

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

APPLE INC.
Petitioner

v.

LIONRA TECHNOLOGIES LTD
Patent Owner

Case No. IPR2023-00796
U.S. Patent No. 7,260,141

**DECLARATION OF ZHI DING, PH.D. IN SUPPORT OF *INTER*
PARTES REVIEW OF U.S. PATENT NO. 7,260,141**

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I, Zhi Ding, Ph.D., declare as follows:

I. INTRODUCTION

1. My name is Zhi Ding. I have been retained as a technical expert on behalf of Petitioner Apple Inc. (“Apple” or “Petitioner”) to provide my opinions regarding the validity of certain claims of U.S. Patent No. 7,260,141 (Ex. 1001, the “’141 Patent”) in view of prior art, anticipation, and obviousness considerations, and understanding of a person of ordinary skill in the art at the time of the alleged invention (“POSITA”) as it relates to the ’141 Patent. I submit this declaration based on my personal knowledge and experience, as well as the materials I reviewed and considered in formulating my opinions. I am over the age of 21 and am competent to make this declaration. I have personal knowledge of the facts and opinions set forth in this declaration and believe them to be true. If called upon to do so, I would testify competently thereto.

2. I am not currently, and never have been, an employee of Apple. I received no compensation for preparing this declaration beyond my normal hourly compensation rate based on my time actually spent in analyzing the issues and preparing this declaration. I will not receive any added compensation based on my opinions or the outcome of this proceeding. I have no financial interest in or affiliation with the Petitioner or the Patent Owner, which I understand is Lionra Technologies Ltd.

II. BACKGROUND AND QUALIFICATIONS

3. I presently hold the title of Distinguished Professor in the Department of Electrical and Computer Engineering at the University of California, Davis. Since my first UC Davis appointment on July 1, 2000, I have held the position of professor for over 20 years and have served as a faculty member at several US universities for over 30 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 to data communications and signal processing.

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

5. My responsibilities as a Professor at the 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.

6. Since 1990, I have been selected as the principal investigator of multiple highly competitive federal and local research grants, including more than a dozen 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.

7. I have published over 210 peer-reviewed research articles in premier international journals, in addition to over 240 refereed technical articles at top international conferences on communications and information technologies. According to Google Scholar, my published works have been cited over 13,000 times by peers. 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,” 5th edition, and was published by the Oxford University Press in 2018. The 4th edition of this book (published in 2009) had been widely adopted as an introductory textbook to communication systems.

8. In addition to over 450 published technical papers that have been cited over 13,000 times according to Google Scholar, I am also co-inventor of 4 issued U.S. Patents on communication technologies.

9. 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 communications. 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 Fellow is conferred by the Board 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.

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

- Chief Information Officer at the IEEE Communications Society from Jan. 2018 to present.
- Chief Marketing Officer at the IEEE Communications Society from Jan. 2020 to present.

- General Chair of the 2016 IEEE International Conferences on Acoustics, Speech, and Signal Processing, the flagship 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 of 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.

11. In 2012, I received the Wireless Communications Technical Committee Recognition Award from the IEEE Communications Society, a prestigious award given to a person with a high degree of visibility and contribution to 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.”

12. 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 on 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.

13. 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, Wi-Fi, Bluetooth, and optical communication networks.

14. Further experience and a complete list of my publications are presented in my Curriculum Vitae, which is attached as Ex. 1010.

15. Based on my experience of over 3 decades in communications technologies as described above, the acceptance of my publications and professional recognition by societies in my field, I believe that I am qualified to be an expert witness in wireless communication systems, communications networks, and signal processing.

16. Based on my experiences described above, and as indicated in my Curriculum Vitae, I am qualified to provide the following opinions with respect to the patents in this case. Additionally, I was at least a person having ordinary skill in the art as of the Critical Date (which I discuss below) of the '141 Patent.

III. METHODOLOGY; MATERIALS CONSIDERED

17. I have relied upon my education, knowledge, and experience in wireless communication systems, communication networks, and signal processing, as well as other materials discussed in this declaration in forming my opinions.

18. For this work, I have been asked to review the '141 Patent including the specification and claims, and the '141 Patent's prosecution history (file history). In developing my opinions relating to the '141 Patent, I have considered the materials cited or discussed herein, including those itemized in the Exhibit Table below.

Exhibit 1001	U.S. Patent No. 7,260,141 (“the ’141 Patent”)
Exhibit 1002	File History for U.S. Patent No. 7,260,141
Exhibit 1004	U.S. Patent Publication No. 2002/0042290 to Williams et al. (“ <i>Williams</i> ”)
Exhibit 1005	U.S. Provisional Application No. 60/239,859 (the “ <i>Williams-Provisional</i> ”)
Exhibit 1006	U.S. Patent No. 5,604,768 to Fulton (“ <i>Fulton</i> ”)
Exhibit 1007	U.S. Patent No. 6,836,673 to Trott (“ <i>Trott</i> ”)
Exhibit 1008	Mark C. Roh, “A Base Station Smart Antenna System for CDMA Cellular,” Massachusetts Institute of Technology, 1997
Exhibit 1009	3G TS 25.213 version 3.2.0 Release 1999 18 ETSI TS 125 213 V3.2.0 (2000-03)
Exhibit 1011	U.S. Patent No. 3,340,531 to Kefalas et al.
Exhibit 1012	U.S. Patent No. 3,500,422 to Cheston et al.
Exhibit 1013	Modern Dictionary of Elec. 7 th (excerpt)
Exhibit 1014	Newton’s Telecom Dictionary 16 (excerpt)
Exhibit 1015	U.S. Patent No. 6,795,424 to Kapoor et al.
Exhibit 1016	U.S. Patent No. 6,240,072 to Lo et al.
Exhibit 1017	U.S. Patent No. 6,052,085 to Hanson et al.
Exhibit 1018	Analysis of new and existing methods...IEEE
Exhibit 1019	Robust Frequency and Timing Synchronization for OFDM
Exhibit 1020	U.S. Patent No. 5,499,268 to Takahashi
Exhibit 1021	U.S. Patent No. 5,206,886 to Bingham
Exhibit 1022	Selecting Mixed Signal Components for Digital Communication Systems
Exhibit 1023	U.S. Patent No. 6,130,602 to O’Toole et al.
Exhibit 1024	U.S. Patent No. 7,039,372 to Sorrells et al.
Exhibit 1025	U.S. Patent No. 6,404,247 to Wang
Exhibit 1026	Understanding Offset 8-PSK Modulation for GSM EDGE
Exhibit 1027	Understanding and Enhancing Sensitivity in Receivers for Wireless Applications
Exhibit 1028	Characteristics of Digital Fixed Wireless Systems Below About 17 GHz
Exhibit 1029	A Complex Multiplier with Low Logic Depth
Exhibit 1030	The Roles of FPGAs in Reprogrammable Systems
Exhibit 1031	Cramming More Components onto Integrated Circuits

19. I have considered these materials from the viewpoint of a person of ordinary skill in the art at the time of the alleged invention (“POSITA”) as of the priority date of the ’141 Patent. For the purposes of this declaration, I have been asked to assume that the priority date of the ’141 Patent is February 28, 2001. I note that my opinions provided in this Declaration are made from the perspective of a POSITA as of the priority date of the ’141 Patent, unless expressly stated otherwise.

20. I may rely upon these materials, my knowledge and experience, and/or additional materials to rebut arguments raised by the Patent Owner. Further, I may also consider additional documents and information in forming any necessary opinions, including documents that may not yet have been provided to me.

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

IV. OVERVIEW AND LEGAL STANDARDS

22. In formulating my opinions, I have been instructed to apply certain legal standards. I am not a lawyer. I do not expect to offer any testimony regarding what the law is. Instead, the following sections summarize the law as I have been instructed to apply it in formulating and rendering my opinions found later in this

declaration. I understand that, in an *inter partes* review proceeding, patent claims may be deemed unpatentable if it is shown that they were anticipated or rendered obvious in view of the prior art. I understand that prior art in an *inter partes* review is limited to patents or printed publications that predate the priority date of the patent at issue. I understand that questions of claim clarity (definiteness) and enablement cannot be considered as a ground for considering the patentability of a claim in these proceedings.

A. Person of Ordinary Skill in the Art

23. I understand that the '141 Patent, the record of proceedings at the Patent Office (which I understand is called the "File History" or "Prosecution History"), and the teachings of the prior art are evaluated from the perspective of a person of ordinary skill in the art ("POSITA"). I understand that the factors considered in determining the ordinary level of skill in the art include: (i) the levels of education and experience of persons working in the field; (ii) the types of problems encountered in the field; and (iii) the sophistication of the technology. I may also consider, if available, the education level of the inventor, prior art solutions to the problems encountered in the art, and/or the rapidity with which innovations are made in the relevant art.

24. I understand that a person of ordinary skill in the art is not a specific real individual, but rather a hypothetical individual having the qualities reflected by

the factors above. This hypothetical person has knowledge of all prior art in the relevant field as if it were arranged on a workshop wall and takes from each reference what it would teach to a person having the skills of a POSITA.

B. Obviousness

25. I understand that a claim may be invalid under § 103(a) if the subject matter described by the claim as a whole would have been “obvious” to a hypothetical POSITA in view of a single prior art reference or in view of a combination of references at the time the claimed invention was made. Therefore, I understand that obviousness is determined from the perspective of a hypothetical POSITA. I further understand that a hypothetical POSITA is assumed to know and to have all relevant prior art in the field of endeavor covered by the patent in suit and all analogous prior art. I understand that obviousness in an *inter partes* review proceeding is evaluated using a preponderance of the evidence standard, which means that the claims must be more likely obvious than nonobvious.

26. I also understand that an analysis of whether a claimed invention would have been obvious should be considered in light of the scope and content of the prior art, the differences (if any) between the prior art and the claimed invention, and the level of ordinary skill in the pertinent art involved. I understand as well that a prior art reference should be viewed as a whole. I understand that in considering whether an invention for a claimed combination would have been obvious, I may assess

whether there are apparent reasons to combine known elements in the prior art in the manner claimed in view of interrelated teachings of multiple prior art references, the effects of demands known to the design community or present in the marketplace, and/or the background knowledge possessed by a POSITA. I also understand that other principles may be relied on in evaluating whether a claimed invention would have been obvious, and that these principles include the following:

- A combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results;
- When a device or technology is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or in a different one, so that if a POSITA can implement a predictable variation, the variation is likely obvious;
- If a technique has been used to improve one device, and a POSITA 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;
- An explicit or implicit teaching, suggestion, or motivation to combine two prior art references to form the claimed combination may demonstrate obviousness, but proof of obviousness does not depend on or require showing a teaching, suggestion, or motivation to combine;
- Market demand, rather than scientific literature, can drive design trends and may show obviousness;
- In determining whether the subject matter of a patent claim would have been obvious, neither the particular motivation nor the avowed purpose of the named inventor controls;
- One of the ways in which a patent's subject can be proved obvious is by noting that there existed at the time of invention a known problem for which there was an obvious solution encompassed by the patent's claims;

- 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;
- “Common sense” teaches that familiar items may have obvious uses beyond their primary purposes, and in many cases a POSITA will be able to fit the teachings of multiple patents together like pieces of a puzzle;
- A POSITA is also a person of ordinary creativity, and is not an automaton;
- A patent claim can be proved obvious by showing that the claimed combination of elements was “obvious to try,” particularly when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions such that a POSITA would have had good reason to pursue the known options within his or her technical grasp; and
- One should not use hindsight in evaluating whether a claimed invention would have been obvious.

27. I also understand that an obviousness determination includes the consideration of various factors such as: (1) the scope and content of the prior art; (2) the differences between the prior art and the asserted claims; (3) the level of ordinary skill in the pertinent art; and (4) the existence of secondary considerations such as commercial success, long-felt but unresolved needs, failure of others, and so forth.

28. I am informed that it is improper to combine references where the references teach away from their combination. I am informed that a reference may be said to teach away when a person of ordinary skill in the relevant art, upon reading

the reference, would be discouraged from following the path set out in the reference, or would be led in a direction divergent from the path that was taken by the patent applicant. In general, a reference will teach away if it suggests that the line of development flowing from the reference's disclosure is unlikely to be productive of the result sought by the patentee. I am informed that a reference teaches away, for example, if (1) the combination would produce a seemingly inoperative device, or (2) the references leave the impression that the product would not have the property sought by the patentee. I also am informed, however, that a reference does not teach away if it merely expresses a general preference for an alternative invention but does not criticize, discredit, or otherwise discourage investigation into the invention claimed.

29. I am informed that even if a *prima facie* case of obviousness is established, the final determination of obviousness must also consider "secondary considerations" if presented. In most instances, the patentee raises these secondary considerations of non-obviousness. In that context, the patentee argues an invention would not have been obvious in view of these considerations, which include: (a) commercial success of a product due to the merits of the claimed invention; (b) a long-felt, but unsatisfied need for the invention; (c) failure of others to find the solution provided by the claimed invention; (d) deliberate copying of the invention by others; (e) unexpected results achieved by the invention; (f) praise of the

invention by others skilled in the art; (g) lack of independent simultaneous invention within a comparatively short space of time; (h) teaching away from the invention in the prior art.

30. I am further informed that secondary considerations evidence is only relevant if the offering party establishes a connection, or nexus, between the evidence and the claimed invention. The nexus cannot be based on prior art features. The establishment of a nexus is a question of fact. While I understand that the Patent Owner here has not offered any secondary considerations at this time, I will supplement my opinions in the event that the Patent Owner raises secondary considerations during the course of this proceeding.

31. Finally, I understand that obviousness in an IPR must be proven by a preponderance of the evidence.

C. Analogous Art

32. I have been informed that for a prior art reference to be proper for use in an obviousness analysis, the reference must be “analogous art” to the claimed invention. I have been informed that a reference is analogous art to the claimed invention if: (1) the reference is from the same field of endeavor as the claimed invention (even if it addresses a different problem); or (2) the reference is reasonably pertinent to the problem faced by the inventor (even if it is not in the same field of endeavor as the claimed invention). For a reference to be “reasonably pertinent” to

the problem, it must logically have commended itself to an inventor's attention in considering his problem. In determining whether a reference is reasonably pertinent, one should consider the problem faced by the inventor, as reflected either explicitly or implicitly, in the specification. I believe that all the references upon which my opinions in this IPR are based are well within the range of references a person having ordinary skill in the art would consult to address the type of problems described in the Challenged Claims.

D. Claim Construction

33. I understand that the claims in this IPR will be construed according to their ordinary and customary meaning as understood in light of the claim language, the patent's description, and the prosecution history viewed from the perspective of a POSITA. I further understand that where a patent defines claim language, the definition in the patent controls, even if there are other definitions that might be understood by those working in the art.

34. I understand that in the parallel litigation, Patent Owner contends that no claim language requires express construction. For purposes of my analysis, I have been instructed to apply the ordinary and customary meaning of the terms as I understand them in light of the claim language as a whole, the patent's description, and the prosecution history as viewed from the perspective of a POSITA.

V. LEVEL OF ORDINARY SKILL IN THE ART

35. Taking these factors into consideration, based on my review and analysis of the '141 Patent, the prior art cited herein, and the ordinary skill factors described above in Section IV.A, a POSITA in the field of the '141 Patent at the time of the earliest possible priority date (February 28, 2001) would have had a bachelor's degree in electrical engineering or an equivalent from an accredited university program with at least two years of work experience in the field of wireless communications. A person with less relevant practical experience but with additional education can also qualify as a POSITA in the field of the '141 Patent provided the additional education focused on wireless communication systems. When I refer to the understanding of a POSITA, I am referring to the understanding of such a person as of February 28, 2001.

36. As of February 28, 2001, I had more than ordinary skill in the art. I am, however, familiar with the skills and knowledge possessed by those I would have considered to be of ordinary skill in the art as of that date. For example, I knew people working in the field through my involvement with IEEE. And I supervised graduate students, including Master's students and Ph.D. candidates who would have qualified as POSITAs at the time, during my time at Auburn University, the University of Iowa, and UC Davis. I am qualified to provide opinions concerning what one of ordinary skill would have known and understood at that time, and my

analysis and conclusions herein are from the perspective of one of ordinary skill as of that date.

