [0026] ("the distortion changes over time"). A POSITA would have understood and found obvious that channel conditions, affected by fading, mobility, and interference, can vary with time and are often fluctuating. *Id.*; APPLE-1007, 179 ("propagation conditions change and therefore need appropriate reestimation regularly"). Medbo emphasizes that this high-resolution channel estimation enables improved channel prediction. APPLE-1005, [0006]-[0015]. Specifically, Medbo's predictions are "configured to operate based on a discrete wave channel model and measured channel responses." APPLE-1005, [0012]. By feeding Medbo's precise channel

estimations to Hardacker's pre-distortion module, the system can proactively adjust transmission parameters to match the predicted channel conditions. APPLE-1005, [0004]. Indeed, Hardacker's "pre-distortion circuit pre-distorts the signals to be transmitted by the transceiver of the given device as a function of the distortion on the communication path" such as the measurements described by Medbo. *Id.*; APPLE-1004, [0004]. This is particularly critical in systems like 3GPP LTE-Advanced cellular networks that employ advanced multi-antenna techniques and experience multi-path propagation affects. APPLE-1004, [0006] ("distortion types, e.g., multi-path, amplitude, frequency, phase and other well[-]known types."), [0034] ("Channel distortion can have phase, amplitude and multipath distortion characteristics which may all be non-linear"). The combination of Medbo's high-resolution channel estimation and Hardacker's feedback and predistortion based on those channel estimates would have used common techniques and known methods (Medbo's processes) to yield predictable results (Hardacker's feedback and pre-distortion based in part on Medbo's measurements).

63. ***Third***, this combination provides a powerful framework for enhanced interference management and spatial exploitation, particularly relevant in dense cellular deployments. In scenarios with multiple transmit and receive antennas (MIMO) or heterogeneous networks, inter-user or inter-cell interference is a significant limiting factor. Hardacker's pre-distortion, when informed by Medbo's

detailed channel knowledge, can enable sophisticated channel adaptation techniques. For instance, the system could utilize knowledge of the channel conditions to improve communication between devices in a high-density deployment landscape. Here, the explicit need for robust interference management in complex radio environments provides a clear motivation for combining these complementary techniques.

64. ***Fourth***, integrating Medbo's efficiency gains with Hardacker's objectives reduces overall system complexity and improves link performance. Hardacker states that its techniques "reduce the complexity of the receiver by placing some of the burden on the transmitter." APPLE-1004, [0030]. It aims to allow "complex modulation" at the source while using "circuits having only limited complexity" at the sink. APPLE-1004, [0006]. Medbo's use of a "windowed likelihood function" significantly improves the computational efficiency and accuracy of channel estimation by enabling the decoupling and "clipping of data." APPLE-1005, [0049], [0061]. The possible "hundredfold" complexity reduction in channel estimation makes it practical to implement the detailed signal and system analyses required to generate the precise channel condition data that Hardacker needs, even within the real-time constraints of a transmitter. APPLE-1005, [0061]; APPLE-1004, [0027]. This synergy means that the burden shift to the transmitter becomes computationally feasible, leading to the

"improved performance, such as fewer bit errors and/or greater link distances" Hardacker promises, while simultaneously reducing the complexity of the end-user devices. APPLE-1004, [0005]. This is a practical design need that makes the combination of these technologies particularly compelling.

E. Combination of Wallace and Medbo (APPLE-1007 and APPLE-1006)

65. A POSITA would have understood and found obvious to combine the teachings of Wallace and Medbo. This motivation stems from the well-known and articulated needs within such sophisticated systems to precisely characterize the dynamic radio channel while maintaining computational feasibility and maximizing system efficiency. Similarly, if a technique has been shown to improve one device and a skilled artisan would recognize its applicability to similar devices, that application is likely obvious. *Id*., 417.

66. ***First***, a POSITA would have understood and found Wallace-Medbo obvious to address the critical need for highly accurate and efficient channel state information for preconditioning. Wallace emphasizes the "present need... for efficient techniques that will provide rapid determination of the channel characteristics" to enable preconditioning and achieve a "higher efficiency, higher performance wireless communications system." APPLE-1006, 1:57-2:22. This rapid and accurate channel condition analysis is vital because "the channel response can change with time due to the movement of the receiver unit or changes

in the environment." *Id*. Medbo addresses "serious accuracy and efficiency problems" in prior art channel estimation, positing "substantial improvements regarding computational efficiency and/or parameter estimate accuracy" through, for one example, a modified Maximum Likelihood (ML) approach. APPLE-1005, [0047]. Medbo's focus is on accurately characterizing radio channels by extracting precise "wave parameters" such as propagation delays and directions. APPLE-1005, [0010]. A POSITA would have recognized that Medbo's ability to provide a more refined and accurate characterization of the fundamental wave parameters of the radio channel would directly translate into more precise channel condition information for Wallace's preconditioning process.

67. ***Second***, a POSITA would have understood and found obvious the Wallace-Medbo combination to enhance data compression and improve the efficiency of channel measurement information feedback on Wallace's reverse link. APPLE-1006, FIG. 1B. Wallace explicitly identifies "compression of the amount of information necessary to reconstruct the characteristics of the propagation channel" as a means to minimize the reverse link reporting "through compression techniques and resource allocation techniques." APPLE-1006, 2:50-63, Abstract. Wallace further notes that "the full CSI is a large amount of information and also highly redundant," making compression critical. APPLE-1006, 18:5-32. Medbo's methodology includes a feature for channel information

data reduction "Reduction of Data Size by Clipping." APPLE-1005, [0155]-[0157]. This technique removes "data which correspond to uncorrelated waves" in delay and/or angle domains, thereby reducing the data set size and "increasing the efficiency of parameter estimation" because "computational complexity is proportional to the size of the data set." *Id*. A POSITA would have discerned that Medbo's clipping mechanism and measured channel responses (similar to those in Wallace's system) would serve as an effective analysis and compression step prior to reporting channel conditions to the transceiver. This direct synergistic benefit, addressing an explicitly stated need for data reduction in Wallace's system with a proven method from Medbo, constitutes a clear motivation for combination, as it represents a predictable use of known elements according to their established functions.

68. ***Third***, a POSITA would have understood and found obvious the Wallace-Medbo combination to facilitate more granular channel knowledge and enhance overall system adaptability. Wallace's system relies on channel information to "optimiz[e] a set of transmission parameters" and for "pre-condition[ing] the data prior to transmission." APPLE-1006, Claim 1, 2:25-63, 8:53-9:3. This preconditioning, in turn, enables channels to compensate for propagation loss and provides for "enhanced flexibility" and maximizing spectral efficiency. APPLE-1006, 3:34-67. One of Medbo's contributions is a "discrete

wave channel model" which yields high-resolution "wave parameters" including "propagation delay(s) and direction(s)." APPLE-1005, [0010]. This detailed parameter extraction is specifically stated to be "suitable for channel prediction and/or simulation purposes" and for "improved channel prediction, which in turn can be used for enhanced link adaptation including controlling coding and/or transmit power." APPLE-1005, [0040], [0003]. A POSITA, with an understanding of radio propagation physics, would have recognized Medbo's output—a detailed, physics-based characterization of individual multipath components—provides a richer and more accurate representation of the channel than typical channel impulse response estimates. This type of fundamental channel knowledge would allow Wallace's preconditioning algorithms to be significantly more effective and robust, adapting with greater precision to complex multipath environments and dynamic channel conditions.

IX. MANNER IN WHICH THE PRIOR ART REFERENCES RENDER THE '347 CLAIMS UNPATENTABLE

A. GROUND 1 – Hardacker – Claims 19, 1, 6, 8, and 14-15

1. Application to Challenged Claims - 19

Claim 19

[19.1] A wireless device for performing wireless communication with a base station with a transmitter via a plurality of propagation paths, the wireless device comprising: a receiver;

69. Hardacker renders obvious [19.1]. A POSITA would have understood

and found obvious that Hardacker's disclosure of wireless devices, that include transmitters, receivers, and distortion determination circuits for communication over a wireless communication network, would satisfy or encompass the understanding of a ***wireless device*** and a ***base station—for performing wireless communication***. For example, the definition of "base station" is "1. [a] fixed station used by a dispatcher to communicate with mobile units. 2. The central transmitter in a communications system that acts as the cell hub for communicating with handsets and/or mobile units." APPLE-1008, 6. Thus, at the very least, which device is the "base station" is not predetermined and the configuration of such a system would be a design choice based on a POSITA's knowledge of such wireless communication systems and commonsense.

70. Moreover, Hardacker discloses ***a base station with a transmitter via a plurality of propagation paths, the wireless device comprising: a receiver***. APPLE-1004, FIG. 2, [0014]-[0016].

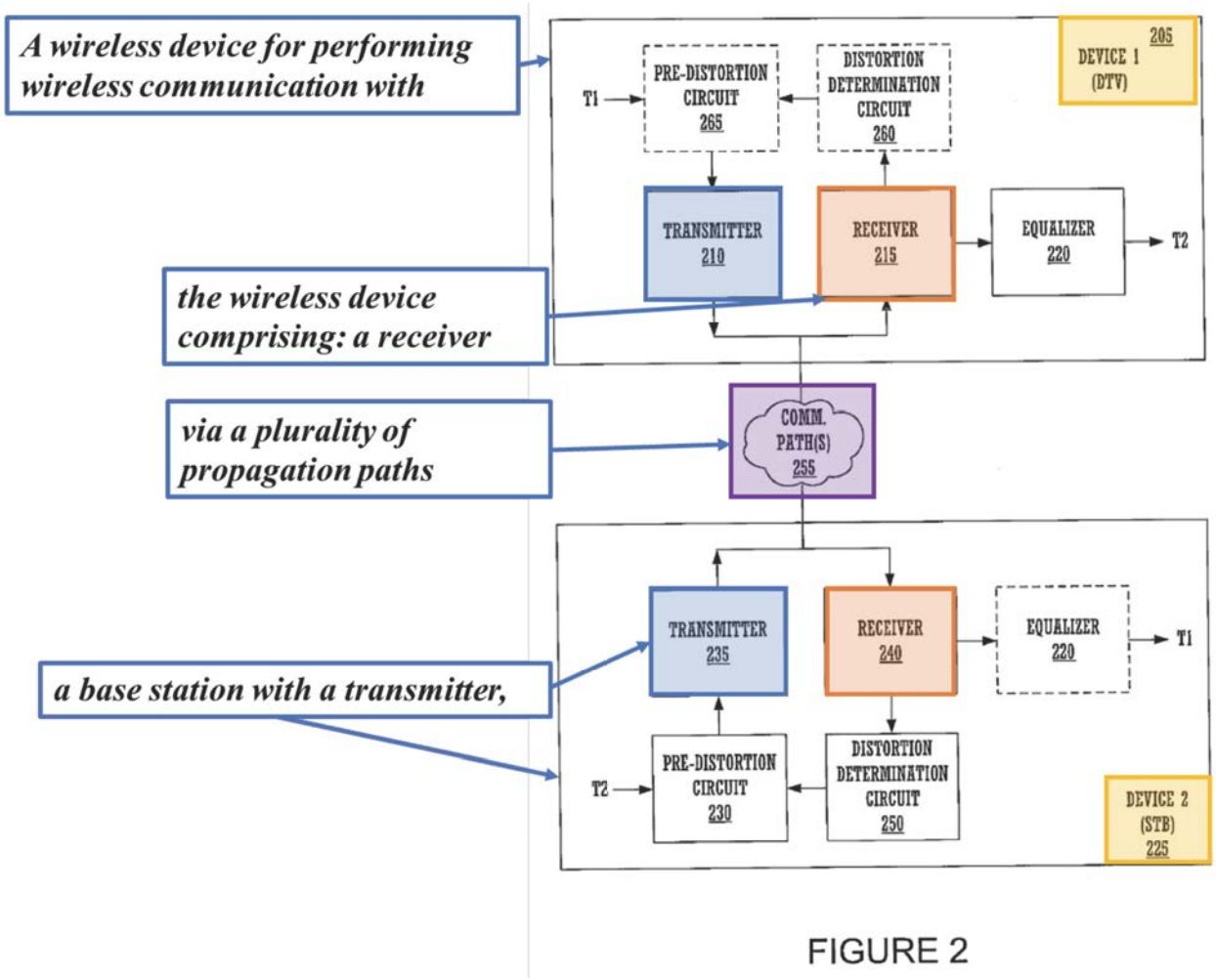


FIGURE 2

APPLE-1004, FIG. 2.

[19.2] a computing device; and a computer-readable storage medium having computer-executable instructions stored thereon that are executable by the computing device to perform operations comprising:

71. Hardacker renders obvious [19.2]. Specifically, a POSITA would have understood and found obvious that the signal processing, pre-distortion, channel determination, and iterative modulation schemes detailed in Hardacker would necessarily be implemented using programmable hardware or software. For instance, Hardacker, filed more than a year after the release of the iPhone, states

that "pre-distortion functionality as described below is performed in the digital domain." APPLE-1004, [0032], [0038] ("reduce the number of necessary bits in the analog to digital converter circuits which in tum reduces power consumption."). Performing operations in the digital domain requires a computing device capable of executing algorithms and processing digital data and is indicated by Hardacker's mention of using "bits." APPLE-1004, [0038]. While Hardacker refers to "circuits" like "pre-distortion circuit" and "distortion determination circuit", it also discusses these circuits compensating for various "distortion types, e.g., multi-path, amplitude, frequency, phase." The adaptive and iterative nature of these compensations strongly indicates that these circuits are not merely fixed analog or simple digital gates, but rather include programmable elements.

72. Thus, in implementing such a system as Hardacker in mobile communication devices available at the time of the critical date, a POSITA would have understood and found obvious that Hardacker's process could be implemented using ***a computing device; and a computer-readable storage medium having computer-executable instructions stored thereon that are executable by the computing device to perform operations comprising*** the measurement and predistortion of signals according to Hardacker's disclosure.

[19.3] receiving a first signal at the receiver via a first propagation path of the plurality of propagation paths;

73. Hardacker renders obvious [19.3]. For example, Hardacker teaches ***a***

"***first*** input ***signal*** [T(1)] is transmitted across the communication path 255 [***via a first propagation path***] by the transmitter 210 . . . and is received by the receiver 240." APPLE-1004, [0017]. Thus, Hardacker renders obvious ***receiving the first signal at the receiver***. Moreover, a POSITA would have understood and found obvious that i) Hardacker's description of transmissions in a system including multiple communication paths ("communication paths 255") and ii) Hardacker's description of "determining the nature of the distortion and/or interference on a communication path" teaches that ***a first signal*** is transmitted ***from the transmitter to the receiver via a first propagation path of the plurality of propagation paths***. APPLE-, [0003], FIG. 1-2, [0014] ("The first and second devices 205 and 225 transmit and receive signals across one or more communication paths 255 of the communication network.").

[19.4] performing a channel estimation based on the first signal to obtain path parameter information of the first propagation path;

74. Hardacker renders obvious [19.4]. For example, Hardacker teaches "***the first*** input ***signal*** [T(1)] is a training or configuration signal specifically utilized to determine the nature of the distortion or interference on the communication path [(***path parameter information of the first propagation path***)] 255." APPLE-1004, [0016].

75. Specifically, Hardacker teaches a "distortion determination circuit 250 determines the distortion [D(1)] on the communication path 255." APPLE-1004,

[0024]. A POSITA would have understood and found obvious that Hardacker's "distortion [] on the communication path" is at least one type of ***path parameter information*** because Hardacker discloses that "types of distortion includ[e] equalization, multi-path, amplitude, frequency, phase and other well[-]known types" of wireless communication path distortion. APPLE-1004, [0024], [0003]. Below, Hardacker's annotated figure 4 demonstrates an example process of receiving ***the first signal***, ***performing a channel estimation based on the first signal***, and feeding that path parameter information back to the transmitter. APPLE-1004, FIG. 4, [0023]-[0027].

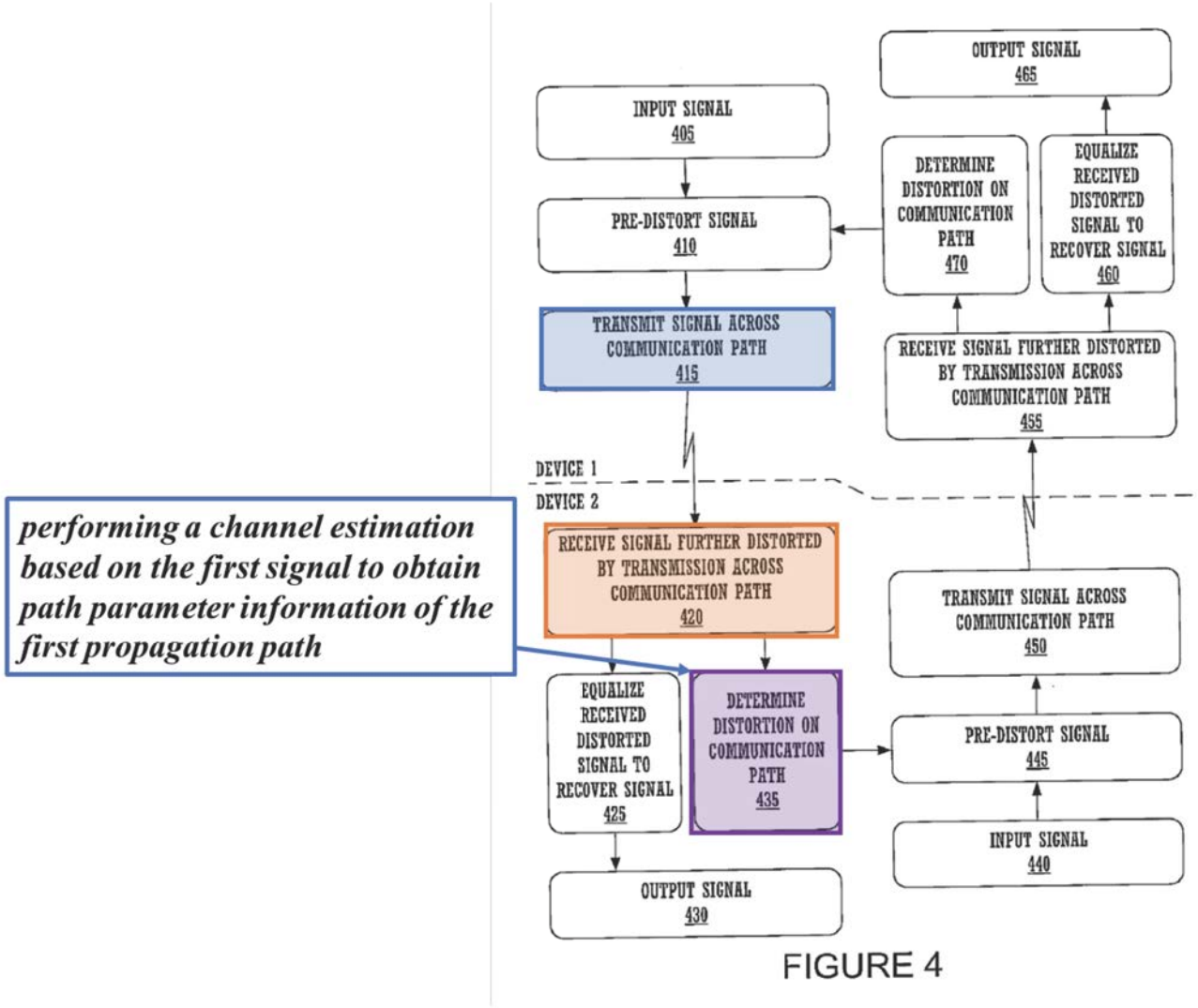


FIGURE 4

APPLE-1004, FIG. 4.

76. Hardacker's "channel estimation" produces ***path parameter information of the first propagation path*** because Hardacker teaches that the path parameter information may not be the same in both directions between the two devices, and for this reason, the data about ***the first propagation path*** is sent back to the transmitter. APPLE-1004, [0027]. Specifically, Hardacker teaches "data [(***channel estimation***)] indicating the distortion [(***path parameter information of***

the first propagation path)] determined at process 435 is transmitted from the second device 225 back to the first device 205 and used by the pre-distortion circuit 260 of the first device 205 to pre-distort the signal (T(1)) transmitted from the first device 205 to the second device 225." APPLE-1004, [0027].

77. Thus, Hardacker renders obvious ***performing a channel estimation based on the first signal to obtain path parameter information of the first propagation path***.

[19.5] sending the channel estimation that includes the path parameter information to the transmitter; and

78. Hardacker renders obvious [19.5]. For example, Hardacker teaches "data [(***the channel estimation***)] indicating the distortion [(***that includes the path parameter information***)] determined at process 435 is transmitted [(***sent***)] from the second device 225 [(receiver)] back ***to the*** first device 205 [(***transmitter***)] and used by the pre-distortion circuit 260 of the first device 205 to pre-distort the signal (T(1)) transmitted from the first device 205 to the second device 225." APPLE-1004, [0027].

79. Thus, Hardacker renders obvious ***sending the channel estimation that includes the path parameter information to the transmitter.***

[19.6] receiving a second signal via the first propagation path, the second signal predistorted in a time domain, a frequency domain, and a spatial domain according to the channel estimation based on the first signal.

80. Hardacker renders obvious [19.6]. For example, Hardacker teaches

"the receiver [(***at the receiver***)] 240 of the second device 225 receives ***the pre-distorted*** [(***second***)] ***signal*** [T(1)]*[D(1)−1] further distorted by [D(1)] after transmission across the communication path [(***via the first propagation path***)]." APPLE-1004, [0024]. A POSITA would have understood and found obvious from Hardacker's disclosure that, at least in some circumstances, the ***second signal*** is ***receiv[ed] via the first propagation path*** because Hardacker teaches using the channel estimation, that characterizes the distortion of the first propagation path, to pre-distort the second signal from the transmitter to the receiver. APPLE-1004, [0027]. For example, Hardacker describes symmetrical circumstances "when the distortion on the communication path 255 is substantially the same" and consequently shows using the first propagation path parameter information to improve subsequent transmissions. APPLE-1004, FIG. 4, [0027]. In asymmetrical circumstances, the "data indicating the distortion [(***the channel estimation based on the first signal***)] determined at process 435 is transmitted from the second device 225 [("the receiver")] back to the first device 205 [("the transmitter")] and used by the pre-distortion circuit 260 of the first device 205 to pre-distort the [(***second***)] ***signal*** (T(l)) transmitted from the first device 205 to the second device 225 at process 410. " Because the subsequent transmission uses measurements of the first propagation path ***based on the first signal***, a POSITA would have understood and found obvious that the "transmitter" is assumed to operate in at

least the next transmission across ***the first propagation path***. APPLE-1004, [0027]. Thus, Hardacker renders obvious ***receiving a second signal via the first propagation path***.

81. Hardacker renders obvious ***predistort[ing] a second signal ... according to the channel estimation based on the first signal***. For example, Hardacker teaches "data [(***channel estimation***)] indicating the distortion determined at process 435 [(at the "receiver")] is transmitted from the second device 225 back to the first device 205 and used by the pre-distortion circuit 260 of the first device 205 [(the "transmitter")] to pre-distort the signal [(***predistorting a second signal***)] (T(1)) transmitted from the first device 205 to the second device 225 at process 410 [(at the transmitter)]." APPLE-1004, [0027]. Hardacker's figure 4 below demonstrates ***predistorting a second signal*** at process 410. APPLE-1004, [0027].

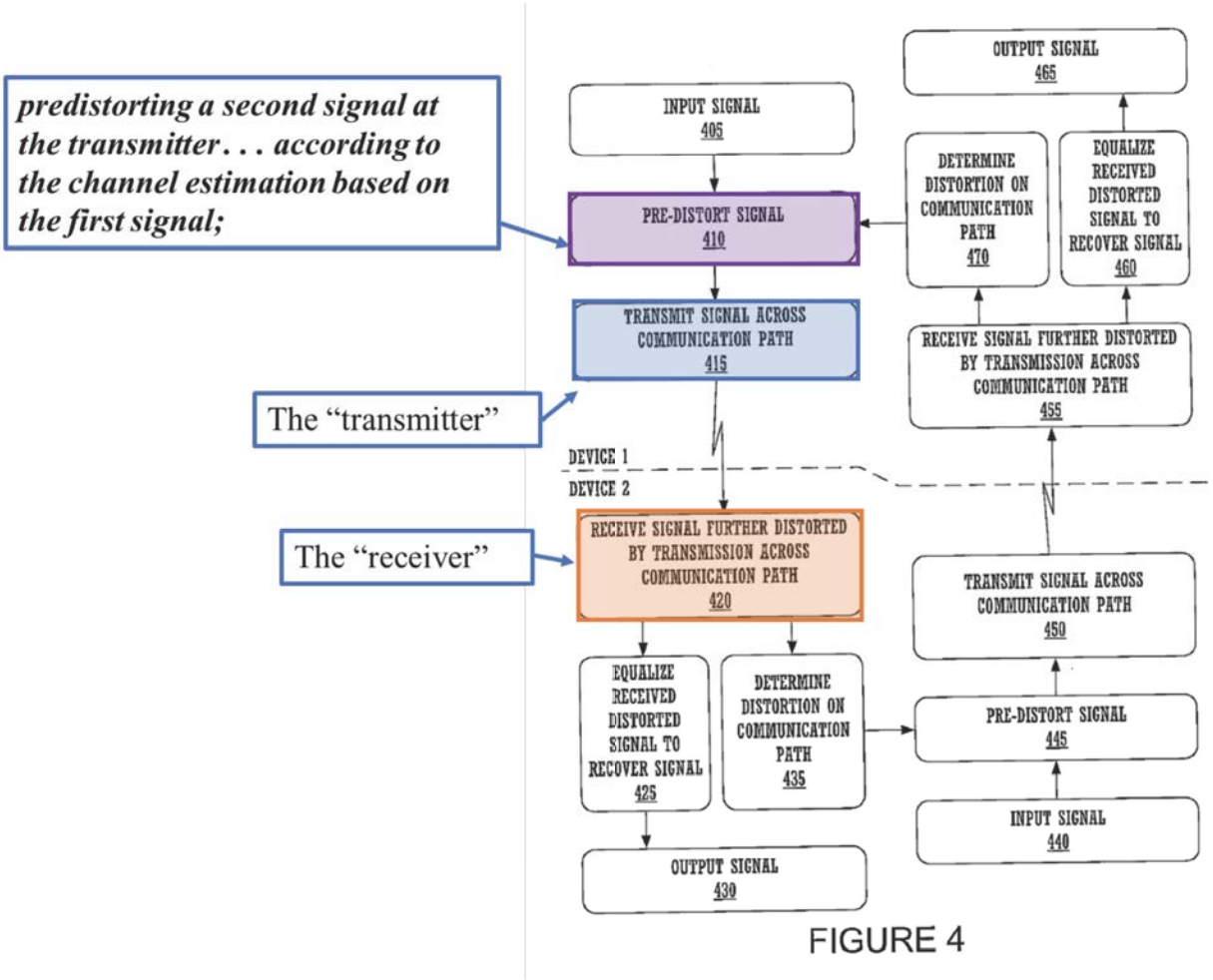


FIGURE 4

APPLE-1004, FIG. 4.

82. A POSITA would have understood and found obvious the pre-distortion performed at Hardacker's step 410 includes at least a pre-distortion in ***a time domain, a frequency domain, and a spatial domain***. First, the distortion measured by Hardacker and transmitted back to the transmitter "may be determined for each signal received by the receiver 215 or periodically when the distortion changes over time." APPLE-1004, [0026]. A POSITA would also have understood that, similarly, the distortion in the opposite direction measured by

Hardacker may also be determined for each signal received by the receiver 240 or periodically when the distortion changes over time. Additionally, Hardacker teaches accounting for well-known propagation path affects "e.g., multi-path, amplitude, frequency, phase and other well[-]known types and is therefore not limited to equalization." APPLE-1004, [0033], [0003]. Subsequently, "[t]he pre-distortion [(of the ***second signal***)] may be accomplished using various types of distortion including equalization, multi-path, amplitude, frequency, phase and other well[-]known types."). *Id*. A POSITA would have understood and found obvious, that Hardacker's disclosure of "types of distortion" includes the "various types of distortion" of wireless signals, commonly known by a POSITA by the critical date, in ***a time domain, a frequency domain, and a spatial domain***.

83. For example, a POSITA would have known that in wireless communication systems, particularly systems in which multi-path propagation occurs, that a given propagation path would be affected in the time domain (e.g., in delayed receipt), the frequency domain (e.g., frequency-selective fading), and in the spatial domain (e.g., phase rotation based on angle of arrival (AoA)). APPLE-1007, pp.407-411 ("differing propagation delays between different UEs"), 438-439 ("The transmitted signal traverses three paths with different delays."), 439 ("In the frequency domain this corresponds to frequency-selective fading"), 439 ("Finally, the multipath characteristics define the frequency, time, and space correlations."),

432-433 (Discussing phase rotation in a multi-antenna array based on angle of arrival at a mobile device). Measuring such propagation path characteristics—through channel estimation—would have been understood to contribute to a "channel model [] to reflect all the instantaneous space-time-frequency characteristics which affect the configuration of diversity, beamforming, and spatial multiplexing techniques" applied to overcome such effects. APPLE-1007, 438.

84. Thus, a POSITA would have understood and found obvious that ***predistorting a second signal. . . according to the channel estimation based on the first signal*** would include predistortion in at least ***a frequency domain, and a spatial domain***.

2. Mirroring Claims 1, 6, 8, 14-15

Claim 1

[1.1] A method for wireless communication in a system including a transmitter, a receiver, and a plurality of propagation paths formed between the transmitter and the receiver which are capable of carrying a signal transmitted by the transmitter to the receiver, the method comprising:

85. Hardacker renders obvious [1.1]. *See* [19.1]. Hardacker teaches a ***wireless communication*** "***method*** of sending and receiving signals [that] includes determining the nature of the distortion and/or interference on a communication path." APPLE-1004, [0003]. Demonstrated in the annotated figure 2 below, Hardacker's signals are sent and received using a ***wireless communication system***

including a transmitter, a receiver, and a plurality of propagation paths formed between the transmitter and the receiver. APPLE-1004, FIG. 1-2, [0002], [0014]-[0015].

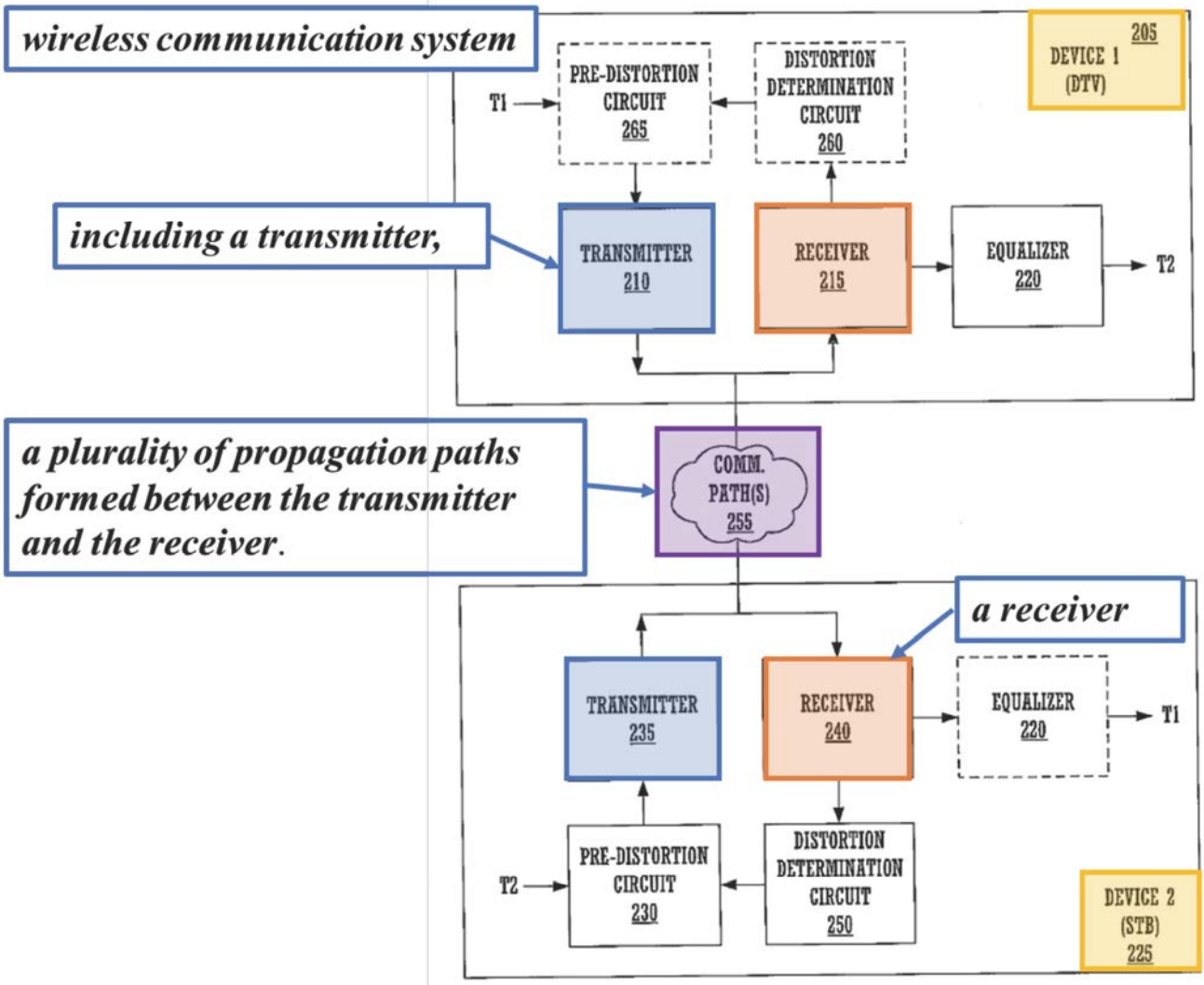


FIGURE 2

APPLE-1004, FIG. 2.

86. Hardacker describes the "[t]he first and second devices 205 and 225 transmit and receive ***signals*** across one or more communication paths [(***a plurality***

of propagation paths formed between the transmitter and the receiver)] 255 of the communication network." APPLE-1004, [0014]. Thus, Hardacker renders obvious that the ***propagation paths. . . are capable of carrying a signal transmitted by the transmitter to the receiver***.

[1.2] transmitting a first signal from the transmitter to the receiver via a first propagation path of the plurality of propagation paths;

87. Hardacker renders obvious [1.2]. For example, Hardacker teaches ***a*** "***first*** input ***signal*** [T(1)] is transmitted across the communication path [(***a first propagation path***)] 255 by the transmitter 210 . . . and is received by the receiver 240." APPLE-1004, [0017]. Thus, a POSITA would have understood and found obvious that i) Hardacker's description of transmission in a system including multiple communication paths ("COMM. PATH(S)") and ii) Hardacker's description of "determining the nature of the distortion and/or interference on a communication path" teaches that ***a first signal*** is transmitted ***from the transmitter to the receiver via a first propagation path of the plurality of propagation paths***. APPLE-1004, [0003], FIG. 1-2, [0014] ("The first and second devices 205 and 225 transmit and receive signals across one or more communication paths 255 of the communication network."); *See* [19.6].

[1.3] receiving the first signal at the receiver;

88. Hardacker renders obvious [1.3]. For example, Hardacker teaches ***the*** "***first*** input ***signal*** [T(1)] is transmitted across the communication path 255 by the

transmitter 210 . . . and is received by the receiver 240." APPLE-1004, [0017]. Thus, a Hardacker renders obvious ***receiving the first signal at the receiver***. *See* [19.3].

[1.4] performing a channel estimation based on the first signal to obtain path parameter information of the first propagation path;

89. *See* [19.4].

[1.5] sending the channel estimation that includes the path parameter information from the receiver to the transmitter via the first propagation path;

90. *See* [19.5]. A POSITA would have understood and found obvious from Hardacker's disclosure that "data[(***the channel estimation***)] indicating the distortion" is sent, at least in some circumstances, ***via the first propagation path*** because Hardacker teaches using the same channel estimation information (of the first propagation path) to pre-distort the signal from the receiver back to the transmitter. APPLE-1004, [0027]. As a POSITA would have understood and found obvious, Hardacker describes circumstances "when the distortion on the communication path 255 is substantially the same" at least for a period of time.. APPLE-1004, FIG. 1, FIG. 4, [0027]. In these circumstances, the "data [(***the channel estimation***)] indicating the distortion determined at process 470 is transmitted from the first device 205 back to the second device and used by the pre-distortion circuit 230 of the second device 225 to pre-distort the signal (T(2)) at process 445" because the transmission back to the "transmitter" is assumed to

operate across ***the first propagation path***. APPLE-1004, [0027]. Thus, when Hardacker describes distorting the return transmission with the same channel estimation, it would have been understood be a POSITA that the return transmission travels across ***the first propagation path*** in the opposite direction and renders obvious ***sending the channel estimation . . . via the first propagation path.*** *See* [19.5].

[1.6] predistorting a second signal at the transmitter in a time domain, a frequency domain, and a spatial domain, according to the channel estimation based on the first signal;

91. *See* [19.6].

[1.7] transmitting the predistorted second signal from the transmitter to the receiver via the first propagation path; and

92. Hardacker renders obvious [1.7]. For example, Hardacker teaches the transmission of signals from the transmitter to the receiver, where the signal is pre-distorted based on measurement of previous transmissions. APPLE-1004, [0023], [0027]. Specifically, Hardacker's transmitter can "pre-distort the signal (T(1)) transmitted [(***transmitting the predistorted second signal***)] ***from the*** first device [(***transmitter***)] 205 ***to the*** second device [(***receiver***)] 225 at process 410" seen in the annotated figure 4 below. APPLE-1004, [0027]. Indeed, Hardacker describes the continued measuring of channel conditions and adjusting predistortion values which accounts for changes in channel conditions over time, thus affecting future pre-distortions applied at 410 to subsequent transmissions. APPLE-1004, [0026]

("the communication path 255 may be determined for each signal received by the receiver 215 or periodically when the distortion changes over time.").

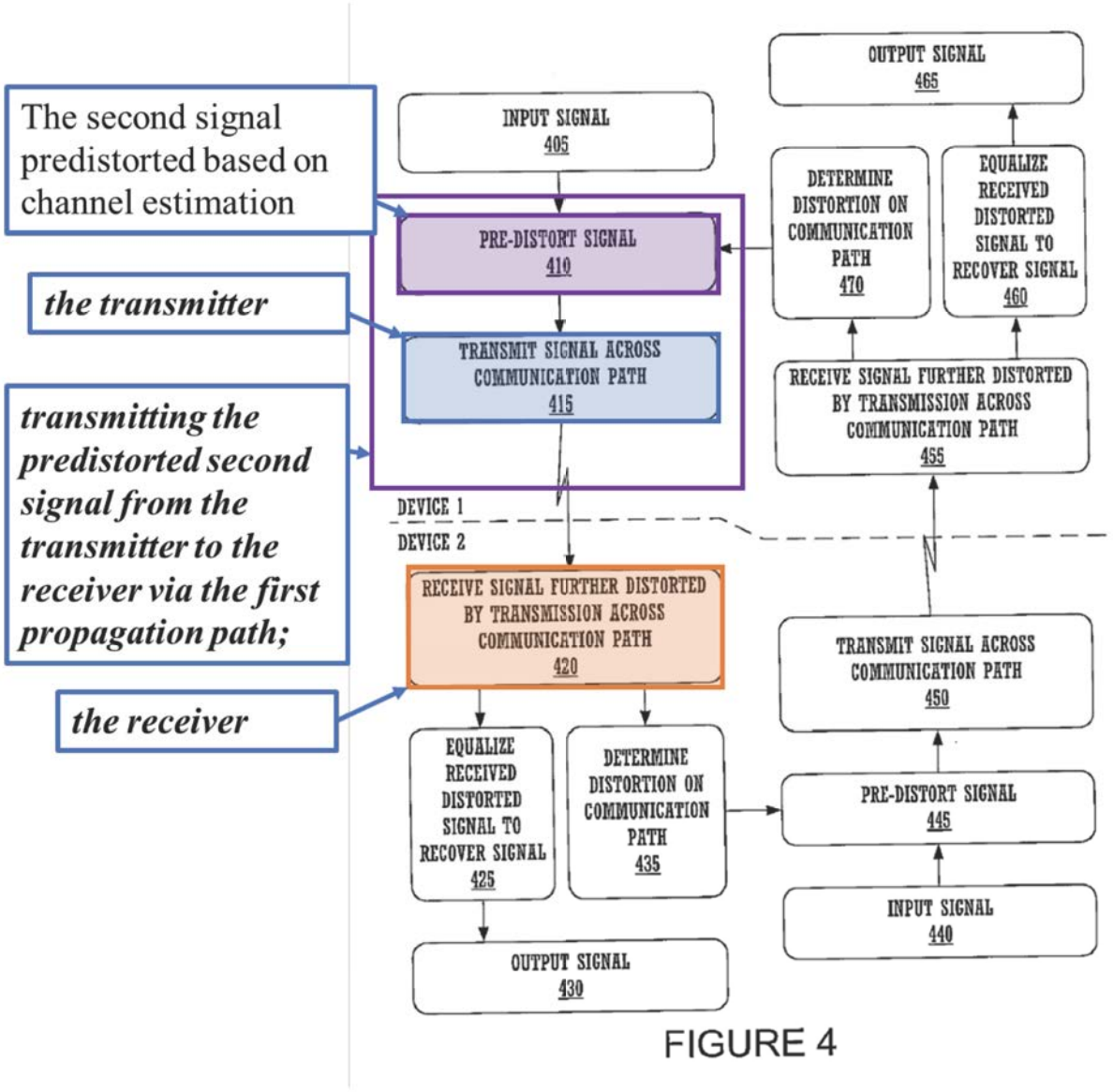


FIGURE 4

APPLE-1004, FIG. 4.