37. My opinions in this declaration would not change in view of minor modifications to this level of ordinary skill.

VI. OVERVIEW OF THE TECHNOLOGY

38. I was asked to briefly summarize the background of the technology from the standpoint of a POSITA prior to February 28, 2001.

A. Phased Array Antennas and Adaptive Antenna Arrays

39. Before the priority date of the '141 Patent, phased array antennas were well known and widely used across the world for applications ranging from wireless communication to radar technology. For example, U.S. Patent No. 3,340,531 to Kefalas et al. is titled "Satellite Communication System" and discloses a satellite communication system wherein the ground terminals utilize linear phased array antennas to communicate with a satellite. (Ex. 1011). And U.S. Patent No. 3,500,422 to Cheston et al. is titled "Sub-Array Horn Assembly for Phased Array Application" and describes a sub-array assembly for use in phased array radar antennas. (Ex. 1012).

40. In general, phased array antennas are a type of radio antenna in which a group of radiating elements is geometrically arranged to form an array. (Ex. 1013 (Modern Dictionary of Elec. 7th)), 551. The individual antenna elements are

interconnected such that a specific, known phase relationship exists among the antenna elements. *Id.* Phased array antennas can form a beam (or beams) for transmission by superposition of the radiation from all the individual elements and can adjust or steer the beam direction by varying the relative phase of the signal applied to each element, or by varying the frequency of the main oscillator. *Id.* In the receive direction, phased array antennas can likewise form a narrow beam pattern for reception by phase shifting the incoming signals from the individual elements using the known phase relationship from the spatial arrangement of the elements and can determine directions of radio signal arrivals. *See id.*

41. Adaptive antenna arrays (or “adaptive arrays”) are a specific implementation of phased array antennas. An adaptive antenna array is an array in which the received signal is continually monitored with respect to interference. (Ex. 1014 (Newton Telecom 16)), 4. Adaptive arrays electronically steer a phased array by weighting both the amplitude and the phase of a signal at each element in response to changes in the propagation environment. (Ex. 1015 (Kapoor ’424)), 3:47–51. The adaptive array’s directional characteristics may be automatically adjusted to null out measured interference, usually through employing computer control. (Ex. 1014 (Newton Telecom 16)), 4. As such, adaptive arrays can provide greater steering flexibility in response to changes in the signal propagation environment. (Ex. 1015 (Kapoor ’424)), 3:51–52.

B. Beamforming

42. This steering of the antenna radiation pattern is known as beamforming. (Ex. 1016 (Lo '072)) 1:18–20. The objective of beamforming is to preferentially receive or transmit a signal from/to a particular direction in space. *Id.* at 1:20–23. In reception, when a phased array antenna is illuminated by a radiation source, samples of the incoming wavefront are recorded at the location of each antenna element. *Id.* at 1:38–40. By appropriately processing the signals from each antenna element (e.g., through phase and/or amplitude adjustments), the applied phasing will arrange for the output of all elements to add coherently in a given direction, while rejecting interferences from other directions. *Id.* at 1:41–51. In transmission, by controlling the phase and amplitude of the signals sent to each antenna element, the beam direction (and other characteristics, such as sidelobes, shape, and Effective Isotropic Radiation Power (EIRP)) can be similarly controlled. *Id.* 3:3–7. With the proper associated processing or beamforming network, multiple beams of offset angles can be formed simultaneously for either transmission and/or reception. *Id.* at 1:61–62, 3:1–2.

C. Baseband and Digital Beamforming

43. Signals incoming and outgoing from an antenna array are at radio frequencies (RF, also referred to as “carrier frequency”). *Id.* at 2:11–12; *see also* (Ex. 1017 (Hanson)), 1:30–31. From the radio frequency, signals may be down-

converted to an intermediate frequency. *Id.* at 3:46–52. Early systems performed beamforming at the carrier frequency or an intermediate frequency. *Id.* at 1:30–31.

44. However, baseband processing and beamforming were well known in the art at the time of the alleged invention of the '141 Patent. For example, *Hanson* teaches a system which beamforms at baseband, forming only those beams which convey information between a base station and mobile. *Id.* at Abstract, 2:19–23. Beamforming at baseband can lead to reduced circuit complexity as compared to systems which beamform at the carrier frequency (RF) or at an intermediate frequency (IF). *Id.*, 7:56–62. Similarly, it can provide greater control over the formation and direction of the formed beams. *See id.*, 7:47–51.

45. Beamforming was also initially performed in the analog domain. *See* (Ex. 1016 (Lo '072)), 1:17, 1:54–60, 2:21–23. However, prior to the time of the alleged invention of the '141 Patent, digital beamforming was also well known. Digital beamforming leverages a combination of both antenna technology and digital processing technology. *Id.*, 2:5–6. In digital beamforming systems, the signals are digitized at the antenna element level. *Id.*, 2:10–12. These signals are converted into two streams of binary baseband signals known as the in-phase (I) and quadrature-phase (Q) channels or components. *Id.*, 2:11–15. Included within these digital signals are the amplitudes and phases of the individual signals for each element of the antenna array. *Id.*, 2:16–18. Digital beamforming is then accomplished by

weighting the individual digital signals, thereby adjusting their amplitudes and phases such that when the signals are superimposed based on amplitude and phase weighting together, they form the desired beam. *Id.*, 2:18–21.

D. Carrier Frequency Offset (CFO)

46. Carrier frequency offset is a frequency error in a received signal caused by frequency differences between transmitter and receiver local oscillators. (Ex. 1018 (Analysis of new and existing methods...IEEE)), 1. Carrier frequency offset causes a rotation of each of the subcarriers and intercarrier interference between subcarriers. *Id.* Carrier frequency offset imparts a phase difference between the phase of the receiver local oscillator and that of the transmitter carrier frequency at the start of a received symbol. *Id.* at 2. The amount of phase rotation depends on the offset between the transmitter and receiver local oscillators. *Id.* Specifically, a carrier frequency offset of Δf causes a phase rotation of $2\pi t\Delta f$. (Ex. 1019 (Robust Frequency and Timing Synchronization for OFDM)), 2.

47. Carrier frequency offset (and correcting for the same) was well-known in the art at the time of the alleged invention of the '141 Patent. For example, U.S. Patent No. 5,499,268 to Takahashi is titled “Adaptive Equalizer Capable of Compensating for Carrier Frequency Offset” and discloses an equalizer which compensates for carrier frequency offset. (Ex. 1020). And U.S. Patent No. 5,206,886 to Bingham is titled “Method and Apparatus for Correcting for Clock and Carrier

Frequency Offset, and Phase Jitter in Multicarrier Modems” and similarly discloses a method for tracking and correcting for impairments from carrier frequency offset between a transmitter and receiver. (Ex. 1021).

E. Symbol-Based Communication

48. Symbol-based communications were well established and understood in the art at the time of the '141 Patent's alleged invention. A symbol in a digital communication system represents the smallest unit of data the communication system can transmit. In other words, A symbol is merely a way to represent data in a transmission. In the simplest case, a symbol may represent a single bit. (Ex. 1022 (Selecting Mixed Signal Components for Digital Communication Systems)), 11. Specifically, in such cases, each symbol value would represent a single bit value (“0” or “1”) to be communicated between a transmitter and receiver. *Id.* One basic type of symbol-based communication scheme is called “pulse-code modulation.” *Id.* In such a scheme, the bit value is encoded in the amplitude of the signal. *Id.*

49. Symbol-based communication was well-known in the art at the time of the '141 Patent's alleged invention. For example, U.S. Patent No. 6,130,602 to O'Toole et al. references “amplitude shift keying,” which employs an “On Off” keying scheme to represent symbols wherein a digital “1” is represented by the presence of the RF carrier signal, and a digital “0” is represented by the absence of the carrier signal. (Ex. 1023). Similarly, U.S. Patent No. 7,039,372 to Sorrells et al.

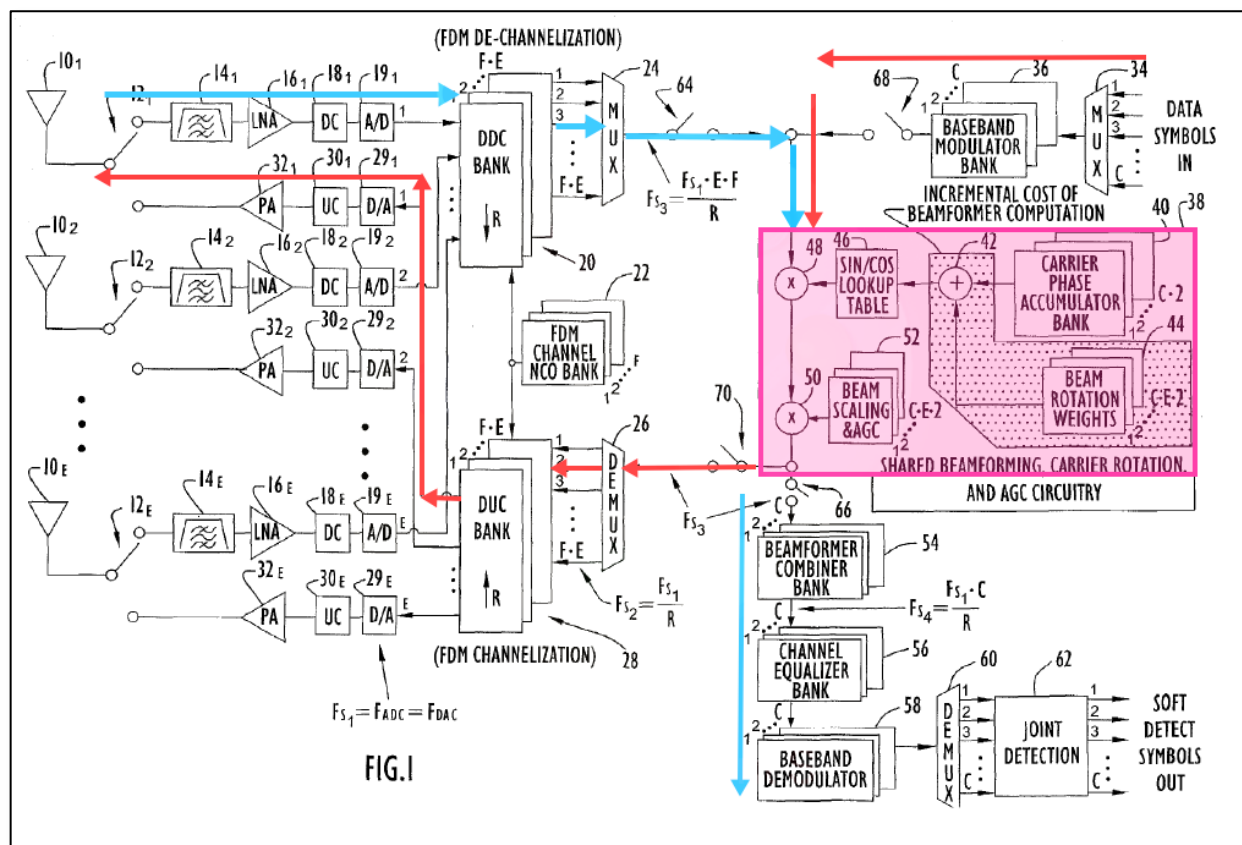
is titled “Method and System for Frequency Up-Conversion with Modulation Embodiments,” and describes “amplitude shift keying,” “where the amplitude of the carrier signal shifts between discrete states rather than varying continuously as it does for analog information.” (Ex. 1024). These references, and more, demonstrate that simple symbol-based communication was well known in the art at the time of the alleged invention of the ’141 Patent.

50. More complex modulation schemes also emerged over time, in which a symbol corresponds to multiple bits. Such schemes were made possible by more finely dividing the signal states that correspond to a given signal. For example, a multi-bit symbol can be transmitted in a scheme with numerous distinct amplitude levels, as opposed to a binary on-off amplitude modulation scheme. (Ex. 1022 (Selecting Mixed Signal Components for Digital Communication Systems)), 11. Numerous such modulation schemes existed at the time of the ’141 Patent, and a POSITA would have been familiar with such schemes. *Id.* (describing frequency modulation, phase modulation, quadrature phase shift keying, and more).

VII. OVERVIEW OF THE ’141 PATENT

51. I have reviewed the ’141 Patent (Ex. 1001). Descriptions of the ’141 Patent that may be pertinent to my analysis are provided herein, and my descriptions of the ’141 Patent are intended only as a summary of the ’141 Patent and/or intended as being pertinent to the Challenged Claims of the ’141 Patent. My opinions

provided herein are not intended as a discussion of my entire understanding of the '141 Patent or any other claims in any related patent to the '141 Patent. The '141 Patent describes a beamforming transceiver that processes signals to and from each antenna element individually at baseband. *Id.* at Abstract. It describes an architecture using a single shared baseband processor to process both transmit and receive signals on a per-channel basis. *Id.* at 3:33–44, 3:56–60. This architecture is depicted in FIG. 1 below with the receive path annotated **blue**, the transmit path annotated **red**, and the shared processor annotated **pink**:



Id. at FIG. 1 (annotated).

52. The '141 Patent's shared baseband processor 38 performs beamforming by applying phase shifts to signals on a per-antenna-element basis. *Id.* at 1:64–67. The '141 Patent contemplates performing beamforming in both the transmit and receive directions. *Id.* at 4:37–40. The '141 Patent also describes applying phase shifts in a shared baseband processor 38 for what the '141 Patent refers to as “carrier phase.” *Id.* at 7:63–8:19.

53. Shared baseband processor 38 includes a carrier phase accumulator bank 40 comprising a single numerically controlled oscillator (NCO), controlled via a bank of memory phase values corresponding to each user channel C for both modulation and demodulation. *Id.* at 7:63–8:1. The NCO supplies a rolling phase for the respective data channels to phase adder 42. *Id.* at 8:1–3. A bank of beam rotation weights 44 contains beamforming weights in the form of phase rotations for each channel and antenna element, which are also supplied to phase adder 42 for each signal. *Id.* at 8:3–7. Phase adder 42 receives the beamforming rotation weights and adjusts the phase supplied by the NCO in accordance with the beamforming phases of the particular antenna elements. *Id.* at 8:10–14. A sin/cos lookup table is then indexed by the adjusted phase value generated from adder 42 and supplies the corresponding sin/cos multiplicands to complex multiplier 48 for adjusting the phases of the input digital baseband signals. *Id.* at 8:14–19. *Id.* at 8:46–50. Thus, the shared baseband processor 38 applies a single phase rotation to the digital baseband

signals accounting for both carrier phase tracking and beamforming. Before leaving shared baseband processor 38, the digital baseband signals are adjusted in amplitude by scalar multiplier 50, which in turn receives control information from power control processor 52. *Id.* at 8:20–23. Scalar multiplier 50 adjusts the amplitude of the signals leaving shared baseband processor 38. *Id.* at 8:20–23.

54. In sum, the '141 Patent's transceiver provides a shared baseband processor 38 which applies a single set of phase shifts to digital baseband signals to account for both beamforming phase shifting and carrier phase error shifting.

VIII. PROSECUTION HISTORY OF THE '141 PATENT

55. I have reviewed the prosecution history for the '141 Patent, which is Ex. 1002. Pertinent aspects of the prosecution history of the '141 Patent are described below.

56. The '141 Patent issued from U.S. Application Serial No. 10/084,614 (the "'614 Application"), filed on February 28, 2002, which claims priority to a provisional application filed on February 28, 2001. '141 Patent (Ex. 1001). The claims of the '614 Application were rejected multiple times over the Examiner's cited prior art.