93. As discussed in [1.5], Hardacker explains that transmissions between the transmitter and receiver can occur over the same path (***the first propagation path***). APPLE-1004, [0026]-[0027]. Specifically, Hardacker teaches that, in some

instances, the distortion of the communication path (***the first propagation path***) "does not regularly fluctuate." APPLE-1004, [0026]. Hardacker teaches that "the pre-distorted signal [T(l)] *[D(l)$^{-1}$] is transmitted by the transmitter 210 across the communication path 255". APPLE-1004, [0023]. A POSITA would have understood and found obvious that the transmission of pre-distorted signal across Hardacker's communication path 255 that does not regularly fluctuate functionally equates to ***transmitting . . . via the first propagation path***, because ***the first propagation path*** is the part of the signal channel from the transmitter to the receiver. In other words, Hardacker transmits a second signal using information learned from transmission measurements of the first signal, therefore the second signal is pre-distorted with the assumption that the second signal will travel ***via the first propagation path***, which is assumed to not have appreciably changed since the measurement. Thus, Hardacker's disclosure renders obvious that when pre-distorting the second signal based on the first channel estimation, that the subsequent transmissions are transmitted ***via the first propagation path*** to take advantage of the pre-distortion. *See* [19.6].

[1.8] receiving the predistorted second signal at the receiver.

94. *See* [19.6].

Claim 6

[6] The method of claim 1, further comprising equalizing the predistorted second signal at the receiver.

95. Hardacker renders obvious [6]. For example, Hardacker discloses a receiver that includes an equalizer. APPLE-1004, [0002], [0006]. Indeed, Hardacker discloses that "equalizer 245 of the second device 225 equalizes the received pre-distorted [(***second***)] ***signal***" ***at the receiver***. APPLE-1004, [0020], [0024]. Hardacker's annotated figure 4 demonstrates the device ***equalizing the predistorted second signal at the receiver***. APPLE-1004, FIG. 4.

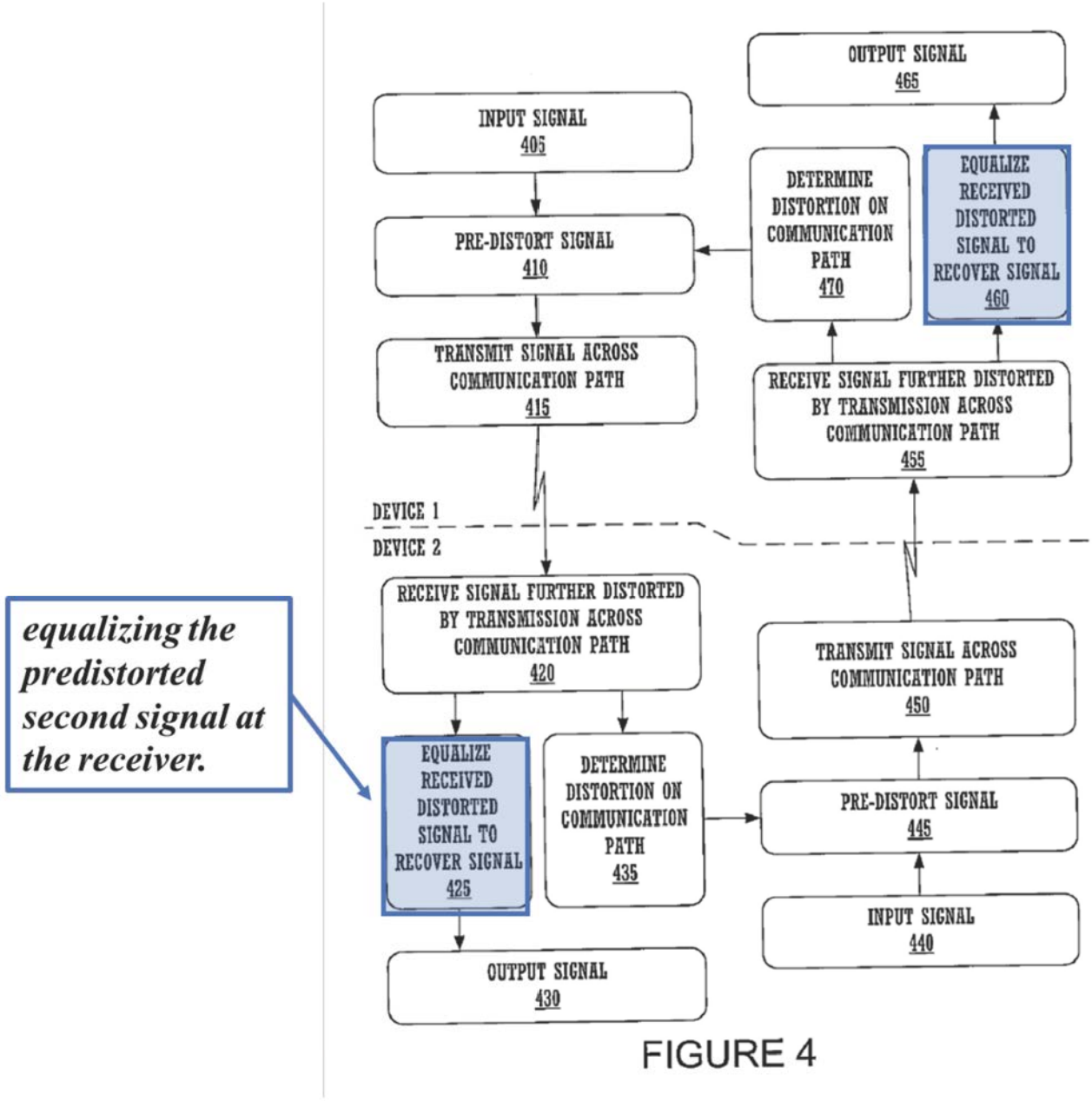


FIGURE 4

APPLE-1004, FIG. 4.

Claim 8

[8.1] ***A system for wireless communication comprising: a receiver; a transmitter; and a plurality of propagation paths formed between the transmitter and the receiver which are capable of carrying a signal transmitted by the transmitter to the receiver,***

96. *See* [19.1], [1.1]-[1.2]; APPLE-1004, [0001].

[8.2] wherein the receiver is configured to receive a first signal that is transmitted along a first propagation path of the plurality of propagation paths from the transmitter,

97. *See* [19.3], [1.2]-[1.3].

[8.3] perform a channel estimation based on the first signal to obtain path parameter information of the first propagation path, and

98. *See* [19.4], [1.4].

[8.4] send the channel estimation that includes the path parameter information to the transmitter via the first propagation path, and

99. *See* [19.5], [1.5].

[8.5] wherein the transmitter is configured to predistort a second signal in a time domain, a frequency domain, and a spatial domain according to the channel estimation that is based on the first signal and received from the receiver and

100. *See* [19.6], [1.6].

[8.6] to transmit the predistorted second signal to the receiver via the first propagation path.

101. *See* [19.6], [1.7].

Claim 14

[14] The system of claim 8, wherein the receiver is further configured to equalize the predistorted second signal.

102. *See* [6].

Claim 15

[15.1] A base station for performing wireless communication with a receiver in a wireless device via a plurality of propagation paths, the base station comprising: a transmitter;

103. Hardacker renders obvious [15.1]. *See* [19.1]. A POSITA would have understood and found obvious that Hardacker's disclosure of devices that include transmitters, receivers, distortion determination circuits for communication over a wireless communication network would satisfy or encompass the understanding of a ***wireless device*** and a ***base station***. For example, the definition of "base station" is "[a] fixed station used by a dispatcher to communicate with mobile units. 2. The central transmitter in a communications system that acts as the cell hub for communicating with handsets and/or mobile units." APPLE-1008, 6. Thus, at the very least, which device is the "base station" is not determined and the configuration of such a system would be a design choice requiring a POSITA's base-line knowledge of such wireless communication systems and commonsense. *See* [1.1] ("a plurality of propagation paths formed between the transmitter and the receiver"), ("system including a transmitter").

[15.2] a computing device; and a computer-readable storage medium having computer-executable instructions stored thereon that are executable by the computing device to perform operations comprising:

104. *See* [19.2].

[15.3] transmitting a first signal from the transmitter to the receiver via a first propagation path of the plurality of propagation paths;

105. *See* [1.2].

[15.4] receiving a channel estimation based on the first signal, the channel estimation including path parameter information of the first propagation path;

106. A POSITA would have understood and found obvious from the teachings that render obvious [1.5], that the "base station" of claim 15 would ***receiv[e] a channel estimation based on the first signal, the channel estimation including path parameter information of the first propagation path*** because claim [1.5] provides for "sending ***the channel estimation*** that ***includes the path parameter information*** from the receiver to the transmitter via the first propagation path." *See* [1.5] ("sending the channel estimation that includes the path parameter information from the receiver to the transmitter via the first propagation path").

[15.5] predistorting a second signal in a time domain, a frequency domain, and a spatial domain according to the channel estimation based on the first signal; and

107. *See* [1.6].

[15.6] transmitting the predistorted second signal from the transmitter to the receiver via the first propagation path.

108. *See* [1.7].

B. GROUND 2 – Hardacker – Medbo – Claims 20-23, 2-4, 6, 9-12, 16

1. Application to Challenged Claims – 20-23

Claim 20

[20] The wireless device of claim 19, wherein the path parameter information of the first propagation path includes at least one of an estimation of a delay, an estimation of a Doppler frequency, an estimation of a direction of arrival, an estimation of a direction of departure, and an estimation of a complex amplitude of the first propagation path.

109. Hardacker-Medbo renders obvious [20]. For example, Hardacker describes measuring or characterizing well-known propagation distortion (***path parameter information***) such as "equalization, multi-path, amplitude, frequency, phase and other well[-]known types." APPLE-1004, [0003]. Medbo further describes the types of well-known distortions teaching "[t]he measured channel responses can for example be represented in frequency, time/delay, code and/or space." APPLE-1005, [0041], [0057] ("desirable to determine ... wave propagation delay of each of these waves"). Thus, a POSITA would have understood and found obvious when ***the path parameter information of the first propagation path includes at least one of an estimation of a delay . . . of the first propagation path.*** *See* [2].

Claim 21

[21] The wireless device of claim 20, wherein the path parameter information of the first propagation path further includes an estimation of a polarization status of the first propagation path.

110. Hardacker-Medbo renders obvious [21]. For example, Medbo teaches "it is desirable to determine the number of discrete waves and at least one of the

wave propagation direction(s) and wave propagation delay of each of these waves." APPLE-1005, [0057]. The inclusion of a "complex polarimetric amplitude matrix" directly provides the estimation of polarization status. "Preferably, the complex amplitudes, described by a complex polarimetric amplitude matrix, for each of the discrete waves should also be determined." APPLE-1005, [0057]. Medbo further explains that "to achieve positive definite $C^H \bullet C$, the antennas used must account for the full polarization matrix." APPLE-1005, [0120]. Medbo then teaches the use of these determined "complex polarimetric amplitude matrix" for later transmission of signals. APPLE-1005, [0120]. From this, a POSITA would have understood and found obvious that the determination and accounting for antenna "polarizations" characteristics, includes ***an estimation of a polarization status of the first propagation path***.

111. Indeed, Sesia corroborates that a POSITA would have understood and found obvious that multi-path propagation parameters, for example "MIMO propagation channel parameters," can include "the arrival and departure angles in addition to the traditional power and delay," and "the polarization information." APPLE-1007, 444-445.

112. Thus, a POSITA would have understood from Hardacker and Medbo's disclosure of determining channel characteristics and Medbo's specific accounting for polarization affects using polarimetric matrices at transmission, that

the path parameter information of the first propagation path further includes an estimation of a polarization status of the first propagation path.

Claim 22

[22] The wireless device of claim 19, wherein the path parameter information is obtained by at least one estimation technique of the group consisting of a maximum likelihood estimation algorithm, periodogram, correlatorgram, spectral-based methods, Bartlett beamformers, Capon beamformers, subspace-based techniques, MUSIC (MUltiple SIgnal Classification), ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques), approximation of the maximum-likelihood method based on iterative schemes, SAGE (Space-Alternating Generalized Expectation-maximization), RiMAX (Richter's Maximum Likelihood method), maximum-a-posteriori based methods, Evidence Framework, Bayesian techniques, tracking algorithms, Kalman filtering techniques, enhanced Kalman filtering techniques, particle filtering techniques, and least-square-error methods.

113. Hardacker-Medbo renders obvious [22]. For example, Medbo teaches channel estimation using a maximum-likelihood (ML) estimation algorithm and other well-known methods for channel estimation. APPLE-1005, [0004]. Specifically, Medbo discloses "[i]t is well known that ***Maximum Likelihood*** [(***estimation algorithm***)] in principle is one of the most accurate methods available." APPLE-1005, [0004]. Additionally, "[d]ifferent methods have previously been proposed for complexity reduction like ***Space Alternating Generalized Expectation*** (***SAGE***) maximization, and a maximum likelihood framework called ***RIMAX***." APPLE-1005, [0004], [0046].

114. Thus, a POSITA would have understood and found obvious that ***the path parameter information is obtained by at least one estimation technique of the group consisting of a maximum-likelihood estimation algorithm, . . . SAGE (Space-Alternating Generalized Expectation-maximization),*** and ***RiMAX (Richter's Maximum Likelihood method)***.

Claim 23

[23] The wireless device of claim 19, wherein the receiver comprises multiple antennas in a multiple-input and multiple-output (MIMO) wireless communication system or a single antenna in a single-input and single-output (SISO) wireless communication system.

115. Hardacker-Medbo renders obvious [23]. For example, Medbo describes measuring the "channel" between transmitters and receivers in "Single-Input Single-Output (SISO), . . . and Multiple-Input Multiple-Output (MIMO) antenna cases." APPLE-1005, [0038], FIG. 1. Thus, a POSITA would have understood and found obvious ***the receiver comprises multiple antennas in a multiple-input and multiple-output (MIMO) wireless communication system or a single antenna in a single-input and single-output (SISO) wireless communication system***. Indeed, Medbo's example in figure 1 is an MIMO system. APPLE-1005, FIG. 1.

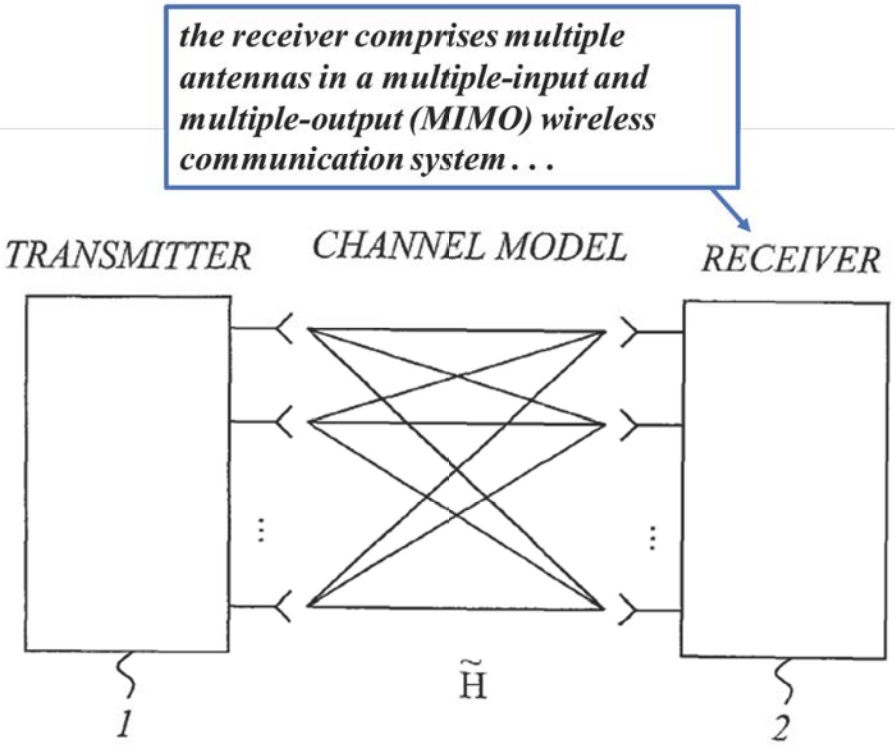


Fig. 1

APPLE-1005, FIG. 1.

2. Mirroring claims 2-4, 6, 9-12, 16

Claim 2

[2] The method of claim 1, wherein the path parameter information of the first propagation path includes at least one of an estimation of a delay, an estimation of a Doppler frequency, an estimation of a direction of arrival, an estimation of a direction of departure, and an estimation of a complex amplitude of the first propagation path.

116. *See* [20].

Claim 3

[3] The method of claim 2, wherein the path parameter information of the first propagation path further includes an estimation of a polarization status of the first propagation path.

117. *See* [21].

Claim 4

[4] The method of claim 1, wherein the path parameter information is obtained by at least one estimation technique of the group consisting of a maximum-likelihood estimation algorithm, periodogram, correlatorgram, spectral-based methods, Bartlett beamformers, Capon beamformers, subspace-based techniques, MUSIC (MUltiple SIgnal Classification), ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques), approximation of the maximum-likelihood method based on iterative schemes, SAGE (Space-Alternating Generalized Expectation-maximization), RiMAX (Richter's Maximum Likelihood method), maximum-a-posteriori based methods, Evidence Framework, Bayesian techniques, tracking algorithms, Kalman filtering techniques, enhanced Kalman filtering techniques, particle filtering techniques, and least-square-error methods.

118. *See* [22].

Claim 6

[6] The method of claim 1, further comprising equalizing the predistorted second signal at the receiver.

119. In addition to the reasons stated in §IX.A.2.[6], Hardacker-Medbo renders obvious [6]. For example, Medbo discloses a receiver that includes an equalizer. APPLE-1005, [0002], [0006]. Indeed, Hardacker discloses "the equalizer 245 of the second device 225 equalizes the received pre-distorted [(***second***)] ***signal*" *at the receiver***. APPLE-1004, [0020], [0024]. Hardacker's

annotated figure 4 demonstrates the devices ***equalizing the predistorted second signal at the receiver***. APPLE-1004, FIG. 4.