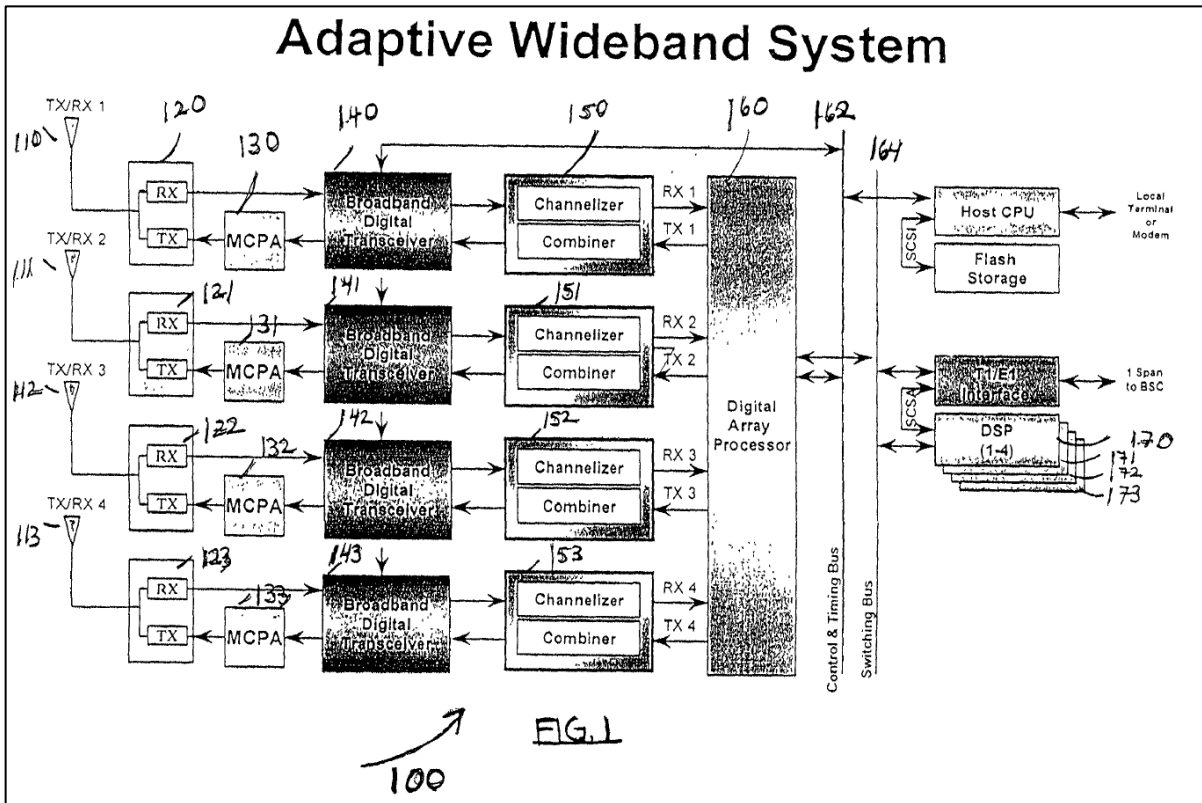
57. The Examiner rejected the '614 Application four times in total. In response to the first, second, and fourth rejections, the Applicant amended the proposed claims. (Ex. 1002), 231–43, 284–95, 351. In response to the Examiner's

third rejection (which was a final rejection), the Applicant submitted remarks and filed a request for continued examination. *Id.* at 302–12. Ultimately, to overcome the Examiners ultimate rejection, the Applicant amended the claims to clarify that the claimed shared baseband processor applies a “single phase adjustment to each of the digital baseband signals to jointly account for both” beamforming and carrier phase rotation. *Id.* at 351.

IX. OPINIONS REGARDING THE COMBINATION OF *WILLIAMS*, *FULTON*, AND *TROTT*

A. Overview of *Williams*

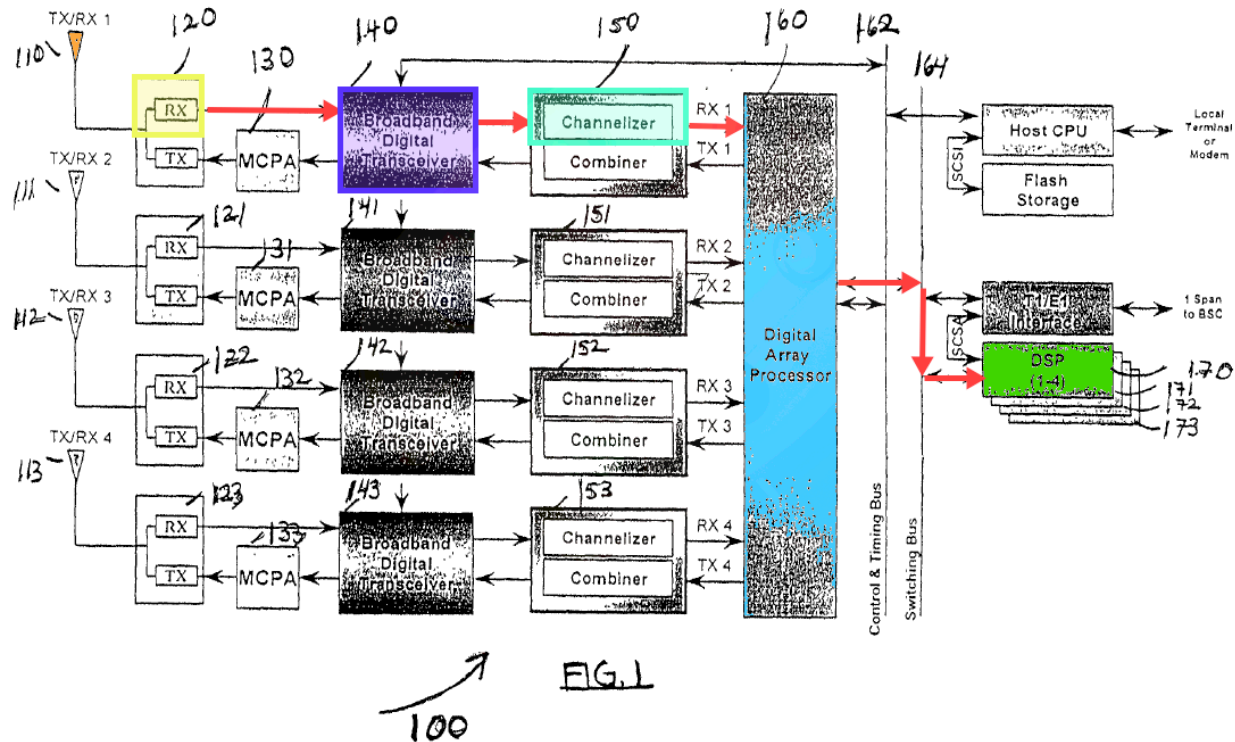
58. *Williams* discloses a digital baseband beamforming system that performs a calibration process to improve beamforming accuracy. *Williams* (Ex. 1004) ¶¶ 4, 13–17, 20. *Williams*’s system includes a base transceiver station (BTS) having an adaptive antenna array and at least one remote device which communicates with the BTS. *Id.* at ¶ 20. *Williams*’s BTS is shown below:



Id. at FIG. 1. *Williams's* system includes a base transceiver station (BTS) having an adaptive antenna array. *Id.* ¶ 20. *Williams's* adaptive antenna array is depicted as having four elements, but *Williams* teaches it may have any number of elements. *Id.* ¶ 34. Each element of *Williams's* adaptive antenna array has a corresponding transmit apparatus chain and receive apparatus chain comprising various hardware elements. *Id.* ¶ 36. The different hardware elements introduce differing phase and frequency errors in each individual apparatus chain. *Id.* ¶ 14, 36. One of *Williams's* goals is to account for these errors to properly perform beamforming and to transmit a coherent signal from the multi-element adaptive antenna array. *Id.* ¶¶ 14–17.

59. A receive apparatus chain is highlighted in the annotated FIG. 1, below:

Adaptive Wideband System



Id., FIG. 1 (annotated). *Williams's* FIG. 1 depicts four separate receive apparatus chains. The signal path in the receive direction is depicted in red. Each receive apparatus chain begins with an antenna element 110. *Id.* ¶ 33. Each antenna element receives RF signals and passes those signals to a filter/duplexer 120 (yellow), which performs amplification, filtering, and down conversion to an intermediate frequency (IF). *Id.* ¶ 34. The analog IF signals are then passed to a broadband digital transceiver 140, which performs analog-to-digital conversion on the signals, then digitally down converts the signals to baseband. *Id.* ¶¶ 34–35. Next, a channelizer/combiner (XMUX) 150 separates the digital baseband signals into I and Q representations for

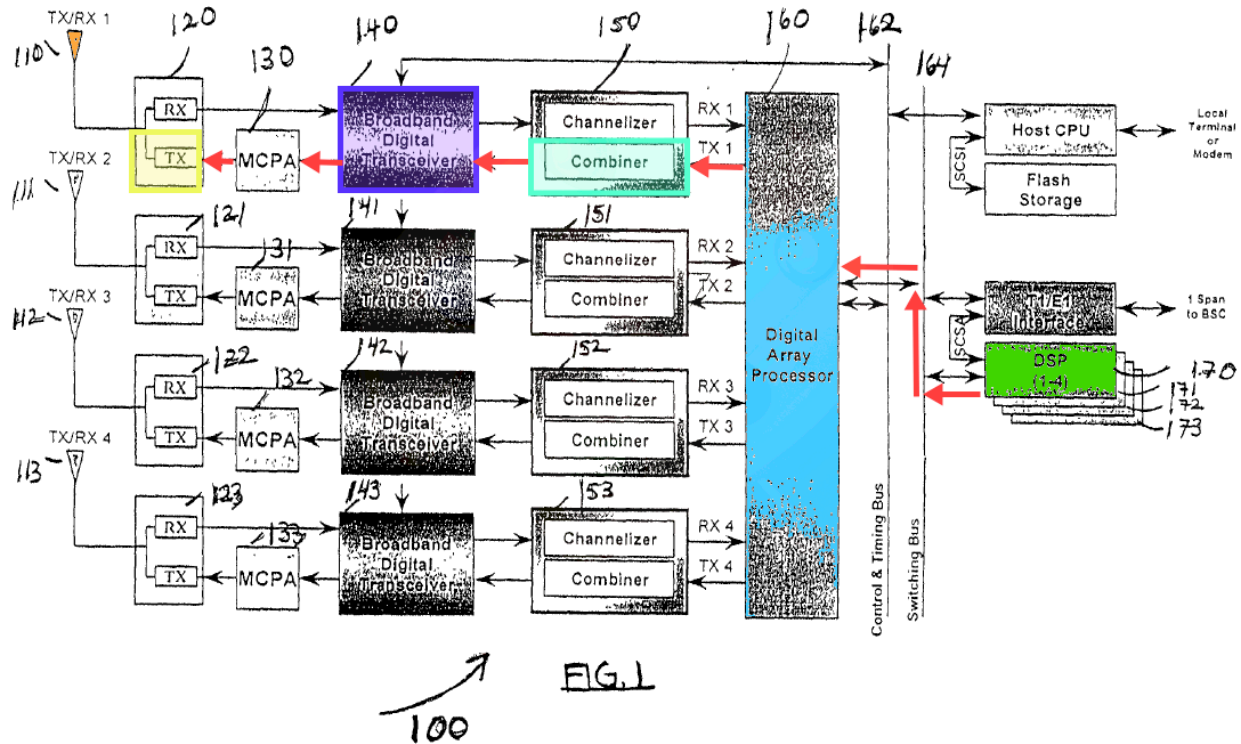
each active channel. *Id.* From there, the signals are communicated to **digital array processor 160**. *Id.* ¶ 35.

60. All incoming and outgoing signals pass through *Williams's* **digital array processor 160**, which is responsible for applying beamforming adjustments. *Id.* ¶ 37, FIG. 1. **Digital array processor 160** beamforms each active communication channel and calculates the calibration factors to account for the hardware differences between the different apparatus chains. *Id.* ¶ 37, FIG. 1. **Processor 160** adds the calculated calibration factors to the beamforming adjustments (which *Williams* refers to as “angular weighting factors”) to allow for a single phase adjustment per signal that both calibrates and beamforms the signal. *Id.* ¶¶ 36–37.

61. Still in the receive direction, **digital array processor 160** outputs the signal components, adjusted with their respective net weighting factors, to a **digital signal processor (DSP) 170**. *Id.* ¶ 38. **DSP 170** then demodulates the signals to recover the combined beamformed communication signal. *Id.*

62. A transmit apparatus chain is highlighted in the annotated FIG. 1, below:

Adaptive Wideband System



Id., FIG. 1 (annotated). *Williams's* FIG. 1 depicts four separate transmit apparatus chains. The signal path in the transmit direction is depicted in red. Each DSP 170 is associated with specific antenna elements 110 and a specific frequency channel for processing outbound communication signals to be transmitted over its respective frequency channel. *Id.* ¶ 39. The DSP 170 modulates and encodes these signals, and outputs them to digital array processor 160. *Id.* Digital array processor 160 then applies the appropriate net weighting factors for each active channel and for each antenna element, and outputs the proper weighted and modulated digital baseband signal to a digital combiner (XMUX) 150. *Id.* The combiner forms a multichannel digital signal, which is then input into the broadband digital transceiver 140. *Id.* ¶ 40.

Broadband digital transceiver 140 then upconverts the signal to IF, digital-to-analog converts the signal, and passes the signal to a multi-carrier power amplifier (MCPA) 130. *Id.* MCPA 130 outputs the resulting composite multi-frequency signal to RF elements 120 for amplification, filtering, and up conversion to RF. *Id.* Finally, the corresponding antenna element 110 radiates the amplified, beamformed multi-frequency RF signal. *Id.*

63. To measure the phase and frequency errors introduced in the respective apparatus chains, *Williams* teaches a remote device which uses a “loopback” mode to retransmit signals from the BTS back to the BTS. *Id.* ¶¶ 55–56. The BTS sends signals, one at a time, from each of the antenna elements, and *Williams*’s remote device “loops back” those signals to the BTS. *Id.* ¶ 56. The BTS, in turn, receives the looped back signals and measures any signal shift present in the received signals to discern the signal shifts for both the transmit and receive apparatus chains. *Id.* ¶¶ 55–56. Using these signal shifts, the BTS can calculate calibration factors corresponding to the signal adjustments necessary to transmit a coherent signal, and use those adjustments to transmit further signals. *Id.* ¶¶ 37, 55–57. Thus, the BTS calculates calibration factors that are applied at baseband to correct for any phase and/or frequency errors measured in the signals. *Id.*

64. *Williams* also discusses other background elements that were known in the art prior to the alleged priority date of the ’141 Patent. For example, *Williams*

discusses adaptive antenna arrays “consist[ing] of N identical antenna elements arranged in a particular geometry.” *Id.* ¶ 9. *Williams* likewise discusses digital beamforming, including “steering a beam and positioning multiple nulls,” and electronically adjusting the phases and amplitudes of the currents supplied to individual antenna elements such that received signals from a certain direction add in phase, and focusing the direction of transmitted energy from the antenna array during transmission. *Id.* ¶¶ 8, 10. Similarly, *Williams* discusses the necessity of transmitting signals from the various elements simultaneously with precisely known phase and amplitude. *Id.* ¶ 13. *Williams* also discusses the varying signal distortions introduced through hardware differences in respective transmit/receive apparatus chains, and the corresponding need for calibration to account for those differences. *Id.* ¶¶ 14–17.

65. *Williams* is in the same field of endeavor as the ’141 Patent, namely, digital wireless communications systems. For example, *Williams* explains “[t]his invention relates to the field of RF communication systems....” *Id.* ¶ 4; *see also* ¶¶ 20 (describing the elements of the disclosed communication system), 30 (describing FIG. 2 as depicting “a block diagram of a wireless communications system deploying a plurality of ... base transceiver stations”), 38–39 (describing receiving and transmitting a communications signal), and 35 (describing digitizing incoming signals). Similarly, the ’141 Patent states “[t]he present invention relates to wireless

communication transceivers and modems....” ’141 Patent, 1:16–17; *see also* 4:37–40 (explaining the alleged invention “can be employed in any communication device...”), 4:53–61 (listing types of devices in which the alleged invention may be employed), and 5:32–48 (describing digitizing incoming signals).

66. *Williams* is also pertinent to a problem to be solved by the claimed invention in the ’141 Patent. For example, *Williams* performs beamforming at baseband using digital baseband signals on a per-antenna element basis. Specifically, *Williams* uses a single processor to apply a single phase adjustment which jointly accounts for both beamforming and signal calibration. *Id.* ¶¶ 35–37. *Williams* also discusses performing these operations on digital baseband signals. *See id.* ¶ 35. *Williams* teaches the digital baseband signals correspond to each antenna element, and that those signals are adjusted by a single phase adjustment in the single baseband processor. *Id.* ¶¶ 35–37. And like the ’141 Patent, *Williams* teaches this process occurs for both transmission and reception. *Id.* ¶¶ 37–39.