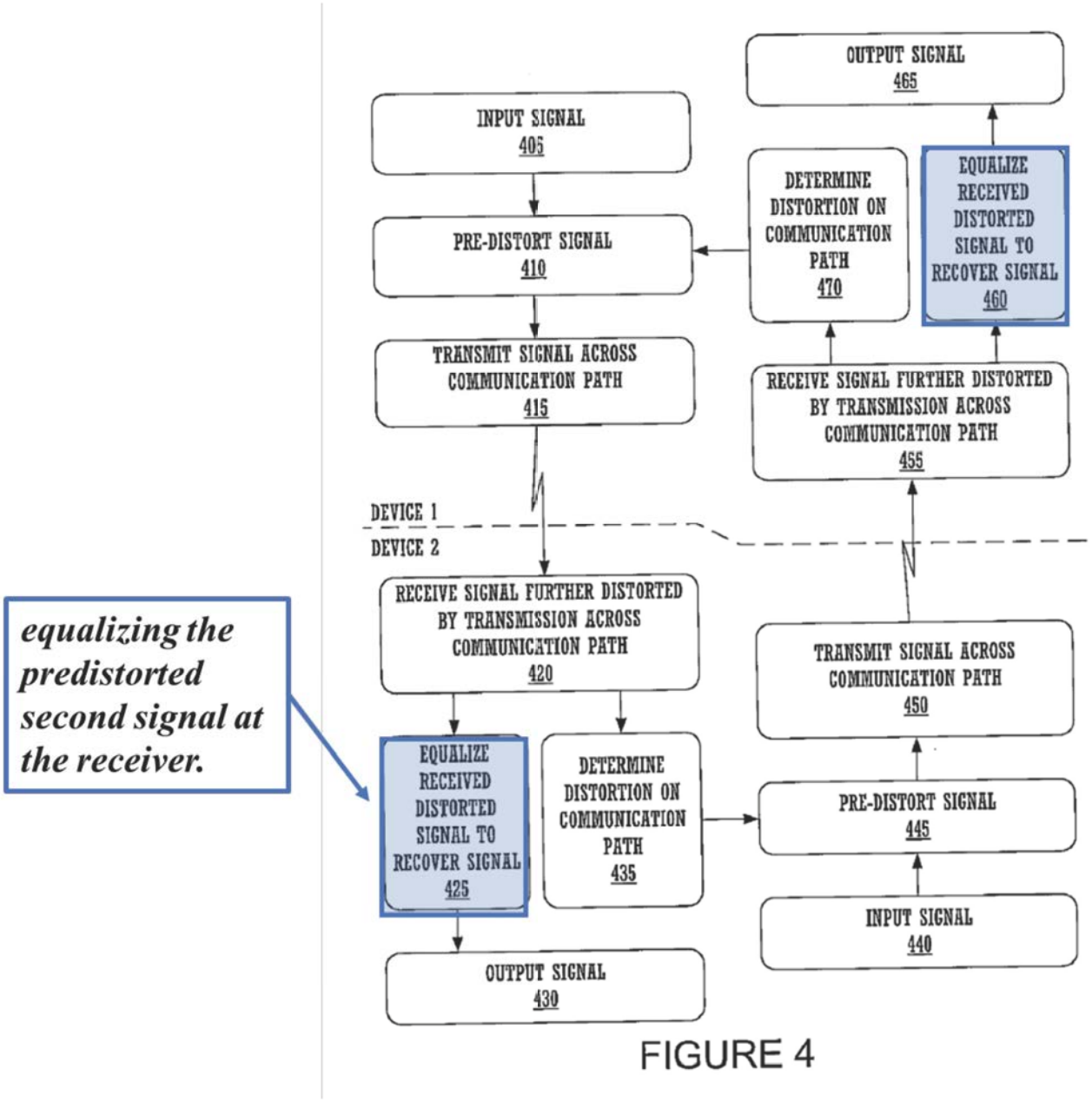


FIGURE 4

APPLE-1004, FIG. 4.

Claim 9

[9] ***The system of claim 8, wherein the path parameter information of the first propagation path includes at least one of an estimation of a delay, an estimation of a Doppler frequency, an estimation of a direction of arrival, an estimation of a direction of departure, and an estimation of a complex amplitude of the first propagation path.***

120. *See* [20], [2].

Claim 10

[10] ***The system of claim 8, wherein the path parameter information of the first propagation path further includes an estimation of a polarization status of the first propagation path.***

121. *See* [21], [3].

Claim 11

[11] ***The system of claim 8, wherein the path parameter information is obtained by at least one estimation technique of the group consisting of a maximum likelihood estimation algorithm, periodogram, correlatorgram, spectral-based methods, Bartlett beamformers, Capon beamformers, subspace-based techniques, MUSIC (MUltiple SIgnal Classification), ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques), approximation of the maximum-likelihood method based on iterative schemes, SAGE (Space-Alternating Generalized Expectation-maximization), RiMAX (Richter's Maximum Likelihood method), maximum-a-posteriori based methods, Evidence Framework, Bayesian techniques, tracking algorithms, Kalman filtering techniques, enhanced Kalman filtering techniques, particle filtering techniques, and least-square-error methods.***

122. *See* [22], [4].

Claim 12

[12] The system of claim 8, wherein the transmitter and the receiver each comprise multiple antennas in a multiple-input and multiple-output (MIMO) wireless communication system or a single antenna in a single-input and single-output (SISO) wireless communication system.

123. *See* [23].

Claim 16

[16] The base station of claim 15, wherein the path parameter information of the first propagation path includes at least one of an estimation of a delay, an estimation of a Doppler frequency, an estimation of a direction of arrival, an estimation of a direction of departure, an estimation of a complex amplitude of the first propagation path, and an estimation of a polarization status of the first propagation path.

124. *See* [20],[2] (". . . an estimation of a complex amplitude of the first propagation path."); *See* [21], [3] ("information of the first propagation path further includes an estimation of a polarization status of the first propagation path").

C. GROUND 3 – Wallace – Claims 19-20, 23, 1-2, 8, 12, 15-17

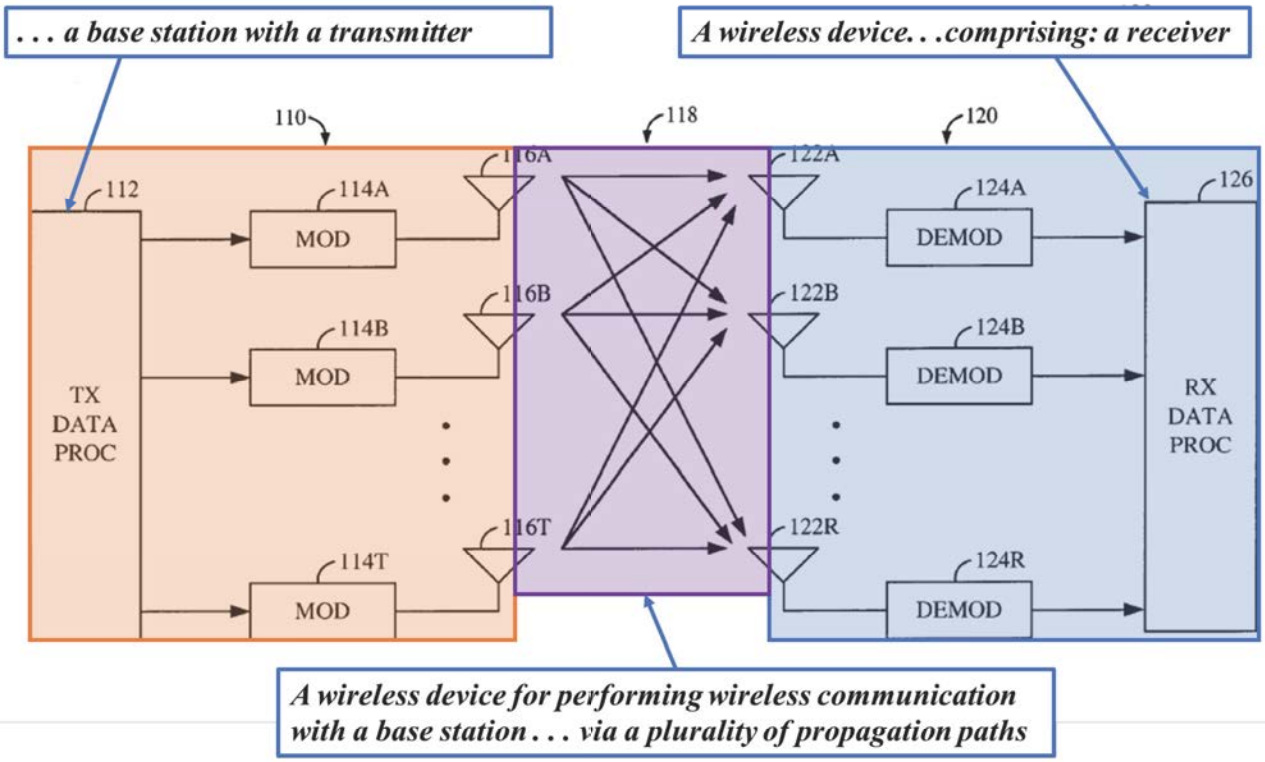
1. Application to Challenged Claims – 19-20, 23

Claim 19

[19.1] A wireless device for performing wireless communication with a base station with a transmitter via a plurality of propagation paths, the wireless device comprising: a receiver;

125. Wallace renders obvious [19.1]. For example, Wallace teaches an "apparatus for the measuring and reporting of channel state information" between ***a base station with a transmitter*** and ***a wireless device*** with ***a receiver***. APPLE-1006, 2:25-48, 3:55-4:28. Specifically, Wallace describes a "communications

system 100 [that] includes a first system 110 [(***a base station with a transmitter***)] in communication with a second system 120 [(***a wireless device*** with ***a receiver***)]." APPLE-1006, 3:55-4:28, FIG. 1.



APPLE-1006, FIG. 1A.

126. In Wallace's figure 1A above, "system 110" (***base station***) is shown as an MIMO system ***with a transmitter***. APPLE-1006, FIG. 1A, 3: 34-4:28. System 120 (the ***wireless device***) includes ***a receiver***. APPLE-1006, FIG. 1A, 3: 34-4:28. Because Wallace's MIMO system showing in figure 1A is a known wireless communication system, a POSITA would have understood and found obvious that system 120 with multiple antennas is a ***wireless device*** for the

purposes of wireless communication via ***a plurality of propagation paths***. APPLE-1006, 1:57-2:8, 6:14-31 ("an RF modulated signal from a transmitter unit may reach the receiver unit via a number of transmission paths."). Wallace's ***wireless device*** (system 120) which includes ***a receiver***. . . ***perform[s] wireless communication with a base station*** (system 110) ***with a transmitter via a plurality of propagation paths*** because Wallace describes communication between the base station and wireless device "over communications links 118 to system 120." APPLE-1006, FIG. 1A, 3:34-4:28.

127. In further detail, Wallace's system describes transmitting "signals over a propagation channel between ***a transmitter*** unit and ***a*** plurality of ***receiver*** units . . . and the propagation channel comprises a plurality of sub-channels between the transmitter unit and the plurality of receiver units," APPLE-1006, 2:25-48. Wallace describes measuring/determining the characteristics of the "plurality of sub-channels" to determining a level of fading along the propagation paths because "[w]hen signals arrive from multiple propagation paths [(***a plurality of propagation paths***)], components of the signals can combine destructively, which is referred to as 'fading.'" APPLE-1006, 1:57-2:8. Specifically, Wallace describes the propagation path characteristics or "characteristics of the propagation channel can be determined through a set of K sub-channels carrying the pilot symbols." APPLE-1006, 2:50-63. A POSITA would have understood and found

obvious that Wallace's "multiple propagation paths" functionally equate to ***a plurality of propagation paths*** formed between the transmitter and the receiver which are capable of carrying a signal transmitted by the transmitter to the receiver. Further, the propagation channel can be characterized by a set of K sub-channels and is capable of carrying at least Wallace's "pilot signals" which is at least one example of a ***first signal***. APPLE-1006, 1:57-2:8 ("Multipath occurs when a transmitted signal arrives at a receiver unit through multiple propagation paths with differing delays.")

128. In more detail, a POSITA would have understood and found obvious that disclosure of devices that include transmitters, receivers, distortion determination circuits for communication over a wireless communication network would satisfy or encompass the understanding of a ***wireless device*** and a ***base station*** communicating wirelessly via multiple propagation paths. For example, the definition of "base station" is "[a] fixed station used by a dispatcher to communicate with mobile units. 2. The central transmitter in a communications system that acts as the cell hub for communicating with handsets and/or mobile units." APPLE-1008, 6. Thus, at the very least, which device is the "base station" is not determined and the configuration of such a system would be a design choice requiring a POSITA's base-line knowledge of such wireless communication systems and commonsense. *See* [1.1] ("a plurality of propagation paths formed

between the transmitter and the receiver").

129. Additionally, Wallace describes that "an RF modulated signal from ***a transmitter*** unit may reach the ***receiver*** unit via a number of transmission paths [(***a plurality of propagation paths***)]." APPLE-1006, 6: 14-31; 3:55-67. Thus, a POSITA would have understood and found obvious that Wallace describes a ***wireless device for performing wireless communication with a base station with a transmitter via a plurality of propagation paths, the wireless device comprising: a receiver***.

[19.2] a computing device; and a computer-readable storage medium having computer-executable instructions stored thereon that are executable by the computing device to perform operations comprising:

130. Wallace renders obvious [19.2]. For example, Wallace describes a processor used for processing the channel characteristics. Notably, each of the base station (system 112) and the wireless device (system 120) have processors. APPLE-1006, FIG. 1A, 3:34-4:28.

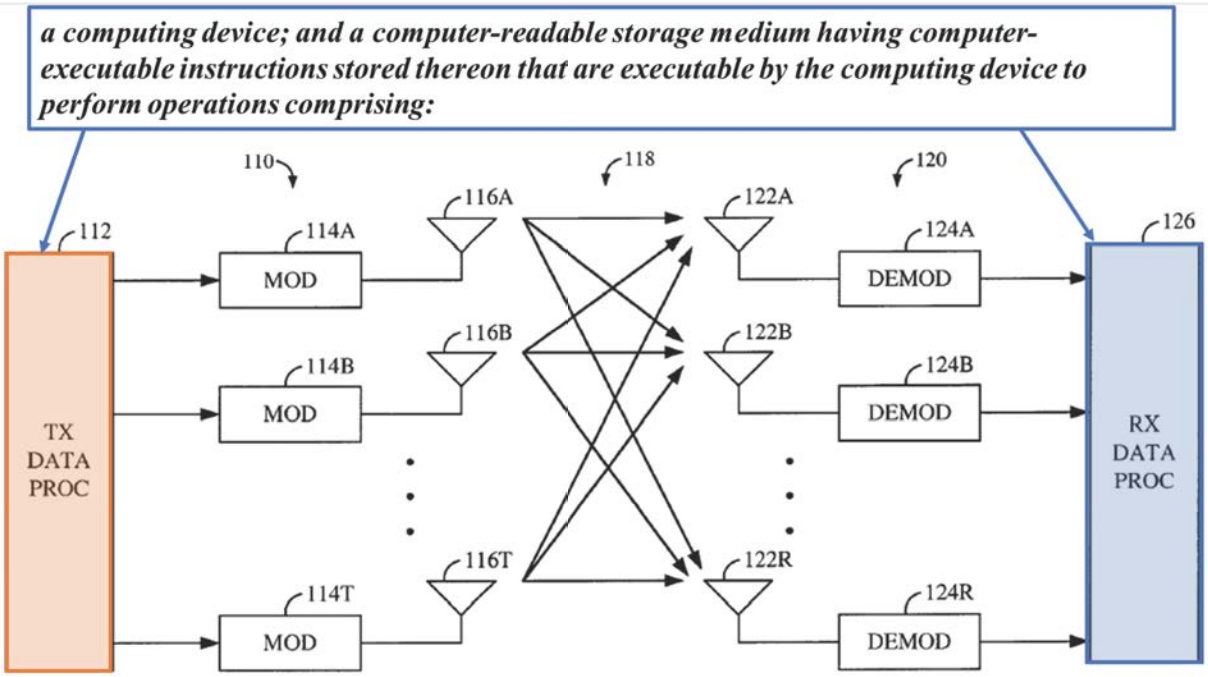


FIG. 1A

APPLE-1006, FIG. 1A.

131. Wallace goes on to describe that the processors "can be implemented in various manners such as . . . a microcontroller, a microprocessor, or other electronic circuits designed to perform the functions described herein." APPLE-1006, 28:58-29:4. And they can be "operated to execute instruction codes that achieve the functions described herein [so that] the processing units described herein can be implemented using hardware, software, or a combination thereof." APPLE-1006, 28:58-29:4. . A POSITA would have understood and found obvious that the implementations called for in Wallace involve ***a computing device; and a computer-readable storage medium having computer-executable instructions stored thereon that are executable by the computing device to perform operations***

comprising.

[19.3] receiving a first signal at the receiver via a first propagation path of the plurality of propagation paths;

132. Wallace renders obvious [19.3]. For example, for the purposes of measuring the channel characteristics, Wallace describes "***receiving***, by a first receive antenna of a first receiver unit [(***at the receiver***)], ***the first*** pilot symbol [(***signal***)]." APPLE-1006, 2:25-49; cl 1. Wallace describes receiving signals "via different transmission paths" where each signal is received ***via a first propagation path of the plurality of propagation paths***. APPLE-1006, 6:39-51, FIG. 1A, 1:57-2:8 ("Multipath occurs when a transmitted signal arrives at a receiver unit through multiple propagation paths with differing delays.").

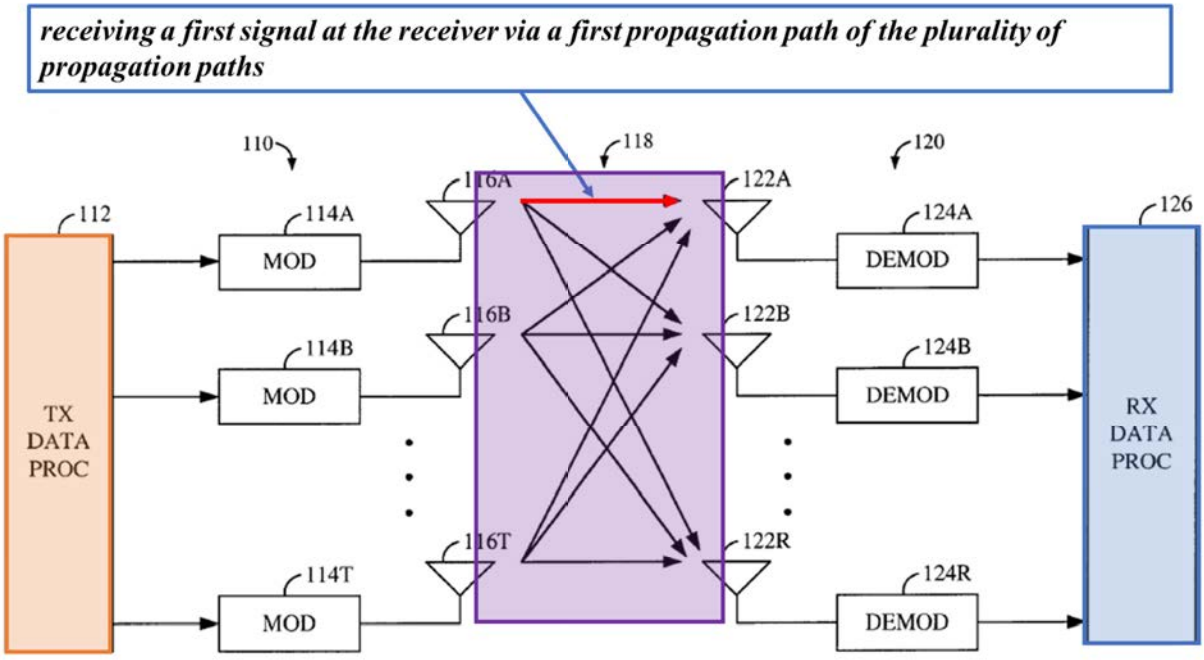


FIG. 1A

APPLE-1006, FIG. 1A.

133. Thus, a POSITA would have understood and found obvious ***receiving a first signal at the receiver via a first propagation path of the plurality of propagation paths***. *See* [1.3] ("receiving the first signal at the receiver"), [1.2] ("transmitting . . . to the receiver via a first propagation path of the plurality of propagation paths").

[19.4] performing a channel estimation based on the first signal to obtain path parameter information of the first propagation path;

134. Wallace renders obvious [19.4]. For example, Wallace teaches "determining a set of transmission characteristics for at least one of the plurality of sub-channels." APPLE-1006, 2:25-49, Abstract ("receiver units determine the CSI [(Channel State Information)] for the disjoint sub-channels that carried pilot symbols."), FIG. 1B.