67. Accordingly, it is my opinion that *Williams* is analogous art to the ’141 Patent.

68. *Williams* was filed on October 11, 2001 but claims priority to a provisional application filed October 11, 2000. (Ex. 1004 (*Williams*)) (22), (63). I have been informed that, for *Williams* to claim priority to the filing date of *Williams*-

Provisional, *Williams-Provisional* must provide sufficient written description support for at least one of the claims of *Williams*, demonstrating that the inventors of *Williams-Provisional* were in possession of the invention claimed in *Williams*.

69. I have reviewed *Williams-Provisional* and compared it to *Williams*. The portions of *Williams* relied upon in the Petition appear substantially identically in *Williams-Provisional*. The most notable difference is the omission of the “Summary of the Invention” section from *Williams* in *Williams-Provisional*. See (Ex. 1004 (*Williams*)) ¶¶ 20–27.

70. I have reproduced the chart from the Petition demonstrating *Williams* claim 1 is supported by *Williams-Provisional*, below:

<i>Williams</i> (Ex. 1004)	Supporting Disclosure from the <i>Williams-Provisional</i> (Ex. 1005) ¹
1. In a wireless communication system having at least one remote device for communicating with a base transceiver station (BTS) and a plurality of mobile stations,	This invention relates to the field of <i>RF communication systems</i>²... P. 3 One method for increasing the efficiency and performance <i>of a cellular system</i> is through the use of adaptive antenna arrays (“adaptive arrays”). P. 3 In the preferred embodiment, <i>a remote wireless translating repeater (“translating repeater”) may be used as the remote device</i> for calibration of an adaptive antenna array included in BTS 200. P. 14-15

¹ All citations are to *Williams-Provisional* (Ex. 1005).

² Unless otherwise noted, all emphasis is added by Petitioner.

	The <i>translating repeater receives and re-transmits</i> loopback signals <i>which are received by all antenna elements of the BTS</i> adaptive array. P. 16 When <i>a mobile user accesses the cellular network</i> using a RACH, the BTS 200 will assign the mobile user one of the 8 SDCCHs, unless the mobile is a GPRS mobile. P. 30 A BTS regularly transmits a ‘neighbor list’ over a control channel <i>that mobile users use</i> to determine the frequencies to scan adjacent cells. P. 34 To ensure <i>the mobile periodically transmits to the BTS</i> so that the BTS can determine the location mobile users and assess the interference environment... P. 36.
said BTS having an adaptive antenna array including a plurality of antenna elements,	One method for increasing the efficiency and performance of a cellular system is through the use of <i>adaptive antenna arrays</i> (“adaptive arrays”). P. 3 Thus, <i>an adaptive antenna array</i> can increase the cell size <i>that a given BTS</i> can serve. P. 4 <i>An antenna array consists of N identical antenna elements</i> arranged in a particular geometry. P. 4 <i>BTS 200 shown includes a 4 element antenna array</i> 210-213 (hereafter 210). P. 10
a method for determining calibration factors for respective transmit and receive paths associated with each of said antenna elements, comprising the steps of:	This invention relates to the field of RF communication systems, and more particularly <i>to a system and method for calibration of adaptive antenna arrays</i>. P. 3 Each adaptive array antenna array element requires a separate transceiver chain for operation of the adaptive array. Thus, <i>each antenna element is provided a dedicated receiver apparatus chain and transmit apparatus chain</i>. PP. 5–6.

	Accurate <i>real-time calibration</i> is required for all receive and transmit apparatus chains... Thus, <i>for an adaptive antenna array</i> to function properly, <i>frequent calibration of the various transmit and receive apparatus chains</i> should be performed. P. 7 Therefore, there is a need for a method <i>to calibrate all transmit apparatus chains and receive apparatus chains</i> without the addition of dedicated calibration hardware such as near and/or far-field transmit sources or receivers. P. 8 <i>In another calibration method</i>, a translating repeater is placed (or if already used in the cellular system, utilized) at a known location with respect to BTS 200. P. 21 Relative signal shift values <i>between each antenna receive apparatus chain</i> adjusted for free space path differences between the translating repeater and the various antenna elements <i>allows the determination of calibration factors which enable the BTS 200 to compensate for variations</i> between the uplink path transfer function and for each receive apparatus chain. The BTS 200 <i>may also determine calibration factors for each transmit apparatus chain using this method</i>. P. 22.
transmitting a downlink signal from said BTS to said remote device from each of said antenna elements;	To initiate of the calibration process, the translating repeater is signaled by the BTS to enter a loopback mode. In the loopback mode, received signals are frequency shifted by the translating repeater and then redirected back to the BTS. P. 21 The BTS 200 <i>transmits a loopback signal</i>, such as a GSM access burst, <i>from each antenna element</i>, one at a time. The <i>translating repeater receives</i> and re-transmits loopback signals which are received by all antenna elements of the BTS adaptive array. P. 16 <i>All signals transmitted from each antenna element are received by the translating repeater</i>. P. 21

	To initiate the calibration process, the translating repeater is signaled to enter a loopback mode. <i>The BTS transmits differing calibration signals (e.g. tones) from each of its antenna elements, all at a first carrier frequency.</i> A composite calibration signal having the plurality of <i>tones is received by the translating repeater</i> and looped back (frequency shifted) to the BTS. P. 24
retransmitting from said remote device said downlink signals back to said BTS as at least one uplink signal;	The BTS 200 transmits a loopback signal, such as a GSM access burst, from each antenna element, one at a time. The <i>translating repeater receives and re-transmits loopback signals</i> which are received by all antenna elements of the BTS adaptive array. P. 16 All signals transmitted from each antenna element are received by the translating repeater. In the loopback mode, <i>the translating repeater mixes the individual signals containing the individual tones to form a composite signal containing all the tones....</i> The single frequency shifted composite signal containing all the <i>tones is transmitted by the translating repeater and received by the adaptive antenna array.</i> P. 21-22 To initiate of the calibration process, the translating repeater is signaled by the BTS to enter a loopback mode. In the loopback mode, <i>received signals are frequency shifted by the translating repeater and then redirected back to the BTS.</i> P. 21
receiving said uplink signal at said BTS, and	The method requires the total delay and magnitude shift (collectively the “signal shift”) for a round trip (TD) of a loopback signal transmitted <i>and received by BTS 200</i> to be measured. P. 15 The translating repeater receives and re-transmits loopback signals which <i>are received by all antenna elements of the BTS adaptive array.</i> P. 16

	The single frequency shifted composite signal containing all the tones is transmitted by the translating repeater <i>and received by the adaptive antenna array</i>. P. 22
determining calibration factors for said respective transmit and receive paths.	These composite amplitude and phase errors in a given antenna signal path can be captured... and <i>a set of receive and transmit calibration factors calculated to equalize... the various receive and transmit apparatus chains</i>. P. 6 <i>[T]he adaptive antenna system will have both transmit and a receive calibration factors....</i> P. 7 Signal shifts for each receive apparatus chain may be measured <i>and calibration factors determined from resulting receive apparatus chain signal shifts</i> measured from receipt of any one of the returned loopback signals originally transmitted by BTS from any antenna element. P. 16 <i>[T]ransmit apparatus chain calibration factors can be determined. ... Since signal shifts are frequency dependent, the calibration process for both transmit and receive apparatus chains are generally repeated for all carrier frequencies supported by BTS 200. Once the receive and transmit chain calibration factors are calculated and stored by the BTS...</i> P. 17 Relative signal shift values between each antenna <i>receive apparatus chain... allows the determination of calibration factors</i> which enable the BTS 200 to compensate for variations between... <i>each receive apparatus chain</i>. The BTS 200 <i>may also determine calibration factors for each transmit apparatus chain using this method</i>. P. 22

71. In my opinion, *Williams-Provisional* is sufficiently detailed to enable a POSITA to make and use the invention claimed in *Williams* claim 1. As I explained above, *Williams* and *Williams-Provisional* have almost identical disclosures. As *Williams-Provisional* provides a highly detailed disclosure, it would be well within the abilities of a POSITA to implement the disclosure in *Williams-Provisional*.

72. I have been informed by counsel that *Williams-Provisional* accordingly provides written description support for *Williams*, and thus *Williams* is entitled to *Williams-Provisional*'s priority date. I have been further informed that this qualifies *Williams-Provisional* as prior art under at least 35 U.S.C. § 102(e) (pre-AIA).

B. Overview of *Fulton*

73. *Fulton* was filed on December 21, 1994 and issued on February 18, 1997. *Id.* (22), (45). I have been informed by counsel that this qualifies *Fulton* as prior art to the '141 Patent under at least 35 U.S.C. §§ 102(a) and (e) (pre-AIA).

74. *Fulton* relates to radio communication systems with accurate frequency and phase control. *Fulton* (Ex. 1006), 1:11–16, 1:52–65, 3:22–25. *Fulton* teaches multiple embodiments of its disclosed radio communication systems, each with a corresponding “continuous data demodulator.” *See, e.g., id.*, 10:66–11:29. *Fulton*'s FIG. 4 depicts one of *Fulton*'s systems, with continuous data demodulator 258 shown in pink:

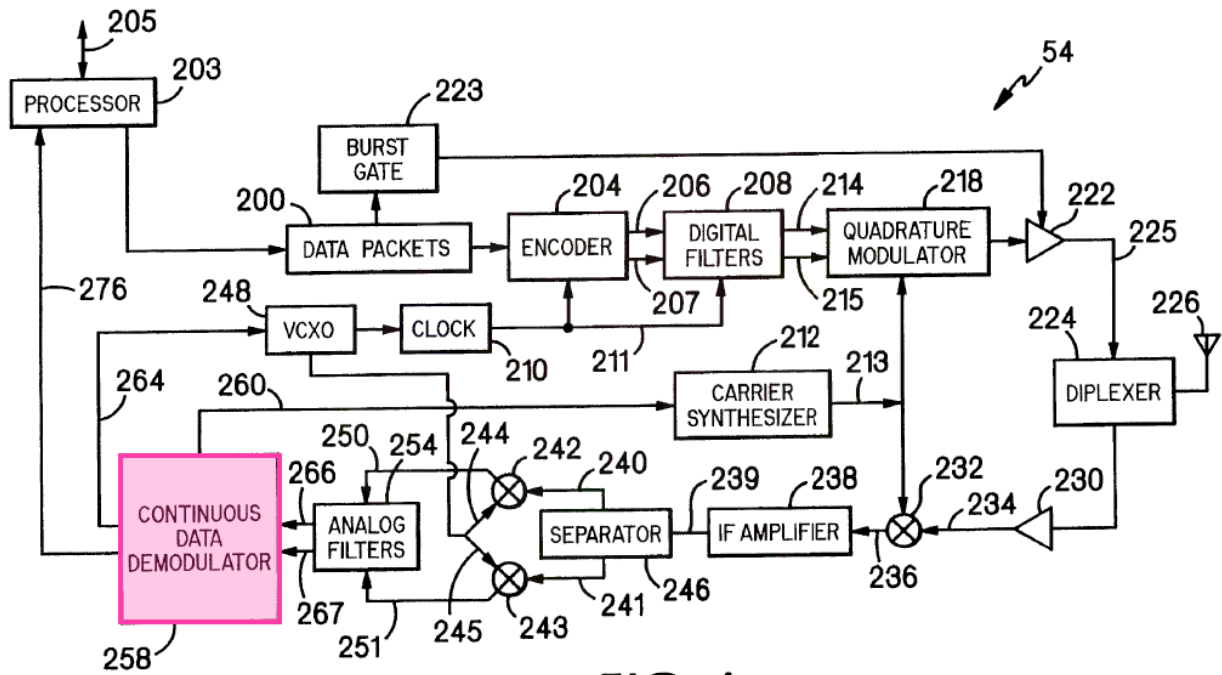


FIG. 4

Id., FIG. 4 (annotated).

75. *Fulton*'s "continuous data demodulator," in turn, contains a "rotator" which applies a phase rotation to digital baseband signals. *Id.* *Fulton*'s FIG. 10 depicts one embodiment of continuous data demodulator (renumbered to 558) containing rotator 280, shown in blue:

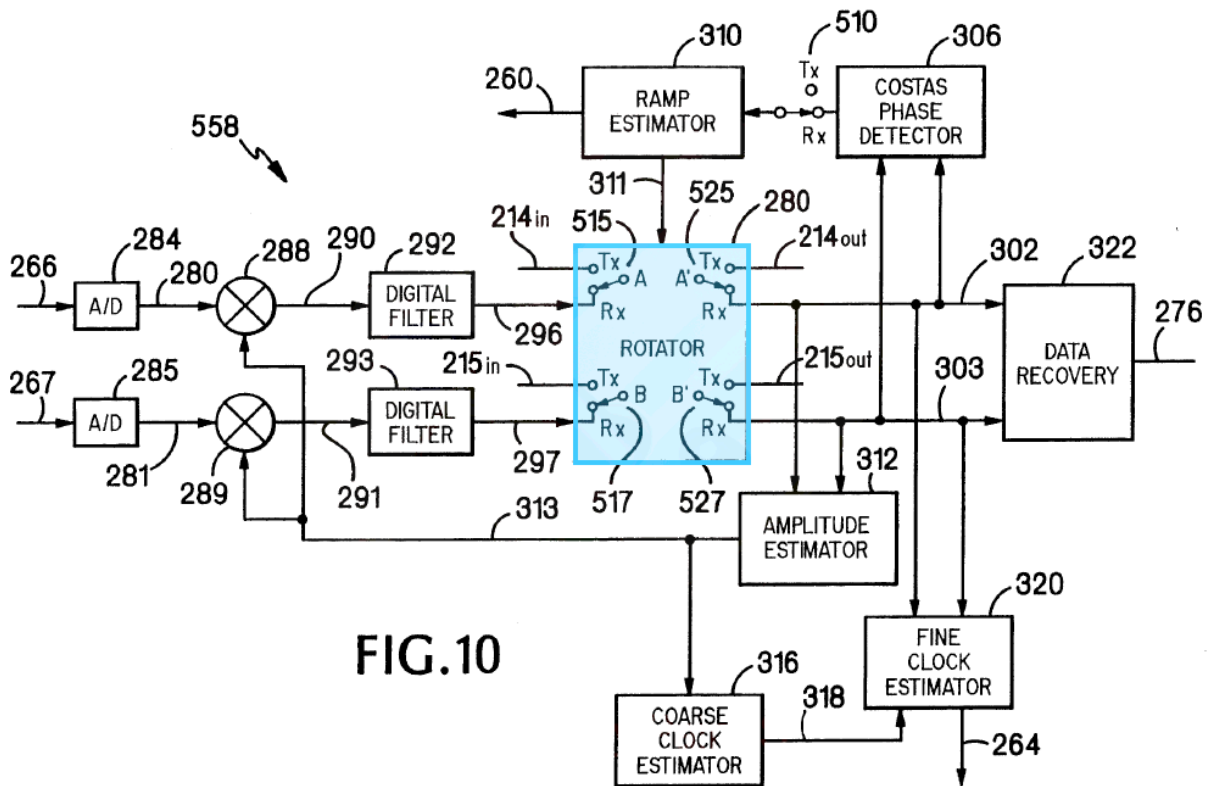


FIG. 10

Id., FIG. 10 (annotated).

76. *Fulton*'s rotator rotates digital baseband signals a given amount ϕ based on a control signal 311. *Id.*, 11:12–36, 11:56–59. Control signal 311 controls rotator 280 in response to the phase error in the signal, which in turn is generated in ramp estimator 310. *Id.*, 9:58–62. Rotator 280 then outputs a signal with an accurate carrier frequency based on the proper signal rotation. *Id.*, 9:58–62, 10:44–65. *Fulton* teaches this process in its rotator “accomplishes the effect of phase-locking within the continuous data demodulator.” *Id.*, 9:66–10:1.

77. *Fulton* is in the same field of endeavor as the '141 Patent, namely, digital wireless communications systems. *Fulton* explains “[t]he present invention is directed to bidirectional communications systems wherein a base station transceiver transmits signals....” *Fulton*, 2:63–65; *see also* 1:11–16 (“The present invention relates generally to bidirectional radio communication systems...”), 2:20–24 (“Another object of the present invention is to provide a radio communication system...”), 5:29–32 (“The processor... translates these directions into a continuous digital data stream”), and 6:20–22 (“Analog baseband signals 150 and 151 are then converted to digital form...”). Similarly, the '141 Patent states “[t]he present invention relates to wireless communication transceivers and modems....” '141 Patent, 1:16–17; *see also* 4:37–40 (explaining the alleged invention “can be employed in any communication device...”), 4:53–61 (listing types of devices in which the alleged invention may be employed), and 5:32–48 (describing digitizing incoming signals).

78. *Fulton* is also pertinent to a problem to be solved by the claimed invention in the '141 Patent. For example, *Fulton* uses a single baseband processor to accomplish carrier phase adjustments in both the transmit and receive directions. *Compare Fulton*, Abstract, 1:11–16, 1:52–65, 3:22–30, 11:44–54, *with* '141 Patent, Abstract, 1:49–67, 3:39–44, 3:56–60, 7:4–9, 8:46–50, 9:32–36.

79. Accordingly, it is my opinion that *Fulton* is analogous art to the '141 Patent.

C. Overview of *Trott*

80. *Trott* was filed December 22, 2000 and issued December 28, 2004. I have been informed by counsel that this qualifies *Trott* as prior art to the '141 Patent under at least 35 U.S.C. § 102(e) (pre-AIA).

81. *Trott* relates to mitigating co- and inter-channel interference in antenna arrays with signal weighting. *Trott* (Ex. 1007), Abstract. *Trott* envisions utilizing its invention in “systems wherein beamforming strategy is dynamically determined based on a changing signal and interference environment.” *Id.*, 9:19–21.

82. *Trott* is in the same field of endeavor as the '141 Patent, namely, digital wireless communications systems. For example, *Trott* explains “[t]he present invention relates to the field of wireless communication systems....” *Id.*, 1:15–17; *see also id.* 1:35–42 (explaining issues with existing communications systems), 5:13–15 (explaining the invention diminishes inter- and co-channel interference in a wireless communication system), and 6:27–31 (explaining baseband signals are digitized before entering the baseband processor). Similarly, the '141 Patent states “[t]he present invention relates to wireless communication transceivers and modems....” '141 Patent, 1:16–17; *see also* 4:37–40 (explaining the alleged invention “can be employed in any communication device...”), 4:53–61 (listing

types of devices in which the alleged invention may be employed), and 5:32–48 (describing digitizing incoming signals).

83. *Trott* is also pertinent to a problem to be solved by the claimed invention of the '141 Patent. For example, *Trott* performs beamforming at baseband on digital signals. *Compare Trott*, Abstract, 6:20–41 (describing down-converting received signals to digital baseband signals and vice versa for transmission), 7:3–13 (describing *Trott*'s beamforming strategy), 7:25–32 (describing receiving desired signals and outputting to a network processor), *with* '141 Patent, Abstract, 1:49–67 (describing beamforming), 3:39–44 (describing performing digital baseband beamforming), 3:56–60 (describing a shared baseband processor), 7:4–9 (describing adjusting phases and amplitudes of signals), 8:46–50 (describing applying a combined phase adjustment to digital baseband signals).

84. Accordingly, it is my opinion that *Fulton* is analogous art to the '141 Patent.

X. OPINIONS REGARDING GROUNDS I AND II IN THE PETITION

i. Independent Claim 1

[1(P)] An apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased antenna array comprising a plurality of antenna elements, the apparatus comprising:

85. In my opinion, *Williams* teaches an apparatus for modulating and demodulating signals transmitted and received via an electronically steerable phased

antenna array comprising a plurality of antenna elements. As I discussed above in Section IX.A, *Williams* teaches an apparatus for modulating and demodulating signals. Specifically, *Williams* teaches a base transceiver station 100 which modulates and demodulates signals in DSPs 170–173. *Williams* ¶¶ 33, 38–39. And as I further discussed in Section IX.A, the modulated/demodulated signals are transmitted/received by *Williams*’s apparatus.

86. Similarly, as I again discussed above in Section IX.A, *Williams* teaches an adaptive antenna array. *See Williams* ¶¶ 33–34. And as discussed above in Section VI.A, “adaptive antenna arrays” are a specific implementation of phased array antennas. Specifically, an adaptive antenna array is an array in which the received signal is continually monitored in respect to interference. (Ex. 1014 (Newton Telecom 16)), 36. Adaptive arrays electronically steer a phased array by weighting the amplitude and phase of a signal at each element in response to changes in the propagation environment. (Ex. 1015 (Kapoor ’424)), 3:47–51. Although *Williams* does not expressly describe its antenna as a “phased array” antenna, a POSITA would have understood that the terms “adaptive array” and “adaptive phased array” were interchangeably used in the art to describe the same technology. (Ex. 1008, Mark C. Roh, “A Base Station Smart Antenna System for CDMA Cellular,” Massachusetts Institute of Technology, 1997), 3 (using both terms interchangeably in the paper’s abstract).

87. Therefore, it is my opinion that *Williams*'s "adaptive antenna array" teaches a phased array antenna, and a POSITA would have recognized as much.

88. Finally, as I discussed above in Sections VI.A and VI.B, adaptive arrays are electronically steerable. Namely, such antennas emit a steerable antenna beam, which is electronically steered via adjusting phase and amplitude of the signals exciting the antenna elements. Ex. 1016 (Lo '072) 1:41–51.

[1(a)] a baseband modulator configured to modulate outbound digital baseband signals to be transmitted via the phased array antenna;

89. As I discussed above in Section IX.A, *Williams* teaches a baseband modulator (DSP 170) configured to modulate outbound signals which are subsequently transmitted by *Williams*'s adaptive antenna array (i.e., adaptive phased array antenna). Namely, DSP 170 modulates and encodes "incoming (voice/data) communication signals to be transmitted." *Williams* ¶ 39.

90. And as I discussed above in Section IX.A, *Williams* teaches that its system operates on digital baseband signals at multiple points. Specifically, in the transmit direction (which as I also discussed above in Section IX.A, is where the modulation occurs), *Williams* teaches "the phase and amplitude net weighting factors are preferably applied after the ***DSP 170 (modulation)*** and before XMUX 150 (***digital*** combiner)." *Williams* ¶ 39. First, a POSITA would have known that ***digital*** signal processors (DSPs) operate on digital signals. Second, a POSITA would likewise understand *Williams*'s ***digital*** combiner 150 also operates on digital signals.

Thus, a POSITA would have understood *Williams* to teach the signals passing from DSP 170, through digital array processor 160, to digital combiner 150 are digital signals.

91. *Williams* continues, “[a]t these points in the signal path, each signal (RF frequency and time slot) is a baseband signal having an I and Q representation.” *Id.* Thus, a POSITA would have understood *Williams* to teach the signals passing from DSP 170, through digital array processor 160, to digital combiner 150 are baseband signals (having an I and Q representation). And taken in combination with the previous sentence, a POSITA would have understood *Williams* to teach these baseband signals are digital baseband signals.

92. Further, *Williams* teaches DSPs 170 process “incoming (voice/data) communication signals to be transmitted over respective frequency channels.” *Id.* *Williams* does not teach that the “incoming (voice/data) communication signals” are up-converted or down-converted in DSP 170. Rather, *Williams* teaches both up-conversion from baseband to IF and digital-to-analog conversion occurs in broadband digital transceiver 140. *Id.* ¶ 40.

93. And further yet, *Williams* teaches “[s]ystem operation in the transmit direction is quite similar to the receive direction.” *Id.* In the receive direction, signals are received by the antenna elements 110–113 at RF frequencies, down-converted to IF in Filter/Duplexer 120, and further down-converted and analog-to-digital

converted in broadband digital transceiver 140. *Id.* ¶¶ 34–35. *Williams* teaches channelizer 150, in turn, outputs “baseband digital signals having an I and Q representation for each active channel.” *Id.* ¶ 35. All components in the receive apparatus chains after broadband digital transceiver 140 are likewise digital components (*digital* channelizer 150; *digital* array processor 160; *digital* signal processor 170).

94. Therefore, a POSITA would have understood the transmit-direction “incoming (voice/data) communication signals” are also digital baseband signals.

[1(b)] a baseband demodulator configured to demodulate incoming digital baseband signals generated from signals received via the phased array antenna; and

95. As I discussed above in Section IX.A, *Williams* teaches a baseband demodulator (DSP 170) configured to demodulate incoming signals which have been received by *Williams*’s adaptive antenna array (i.e., adaptive phased array antenna). Namely, DSP 170 “demodulates [] signals to recover the combined beamformed communication signal.” *Williams* ¶ 38. These signals originate as “received RF signals.” *Id.* ¶ 34.

96. Further, a POSITA would have known that the purpose of an antenna (including a phased array or adaptive antenna array) is to capture (or transmit) wireless signals and generate a corresponding electrical signal for processing in an associated system. Therefore, a POSITA would have understood that *Williams*’s

disclosed system receives transmitted RF signals through its antenna array (antenna elements 110–113) and generates a corresponding signal. Thus, the baseband signals are generated from signals received via *Williams*'s adaptive antenna array, since the adaptive antenna array would generate the referenced, electrical “received RF signals,” which are down converted to IF, then digitized and down converted to baseband. *Id.* ¶¶ 34–35.

[1(d)] said shared baseband processor applying a single phase adjustment to each of the digital baseband signals to jointly account for both beamforming phase rotation and carrier phase rotation of individual antenna elements.

97. As I discussed above in Section IX.A, *Williams* teaches a digital array processor 160, which is a shared baseband processor because it performs beamforming and gain control for all channels in both the transmit and receive directions. *Williams* ¶ 37, 10. As set forth below, *Williams* teaches that its shared baseband processor applies beamforming phase rotations to signals in both transmit and receive directions and also teaches that this phase rotation is combined (i.e., summed) with a calibration factor such that only a single phase adjustment is made to account for both beamforming and calibration. As further set forth below, a POSITA would have been motivated to supplement *Williams* with the carrier phase rotation disclosed by *Fulton* to correct for carrier phase offset and would have been motivated to implement this phase rotation summed with *Williams*' beamforming adjustment.

98. Before addressing this combination, however, it is helpful to briefly discuss the meaning of the claimed carrier phase rotation in the '141 Patent. The '141 Patent explains “to support signal modulation and demodulation, baseband processors typically perform the functions of carrier phase tracking (involving carrier phase rotation) and automatic gain control....” '141 Patent, 7:4–7. “In the receive case, the NCO’s of the carrier phase accumulator bank 40 respectively track the carrier phase of the signal in each of the C user channels based on feedback from a phase discriminator within the corresponding baseband demodulator 58.” *Id.* at 9:32-36. As I discussed above in Section VI.D, a POSITA would understand this to refer to the well-known process of tracking carrier frequency offset (CFO), which includes tracking the phase of the carrier. *See* (Ex. 1018 (Analysis of new and existing methods...IEEE)), 1–2. Specifically, tracking the CFO involves measuring the difference (error) between the received signal’s carrier phase, and the expected carrier phase, which is imparted due to multiple factors including imperfections between the transmitter and receiver’s local oscillators. *Id.* This error can be fed back, in a well-known manner, *see, e.g.*, Takahashi (Ex. 1020), to correct for such error. As the receiver can measure the CFO between the received signal and the expected received signal, CFO tracking is typically only performed in the receive direction. *See* (Ex. 1019 (Robust Frequency and Timing Synchronization for OFDM)), 1. A POSITA would have known that such an issue would face any

receiver/transmitter pairing, since in practice, no two separate oscillators resonate precisely the same. And even if two oscillators were exactly in tune with one another, other disturbances would introduce some form of CFO, such as signal scattering or doppler shift.

99. As I discussed above in Section IX.A, *Williams* applies a single phase adjustment to signals in its shared baseband processor (digital array processor 160) to account for beamforming and calibration, which *Williams* refers to as a “net weighting factor.” *Williams* ¶¶ 36–37. And as I discussed above in Section VI.B, beamforming is performed by phase-shifting transmitted or received signals such that the signals add in phase in a given spatial direction. *See, e.g.*, (Ex. 1016 (Lo ’072) 1:41–51; *Williams* ¶¶ 7–11. A POSITA would have understood the ’141 Patent’s phase “rotations” to mean applying phase “adjustments,” which was well known in the art at the time of the alleged invention of the ’141 Patent.

100. Although *Williams* adds and jointly applies a phase adjustment (rotation) to account for beamforming and calibration, it does not teach in detail that an adjustment for carrier phase rotation (which, as I discussed above, a POSITA would understand to refer to CFO tracking) would also be applied jointly at part of this combined phase adjustment process. As set forth below, a POSITA would have been motivated to do so pursuant to *Fulton*’s teachings, at least because a POSITA

would have recognized that carrier phase rotation (i.e., for CFO compensation) would be an issue facing transmission system such as that described in *Williams*.

101. As I discussed above in Section IX.B, *Fulton* teaches a “rotator” which rotates transmitted and received signals based on the amount of measured phase error, accomplishing the effect of phase-locking. *Fulton*, 9:44–10:1. A POSITA would have understood *Fulton*’s “phase-locking” to teach the ’141 Patent’s carrier phase rotation, because phase-locking refers to the well-known process of correcting a phase error by a given offset amount. *See* (Ex. 1025 (U.S. Patent No. 6,404,247 to Wang)), 1:11–15 (“A phase-locked loop (PLL) is an electronic circuit for locking an oscillator in phase with an input signal. In other words, a PLL is an electronic circuit for synchronizing, in frequency as well as in phase, an output signal with a reference signal.”). Therefore, a POSITA would have understood *Fulton*’s phase rotation based on the phase error in the carrier frequency to teach CFO tracking and correction (i.e., the claimed “carrier phase rotation”).

102. For at least the reasons discussed in the following paragraphs, A POSITA would have been motivated to combine *Fulton*’s carrier phase rotation into *Williams*’s net weighting factor (i.e., single phase adjustment that accomplishes a calibrated beamforming adjustment and carrier phase correction).

103. I understand that, “if a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar

devices in the same way, using the technique is obvious[.]” *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 417 (2007). Here, a POSITA would have recognized that *Fulton*’s phase error correction performed in rotator 280 would benefit *Williams*’s communications system in the same way it benefits *Fulton*, correcting for phase error in transmitted and received signals at baseband via a feedback loop. Indeed, such functionality would be desirable to implement in *Williams*’s system because it would provide for greater accuracy in signal transmission and reception, which in turn may provide greater throughput due to less need to retransmit incorrectly received signals. A POSITA would have understood that incorporating *Fulton*’s teachings regarding the well-known process of carrier phase rotation would have resulted in a system with even further improved signaling accuracy by correcting for a different, but likewise important, form of signaling error. This increased accuracy would lead to greater throughput and system efficiency because fewer signals would be lost due to signaling errors. A POSITA would have recognized, in turn, that fewer lost signals would lead to greater data throughput for the system, since less time would be lost re-transmitting lost signals. Indeed, this is one of *Fulton*’s identified objects of its invention: “to provide a low-cost method of generating a high accuracy transmission carrier[.]” and providing a “high data through-put” radio system. *Fulton*, 2:6–7, 2:15–24. Furthermore, *Fulton* identifies “an object of this invention is to simplify the circuitry of a receiver ... by providing a reception circuit which is

coupled to the transmission circuit to produce transmission carrier stabilization[.]” *Fulton*, 2:45–49. These benefits would similarly have been realized and improved the system described by *Williams*.

104. A POSITA would have understood that *Williams* and *Fulton* describe “similar devices,” and a POSITA would have had a reasonable expectation of success in making the proposed combination due to the similarities in their function and architecture. For example, both *Williams* and *Fulton* teach radio communication systems that apply phase and amplitude shifts to correct for frequency errors. *See, e.g., Williams* ¶¶ 4 (“This invention relates to the field of RF communication systems, and more particularly to a system and method for calibration of adaptive antenna arrays.”), 14–15 (explaining hardware differences in the various transmit/receive apparatus chains introduce varying errors which must be accounted for), 17 (“Accurate real-time calibration is required for all receive and transmit apparatus chains.”), 25 (“A self-calibrating communications system...”), 36 (teaching calculating calibration factors “to compensate for relative path delay and amplitude variations that occur when signals traverse the various ... apparatus chains” and applying phase and amplitude shifts to the signals); *Fulton*, 1:11–16 (“The present invention relates generally to bidirectional radio communications systems...”), 2:63–3:3 (explaining the claimed system, including a remote station which “utilizes the extracted information to stabilize the frequency of the remote

station carrier”), 6:32–35 (teaching scaling the phase and amplitude of signals to effect “errorless decoding”), 9:11–19 (teaching measuring and feeding back phase errors). Additionally, both *Williams* and *Fulton* teach systems which perform their respective corrections in both the transmit and receive direction. *See Williams*, ¶ 37 (“Through application of net weighting factors to each of the respective apparatus chains, digital array processor 160 can adjust the baseband digital signals received from and for transmission by each antenna element 110...”); *Fulton*, 11:55–67 (“During reception, switches 510... are in the Rx positions.... During transmission, switches 510... are in the Tx positions....”).