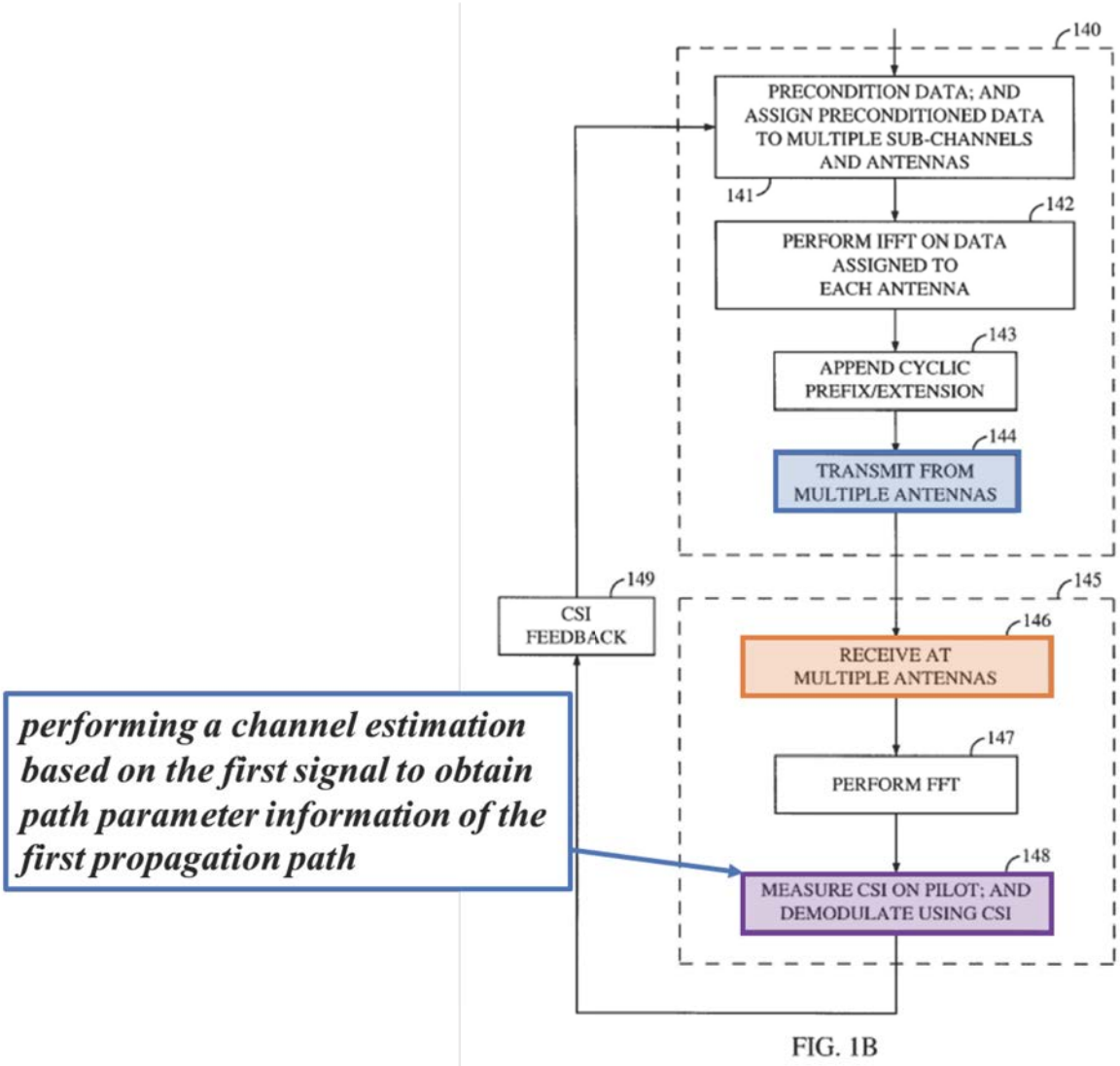


FIG. 1B

APPLE-1006, FIG. 1B.

135. As seen in figure 1B above, Wallace describes ***performing a channel estimation*** based on the received signal to determine Channel State Information (CSI). APPLE-1006, 14:56-15:2. Wallace describes "[f]ull CSI includes sufficient characterization of the propagation path (i.e., amplitude and phase) between all pairs of transmit and receive antennas for each sub-band . . . . [and] also includes

the information of the relative levels of interference and noise in each sub-channel." APPLE-1006, 8:53-9:3. Wallace's "CSI may be embodied in a set of matrices of complex gain values that are descriptive of the conditions of the transmission paths from the transmit antennas to the receive antennas." APPLE-1006, 8:53-9:3; 13:3-21. Because the measurement of the received signal would indicated the characteristics of the path traveled by the signal (***the first propagation path***), a POSITA would have understood and found obvious that Wallace's performance of ***channel estimation*** is ***based on the first signal*** in order ***to obtain path parameter information of the first propagation path***.

136. Wallace provides an additional method of ***performing channel estimation*** when it is undesirable to compress CSI for transmission. APPLE-1006, 18:33-45. When employing this option, the channel state (e.g., how received signals are affected by "multipath components"), is represented in a matrix "a time-domain representation of the channel response" or ***channel estimation based on the first signal***. APPLE-1006, 18:33-45. This representation captures the effect of multipath propagation, where signals reach the receiver via multiple paths, each with a different delay and amplitude. Wallace's "resulting channel impulse responses [(***channel estimation***)] are then translated into a set of amplitudes and delays [(***to obtain path parameter information of the first propagation path***)] that are reported to the transmitter" in order to precondition (i.e., pre-distort) the

transmissions between the transmitter and receiver. APPLE-1006, 18:33-45; *See* [1.4]. The channel estimation may also "be embodied in a set of matrices of complex gain values that are descriptive of the conditions of the transmission paths from the transmit antennas to the receive antennas." APPLE-1006, 13:3-21.

[19.5] sending the channel estimation that includes the path parameter information to the transmitter; and

137. Wallace renders obvious [19.5]. For example, Wallace teaches the "deriv[ation of] characteristics of the propagation channel and to report such characteristics to the transmission site." APPLE-1006, 18:5-32. Specifically, Wallace teaches "reporting [(***sending***)] an information signal [(***the channel estimation***)] from each of the plurality of receiver units [(from the receiver)] ***to the transmitter*** unit, wherein the information signal carries the set of transmission characteristics for at least one of the plurality of sub-channels [(***the channel estimation that includes the path parameter information***)]." APPLE-1006, 2:25-49. Shown in Wallace's figure 1B below, the measured channel estimation is sent to the transmitter for later "preconditioning" or pre-distortion of future signals. APPLE-1006, 14:56-15:7, FIG. 1B.

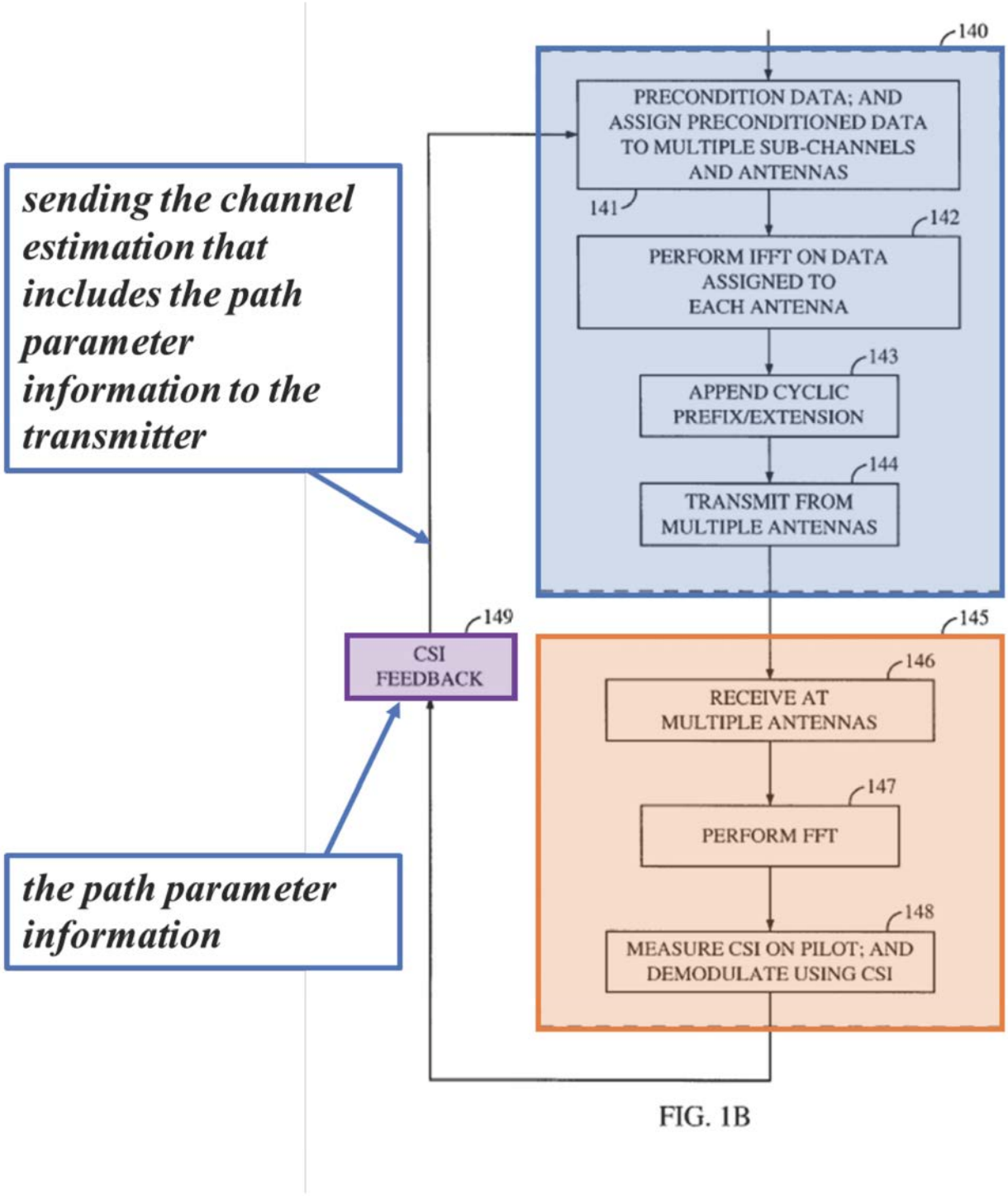


FIG. 1B

APPLE-1006, FIG. 1B.

138. Thus, a POSITA would have understood and found obvious from Wallace's teachings that after performing channel estimation, the device would

send[] the channel estimation that includes the path parameter information to the transmitter. *See* [1.5] ("sending the channel estimation that includes the path parameter information . . . to the transmitter. . . ").

[19.6] receiving a second signal via the first propagation path, the second signal predistorted in a time domain, a frequency domain, and a spatial domain according to the channel estimation based on the first signal.

139. Wallace renders obvious [19.6]. First, Wallace renders obvious ***receiving a second signal via the first propagation path***. For example, "[a]s long as the channel does not change appreciably from the time it is measured by the receiver unit and subsequently sent back to the transmitter and used to precondition the transmission, the intended receiver unit can demodulate the [pre-distorted] transmission [(***receiving a second signal via the first propagation path***)]." APPLE-1006, 9:4-15. A POSITA would have understood and found obvious from the above disclosure, that the ***second signal***, which is pre-distorted based on earlier measurements, is received ***via the*** same ***first propagation path***. In addition, a POSITA would have understood and found obvious that Wallace demonstrates that the transmitter preconditions (***predistorts***) the transmission of a second signal for the very purpose ***receiving the predistorted second signal at the receiver via the first propagation path*** that does not change appreciably from the time it is measured by the receiver unit. *Id*.

140. Second, Wallace renders obvious ***the second signal predistorted in a***

time domain, a frequency domain, and a spatial domain according to the channel estimation based on the first signal. For example, Wallace teaches using the previously measured "information as to the characteristics of the propagation channel [(***channel estimation***)] . . . in order to precondition [(***predistort[]***)] the signal before transmission." APPLE-1006, 1:57-2:8. Shown in Wallace's figure 1B below, step 149, the system performs the process of ***predistorting a second signal at the transmitter . . . according to the channel estimation based on the first signal***. APPLE-1006, 14:56-15:2, cl. 19 ("preconditioning a transmission symbol according to the determined CSI."). Wallace's preconditioning (***predistorting***) based on the previously measured channel conditions (***channel estimation***) would have been understood and obvious to a POSITA as applied to a ***second signal*** (e.g., a signal sent after Wallace's pilot signals), that was ***predistort[ed] . . . at the transmitter . . . according to the channel estimation based on the first signal***.

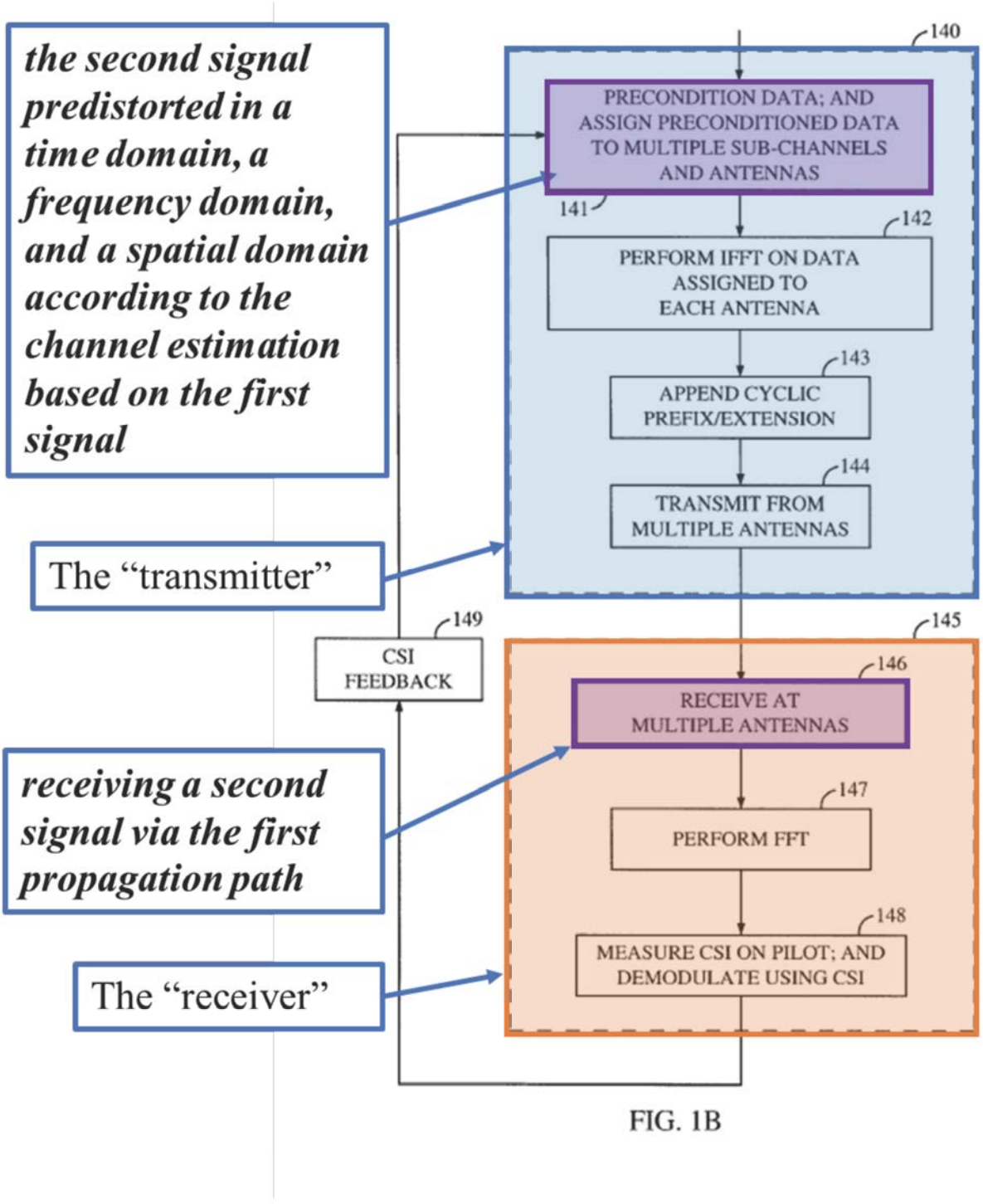


FIG. 1B

APPLE-1006, FIG. 1B.

141. Wallace teaches that the measured ***channel estimation***, used to pre-distort the second signal, includes information about ***a time domain, a frequency***

domain, and a spatial domain. APPLE-1006, 3:55-66. Indeed, as Wallace explains and a POSITA would have found obvious, a "combination of antenna [(***spatial domain***)], frequency [(***frequency domain***)], and temporal [(***time domain***)] diversity allows the communications system of the invention to provide robust performance." APPLE-1006, 7:33-43; *Id*. 3:34-54. Specifically, Wallace teaches the preconditioning of a signal, prior to transmission, to provide ***a time domain, a frequency domain, and a spatial domain*** diversity. APPLE-1006, 3:55-66. Wallace discloses that "***frequency*** and ***temporal diversity*** may be used in conjunction with the different transmit antennas. For receive diversity, modulated signals are received on ***multiple receive antennas, and diversity*** is achieved by simply receiving the signals via ***different transmission paths***." APPLE-1006, 6:44-51. A POSITA would have understood that different transmit/receive antennas and transmission paths provide spatial domain diversity. Wallace teaches that, at the transmitter, data—which can include the channel estimation data received from the previous transmission—is used prior to transmission "to provide antenna [(spatial)], frequency, or temporal diversity, or a combination thereof." APPLE-1006, 3:55-66; 5:46-6:5 ("The communications system of the invention provides the above-described features and advantages . . . by employing antenna, frequency, or temporal diversity, or a combination thereof. Antenna, frequency, or temporal diversity can be independently achieved and dynamically selected."), 7:33-44;

APPLE-1008, 7 ("diversity- 1. A form of transmission and/or reception using several modes, usually in space or in time, to compensate for fading or outages . . . using different frequencies or different polarization.").

142. In addition, a POSITA would have understood and found obvious that Wallace discloses frequency domain channel state information (CSI) with the use of OFDM modulation:

> Given the complexity of a system using multiple transmit antennas and multiple receive antennas, with the associated dispersive channel effects, the preferred modulation technique is OFDM, which effectively decomposes the channel into a set of non-interfering narrowband channels, or sub-channels. With proper OFDM signal design, a signal transmitted on one subchannel sees "flat fading", i.e., the channel response is effectively constant over the subchannel bandwidth. The channel state information or CSI includes sufficient characterization of the propagation path (i.e., amplitude and phase) between all pairs of transmit and receive antennas for each sub-channel. APPLE-1006, 13:3-14.

143. In more detail, Wallace's disclosure at 5:45- 6:67, including Wallace's description regarding adjusting transmissions, based on channel estimation, teaches the preconditioning of a signal in ***a time domain, a frequency domain, and a spatial domain***. APPLE-1006, 5:45- 6:67. Specifically, Wallace discloses compensating for transmission characteristics in the ***spatial domain*** includes the "use of more than one transmit antenna in a manner to improve the reliability of the communications link." APPLE-1006, 5:45- 6:67. Wallace's

compensation in the ***frequency domain*** "can be provided by use of a multi-carrier modulation Scheme Such as Orthogonal frequency division multiplexing (OFDM)." *Id*. Wallace's compensation in the ***time domain*** "is achieved by transmitting the data over different times." *Id*. Indeed, Wallace's "information indicative of the conditions (i.e., the 'state') of the communications links," can include "a ***time-domain*** representation of the channel response." APPLE-1006, 8:53-9:3, 18:33-44 Finally, Wallace discloses combining and compensating for all of these domains to "improve the reliability of the communications link." *Id*. Thus, a POSITA would have understood and found obvious [19.6].

Claim 20

[20] The wireless device of claim 19, wherein the path parameter information of the first propagation path includes at least one of an estimation of a delay, an estimation of a Doppler frequency, an estimation of a direction of arrival, an estimation of a direction of departure, and an estimation of a complex amplitude of the first propagation path.