105. As I discussed above in Section VI.A-B, at the time of the ’141 Patent’s purported invention, phased array (or adaptive phased array, or adaptive array) antenna systems were well-known in the art for the advantages they provide in terms of enhancing antenna gains, reducing signal interference, and more. Thus, given the popularity of phased array antenna technology at the time, a POSITA would have recognized that *Fulton* and *Williams* are compatible and the proposed combination would have been well-within the skillset of a POSITA. Additionally, both *Fulton* and *Williams* teach correcting the phase of transmitted and received signals. Just as *Williams* teaches calibrating signals traveling along varying transmit apparatus chains such that the signals are received simultaneously (phase), *Fulton* teaches

feeding back phase and frequency errors to measure and correct those errors.

Compare Williams ¶¶ 42–44, 56–57, *with Fulton*, 9:11–19, 9:55–10:2.

106. Although *Williams*’s discussion focuses on internal phase compensation, a POSITA would have expected a system like *Williams* to incorporate some form of CFO compensation such as that described by *Fulton*. Indeed, one of *Williams*’s goals is to measure, and compensate for, phase offsets experienced by the transmit and receive paths within its system, proposing “[a] method for determining calibration factors for respective transmit and receive paths associated with an adaptive antenna array having a plurality of antenna elements[,]” wherein the base transceiver station “determines calibration factors for the respective antenna transmit and receive paths.” *Williams* ¶ 20. Specifically, *Williams* contemplates calibrating the received and transmitted signals to account for phase differences induced by the different hardware from the receive and transmit apparatus chains: “***both transmitted and received signals*** must be calibrated so that unweighted signals traveling along the various antenna apparatus chains from respective DSPs 170 to antenna element 110 each reach antenna element 110 (transmit) and DSPs 170 (receive) simultaneously (***phase***) and with the same amplitude.” *Williams* ¶ 42. A POSITA would have recognized the benefits of further compensating for carrier phase offset experienced between the sending and receiving devices as described by *Fulton*. Indeed, as discussed above, accounting for CFO would be expected in any

communication system such as that described by *Williams* and provides a number of well understood benefits. For example, compensating for carrier phase offset would have enabled *Williams*'s system to form a more precise, focused (and therefore longer-reaching) antenna beam. In turn, such a more focused, long-range antenna beam would similarly enable *Williams*'s system to serve larger communications system cell sizes. *Fulton* accomplishes its carrier frequency stabilization, in part, by applying phase rotations in its "rotators," which I described above in Section IX.B. *Fulton*'s rotators apply a "rotation ϕ ... such that signals 302 and 303 become the in-phase and quadrature components, respectively, of the transmission." *Fulton*, 9:59–62. This accomplishes the effect of phase-locking the signals passing through *Fulton*'s rotator. *Id.*, 9:66–10:2. *Williams* already teaches applying a single "net weighing factor" which incorporates multiple phase shifts into one coherent signal adjustment: "[t]he phases and amplitudes of the calibration factors and angular weighting factors are effectively added together to result in a net weighting factor that is applied to signals traveling in each antenna apparatus chain...." *Williams* ¶ 36. A POSITA would have recognized that adding another similar phase adjustment to *Williams*'s net weighing factor—namely, *Fulton*'s carrier phase rotation—would require minimal modification and processing, since multiple phase adjustments and multiple amplitude adjustments (in dB) simply superimpose via addition and subtraction.

107. A POSITA would have been specifically motivated to implement *Fulton*'s phase feedback and correction (performed by rotator 280) in *Williams*'s digital array processor 160. When combined as proposed, digital array processor 160 would then perform a further calibration (*Williams* ¶¶ 37, 83) calculation to account for carrier phase errors (i.e., carrier phase rotation) in addition to the calibration and beamforming calculations it already performs on an antenna element-by-element basis, resulting in digital array processor 160 applying a single phase shift to jointly account for both beamforming phase rotation and carrier phase rotation of individual antenna elements, as claimed. In other words, when deciding where to apply a baseband CFO phase adjustment per *Fulton*'s teachings, a POSITA would have found it obvious to consolidate all the baseband phase adjustments into a single step. Indeed, *Williams* already teaches applying a multi-faceted signal adjustment accounting for both beamforming and calibration as a single "net weighting factor" created by adding phases and amplitudes (in dB) of the separate corrections. *Williams* ¶ 36. Incorporating a third phase shift to *Williams*'s already consolidated phase adjustment would, accordingly, have been straightforward and yielded predictable results.

ii. Claim 2

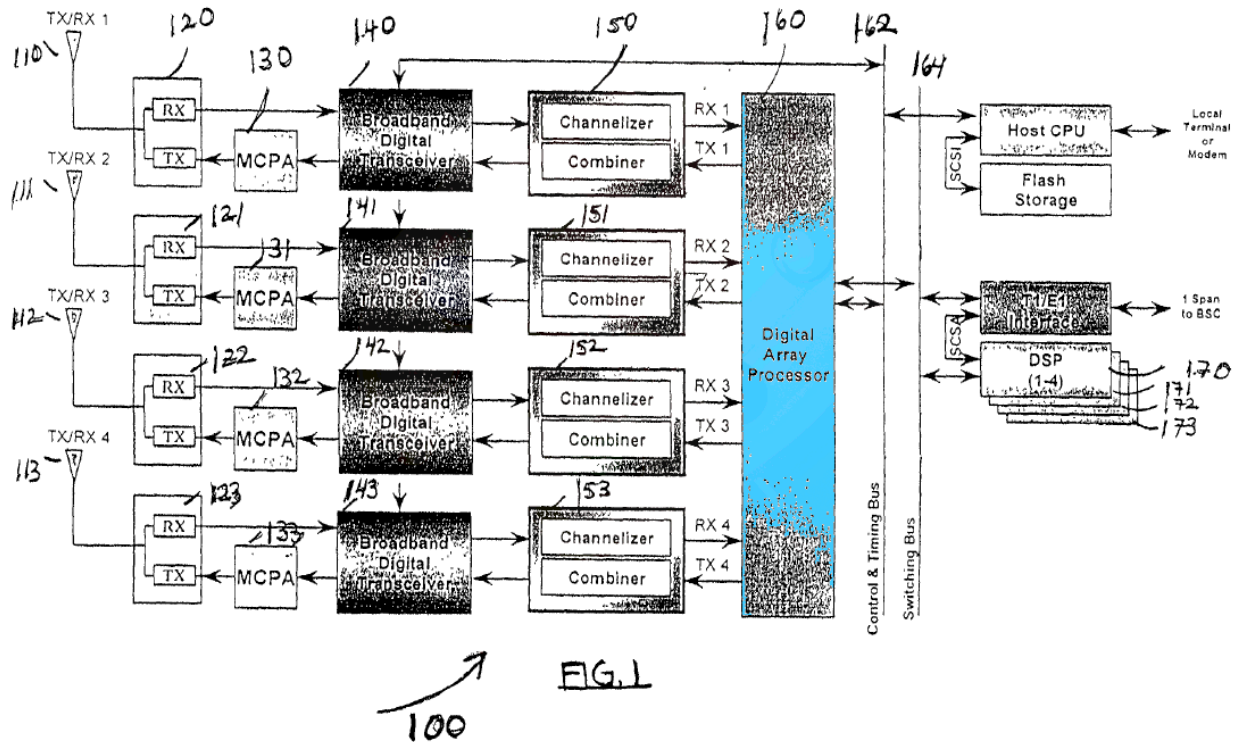
The apparatus of claim 1, wherein said digital baseband signals received by said shared baseband processor are time multiplexed, and said shared baseband

processor operates on said digital baseband signals on a time-slot-by-time-slot basis.

108. *Williams* teaches its system employs time division multiplexing (TDM): “In the preferred embodiment of the invention, 96 channels are supported by BTS 100 through use of 12 RF carriers and 8 TDM time slots.” *Williams* ¶ 41. A POSITA would have understood that each channel corresponds to a pairing of a given RF carrier and a given time slot (12 RF carriers x 8 time slots = 96 channels). *Williams* also teaches “net weighting factors may be determined by the digital array processor 160 and be separately applied to each active timeslot to point a beam....” *Id.* ¶ 80. Similarly, *Williams* teaches “digital array processor 160 can adjust the baseband digital signals received from and for transmission by each antenna element 110 to beamform each active channel.” *Id.* ¶ 37. And *Williams* teaches digital array processor 160 applies these net weighting factors “to each active channel and for each transmit apparatus chain associated with each antenna element[.]” *Id.* ¶ 39. Thus, *Williams* teaches separately applying the net weighting factors on a time-slot-by-time-slot basis, since these signals are “separately applied to each active time slot[.]” *Id.*

109. Furthermore, in the transmit direction, “the phase and amplitude net weighting factors are preferably applied after the DSP 170 (modulation) and before the XMUX 150 (digital combiner).” *Id.* ¶ 39. As shown below, digital array processor 160 is the only component between DSP 170 and XMUX 150:

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Id., FIG. 1 (annotated). *Williams* further teaches “DSPs 170 are associated with specific antenna elements 110 and a specific frequency channel[.]” *Id.* ¶ 39. Therefore, *Williams* teaches the signals entering digital array processor are for a specific RF frequency channel (i.e., corresponding to one of the 12 RF carriers). And as I discussed, each RF frequency channel has 8 active transmission channels corresponding to the 8 TDM time slots. Therefore, in combination with the above teachings that digital array processor 160 applies net weighting factors on a time slot by time slot basis, a POSITA would have understood that the signals digital array processor 160 receives from DSPs 170 are single signals for each time slot and RF frequency.

110. Indeed, *Williams* teaches the same process occurs in both the receive and transmit directions, and a POSITA would have recognized as much. For example, in the receive direction, *Williams* teaches digital channelizer 150 separates the multi-channel digital signal output by broadband digital transceiver 140 “into baseband digital signals having an I and Q representation for each active channel.” *Id.* ¶ 35. Similarly, in the receive direction, *Williams* teaches “digital array processor 160 can adjust the baseband digital signals received from and for transmission by each antenna element 110 to beamform each active channel.” *Id.* ¶ 37. As I discussed above, “each active channel” in both of these instances corresponds to a single RF carrier/TDM time slot pairing. Therefore, a POSITA would have recognized that the signals digital array processor 160 receives from XMUX 150 are single signals for each time slot and RF frequency.

111. Accordingly, *Williams*’s digital array processor 160 receives digital baseband signals in a time multiplexed manner, where each signal corresponds to an active channel (which in turn corresponds to a single RF carrier/time slot pairing) and operates on those signals on a time-slot-by-time-slot basis.

iii. Claim 3

The apparatus of claim 1, wherein said baseband modulator receives data symbols from a plurality of user channels and supplies to said shared baseband processor

a time-multiplexed stream of modulated digital data symbols from said plurality of user channels.

112. As I discussed above in Section VI.E, symbol-based communication was well-known at the time of the alleged invention of the '141 Patent. In such symbol-based communication schemes, payload data information (i.e., bits) are mapped to varying states of a carrier wave. In the simplest case, such bits are mapped to the presence (representing a “1”) or absence (representing a “0”) of the carrier wave, though more finite distinctions may be employed to transmit symbols representing multiple bits at a time. (Ex. 1022 (Selecting Mixed-Signal Components for Digital Communication Systems)), 11. Such a system, wherein the amplitude of the signal represents the data to be transmitted, is known as “amplitude shift keying,” or “amplitude modulation.” *See Id.*

113. Throughout its disclosure, *Williams* refers to the GSM standard as an exemplary wireless standard on which its system may be implemented. For example, *Williams* repeatedly refers to the 8 time slots in GSM, and teaches a “GSM type access burst[.]” *Williams* ¶¶ 37, 41, 55–56. A POSITA would have known there were different GSM modulation schemes used over the course of its evolution. Further, other modulation schemes were well-known at the time of the '141 Patent's alleged invention. For example, GSM's “EDGE” evolution used 8-PSK to provide higher data rates. (Ex. 1026 (Understanding Offset 8-PSK Modulation for GSM EDGE)), 1. 8-PSK is a modulation scheme which utilizes multiple phase variations to

represent data symbols. *Id.* In M-PSK (i.e., M-Phase Shift Keying), the information to be transmitted is conveyed onto the phase of the carrier. *Id.* In 8-PSK, 8 distinct symbols can be encoded and transmitted, representing 3 bits each. *Id.* at 2. And later systems, such as the 3rd Generation UMTS cellular networks utilize QPSK, which maps two bits per symbol. *See* (Ex. 1009 (3G TS 25.213 version 3.2.0 Release 1999 18 ETSI TS 125 213 V3.2.0 (2000-03))), 18.

114. However, the original GSM standard utilized a far simpler encoding scheme, namely, binary Gaussian Minimum Shift Keying (GMSK), which mapped a single bit per symbol. *See* (Ex. 1027 (Understanding and Enhancing Sensitivity in Receivers for Wireless Applications)), 14 (explaining values of +1 and -1 correspond to higher and lower frequencies in the modulation scheme and each bit has a phase shift of $\pm \pi/2$), 16 (showing E-GSM900 used the GMSK modulation scheme).

115. A POSITA would have understood *Williams* contemplates using the GMSK modulation scheme because of *Williams*'s repeated references to operating in a GSM system. Further, a POSITA would have understood that using such a modulation scheme, *Williams*'s digital array processor 160 would have received a time-multiplexed stream of modulated digital baseband data symbols from the DSP 170 modulators, corresponding to the plurality of user channels. Specifically, a POSITA would have recognized that a “modulator” “modulates” bits into symbols based on a chosen modulation scheme (such as GSM's GMSK). And as I discussed

above in Section X.A.ii, with reference to claim 2, *Williams* teaches the data stream is time multiplexed, and the modulated data exiting DSP 170 corresponds to a plurality of user channels. Thus, the stream of data exiting the modulator (i.e., DSP 170) is a time-multiplexed stream of modulated digital data symbols corresponding to the plurality of user channels.

116. Similarly, as I explained above and in Section VI.E, a POSITA would have been motivated to explore other modulation schemes, such as a PSK scheme (e.g., the 8-PSK scheme described above) or a quadrature phase shift keying (QPSK) system such as that standardized by 3GPP for the 3rd generation UMTS cellular networks. *See* (Ex. 1009 (3G TS 25.213 version 3.2.0 Release 1999 18 ETSI TS 125 213 V3.2.0 (2000-03)), 18. Such systems were likewise well-known at the time of the alleged invention of the '141 Patent, and as such a POSITA would have been well familiar with the modulation schemes embodied in such systems. *See id.*

117. Another modulation scheme a POSITA would have recognized were options to implement in *Williams*'s system would have been the modulation schemes contemplated in *Fulton*. *Fulton* discloses a modulation scheme in which symbols correspond to 2 bits each: "the demodulator 158 can handle data transmissions as short as 6 bits (3 symbols) in length." *Fulton*, 6:25–27. *Fulton* also teaches 9QPR modulation in its preferred embodiment. *See Fulton*, 5:4–6. Such a modulation scheme encodes data on both the sine and cosine (or in-phase and quadrature)

components of a carrier, with symbols corresponding to values of +1, 0, and -1. *Id.*, 7:8–10.

118. For several reasons, a POSITA would have been motivated to implement *Fulton's* 9QPR modulation scheme in *Williams's* wireless communication system. First, *Fulton's* modulation scheme would benefit *Williams's* system in the same way it benefits *Fulton's* system, namely, in increasing computational efficiency and decreasing the number of operations required to transmit the same amount of information. This is because *Fulton's* 9QPR scheme transmits symbols corresponding to multiple bits each, compared to GSM's GMSK modulation which only transmits a single bit per symbol. *See, e.g.*, (Ex. 1028 (Characteristics of Digital Fixed Wireless Systems Below About 17 GHz)), 22 (showing 9-QPR transmits 3 bits per symbol). Further, 9QPR is a form of quadrature partial response (QPR) modulation, which was well-known at the time of the alleged invention of the '141 Patent. *See, id.* at 13–14 (comparing 9-QPR modulation to other well-known modulation schemes, including PSK). Such a change would increase the system's throughput compared to modulation schemes which do not use multi-bit data symbols, since each transmission under a multi-bit modulation scheme would require multiple non-multi-bit-modulated transmissions to transmit the same data. Further, such systems were well-known at the time of the alleged invention of

the '141 Patent. *See, e.g.*, (Ex. 1028 (Characteristics of Digital Fixed Wireless Systems Below About 17 GHz)), 22.

119. A POSITA would have further recognized that *Williams's* system would have benefitted in the same manner as *Fulton's* system in implementing a higher order modulation scheme that modulated larger numbers of bits onto a single symbol. Further, a POSITA would have recognized that *Fulton's* disclosed modulation schemes were one example in which to attain those multi-bit symbol benefits, since *Fulton's* modulation schemes (and their attendant advantages) were well-known in the art at the time of the alleged invention of the '141 Patent. Additionally, as I discussed above in Section X.A.i (in reference to claim [1(d)]), one of *Williams's* stated goals was to provide a more performant and efficient radio system, which such a higher-order modulation scheme would have helped attain. *See Williams* ¶ 6.

120. And as I discussed above, a POSITA would have had a reasonable expectation of success in making the proposed combination given the similarities in *Fulton's* and *Williams's* system architecture, both as explained above and in terms of the signals being processed in the two systems. Thus, in combination with modulation schemes such as 9QPR's well-known nature, such a combination would have been well-within the skillset of a POSITA. Accordingly, a POSITA would have been motivated to implement *Fulton's* symbol-based 9QPR modulation scheme at

all points in *Williams*'s system (i.e., at all points in both transmission and reception, including when input to/output from DSP 170) with a reasonable expectation of success.

iv. Claim 4

The apparatus of claim 3, wherein, for each input digital data symbol, said baseband modulator generates a plurality of modulated digital data symbols in the time-multiplexed stream respectively corresponding to the plurality of antenna elements.

121. As I discussed above in Section VI.B, beamforming is performed by appropriately processing the signals from each antenna element (e.g., through phase and/or amplitude adjustments). *See, e.g.,* (Ex. 1016 (Lo '072)) 1:41–51. In transmission, by controlling the phase and amplitude of the signals sent to each antenna element, the beam direction can be controlled. *Id.* 3:3–7. In beamforming, the same signal (e.g., a symbol) is sent to the entire aperture antenna so that the array can focus the antenna beam along a specific direction in space. *See id.* 1:18–23, 2:3–5, 3:51–55 (receiving a single signal in the receive direction), 4:22–24 (explaining that different signals form beams in different directions). This signal is duplicated for each antenna element, with each antenna element receiving its own phase/amplitude adjustment, such that the multiplied signal (corresponding to duplicates of the same symbol) adds in phase in a given direction and cancel in phase in other directions to create nulls. *Williams* ¶ 10.

122. Therefore, when *Williams* teaches beamforming in digital array processor 160, a POSITA would have understood that *Williams*'s digital array processor 160 is processing the same signal (i.e., the same symbol) multiple times (corresponding to the number of individual elements making up the antenna—four times in *Williams*'s primary embodiment) in order to apply separate and distinct beamforming and calibration adjustments on a per-antenna element basis. This is further supported by the fact that *Williams* teaches separate transmit/receive apparatus chains for each antenna element, each requiring distinct calibration factors which are simultaneously applied with *Williams*'s angular weighting factors (i.e., beamforming adjustments). *Williams* ¶¶ 17, 36–37.

123. *Williams* also teaches that a single baseband modulator generates a plurality of modulated digital data symbols for each input digital data symbol, which in turn correspond to the plurality of antenna elements. *Williams* teaches two embodiments for DSP 170 (i.e., the baseband modulator). In the first, *Williams* teaches “DSPs 170 are associated with specific antenna elements 110[.]” *Williams* ¶ 39. In this embodiment, the DSPs are paired as part of the transmit/receive apparatus chains, and are paired with antenna elements at a 1:1 ratio. In this embodiment, the collection of DSPs 170 will generate multiple copies of a given input digital data symbol, one copy from each DSP to be radiated from the DSP's corresponding antenna element.

124. In the second embodiment, *Williams* teaches “each [DSP board 170] may provide a plurality of digital signal processors per board. For example, 24 digital signal processors may be provided per DSP board 170.... A separate digital signal processor may be dedicated to each channel (timeslot), or a digital signal processor having sufficient processing speed may process multiple channels, such as all eight channels (timeslots) in GSM systems.” *Id.* ¶ 41. In this embodiment, a single DSP 170 contains multiple (up to 24, or 6 times as many DSPs as the 1:1 embodiment above) DSPs and handles all communications for a given timeslot, or may even handle all communications for all channels simultaneously. In this embodiment, a POSITA would have found it obvious for the single DSP handling multiple (or all) channels to generate multiple copies of each symbol for the digital array processor 160 to process. This way, the digital array processor 160 can process an incoming stream of data symbols—on an antenna element-by-element basis—as a time-multiplexed stream of data symbols with one copy of each symbol for each antenna element through which the symbols will be radiated.

v. Claim 7

The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals relating to a plurality of user channels in a time-multiplexed manner.

125. First, a POSITA would have recognized that *Williams*’s plurality of channels (i.e., the 96 channels supported by BTS 100) are user channels. *Williams*

teaches “[u]sing the angle of arrival data determined for mobile users for all active timeslots for each RF carrier[.]” *Williams* ¶ 80. As I discussed above, each of *Williams*’s 96 channels is a distinct combination of a single time slot (8) and RF carrier (12). *See id.* ¶ 41, 75. Therefore, a POSITA would have understood *Williams*’s teaching that users are on active time slots and RF carriers to teach that *Williams*’s disclosed 96 channels corresponding to 12 RF carriers on 8 time slots are user channels.

126. Next, a POSITA would have understood *Williams* to teach complex multiplication of digital baseband signals. *Williams* teaches “[t]hrough application of net weighting factors... digital array processor 160 can adjust the baseband digital signals received from and for transmission... to beamform each active channel.” *Id.* ¶ 37. Further, *Williams* teaches “adjust[ing] the amplitude and phases of the individual [antenna] array currents” by placing “**complex weights**... in the signal path of each antenna element.” *Id.* ¶ 11. A POSITA would have recognized that applying “weights” teaches multiplying the signals by those weights. A POSITA would have further understood that applying “complex weights” entails complex multiplication of the signal by those weights.

127. Further, a POSITA would have understood that digital array processor 160, which applies the weights (i.e., multiplies the signals by the appropriate weight) would contain a multiplier to perform such multiplication. At the time of the alleged

invention of the '141 Patent, such multipliers were well-known, standard components in processors, and were a standard way of performing complex multiplication. For example, Berkeman describes a complex multiplier designed for use in Fast Fourier Transform processors. (Ex. 1029 (A Complex Multiplier with Low Logic Depth)), 2. A POSITA would have been familiar with such complex multipliers, and would have known such implements were a standard component of processors that needed to perform complex multiplication operations.

128. Alternatively, *Fulton* teaches multipliers which operate on complex digital baseband signals, which were of the same well-known type contemplated in the '141 Patent. *Fulton*, 9:40–42 (“digital signals 280 and 281 are scaled by two multipliers 288 and 289 to produce amplified signals 290 and 291”).

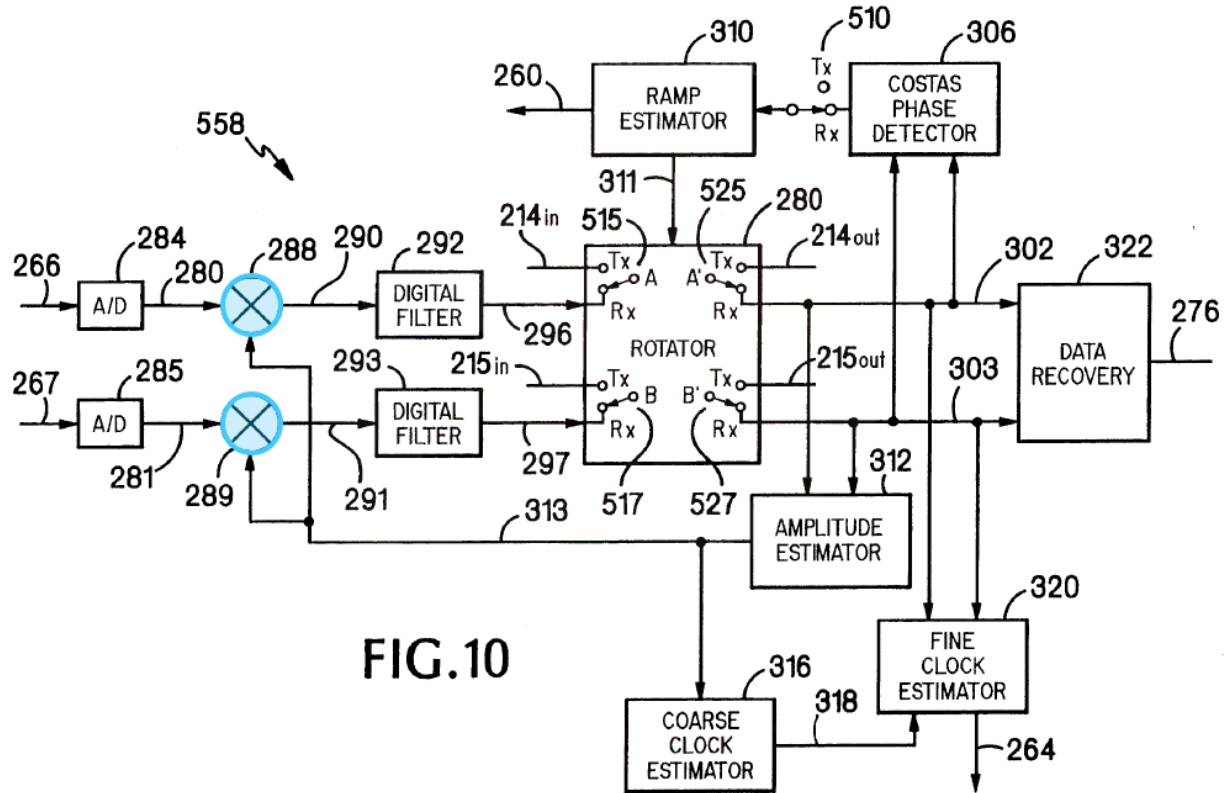


FIG. 10

Fulton, FIG. 10 (annotated). *Fulton*'s multipliers are inversely controlled by amplitude estimate 313 (i.e., a gain control signal), which in turn originates in amplitude estimator 312. *Id.*, 10:5–10. *Fulton*'s multipliers stabilize the amplitudes of signals 290 and 291. *Id.*

129. For the reasons I discussed above in Section X.A.iii, a POSITA would have been motivated to implement *Fulton*'s multipliers because such multipliers were a well-known implement for performing complex multiplication of the type contemplated in both the '141 Patent and in *Williams*.

vi. Claim 8

The apparatus of claim 1, wherein said shared baseband processor comprises a multiplier which performs complex multiplication on digital baseband signals associated with a plurality of individual antenna elements in a time-multiplexed manner.

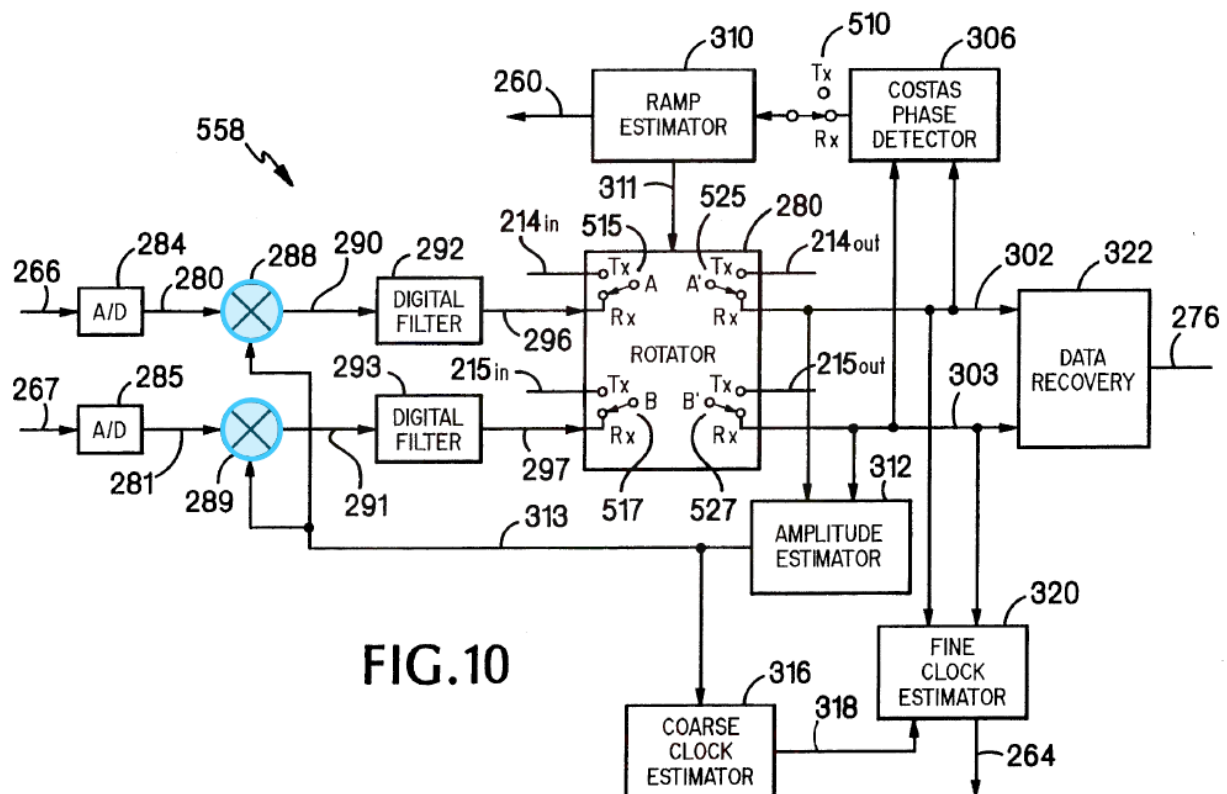
130. As demonstrated above with respect to claims [1(a)] through [1(d)], 2, 3, and 7, *Williams* in view of *Fulton* teaches the apparatus of claim 1 wherein digital array processor 160 (i.e., the claimed shared baseband processor) comprises a multiplier which performs complex multiplication on digital baseband signals in a time-multiplexed manner. *Williams* ¶ 81. *Williams* also teaches the digital baseband signals are associated with a plurality of individual antenna elements. Specifically, *Williams* teaches “digital array processor 160 can adjust the baseband digital signals received from and for transmission ***by each antenna element 110*** to beamform each active channel.” *Williams* ¶ 37. In *Williams*’s disclosed embodiment, the adaptive antenna array is comprised of 4 antenna elements 110. *Williams* ¶ 34. Therefore, *Williams* teaches the digital baseband signals are associated with a plurality of individual antenna elements, as claimed.

vii. Claim 9

[9(a)] The apparatus of claim 1, wherein said shared baseband processor comprises a beam scaling and power control processor configured to generate a time-multiplexed stream of gain control signals for digital baseband signals corresponding to individual antenna elements for each of a plurality of user

channels, the gain control signals jointly accounting for power control and antenna element beam scaling; and