144. Wallace renders obvious [20]. For example, Wallace teaches the communication system can "support a number of processing modes" for ascertaining "information indicative of the conditions (i.e., the 'state') of the communications links," which can include amplitude and delay parameters in "partial-CSI [channel state information] or no-CSI processing modes." APPLE-1006, 8:53-9:3, 9:16-27. Whether using "full CSI or partial CSI, the transmitter unit pre-conditions the data prior to transmission to receiver unit." APPLE-1006,

8:53-9:3.

145. First, Wallace's teaching of "information [(***the path parameter information***)] indicative of the conditions (i.e., the 'state') of the communications links [(***of the first propagation path***)]," can include "channel impulse responses are then translated into a set of amplitudes and ***delays*** that are reported to the transmitter." APPLE-1006, 8:53-9:3; 18:33-44. A POSITA would have understood and found obvious that such disclosure renders obvious ***the path parameter information of the first propagation path includes at least one of an estimation of a delay***.

146. Second, Wallace teaches measuring "sufficient characterization of the propagation path (i.e., ***amplitude*** and phase)" between pairs of transmit and receive antennas (***of the first propagation path***). APPLE-1006, 8:53-9:3. A POSITA would have understood and found obvious that Wallace's ***the path parameter information of the first propagation path includes at least one of . . . an estimation of a complex amplitude of the first propagation path*** because Wallace's "characterization of the propagation path" can include information on the "***amplitude*** and phase" of a channel gain value. In fact, Wallace states that the channel information is often "embodied in a set of matrices of complex gain values that are descriptive of the conditions of the transmission paths from the transmit antennas to the receive antennas." APPLE-1006, 8:53-9:3.

147. Third, Wallace's "information indicative of the conditions (i.e., the 'state') of the communications links [(***of the first propagation path***)]," can include "a time-domain representation of the channel response [(***the path parameter information***)]." APPLE-1006, 8:53-9:3, 18:33-44; *See* [19.5]. The "time-domain representation" is an alternative CSI. APPLE-1006, 18:33-44. Rather than reporting complex gain matrices across all sub-bands, the receiver can perform an Inverse Fast Fourier Transform (IFFT) on a determined channel response to obtain the channel impulse responses in the time domain. APPLE-1006, 18:33-44. These impulse responses are then simplified and reported as a set of time domain "amplitudes and delays that are reported to the transmitter." APPLE-1006, 18:33-44. This method is particularly efficient when the time-domain representation of the channel is "simple, as in cases where there are only two or three multipath components", effectively summarizing the channel's time-dispersive properties (e.g., amplitudes and delays). APPLE-1006, 18:33-44. Thus, a POSITA would have recognized and found obvious that Wallace's alternative time-domain representations include ***path parameter information of the first propagation path includes at least one of an estimation of a delay . . . and an estimation of a complex amplitude of the first propagation path***.

148. Notably, all of Wallace's approaches (full CSI, partial CSI, and an alternative CSI) align with a narrower interpretation of the '347 Patent teachings.

Specifically, the '347 Patent states that its approach differs from conventional precoding techniques, which often use "simplified representations of channel, e.g. in terms of code-book," APPLE-1001, 11:60-12-7, 14:17-24 ("the systems and methods described herein make use of the parameters of propagation instead of the simplified channel status information"). *See* [2].

Claim 23

[23] The wireless device of claim 19, wherein the receiver comprises multiple antennas in a multiple-input and multiple-output (MIMO) wireless communication system or a single antenna in a single-input and single-output (SISO) wireless communication system.

149. Wallace renders obvious [23]. Wallace's describes examples where ***the transmitter and the receiver each comprise multiple antennas in a multiple-input and multiple-output (MIMO) wireless communication system***. APPLE-1006, 1:57-2:8 ("In order to improve the efficiency and decrease the complexity of the MIMO system, information as to the characteristics of the propagation channel can be transmitted back to the transmitter unit in order to precondition the signal before transmission.") In fact, Wallace's figure 1 is "a diagram of a multiple-input multiple-output (MIMO) communications system" that is "capable of implementing some embodiments of the invention." APPLE-1006, 3:4-5, 34-54; FIG. 1; *See* [12].

2. Mirroring claims 1-2, 8, 12, 15-17

Claim 1

[1.1] A method for wireless communication in a system including a transmitter, a receiver, and a plurality of propagation paths formed between the transmitter and the receiver which are capable of carrying a signal transmitted by the transmitter to the receiver, the method comprising:

150. Wallace renders obvious [1.1]. For example, Wallace teaches a "***method*** and apparatus for the measuring and reporting of channel state information" in ***wireless communication*** systems. APPLE-1006, 2:25-48. Wallace's system includes transmitting "***signals*** over a propagation channel between ***a transmitter*** unit and ***a*** plurality of ***receiver*** units . . . and the propagation channel comprises a plurality of sub-channels between the transmitter unit and the plurality of receiver units," APPLE-1006, 2:25-48. Wallace describes measuring the characteristics representing a "plurality of sub-channels" making up the propagation channel to determine a level of fading along the propagation paths because "[w]hen signals arrive from multiple propagation paths [(***a plurality of propagation paths***)], components of the signals can combine destructively, which is referred to as 'fading.'" APPLE-1006, 1:57-2:8. Specifically, Wallace describes the propagation path characteristics or "characteristics of the propagation channel can be determined through a set of K sub-channels carrying the pilot symbols." APPLE-1006, 2:50-63. Additionally, Wallace describes that "an RF modulated ***signal*** from ***a transmitter*** unit may reach the ***receiver*** unit via a number of transmission paths [(***a plurality of propagation paths***)]." APPLE-1006, 6: 14-31;

3:55-67. A POSITA would have understood and found obvious that Wallace's "multiple propagation paths" functionally equate to ***a plurality of propagation paths formed between the transmitter and the receiver which are capable of carrying a signal transmitted by the transmitter to the receiver***. Further, the propagation channel can be characterized by a set of K sub-channels and is capable of carrying at least Wallace's "pilot signals." APPLE-1006, 1:57-2:8 ("Multipath occurs when a transmitted signal arrives at a receiver unit through multiple propagation paths with differing delays.")

151. Thus, a POSITA would have understood and found obvious that Wallace's ***system includ[es] a transmitter, a receiver, and a plurality of propagation paths formed between the transmitter and the receiver which are capable of carrying a signal transmitted by the transmitter to the receiver, the method comprising***.

[1.2] transmitting a first signal from the transmitter to the receiver via a first propagation path of the plurality of propagation paths;

152. Wallace renders obvious [1.2]. For example, Wallace describes "***transmitting*** the plurality of pilot signals [(***a first signal***)] over a propagation channel [(***via a first propagation path***)] between a transmitter unit and a plurality of receiver units [(***from the transmitter to the receiver***)] . . . the propagation channel comprises a plurality of sub-channels [(***of the plurality of propagation paths***)] between the transmitter unit and the plurality of receiver units." APPLE-

1006, 2:25-49. Specifically, Wallace teaches the "pilot wave form[] is transmitted over a separate one [(***a first propagation path***)] of the plurality of sub-channel subsets [(***of the plurality of propagation paths***)]." APPLE-1006, cl. 19; cl. 1 ("transmitting, by the first transmit antenna, a first pilot symbol over the sub-channels of the first subset of sub-channels"). Wallace explains and a POSITA would have understood and found obvious that Wallace's transmission of a pilot symbol (the ***first signal***) over the various paths would have sent the same pilot signal (the ***first signal***) over various different propagation paths, at least one of them arriving at a receiver via ***a first propagation path***. APPLE-1006, cl. 2 ("transmitting the first pilot symbol over each of the sub-channels of a first subset of the plurality of OFDM sub-channel subsets."), 2:50-63 ("pilot symbols are transmitted on a plurality of disjoint OFDM sub-channel sets."), cl. 19 ("transmitting a plurality of Orthogonal Frequency Division Multiplexed (OFDM) pilot waveforms from the at least one transmitter unit to at least one receiver unit, wherein each of the plurality of OFDM pilot wave forms is transmitted over a separate one of the plurality of sub-channel subsets,").

153. Indeed, one of Wallace's goals is to "precondition the signal before transmission" based on "information as to the characteristics of the propagation channel." APPLE-1006, 1:57-2:8. These characteristics are determined from measured "deleterious effects of multipath. . . [that] occurs when a transmitted

signal arrives at a receiver unit through multiple propagation paths with differing delays. APPLE-1006, 1:57-2:8.

[1.3] receiving the first signal at the receiver;

154. Wallace renders obvious [1.3]. For example, Wallace describes "***receiving***, by a first receive antenna of a first receiver unit [(***at the receiver***)], ***the first*** pilot symbol [(***signal***)]." APPLE-1006, cl 1; *See* [19.3].

[1.4] performing a channel estimation based on the first signal to obtain path parameter information of the first propagation path;

155. *See* [19.4].

[1.5] sending the channel estimation that includes the path parameter information from the receiver to the transmitter via the first propagation path;

156. *See* [19.6] ("....predistorted in a time domain, a frequency domain, and a spatial domain according to the channel estimation based on the first signal"). Given the well-known nature of "multipath delay spread or differential path delay introduced by the propagation environment between the transmitting antenna and the receiver antenna," a POSITA would have understood and found obvious that such a transmission "between the transmitting antenna and the receiver antenna" could occur ***via the first propagation path***. APPLE-1006, 25:44-48. For example, Wallace explains, and a POSITA would have understood and found obvious that channel conditions between a transmitter and receiver stay nearly the same, at least for a short period of time. APPLE-1006, 9:4-15. In fact, Wallace's system relies on

the assumption that the communication path between the transmitter and receiver "does not change appreciably from the time it is measured by the receiver unit and subsequently sent back to the transmitter and used to precondition the transmission." APPLE-1006, 9:4-15; Abstract ("Channel state information (CSI) can be used by a communications system to precondition transmissions between transmitter units and receiver units."); 2:9-22 ("channel characteristics, such as fading and interference statistics, be determined and transmitted quickly to the transmitter unit before the channel characteristics change significantly."). Thus, Wallace renders obvious that the return transmission experiences nearly equivalent propagation path in the opposite direction and functionally equates to ***sending the channel estimation . . . via the first propagation path***.

[1.6] predistorting a second signal at the transmitter in a time domain, a frequency domain, and a spatial domain, according to the channel estimation based on the first signal;

157. *See* [19.6].

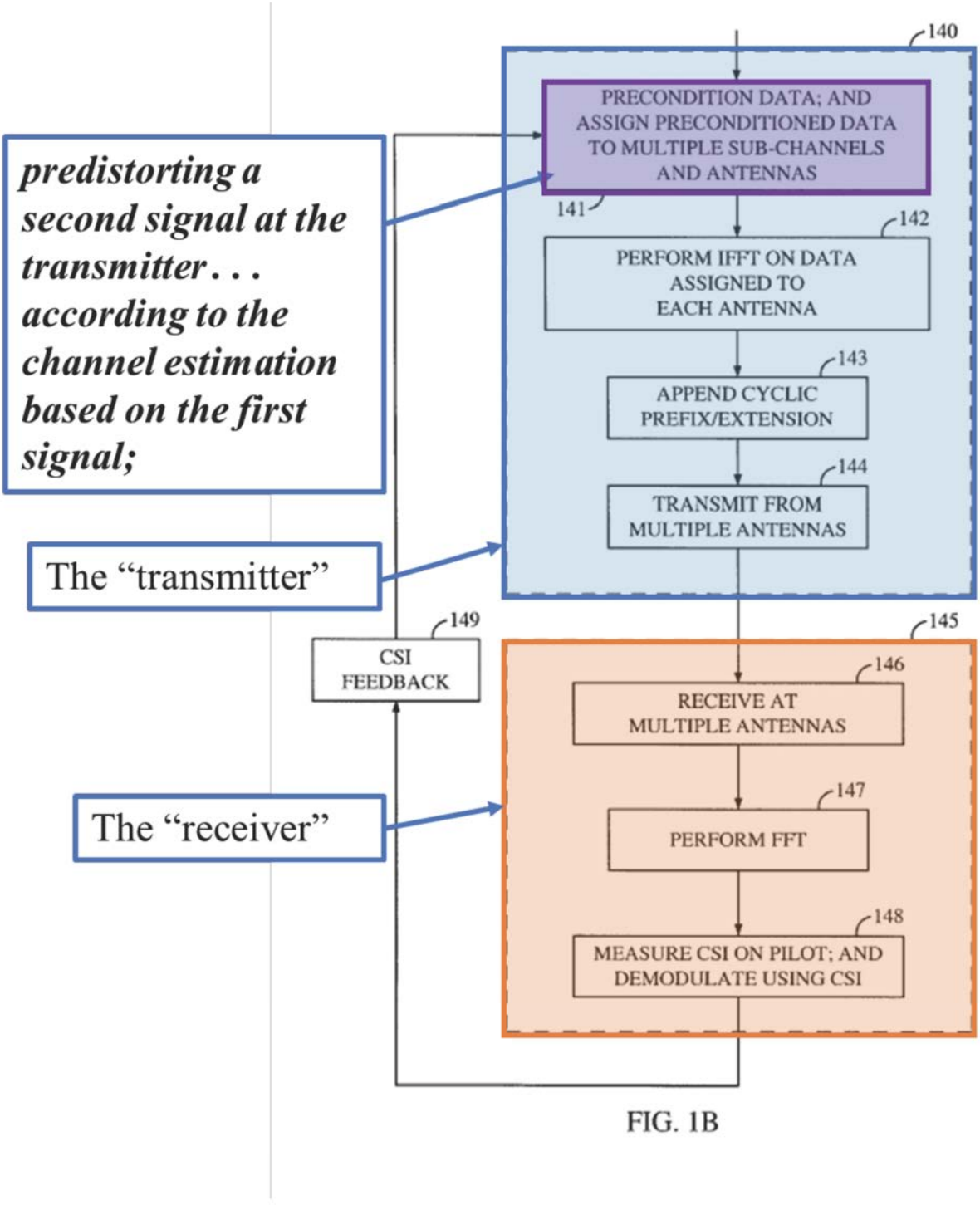


FIG. 1B

APPLE-1006, FIG. 1B.

[1.7] transmitting the predistorted second signal from the transmitter to the receiver via the first propagation path; and

158. Wallace renders obvious [1.7]. For example, Wallace teaches "information as to the characteristics of the propagation channel can be transmitted back to the transmitter unit in order to precondition the signal before transmission." APPLE-1006, 1:57-2:8. Thus, the transmitter utilizes the information about the channel estimation (sent to the transmitter in [1.5]) in ***transmitting the predistorted second signal from the transmitter to the receiver via the first propagation path***. APPLE-1006, 1:57-2:22, FIG. 1B.

159. Wallace's system describes providing channel estimation information in order for the transmitter to pre-distort and transmit a ***second signal*** . . . ***via the first propagation path*** because "information regarding channel characteristics, such as fading and interference statistics, [should] be determined and transmitted quickly to the transmitter unit before the channel characteristics change significantly." APPLE-1006, 2:9-22. Wallace aims to take advantage of the measured conditions of ***the first propagation path*** in subsequent transmission and indeed is preconditioning the second signal optimized for ***the first propagation path***. APPLE-1006, 2:25-63. In other words, Wallace transmits a second signal using information learned from transmission measurements of the first signal, therefore the second signal is pre-distorted with the assumption that the second signal will travel ***via the first propagation path***, which is assumed to not have appreciably changed since the measurement. Thus, Wallace renders obvious [1.7].

[1.8] receiving the predistorted second signal at the receiver.

160. Wallace renders obvious [1.8]. For example, Wallace teaches that "[a]s long as the channel does not change appreciably from the time it is measured by the receiver unit and subsequently sent back to the transmitter and used to precondition the transmission, the intended receiver unit can demodulate the [preconditioned] transmission." APPLE-1006, 9:4-15. In addition, a POSITA would have understood and found obvious that Wallace teaches that such transmissions are preconditioned (***predistorted***) for the very purpose ***receiving the predistorted second signal at the receiver***. *See* [19.6].

Claim 2

[2] The method of claim 1, wherein the path parameter information of the first propagation path includes at least one of an estimation of a delay, an estimation of a Doppler frequency, an estimation of a direction of arrival, an estimation of a direction of departure, and an estimation of a complex amplitude of the first propagation path.

161. *See* [20].

Claim 8

[8.1] A system for wireless communication comprising: a receiver; a transmitter; and a plurality of propagation paths formed between the transmitter and the receiver which are capable of carrying a signal transmitted by the transmitter to the receiver,

162. *See* [19.1]; APPLE-1006, cl. 19; [1.1]-[1.2].

[8.2] wherein the receiver is configured to receive a first signal that is transmitted along a first propagation path of the plurality of propagation paths from the transmitter,

163. *See* [19.3], [1.2]-[1.3].

[8.3] perform a channel estimation based on the first signal to obtain path parameter information of the first propagation path, and

164. *See* [19.4], [1.4].

[8.4] send the channel estimation that includes the path parameter information to the transmitter via the first propagation path, and

165. *See* [19.5], [1.5].

[8.5] wherein the transmitter is configured to predistort a second signal in a time domain, a frequency domain, and a spatial domain according to the channel estimation that is based on the first signal and received from the receiver and

166. *See* [19.6], [1.6].

[8.6] to transmit the predistorted second signal to the receiver via the first propagation path.

167. *See* [19.6], [1.7].

Claim 12

[12] The system of claim 8, wherein the transmitter and the receiver each comprise multiple antennas in a multiple-input and multiple-output (MIMO) wireless communication system or a single antenna in a single-input and single-output (SISO) wireless communication system.

168. *See* [23].

Claim 15

[15.1] A base station for performing wireless communication with a receiver in a wireless device via a plurality of propagation paths, the base station comprising: a transmitter;

169. A POSITA would have understood and found obvious that Wallace's disclosure of devices that include transmitters, receivers, distortion determination circuits for communication over a wireless communication network would satisfy or encompass the understanding of a ***wireless device*** and a ***base station***. For example, the definition of "base station" is "[a] fixed station used by a dispatcher to communicate with mobile units. 2. The central transmitter in a communications system that acts as the cell hub for communicating with handsets and/or mobile units." APPLE-1008, 6. Thus, at the very least, which device is the "base station" is not determined and the configuration of such a system would be a design choice requiring a POSITA's base-line knowledge of such wireless communication systems and commonsense. *See* [1.1] ("a plurality of propagation paths formed between the transmitter and the receiver"), ("system including a transmitter"); [19.1].

[15.2] a computing device; and a computer-readable storage medium having computer-executable instructions stored thereon that are executable by the computing device to perform operations comprising:

170. *See* [19.2].

[15.3] transmitting a first signal from the transmitter to the receiver via a first propagation path of the plurality of propagation paths;

171. *See* [19.3], [1.2].

[15.4] receiving a channel estimation based on the first signal, the channel estimation including path parameter information of the first propagation path;

172. A POSITA would have understood and found obvious from the teachings that render obvious [19.5] and [1.5], that the "base station" of claim 15 would ***receiv[e] a channel estimation based on the first signal, the channel estimation including path parameter information of the first propagation path*** because claim [1.5] provides for "sending ***the channel estimation*** that ***includes the path parameter information*** from the receiver to the transmitter via the first propagation path." *See* [19.5], [1.5] ("sending the channel estimation that includes the path parameter information from the receiver to the transmitter via the first propagation path").

[15.5] predistorting a second signal in a time domain, a frequency domain, and a spatial domain according to the channel estimation based on the first signal; and

173. *See* [1.6].

[15.6] transmitting the predistorted second signal from the transmitter to the receiver via the first propagation path.

174. *See* [1.7].

Claim 16

[16] The base station of claim 15, wherein the path parameter information of the first propagation path includes at least one of an estimation of a delay,

an estimation of a Doppler frequency, an estimation of a direction of arrival, an estimation of a direction of departure, an estimation of a complex amplitude of the first propagation path, and an estimation of a polarization status of the first propagation path.

175. *See* [2] (". . . an estimation of a complex amplitude of the first propagation path."); *See* [3] ("information of the first propagation path further includes an estimation of a polarization status of the first propagation path").