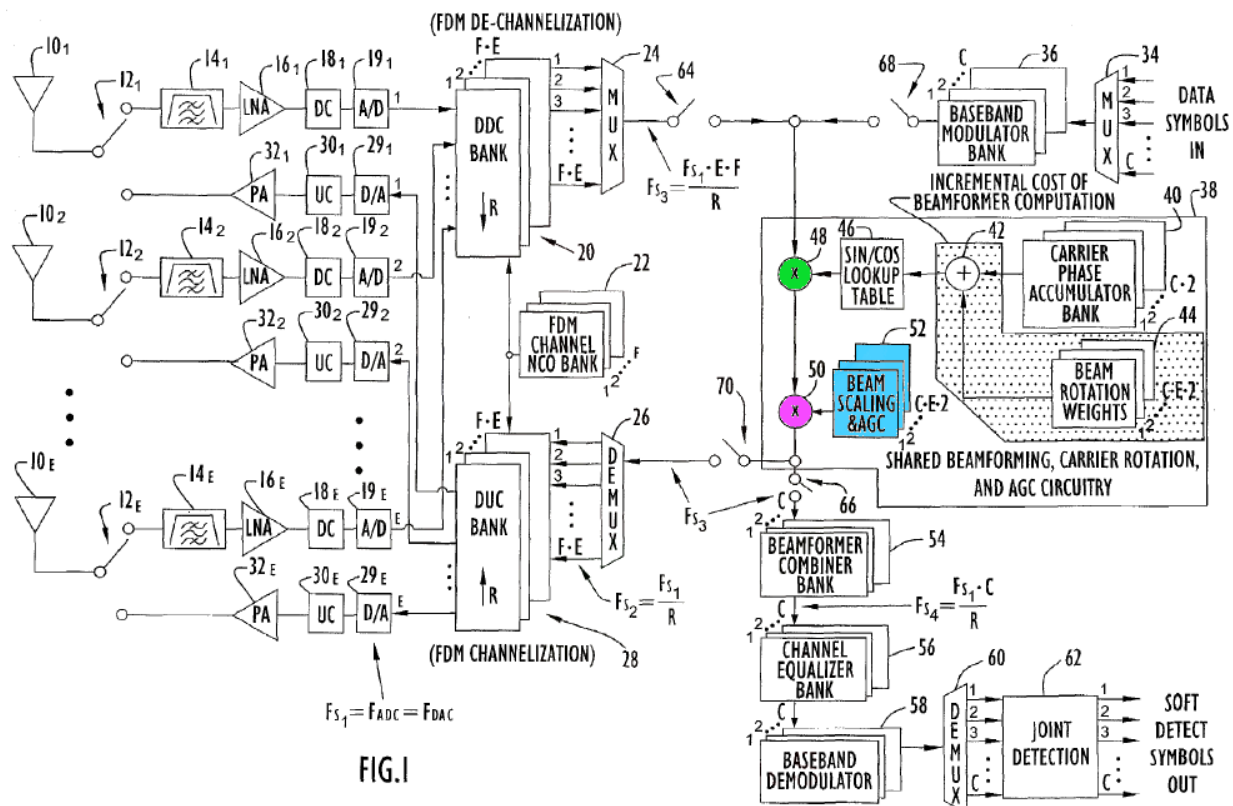
131. *Fulton* teaches “utiliz[ing] an automatic gain control algorithm to maintain a constant signal level over 24 dB of signal level variations.” *Fulton*, 10:3–5. And As I discussed above in Section XI.A.v, *Fulton*’s multipliers 288 and 289 stabilize the amplitude of signals 290 and 291. *Fulton*’s multipliers are depicted in the annotated FIG. 10, below.



Fulton, FIG. 10 (annotated). *Fulton*’s multipliers 288 and 289 perform the disclosed automatic gain control algorithm. Specifically, amplitude estimator 312 “calculates the sum of the squares of signals 302 and 303 from the rotator 300 to generate amplitude estimate 313. The magnitude of the estimate 313 is directed to inverse

gain controls of multipliers 288 and 289, thereby stabilizing the amplitude of signals 290 and 291.” *Id.*, 10:5–10. A POSITA would have recognized amplitude estimate 313 is a form of a gain control signal.

132. The '141 Patent's annotated FIG. 1 from the Petition is reproduced below.



'141 Patent, FIG. 1 (annotated). The '141 Patent explains **complex multiplier 48** outputs a baseband signal to **scalar multiplier 50**. See '141 Patent, 8:20–23. **Scalar multiplier 50**, in turn, adjusts the amplitude of the baseband signal “based on scaling information received from beam scaling and **AGC/power control processor 52**[.]” '141 Patent, 8:20–23. The '141 Patent continues, “automatic gain control adjusts the

signal level [(i.e., the amplitude)] to be within the operational range of downstream processing, simultaneously taking into account the relative scaling of the different antenna elements for proper beamforming.” ’141 Patent, 8:29–34. Further, “the magnitude scaling component of beam weighting is incorporated into the existing AGC or power-control scalar multiplication.” ’141 Patent, 8:50–53.

133. This disclosure closely mirrors *Fulton*’s disclosure of performing automatic gain control to maintain a constant signal level over 24 dB of signal level variations by adjusting the signal amplitude in multipliers 288 and 289. *Fulton*, 10:3–10.

134. As I discussed in detail in Sections X.A.i, X.A.iii, and X.A.v, a POSITA would have been motivated to combine *Williams* and *Fulton* and would have had a reasonable expectation of success in doing so because of the similarity and compatibility of the systems. A POSITA would have been further motivated to implement *Fulton*’s amplitude estimator in *Williams*’s digital array processor 160. First, *Williams*’s digital array processor 160 already performs much of, if not all, the functionality of the claimed beam scaling and power control processor. Specifically, *Williams* teaches “[c]alibration factors are used *to compensate for relative... amplitude variations* that occur when signals traverse the various... receive apparatus chains[.]” *Williams* ¶ 36. And *Williams* teaches applying the calibration factors in digital array processor 160 through the net weighting factor, which

combines the calibration factors and angular weighting (beamforming) factors. *Williams* ¶ 36–37. A POSITA would have recognized this similarly mirrors *Fulton*’s disclosure of performing automatic gain control to maintain a constant signal level over 24 dB of signal level variations by adjusting the signal amplitude in multipliers 288 and 289. *Fulton*, 10:3–10.

135. Furthermore, with respect to beamforming, *Williams* teaches “phases *and amplitudes* of the currents . . . on the antenna array elements can be electronically adjusted such that received signals from a certain direction add in phase, *and maximum gain is achieved in that direction.*” *Williams* ¶ 10. *Williams* also teaches, with respect to power control, “[s]ince mobile subscribers cannot detect signals below a minimum threshold level of power, increasing antenna gain extends the distance a carrier wave can travel.” *Williams* ¶ 7. A POSITA would have again recognized that this similarly mirrors *Fulton*’s disclosure of performing automatic gain control to maintain a constant signal level over 24 dB of signal level variations by adjusting the signal amplitude in multipliers 288 and 289. *Fulton*, 10:3–10. Similarly, a POSITA would have recognized that in combination, *Fulton*’s power control (calibration) and beamforming teachings adjust the antenna beam in given user’s direction, jointly accounting for power control and antenna element beam scaling.

136. Accordingly, a POSITA would have recognized incorporating *Fulton's* amplitude estimator 312 as a straightforward and obvious way to implement *Williams's* described functionality within digital array processor 160, because *Williams's* system discloses much of the same functionality and goals of *Fulton's* system. Furthermore, a POSITA would have recognized *Fulton's* amplitude estimator 312 would provide the same benefit in *Williams's* system as it does in *Fulton*, namely, providing inverse gain control to keep the signal amplitude within a given level.

137. A POSITA also would have had a reasonable expectation of success in making the proposed combination for much the same reasons. Specifically, a POSITA would have had a reasonable expectation of success due to the similarity of *Fulton's* amplitude estimator 312's amplitude (power and gain) scaling, and *Williams's* digital array processor's amplitude scaling. Further, since amplitude estimator 312 is already a sub-component of a larger processing assembly, namely, continuous data demodulator 558, a POSITA would have understood that it could be incorporated into *Williams's* similar digital array processor 160, especially in light of the existing combination contemplated above in Sections X.A and XI.A.i. Specifically, a POSITA would have had a reasonable expectation of success in adding further, common, well-known components from *Fulton's* continuous data demodulator to 558 since the above combinations already incorporate portions of

Fulton's continuous data demodulator 558 into *Williams's* digital array processor

160. Accordingly, the proposed combination would have been straightforward to a POSITA and would have yielded the predictable results described.

[9(b)] a multiplier configured to adjust amplitudes of a time-multiplexed stream of digital baseband signals corresponding to the plurality of user channels in accordance with the gain control signals.

138. As I discussed above in Section X.A.vi ([9(a)]), a POSITA would have recognized amplitude estimate 313 is a gain control signal, since it controls the amplitude adjustment (i.e., the gain adjustment) of multipliers 288 and 289.

139. And as I discussed above in Section X.A.vi ([9(a)]), a POSITA would have been motivated to incorporate *Fulton's* amplitude estimator 312 into *Williams's* digital array processor 160, and would have had a reasonable expectation of success in making the proposed combination because such multipliers were well-known, standard components. Furthermore, a POSITA would have been motivated to incorporate one or more of *Fulton's* accompanying multipliers 288 and 289, since it would have allowed incorporating *Fulton's* full gain control (amplitude scaling) system into *Williams's* digital array processor 160.

viii. Claim 18

The apparatus of claim 1, wherein said apparatus employs time division multiple access (TDMA) to transmit and receive signals.

140. As I discussed above, *Williams* teaches 96 channels supported by 12 RF carriers and 8 time slots. *Williams* ¶ 41. TDMA is a well-known method of

multiple access in which the available radio spectrum is divided into time slots, and time slots differentiate users. (Ex. 1027 (Understanding and Enhancing Sensitivity in Receivers for Wireless Applications)), 7. *Williams* also repeatedly teaches operating on the digital baseband signals per time slot. *See, e.g., Williams* ¶¶ 36–37, 39, 41, 80–81. *Williams* even expressly refers to these time slots “TDMA time slots[.]” *Id.* ¶ 75. Additionally, *Williams* teaches the disclosed system is “multiple access[.]” Specifically, *Williams* teaches determining angle of arrival data “for mobile users for all active timeslots for each RF carrier in a TDM system[.]” *Id.* ¶ 80. As discussed above, *Williams*’s users are allocated channels, which in turn correspond to a given RF carrier and time slot. *See id.* ¶ 41. A POSITA would have recognized that in a situation in which multiple users are assigned separate channels, the channels may correspond to different timeslots. Indeed, in situations of more than one but up to eight users or more on separate channels but using the same RF carrier, each user must be allocated a time slot separate and distinct from the remaining users, since there are 8 time slots to allocate as separate channels. Similarly, in the case of 96 concurrent users (i.e., a user on every channel), each time slot would be filled with 12 users on the 12 RF carriers, and the groups on each RF carrier would be separated by time slot. Accordingly, a POSITA would have recognized *Williams* teaches TDMA.

ix. Claim 19

The apparatus of claim 1, wherein said apparatus employs frequency division multiple access (FDMA) to transmit and receive signals.

141. As I discussed above, *Williams* teaches 96 channels supported by 12 RF carriers and 8 time slots. *Williams* ¶ 41. FDMA divides the frequency spectrum into narrow bandwidth channels where each user is assigned a specific frequency or frequencies for transmission and reception. (Ex. 1027 (Understanding and Enhancing Sensitivity in Receivers for Wireless Applications)), 9. *Williams* “assum[es] multiple frequency channels are active at any given instant[.]” *Williams* ¶ 34. Further, *Williams* repeatedly teaches operating on the digital baseband signals per RF carrier (i.e., per frequency channel). *See, e.g., id.* ¶¶ 36–37, 39, 80.

142. Further, *Williams* teaches the disclosed system is “multiple access[.]” Specifically, *Williams* teaches determining angle of arrival data “for mobile users for all active timeslots for each RF carrier in a TDM system,” (i.e., for each user channel). *Id.* ¶ 80. As discussed above, *Williams*’s users are allocated channels, which in turn correspond to a distinct pairing of an RF carrier and time slot. *See id.* ¶ 41. A POSITA would have recognized that in a situation in which multiple users are assigned separate channels, channels may correspond to different frequencies. Indeed, in situations of 13 users or more on separate channels, it is not possible to allocate all 13 users in the same time slot since there are only 12 RF carriers to allocate. Similarly, in the case of 96 concurrent users (i.e., a user on every channel),

each frequency would be filled with 8 users in the 8 time slots, and the groups in each time slot would be separated by frequency. Accordingly, a POSITA would have recognized *Williams* teaches FDMA.

x. Claim 20

The apparatus of claim 1, wherein said apparatus is a field programmable gate array (FPGA).

143. As I discussed above in Section X.A.i ([1(d)]), a POSITA would have been motivated to combine *Williams* and *Fulton* to arrive at the apparatus of claim 1. For a number of reasons, a POSITA would also have been motivated to implement the claimed apparatus as an FPGA pursuant to *Trott*.

144. *Trott* teaches a base station apparatus to diminish co-channel and inter-channel interference in wireless communications systems through using adaptive array antennas. *Trott*, 5:13–15, 5:49–51. *Trott* teaches each of the processor elements may be “a digital signal processor, general purpose microprocessor, **FPGA**, ASIC, a combination thereof, etc.” *Trott*, 15:44–46. A POSITA would have been familiar with such processing options, including FPGAs, and would have been motivated to implement the apparatus of claim 1 as a field programmable gate array for the numerous benefits associated with such devices, including the ability to change or tweak the apparatus’s functionality after manufacturing. An FPGA provides well-known benefits such as being easily and rapidly reprogrammable and reconfigurable to incorporate bug fixes or upgrades. See (Ex. 1030 (The Roles of FPGAs in

Reprogrammable Systems)), 3. This reconfigurability brings the benefit of supporting updates to function with new communications standards without the need for new hardware or hardware redesign. Accordingly, a POSITA would have been motivated and found it obvious to implement the apparatus of claim 1 as a field programmable gate array (FPGA) as claimed. Given the well-known benefits and ubiquity of such systems, a POSITA would have had a reasonable expectation of success in making the proposed combination. Accordingly, a POSITA would have been motivated to implement the apparatus arrived at from combining *Williams* and *Fulton* as a field programmable gate array.

xi. Claim 21

The apparatus of claim 1, wherein the apparatus is implemented via a very large scale integration (VLSI) circuit or an application specific integrated circuit (ASIC).

145. As I discussed above in Section X.A.i ([1(d)]), a POSITA would have been motivated to combine *Williams* and *Fulton* to arrive at the apparatus of claim 1. And as I discussed above with reference to Claim 20, a POSITA would have been further motivated to implement the combination of *Williams* and *Fulton* as an FPGA pursuant to *Trott*, recognizing that FPGAs were one of a small number of options for such and, in making such a combination, realizing the well-known benefits of FPGAs. The same logic would have motivated a POSITA to implement the combination of *Williams* and *Fulton* as an ASIC pursuant to *Trott*. Namely, as *Trott*

recognizes, ASIC was another option among a handful of recognized technologies with which to implement systems of this sort. Accordingly, a POSITA would have been motivated to utilize an ASIC (rather than an FPGA) in order to realize the well-known benefits of an ASIC such as lower costs and greatly simplified designs compared to non-integrated components. (Ex. 1031 (Cramming More Components onto Integrated Circuits)), 2. Indeed, the decision of whether to prioritize reconfigurability by using an FPGA or lower cost by using an ASIC is a design decision that a POSITA would have been familiar with. Further, given the well-known benefits and ubiquity of such systems, a POSITA would have had a reasonable expectation of success in making the proposed combination. Accordingly, a POSITA would have been motivated to implement the apparatus arrived at from combining *Williams* and *Fulton* as an application specific integrated circuit.

xii. Claim 22

The apparatus of claim 1, wherein said apparatus is a modem.

146. A POSITA would have been familiar with modems, and would have known that “modem” is a portmanteau of “modulator” and “demodulator.” Because *Williams* teaches DSP 170 modulates and demodulates signals, a POSITA would have recognized that *Williams*’s system is a modem.

XI. CONCLUSION

I hereby declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct, and that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I understand that willful false statements are punishable by fine or imprisonment or both. *See* 18 U.S.C. § 1001. If called to testify as to the truth of the matters stated herein, I could and would testify competently.

Date: April 3, 2023

Respectfully submitted,



Digitally signed
by Zhi Ding
Date: 2023.04.03
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Dr. Zhi Ding, Ph.D.