Claim 17

[17] The base station of claim 15, wherein the transmitter comprises multiple antennas in a multiple-input and multiple-output (MIMO) wireless communication system or a single antenna in a single-input and single-output (SISO) wireless communication system.

176. *See* [23], [12].

D. GROUND 4 – Wallace and Medbo – Claims 20-22, 2-4, and 16

1. Application to Challenged Claims -20-22

Claim 20

[20] The wireless device of claim 19, wherein the path parameter information of the first propagation path includes at least one of an estimation of a delay, an estimation of a Doppler frequency, an estimation of a direction of arrival, an estimation of a direction of departure, and an estimation of a complex amplitude of the first propagation path.

177. Wallace-Medbo renders obvious [20] in addition to the reasons stated in Grounds 2 and 3. In addition, Medbo further describes the types of well-known distortion characteristics teaching "[t]he measured channel responses can for

example be represented in frequency, time/delay, code and/or space." APPLE-1005, [0041], [0057] ("desirable to determine ... wave propagation delay of each of these waves"). Thus, a POSITA would have understood and found obvious when ***the path parameter information of the first propagation path includes at least one of an estimation of a delay . . . of the first propagation path***.

Claim 21

[21] The wireless device of claim 20, wherein the path parameter information of the first propagation path further includes an estimation of a polarization status of the first propagation path.

178. Wallace-Medbo render obvious [21] for the same reasons as Ground 2. For example, Medbo teaches when determining channel characteristics that "[p]referably, the complex amplitudes, described by a complex polarimetric amplitude matrix, for each of the discrete waves should also be determined." APPLE-1005, [0057]. The inclusion of a "complex polarimetric amplitude matrix" directly implies the estimation of polarization status. Medbo further explains that "to achieve positive definite $C^H \bullet C$, the antennas used must account for the full polarization matrix." APPLE-1005, [0120]. Medbo then teaches the use of these determined "complex polarimetric amplitude matrix" for later transmission of signals. APPLE-1005, [0120]. From this, a POSITA would have understood and found obvious that the determination and accounting for antenna "polarizations" characteristics, includes ***an estimation of a polarization status of the first***

propagation path.

179. Indeed, Sesia corroborates that a POSITA would have understood and found obvious that multi-path propagation parameters, for example "MIMO propagation channel parameters," can include "the arrival and departure angles in addition to the traditional power and delay," and "the polarization information." APPLE-1007, pp. 444-445, 665 ("sub-band reporting can be useful for the spatial component that captures co-phasing across polarizations (referred to as W_2)."). A POSITA would have understood and found obvious that polarization information was an important measurement in MIMO systems and measuring such properties would be part of the channel conditions thus rendering obvious that ***the path parameter information of the first propagation path further includes an estimation of a polarization status of the first propagation path***.

Claim 22

[22] The wireless device of claim 19, wherein the path parameter information is obtained by at least one estimation technique of the group consisting of a maximum likelihood estimation algorithm, periodogram, correlatorgram, spectral-based methods, Bartlett beamformers, Capon beamformers, subspace-based techniques, MUSIC (MUltiple SIgnal Classification), ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques), approximation of the maximum-likelihood method based on iterative schemes, SAGE (Space-Alternating Generalized Expectation-maximization), RiMAX (Richter's Maximum Likelihood method), maximum-a-posteriori based methods, Evidence Framework, Bayesian techniques, tracking algorithms, Kalman filtering techniques, enhanced

Kalman filtering techniques, particle filtering techniques, and least-square-error methods.

180. Wallace-Medbo renders obvious [22]. For example, Medbo teaches channel estimation using a maximum-likelihood (ML) estimation algorithm and other well-known methods for channel estimation. APPLE-1005, [0004]. Specifically, Medbo discloses "[i]t is well known that ***Maximum Likelihood*** [(***estimation algorithm***)] in principle is one of the most accurate methods available" Additionally, "[d]ifferent methods have previously been proposed for complexity reduction like ***Space Alternating Generalized Expectation*** (***SAGE***) maximization, and a maximum likelihood framework called ***RIMAX***." APPLE-1005, [0004], [0046].

181. Thus, a POSITA would have understood and found obvious that ***the path parameter information is obtained by at least one estimation technique of the group consisting of a maximum-likelihood estimation algorithm, . . . SAGE (Space-Alternating Generalized Expectation-maximization), RiMAX (Richter's Maximum Likelihood method)***.

2. Mirroring Claims 2-4, and 16

Claim 2

[2] The method of claim 1, wherein the path parameter information of the first propagation path includes at least one of an estimation of a delay, an estimation of a Doppler frequency, an estimation of a direction of arrival,

an estimation of a direction of departure, and an estimation of a complex amplitude of the first propagation path.

182. *See* [20].

Claim 3 –21

[3] The method of claim 2, wherein the path parameter information of the first propagation path further includes an estimation of a polarization status of the first propagation path.

183. *See* [21].

Claim 4 – 22

[4] The method of claim 1, wherein the path parameter information is obtained by at least one estimation technique of the group consisting of a maximum-likelihood estimation algorithm, periodogram, correlatorgram, spectral-based methods, Bartlett beamformers, Capon beamformers, subspace-based techniques, MUSIC (MUltiple SIgnal Classification), ESPRIT (Estimation of Signal Parameters via Rotational Invariance Techniques), approximation of the maximum-likelihood method based on iterative schemes, SAGE (Space-Alternating Generalized Expectation-maximization), RiMAX (Richter's Maximum Likelihood method), maximum-a-posteriori based methods, Evidence Framework, Bayesian techniques, tracking algorithms, Kalman filtering techniques, enhanced Kalman filtering techniques, particle filtering techniques, and least-square-error methods.

184. *See* [23].

Claim 16

[16] The base station of claim 15, wherein the path parameter information of the first propagation path includes at least one of an estimation of a delay, an estimation of a Doppler frequency, an estimation of a direction of arrival, an estimation of a direction of departure, an estimation of a

complex amplitude of the first propagation path, and an estimation of a polarization status of the first propagation path.

185. *See* [20] (". . . an estimation of a complex amplitude of the first propagation path."); *See* [3] ("information of the first propagation path further includes an estimation of a polarization status of the first propagation path").

X. CONCLUSION

186. For all the reasons I have noted in the foregoing paragraphs, the Challenged Claims of the '347 Patent are obvious in view of the references discussed above.

187. I currently hold the opinions set expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

APPENDIX A

Expert/Consultant Curriculum Vitae

Professor Zhi Ding

Ph.D. and Fellow of IEEE

Expertise

- Wireless Communication Systems
- Cellular Wireless (2G, 3G, 4G, 5G)
- Communication Network Protocols
- Multi-Antenna Technologies
- WLAN (WiFi, Bluetooth)
- xDSL Internet Services
- DOCSIS Modems
- Optical Networks

Professional Summary

- Professor of major US universities for 35 years.
- *Consulted for multiple major technology companies*
- Worked as expert on multiple patent infringement cases.
- Conducted research works on Communications and Signal Processing for over 30 years.
- Supervised over 30 PhD students.
- Author of more than 200 journal papers and 2 books on communication technologies.

Dr. Zhi Ding has been a professor of electrical engineering at major US universities for 32 years. Since 1995, he has consulted for both engineering companies such as Nortel, Analog Devices, Intel, and worked as expert for major law firms from US, UK, China, and Canada including Kirkland & Ellis, WilmerHale, Quinn Emanuel, Fish & Richardson, Sheppard Mullin, Sidley Austin, Mayer Brown, Venable, and Finnegan, on multiple technical and patent infringement cases. He has been conducting research works on wireless communications and signal processing since 1984. He has supervised over 30 PhD students. He is an author of 500 peer-reviewed papers and 2 technical books on communication technologies. He has taught classes that cover the fundamentals of signal detection, communications, and systems.

Dr. Ding currently holds the position of Distinguished Professor at the University of California, where he was also the Child Family Professor of Engineering and Entrepreneurship in 2009-2014. He served as the steering committee chair of the IEEE Transactions on Wireless Communications. He was elevated to Fellow of IEEE in 2002 by the IEEE Signal Processing Society. He also served as the Technical Program Chair of the IEEE Globecom 2006 (the flagship conference of the IEEE Communications Society), Dr. Ding is an eminent scholar and expert of wireless technologies AND signal processing. He received the IEEE Communications Society's 2012 TC Recognition Award and the 2020 Education Award.

Intellectual Property Dispute Consulting:

Past Client	Past Engagement
Kirkland & Ellis LLP	2007 (Intel v. WiLAN)
	2008 (Cisco, Motorola, etc., v. R.),
	2008 (Apple v. N.)
	2009 (Cisco v. WiAV)
	2009 (Apple v. P.)
	2009 (Cisco v. M.)
	2010 (Netgear v. R.)
	2011 (Intel v. E.)
	2011 (Cisco v. M.)
	2011 (Cisco, Motorola v. I.)
	2011 (Netgear v. E.)
	2013 (Alcatel Lucent matter)
	2015 (Intel "project Impala")
	2020 (Xiaomi Global)
	2021 (Samsung v. E.)
	2023 (TP v. N.)
Wilmer Cutler Pickering Hale, & Dorr, LLP	2009 (Apple v. N.)
	2011 (Apple v. S.)
	2013 (Apple v. A.)
	2015 (Apple v. E.)
	2018 (Unified matter)
	2019 (Apple v. O.)
	2023 (Z. v. N.)
	2023 (Apple v. Lionra)
Fish and Richardson, LLP	2014 (Marvell v. I.)
	2018 (NEC v. X.)
	2020 (DISH v. T.)
	2020 (Huawei SEP)
	2020 (Samsung v. E.)
	2021 (LG Electronics, Dell v. N.)
	2021 (Quectel v. P.)
	2021 (Apple v. E.)
	2022 (Apple v. S.)
	2022 (LG Electronics v. C.)
	2023 (Dish v. E.)
	2023 (G Project)
	2024 (A. vs. V.H.)
	2024 (A. vs. A. B.)
	2025 (S. vs. W.)
Kaye Scholer LLP	2012 (Timer Warner+Ceres+Atlanta Broadband Finance v. K.)

Bridges and Mavrakakis, LLP	2011(Apple matter)
	2014 (Apple v. C.)
	2015 (Marvell "IP evaluation matter")
Sterne, Kessler, Goldstein & Fox, LLC	2014 (Marvell, MediaTek v. B.)
	2019 (Volkswagen v. C.)
	2020 (Apple v. S.)
Bramson, Plutzik, Mahler & Birkhaeuser	2013 (Karim v. H.)
Gibson, Dunn & Crutcher, LLP	2014 (AT&T v. I)
Desmarias	2024 (C. v. OptiMorphix)
Quinn Emanuel	2014 (Canon v. I.)
	2023 (Z. v. E.)
	2024 (ASSA v. Charter)
Norton Rose Fulbright US LLP	2015 (Qualcomm v. B.)
	2018 (Qualcomm v. A.)
	2021 (NXP v. Me.)
	2023 (NXP v MI.)
Sheppard, Mullin, Richter, and Hampton, LLP	2015 (TLC v. E.)
	2017 (ZTE v. H.)
	2018 (HTC v. I.)
	2019 (Motorola v. U.)
	2019 (U-Blox AG v. I.)
	2019 (Continental v. A.)
	2019 (Toyota matter)
	2020 (Oppo v. S.)
	2021 (HTC v. S.)
Duane Morris	2015 (Comcast, Cox, Time Warner, Verizon v. T.)
Rothwell, Figg, Ernest, & Manbeck, P.C.	2016 (LG Electronics v. O.)
Mayer Brown LLP	2016 (LG Electronics v. N.)
Sidley Austin, LLP	2016 (Huawei v. S.)
	2018 (Huawei v. O.)
Irell & Manella, LLP	2016 (Juniper v. M.)
	2021 (NXP v. M.)
Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P	2017 (LGE v. BLU)
	2017 (Sol IP)
Arnold, Porter, Kaye, and Scholer	2017 (Charter v. S.)
	2021 (Samsung v. X.)
Venable, LLP	2017 (Verizon v. S.)
Pillsbury LLP	2017 (ZTE v. H.)
Alston, Bird, LLP	2018 (ASUSTeK v. H.)
Gibson, Dunn & Crutcher, LLP	2019 (AT&T v. S.)
Allen & Overy, LLP, UK	2019 (Huawei v. Conversant.)
Erise IP	2019 (Apple v. I.) 2022 (Apple v. L.)
Xiaomi (China)	2020 (Siemens)

Munger Tolles & Olson, LLP (Tesla)	2021 (Tesla v. O.)
	2023 (G. v. U.)
Orrick, Herrington, & Sutcliffe, LLP	2021 (Canon v. W.)
Saikrishna & Associates (India)	2019 (Xiaomi v. Ericsson)
	2020 (OPPO v. NOKIA)
	2022 (OPPO v. Phillips) (OPPO v. IDC)
	2023 (OPPO v. Voiceage)
	2022 (vivo v. Nokia)
	2024 (vivo v. Phillips)
Anand & Anand (India)	2025 (SEC in India)
Dannemann Siemsen (Brazil)	2023 (OPPO v. NOKIA)
Continental	2022 (Continental v. N.)
Kelley Dryer	2022 (Keep Truckin v. F.)
Haynes Boone	2022 (Apple v. T.)
	2024 (T. v. IV)
Quinsumbing Torres (Philippines)	2022 (vivo v. N.)
Biro Oktroi Roosseno (Indonesia)	2022 (vivo v. N.)
Paul Hastings	2022 (Samsung v. G.)
Cabello Hall Zinda, PLLC	2023 (K. v. E.)
DLA Piper	2023 (D. & M. v. Ozmo)
King and Spalding	2024 (DGS v. D)
Kilpatrick Townsend & Stockton LLP	2024 (IV et al. v. Lenovo) (Iv et al. v. Zebra)
Warren Kash Warren LLP	2024 (Viasat)
Bookoff	2024 (L.v. I.V.)

Expert Testifying and Depositions (13 Trials and 18 Depositions)

Clients	**Deposition/Testifying Experience**
Bramson, Plutzik, Mahler & Birkhaeuser LLP	2013: ***Deposition*** on Case No. CV 12-05240 PJH Nad Karim v. Hewlett Packard, Co. UNITED STATES NORTHERN DISTRICT COURT OF CALIFORNIA. Settlement ordered Jan. 18, 2017.
Fish and Richardson	2015 (Feb): ***Deposition*** for Marvell. US PTAB *Inter Partes* Review IPR2014-00548 Marvell Semiconductor, Inc. v. Intellectual Ventures I LLC
	2015 (August): ***Deposition*** for Marvell. US PTAB *Inter Partes* Review IPR2014-00548 Marvell Semiconductor, Inc. v. Intellectual Ventures I LLC
Norton, Rose, Fulbright, US, LLP	2016 (April): ***Deposition*** for Qualcomm. US PTAB *Inter Partes* Review cases IPR2015-10577, IPR2015-10580, IPR2015-10581 Qualcomm Inc. v Bandspeed Inc.

Sheppard, Mullin, Richter, and Hampton, LLP	2016 (May): ***Deposition*** for in *TCL Communication Technology Holdings, LTD., et al. v. Ericsson, et al.,* Case No. 8:14-cv-341 (C. D. CA).
	2017 (Feb): **Testified at C.D. California** bench trial.
Sidley Austin, LLP	2016 (December): **Testified at** trial involving Huawei Technologies, Co. Ltd v. Samsung regarding FRAND licensing disputes in Shenzhen Court, P.R. China.
	2018 (June): ***Deposition*** for N.D. CA on IP matter concerning Huawei Technologies, Co. Ltd v. Samsung.
	2018 (December): **Testified at** trial involving Huawei Technologies, Co. Ltd v. Samsung regarding FRAND licensing disputes in Beijing Court of Intellectual Properties, P.R. China.
Mayer Brown LLP	2017 (January): **Testified during tribunal proceeding** for LG Electronics, Inc. in standard essential patent (SEP) licensing dispute of Nokia Technologies, Ltd. *v*. LG Electronics, Inc. During arbitration hearing in Paris, France.
Venable LLP	2017 (October): ***Deposition*** as expert witness for Verizon Services Corp. in Case No. 2:16-CV-588-WCB (E. D. TX) on US Patent disputes.
Pillsbury LLP	2018 (Feb): ***Deposition*** (E. D. Texas Case No. 5:16-cv-00179-RWS)
	2018 (June): **Testified at E. D. Texas** (Texarkana) jury trial (Case No. 5:16-cv-00179-RWS).
Allen & Overy LLP UK	2019 (April) **Testified at** trial involving Huawei Technologies, Co. Ltd v. Conversant regarding FRAND licensing disputes in Nanjing Intermediate Court, P.R. China.
Sidley Austin LLP, US	2019 (Sept.) **Testified at** trial involving Huawei Technologies, Co. Ltd v. PanOptics, regarding FRAND licensing disputes in Shenzhen Intermediate Court, P.R. China.
Sheppard, Mullin, Richter, and Hampton, LLP	2019 (Dec. 3rd): ***Deposition*** for HTC and Apple in *HTC Corporation, HTC America, Inc., and Apple Inc. v. INVT SPE LLC,* Case Nos. IPR2018-01555 and IPR2018-01581.
Sterne, Kessler, Goldstein & Fox, LLC	2020 (Feb.): ***Deposition*** for Volkswagen Group of America, In. v. Carucel Investments, L.P. Case Nos. IPR2019-01573 and IPR2019-01101.
Jincheng Tongda & Neal, LLP	2021 (June) **Testified at** trial involving TCL. v. Ericsoon, regarding FRAND licensing disputes in Shenzhen Intermediate Court, P.R. China.
Orrick, Herrington, & Sutcliffe, LLP	2021 (October): ***Deposition*** for Canon, Inc, in Canon, v. WSOU Investments, LLC d/b/a/ Brazos Licensing, W.D. Texas, Case No. 6:20-cv-980.
Fish & Richardson, P.C.	2021 (November) 1st ***Deposition*** for Petitioner IPR 2021-00560 in Quectel v. Koninklijke Philips N.V.
	2021 (December) 1st ***Deposition*** for Petitioner on IPR 2021-00563 Proceeding in Quectel v. Koninklijke Philips N.V.
	2022 (March 31) 2nd ***Deposition*** for Petitioner IPR 2021-00560

	in Quectel v. Koninklijke Philips N.V. (028) (-)
	2022 (April 1) 2nd ***Deposition*** for Petitioner on IPR 2021-00563 Proceeding in Quectel v. Koninklijke Philips N.V. (+)
	2022 (Oct. 28) ***Deposition*** for Petitioner on IPR 2022-00339 in Apple v. Ericsson.
	2023 (Nov. 18) ***Deposition*** for Petitioner on IPR 2023-00496 Proceeding (Apple).
Jauar Jahja and Partners (Indonesia)	2022 (April 25) **Testified** at trial involving OPPO v. Nokia regarding one patent disputes at Court in Jakarta, Indonesia. ***Successful denial of temporary injunction.*** 2022 (April 26) **Testified** at trial involving OPPO v. Nokia regarding another patent dispute at Court in Jakarta, Indonesia. ***Successful denial of temporary injunction.***
Quinsambing & Torres (Philippines)	2022 (September) **Testified** on site at trial involving vivo v. Nokia regarding patent disputes in Regional Trial Court in Manila, the Philippines. ***Successful denial of temporary injunction.***
Orrick, Herrington, & Sutcliffe, LLP	2021 (Oct. 12) ***Deposition*** Western D. of Texas cas: 6:20-cv-00980-ADA (Canon**)**
Arnold, Porter, Kaye, and Scholer	2022 (Dec. 30) ***Deposition*** for Petitioner on IPR 2022-00613 Proceeding (Samsung)
Biro Oktroi Roosseno (Indonesia)	2023 (Jan. 4) **Testified** online at trial involving vivo v. Nokia regarding patent disputes at Court in Jakarta, Indonesia. ***Successful denial of temporary injunction.*** 2023 (Feb. 1) **Testified** on site at trial involving vivo v. Nokia regarding patent disputes at Court in Jakarta, Indonesia. ***Successful denial of temporary injunction.***
Paul Hastings	2023 (June 22) ***Deposition*** for Petitioner on IPR 2022-01598 Proceeding (Samsung)
	2023 (Sept. 23) ***Deposition*** for Petitioner on IPR 2023-00171 Proceeding (Samsung)
Kirkland & Ellis LLP	2024 (May 31) ***Deposition*** for Petitioner on IPR 2023-01469 Proceeding (TP Link)

IPR Opinions 70+	**Expert Opinions (Excluding links before 2019 for brevity):**
Older IPR Cases	IPR2014-00547 IPR2014-00548 IPR2014-01562 IPR2015-00237 IPR2015-00314 IPR2015-00315 IPR2015-00316 IPR2015-00531 IPR2015-01577 IPR2015-01580 IPR2015-01581

	IPR2015-01582 IPR2016-00620 IPR2016-00623 IPR2018-00237 IPR2018-01160 IPR2018-01190 IPR2018-01555 IPR2018-01581 IPR2019-00070
Recent IPR Declarations	IPR2019-01573 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2020-01-22); Final Decision: Unpatentable (2020-11-20) IPR2019-01105 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2019-12-02); Final Decision: Unpatentable (2020-11-20) IPR2019-01101 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2019-12-02); Final Decision: Unpatentable (2020-11-20) IPR2020-00038 Expert Declaration to the Patent Trial and Appeal Board (Filed 2019-10-11); Institution Decision: (2020-04-13). IPR2021-00560 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2021-09-13); Final Decision: (2022-09-09) IPR2021-00563 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2021-09-15); Final Decision: Unpatentable (2022-9-13) IPR2021-00587 Expert Declaration to the Patent Trial and Appeal Board. Filed (2021-02-26); Withdrawn. IPR2021-00644 Expert Declaration to the Patent Trial and Appeal Board. Filed (2021-03-12); Settled. IPR2021-00683 Expert Declaration to the Patent Trial and Appeal Board. Filed (2021-03-19); Withdrawn. IPR2021-01468 Expert Declaration to the Patent Trial and Appeal Board. Filed (2021-09-01). IPR2021-01486 Expert Declaration to the Patent Trial and Appeal Board. Filed (2021-09-16).

	IPR2022-00339 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2022-08-22); Settlement (2022-12-20). IPR2022-00348 Expert Declaration to the Patent Trial and Appeal Board, Filed (2022-02-15). IPR2022-00349 Expert Declaration to the Patent Trial and Appeal Board, Filed (2022-02-15), Settled. IPR2022-00616 Expert Declaration to the Patent Trial and Appeal Board, Filed (2022-02-18), Withdrawn. IPR2022-00619 Expert Declaration to the Patent Trial and Appeal Board, Filed (2022-02-25). IPR2022-00613 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2022-10-20); Settled. IPR2022-01512 Expert Declaration to the Patent Trial and Appeal Board. Filed (2022-09-09); Instituted (2023-05-15). IPR2022-01598 Expert Declaration to the Patent Trial and Appeal Board. Filed (2022-10-04); Instituted (2023-04-04). IPR2023-00136 Expert Declaration to the Patent Trial and Appeal Board. Filed (2022-11-30); Instituted (2023-05-22). IPR2023-00151 Expert Declaration to the Patent Trial and Appeal Board; Filed (2022-11-30); Instituted (2023-06-09). IPR2023-00174 Expert Declaration to the Patent Trial and Appeal Board, Filed (2022-11-30); Instituted (2023-05-19). IPR2023-00171 Expert Declaration to the Patent Trial and Appeal Board. Filed (2022-11-08); Instituted (2023-05-31). IPR2023-00441 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-01-05); Instituted (2023-08-03). IPR2023-00496 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-01-20); Institute (2023-08-21). IPR2023-00525 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-07-10); Institute (2023-10-02).

	IPR2023-00644 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-03-07); Institute (2023-10-11). IPR2023-00645 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-03-22); Institute (2023-10-11). IPR2023-00665 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-03-22) IPR2023-00720 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-03-16). IPR2023-00721 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-03-16); Institute (2023-10-11). IPR2023-00796 IPR2023-01393 Expert Declaration to the Patent Trial and Appeal Board. Instituted (2023-11-13). IPR2023-01060 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-09-07); Instituted (2024-01-16). IPR2023-01393 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-09-07). IPR2023-01400 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-09-07); Instituted (2024-03-08). IPR2023-01403 Expert Declaration to the Patent Trial and Appeal Board; Instituted (2024-03-06). IPR2023-01429 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-09-18). IPR2023-01469 Expert Declaration to the Patent Trial and Appeal Board, Instituted (2024-04-02). Settled. IPR2024-00125 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-10-30). Settled. IPR2024-00148 Expert Declaration to the Patent Trial and Appeal Board, Filed (2023-11-10). IPR2024-00883 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-05-01). IPR2024-01224 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-08-02).

	IPR2024-01358 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-08-28). IPR2024-01362 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-08-30). Instituted (2025-03-11). IPR2024-01363 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-08-30). Instituted (2025-03-11). IPR2024-01364 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-08-30). Instituted (2025-03-11). IPR2025-00049 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-10-14). IPR2025-00194 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-11-19). IPR2025-00218 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-11-21). IPR2025-00220 Expert Declaration to the Patent Trial and Appeal Board, Filed (2024-11-25). IPR2025-00343 Expert declaration to the Patent Trial and Appeal Board, Filed (2024-12-31).

Employment History

From:	2000	**University of California at Davis**
To:	Present	Davis, CA
	Position:	*Professor* (2000-2020) and *Distinguished Professor* (2020-), *Department of Electrical and Computer Engineering*

From:	01/1999	**University of Iowa**
To:	09/2000	Iowa City, IA
	Position:	*Assoc. Professor, Department of Electrical and Computer Engineering*

From:	01/1997	**Hong Kong University of Science and Technology**
To:	12/1997	Hong Kong

Position: *Visiting Associate Professor, Department of Electrical and Electronic Engineering*

From: 09/1995 **Auburn University**
To: 12/1998 Auburn, AL
Position: *09/1995-12/1998: Associate Professor, Department of Electrical and Computer Engineering*
09/1990-08/1995: Assistant Professor, Department of Electrical and Computer Engineering

From: 08/1993 **Australian National University**
To: 09/1993 Canberra, Australia
Position: *Visiting Research Fellow, Faculty of Information Technology and Engineering*

From: 06/1993 **US Air Force Wright Laboratory**
To: 08/1993 Eglin AFB, Florida
Position: *Faculty Research Associate, Armament Directorate*

From: 06/1992 **NASA Lewis Research Center**
To: 08/1992 Cleveland, OH
Position: *Visiting Faculty Research Fellow*

From: 08/1987 **Cornell University**
To: 08/1990 Ithaca, NY
Position: *Research Assistant*

From: 09/1984 **University of Toroto**
To: 08/1987 Toronto, Ontario, Canada
Position: *Research Assistant*

Technical Consulting

Consulted for multiple major technology companies, aside from IP litigation related matters.

Patents (Granted and/or Licensed)

Patent Number	Date Issued	Title

US 6,396,885	Mar.28, 2002	Co-channel interference reduction in wireless communications systems
US 6,463,099	Oct.8, 2002	Blind channel equalizers and methods of blind channel equalization (Licensed)
US 7,379,513	Mar. 20, 2008	Channel estimation in CDMA communications systems using both lower power pilot channel and higher power date channel
US 9,554,388	Jan. 24, 2017	Method and apparatus of resource sharing for device-to-device and cellular communications
US 10,623,230	Apr. 14, 2020	Trans-layer robust header-compression technique
US 11,019,530	May 25, 2021	Trans-layer bidirectional robust header compression system
US 11,368,940	June 21, 2022	Systems and Methods for Data transmission over Wi-Fi and LTE-U coexistence framework

Education

1990	Cornell University, Ithaca, NY	Ph.D., Electrical Engineering
1987	University of Toronto, Toronto, Canada	MS, Electrical Engineering
1982	Nanjing Institute of Technology, Nanjing, China	BS, Wireless Engineering

Publications

Books & Book Chapters

[1] B. P. Lathi and Z. Ding, *Modern Digital and Analog Communication Systems,* 5th edition, Oxford University Press, 2018.

[2] Zhi Ding and Ye Li, *Blind Equalization and Identification*, Marcel Dekker, New York, 2001.

[3] Z. Ding, "Chapter 7: Linear Predictive Algorithms for Blind Multichannel Identification," in *Signal Processing Advances in Wireless and Mobile Communications*, Vol. I: Trends in Channel Estimation and Equalization, G. B. Giannakis, Y. Hua, P. Stoica, and L. Tong (Editors), Prentice Hall, 2000.

[4] Z. Ding, "Blind Channel Identification and Equalization using Spectral Correlation Measurements: Frequency Domain Analysis," in *Cyclostationarity in Communications and Signal Processing*, William A. Gardner, Ed., pp.417-436, IEEE Press, 1993.

[5] Z. Ding, C. R. Johnson, Jr., and R. A. Kennedy, "Chapter 3: Global Convergence Issues with Linear Blind Adaptive Equalizers," in *Blind Deconvolution*, Simon Haykin, Ed., pp.60-120, Prentice-Hall, 1994.

[6] Z. Ding, "Adaptive Filters for Blind Equalization," in *IEEE DSP Handbook*, Douglas B. Williams, Ed., pp.24.1-24.17, IEEE Press, 1998.

Journal Papers

[1] K. Wang, Z. Ding, D. K. C. So and Z. Ding, ``Exploring Age-of-Information Weighting in Federated Learning under Data Heterogeneity'', in IEEE Transactions on Wireless Communications, doi: 10.1109/TWC.2025.3545456, 2025.

[2] Zhang, Songyang, Brian Choi, Feng Ouyang, and Zhi Ding, ``Physics-inspired machine learning for radiomap estimation: Integration of radio propagation models and artificial intelligence. IEEE Communications Magazine, 62, no. 8, pp. 155-161, 2024. doi: 10.1109/MCOM.001.2300782.

[3] Wang, Kaidi, Yi Ma, Mahdi Boloursaz Mashhadi, Chuan Heng Foh, Rahim Tafazolli, and Zhi Ding, ``Convergence Acceleration in Wireless Federated Learning: A Stackelberg Game Approach." IEEE Transactions on Vehicular Technology, 2024. doi: 10.1109/TVT.2024.3452933

[4] Q. Deng, Y. Zhang, M. Li, S. Zhang and Z. Ding, ``Efficient Eigen-Decomposition for Low-Rank Symmetric Matrices in Graph Signal Processing: An Incremental Approach," IEEE Transactions on Signal Processing, 2024 doi: 10.1109/TSP.2024.3438676.

[5] Q. Deng, S. Zhang and Z. Ding, ``Body Motion Segmentation via Multilayer Graph Processing for Wearable Sensor Signals," IEEE Open Journal of Signal Processing, Volume 5, pp. 934-947, 2024 doi: 10.1109/OJSP.2024.3407662.

[6] S. Jing, S. Zhang and Z. Ding, ``Reinforcement Learning for Robust Header Compression (ROHC) Under Model Uncertainty," IEEE Transactions on Machine Learning in Communications and Networking, vol. 2, pp. 1033-1044, 2024, doi: 10.1109/TMLCN.2024.3409200.

[7] A. Wijesinghe, S. Zhang and Z. Ding, ``PS-FedGAN: An Efficient Federated Learning Framework With Strong Data Privacy," IEEE Internet of Things Journal, vol. 11, no. 16, pp. 27584-27596, 15 Aug.15, 2024, doi: 10.1109/JIOT.2024.3399226.

[8] Z. Liu, L. Wang, L. Xu and Z. Ding, ``Deep Learning for Efficient CSI Feedback in Massive MIMO: Adapting to New Environments and Small Datasets," IEEE Transactions on Wireless Communications, 2024. doi: 10.1109/TWC.2024.3390583.

[9] C. -H. Hsu and Z. Ding, ``Unsupervised Learning for Resource Allocation and User Scheduling in Wideband MU-MIMO Systems," IEEE Open Journal of the Communications Society, vol. 5, pp. 2240-2256, 2024, doi: 10.1109/OJCOMS.2024.3384110.

[10] S. Zhang, T. Yu, B. Choi, F. Ouyang and Z. Ding, ``Radiomap Inpainting for Restricted Areas based on Propagation Priority and Depth Map," *IEEE Transactions on Wireless Communications,* 23(8): 9330-9344, August 2024. doi: 10.1109/TWC.2024.3360872.

[11] K. Wang, Z. Ding, D. K. C. So and Z. Ding, ``Age-of-Information Minimization in Federated Learning based Networks with Non-IID Dataset," *IEEE Transactions on Wireless Communications,* 23(8): 8939-8953, August 2024. doi: 10.1109/TWC.2024.3357208.

[12] C. Feres, B. C. Levy and Z. Ding, ``Over-the-Air Multisensor Collaboration for Resource Efficient Joint Detection," *IEEE Transactions on Signal Processing,* vol. 72, pp. 384-399, 2024, doi: 10.1109/TSP.2023.3310895.

[13] Y. -C. Lin, T. -S. Lee and Z. Ding, ``A Scalable Deep Learning Framework for Dynamic CSI Feedback With Variable Antenna Port Numbers," *IEEE Transactions on Wireless Communications,* vol. 23, no. 4, pp. 3102-3116, April 2024, doi: 10.1109/TWC.2023.3305546.

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[15] Y. -C. Lin, T. -S. Lee and Z. Ding, ``Exploiting Partial FDD Reciprocity for Beam Based Pilot Precoding and CSI Feedback in Deep Learning," IEEE Transactions on Wireless Communications, doi: 10.1109/TWC.2023.3289929.

[16] S. Zhang, Q. Deng and Z. Ding, ``Signal Processing Over Multilayer Graphs: Theoretical Foundations and Practical Applications," IEEE Internet of Things Journal, vol. 11, no. 2, pp. 2453-2471, 15 Jan.15, 2024, doi: 10.1109/JIOT.2023.3294470.

[17] W. Cao, X. Ling, J. Wang, Z. Ding and X. Gao, ``A Framework for QoS-Guaranteed Fast Access Services in Blockchain Radio Access Network," IEEE Transactions on Wireless Communications, vol. 23, no. 4, pp. 2711-2725, April 2024, doi: 10.1109/TWC.2023.3302415

[18] Q. Deng, Y. Ge and Z. Ding, ``Jamming Suppression via Resource Hopping in High-Mobility OTFS-SCMA Systems," IEEE Wireless Communications Letters, vol. 12, no. 12, pp. 2138-2142, Dec. 2023, doi: 10.1109/LWC.2023.3309787.

[19] X. Liang, W. Fang, J. Wang, Z. Ding, X. Gao and C. Zhao, ``Robust Transceiver Design for RIS-Aided Spatially Correlated MIMO Channels With Uncertainty," IEEE Wireless Communications Letters, vol. 12, no. 12, pp. 2013-2017, Dec. 2023, doi: 10.1109/LWC.2023.3304335.

[20] Qi S, He M, Hoang R, Zhou Y, Namadi P, Tom B, Sandhu P, Bai Z, Chung F, Ding Z, Anderson J. ``Salinity Modeling Using Deep Learning with Data Augmentation and Transfer Learning" .*Water,* 15(13):2482, 6 July, 2023.

[21] S. Zhang, A. Wijesinghe and Z. Ding, ``RME-GAN: A Learning Framework for Radio Map Estimation based on Conditional Generative Adversarial Network" *IEEE Internet of Things Journal* 2023. doi:10.1109/JIOT.2023.3278235.

[22] Y. Ge, Q. Deng, D. Gonzalez G., Y. L. Guan and Z. Ding, ``OTFS Signaling for SCMA With Coordinated Multi-Point Vehicle Communications," *IEEE Transactions on Vehicular Technology*, doi: 10.1109/TVT.2023.3248119.

[23] H. Ma, X. Yuan, Z. Ding, D. Fan and J. Fang, "Over-the-Air Federated Multi-Task Learning via Model Sparsification, Random Compression, and Turbo Compressed Sensing," *IEEE Transactions on Wireless Communications,* doi: 10.1109/TWC.2022.3231088.

[24] Siyu Qi, Minxue He, Zhaojun Bai, Zhi Ding, Prabhjot Sandhu, Francis Chung, Peyman Namadi, Yu Zhou, Raymond Hoang, Bradley Tom, Jamie Anderson, and Dong Min Roh, "Novel Salinity Modeling Using Deep Learning for the Sacramento-San Joaquin Delta of California" in *Water* , 2022, 14(22), 3628; https://doi.org/10.3390/w14223628

[25] M. Del Rosario and Z. Ding, ``Learning-Based MIMO Channel Estimation under Practical Pilot Sparsity and Feedback Compression," in IEEE Transactions on Wireless Communications, 2022, doi: 10.1109/TWC.2022.3202750.

[26] C. Sun, X. Gao and Z. Ding, ``Optimization of Workload Balancing and Power Allocation for Wireless Distributed Computing," in IEEE Transactions on Wireless Communications, vol. 21, no. 9, pp. 7682-7695, Sept. 2022, doi: 10.1109/TWC.2022.3160493.

[27] C. -H. Hsu, C. Feres and Z. Ding, ``Wirtinger Flow for Nonconvex Blind Demixing with Optimal Step Size," in IEEE Wireless Communications Letters, 2022, doi: 10.1109/LWC.2022.3203313.

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[29] C. Feres and Z. Ding, ``An Unsupervised Learning Paradigm for User Scheduling in Large Scale Multi-Antenna Systems," in IEEE Transactions on Wireless Communications, 2022, doi: 10.1109/TWC.2022.3215471.

[30] L. D. Chamain, S. Qi, and Z. Ding, ``End-to-End Image Classification and COmpression with variational autoencoder" IEEE Internet of Things Journal, vol. 70, 2022, doi: 10.1109/JIOT.2022.3182313.

[31] C. Feres and Z. Ding, ``A Riemannian Geometric Approach to Blind Signal Recovery for Grant-Free Radio Network Access," IEEE Transactions on Signal Processing, vol. 70, pp. 1734-1748, 2022, doi: 10.1109/TSP.2022.3159988.

[32] Q. Deng, S. Zhang and Z. Ding, ``An Efficient Hypergraph Approach to Robust Point Cloud Resampling," IEEE Transactions on Image Processing, vol. 31, pp. 1924-1937, 2022, doi: 10.1109/TIP.2022.3149225.

[33] X. Ling, B. Zhang, H. Xie, J. Wang, Z. Ding, Hash Access in Blockchain Radio Access Networks: Characterization and Optimization IEEE Internet of Things Journal, 9(11): 8053-8066, 1 June 2022 doi: 10.1109/JIOT.2021.3111915.

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Professional Services and Achievements

- Chief Information Officer, IEEE Communications Society, 2018-2022
- Chief Marketing Officer, IEEE Communications Society, 2020-2022, 2024-Present
- Parliamentarian, IEEE Communications Society, 2022-2024
- Steering Committee Chairman, *IEEE Transactions on Wireless Communications,* 1.2008-1-2010
- Canadian National Science and Engineering Research Council Panelist, 2009-2012
- Fellow of IEEE
- Steering Committee Member, *IEEE Transactions on Wireless Communications,* 1.2006-1-2008
- General Chair, IEEE 2016 International Conference on Acoustics, Speech, and Signal Processing, Shanghai, China.
- Technical Program Chair, *IEEE 2006 Globecom*, San Francisco, CA.
- Editorial Board Member, *IEEE Signal Processing Magazine*, 1/2003-1/2007.
- Associate Editor, *IEEE Signal Processing Letters*, 1.2002-1.2005.
- Associate Editor, IEEE Transactions on Signal Processing, 1.2001-1.2004.
- Editor, Special Issue on Multiuser Detection and Blind Estimation, *EURASIP Journal on Applied Signal Processing*, Dec. 2002.
- Member, IEEE Statistical Signal and Array Processing Technical Committee, 1993-1998.
- Member, IEEE Signal Processing for Communications Technical Committee, 1998-2004.
- Associate Editor, IEEE Transactions on Signal Processing, 1994-1997.
- Technical Program Committee Member, 3rd IEEE Workshop on Signal Processing Advances in Wireless Communications, Taiwan, March 2001.
- Organization Committee Member, 1st IEEE Workshop on Signal Processing Advances in Wireless Communications, Paris, France, April 1997.
- Review Panelist, National Science Foundation, 1997, 2003, 2004, 2005, 2007, 2008, 2010, 2014, 2015, 2016.