

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

NOKIA OF AMERICA CORPORATION, AT&T SERVICES, INC., T-MOBILE USA, INC.

Petitioners,

v.

WOODBURY WIRELESS LLC

Patent Owner.

In re *Inter Partes* Review of:
U.S. Patent Nos. 9,496,930
IPR2025-00048

**DECLARATION OF DR. MARK P. MAHON UNDER 37 C.F.R.
§ 1.68 IN SUPPORT OF PETITION FOR INTER PARTES REVIEW**

By:

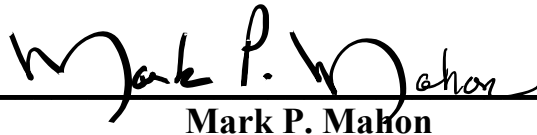

Mark P. Mahon

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I, Dr. Mark P. Mahon declare as follows:

I. INTRODUCTION

1. I have been retained by Duane Morris on behalf of Petitioners as an independent, technical expert consultant in this proceeding before the United States Patent and Trademark Office (USPTO).¹ I have been ask to consider whether certain references disclose or suggest the limitations found in U.S. Pat. No. 9,496,930 (“’930 patent”) which I reference as the “challenged patent” in this declaration as discussed in detail below. My opinions are set forth below. In a separate declaration in IPR2023-01364 on behalf of different Petitioners, I have addressed U.S. Pat. No 10,211,895 (the “’895 patent”) which is related to the ‘930 patent.
2. I am being compensated at my rate of \$500 per hour for my services. No part of my compensation depends on my opinions or the outcome of this proceeding. I have no financial interest in any of the parties to this proceeding.
3. The ’930 and ‘895 patents have largely the same specification with some limited exceptions including: (1) the ’930 Abstract and Summary of the Invention were added long after the priority application was filed (see below) and do not exist in the ‘895 patent; (2) the ‘895 Abstract and Summary of the Invention were added in the

¹ Where appropriate, I refer to exhibits that I understand are to be attached to the petition for Inter Partes Review of the challenged patent.

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'895 patent filing in 2017; and (3) the Figures of the '895 patent were altered in or around 2017 to recite content that was not present in the priority application.

4. In my analysis below, I generally refer to the '930 patent for citations unless otherwise noted.
5. Unless otherwise indicated, the emphasis in quotations has been added.

II. BACKGROUND AND QUALIFICATIONS

6. My complete qualifications and professional experience are described in my Curriculum Vitae, a copy of which can be found in Appendix B to this Declaration.
7. The following is a brief summary of my relevant qualifications and professional experience
8. I am a Teaching Professor in the School of Electrical Engineering and Computer Science at Pennsylvania State University, University Park, PA ("Penn State" or "PSU"). I have worked on telecommunications and wireless networks, including Z-Wave, Bluetooth, Zigbee, Wi-Fi, NFC, AMPS, IS-95, CDMA2000, GSM, EDGE, UMTS/WCDMA, LTE, and 5G cellular systems since 1988.
9. I received my B.S. in Electronics Engineering from the University of Scranton in 1987. I received my M.S. in Electrical Engineering and Ph.D. in Acoustics from Penn State in 1991 and 2001, respectively.
10. In 1988, after I received my bachelor's degree, I joined the Central Intelligence Agency (CIA) while pursuing my M.S. degree at Penn State part-time. My first job

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at the CIA involved designing and testing systems to automatically capture and characterize telecommunication signals and emissions from various wireless and computer networking devices.

11.I returned to Penn State in early 1990 to pursue graduate research full-time and complete my M.S. degree. My graduate research work focused on wideband beamforming and adaptive signal processing. After completing my M.S. degree in EE in 1991, I accepted a full-time faculty research position at the Applied Research Lab at PSU, primarily working on classified programs, and began working on diverse radio frequency and acoustic sensor systems including wireless communications and small wireless networks for acoustic tracking, source localization, and feature extraction.

12.I began pursuing my Ph.D. part-time in 1993 while continuing my faculty research position. In 1997, as part of my faculty research position, I began working on classified programs focused on mathematical analytical modeling of cellular communication networks and the development of hardware and software systems to test against cellular networks. My role was to develop the algorithms and write the code running on a specially developed embedded system. For this work, I received a letter of recognition as the “genius behind the VELA software algorithms” from the Director of National Reconnaissance Office (NRO) Systems Engineering and Technology Office. As part of this same work, I was extensively involved in protocol

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and signaling analysis as well as researching model-specific performance and unique functional characteristics associated with individual mobile devices. The work involved testing dozens of handsets from many manufacturers in controlled and real-world environments against network simulators and live operational networks for each research project.

13. In 2000 my research extended into utilizing non-orthogonal wavelets for improving detection and localization of cellular handsets from high altitude sensor systems. In 2001, I completed my Ph.D. and my research focused on the utilization of advanced communication signals for wideband characterization and remote sensing of propagation channels.

14. Beginning in 1997 my cellular communications research work focused on CDMA, GSM, EDGE, UMTS, LTE, and 5G cellular systems primarily under grants sponsored principally by the Department of Defense. This classified research work required 3GPP protocol analysis and development of real-time embedded hardware and software systems capable of interacting with cellular networks and cellular handsets. A large portion of my work was directed at architectures, protocols, software, and signaling.

15. I have been working on classified projects since 1988. Before 1998, because the work was not deemed highly classified, I was able to publish eight journal and conference papers prior to 2000. Between 1999 and 2015, however, I was allowed to publish

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only one article in an unclassified symposium and published and presented about a dozen articles in classified settings. This is because during this period, the vast majority of my research was highly classified. As a result, nearly all of my research results were summarized in classified reports and not available to the general public. Further, because the U.S. government owns any intellectual property resulting from the sponsored research work, I did not pursue or file patent applications.

16. In 2015, I transferred to the School of Electrical Engineering and Computer Science at Penn State as a teaching faculty member. In that role, I have continued teaching graduate and undergraduate courses, guiding Ph.D. and M.S. students in communication and mobile networking (including LTE and 5G cellular networks), and pursuing research in this and related areas. Since 2015, I have been an author on nine refereed papers as listed in my curriculum vitae (CV) (attached as Exhibit A).
17. Because of my decades of research and my continuing work at Penn State, I have intimate knowledge of telecommunication networks, including the technology involved in the patents in this case. I have been highly recognized as an expert in such systems within the research community. I was recognized twice by the National Reconnaissance Office with commendation letters for work dealing with detecting cellular signals in low signal to noise ratio environments. The U.S. government awarded me over \$12M in grants between 2003 and 2015 for projects focused on

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mobile communication devices and networks, in which I served as a Principal Investigator (PI), Co- PI, and/or technical lead.

18. Additionally, during my research career, I interacted extensively with computer scientists and engineers responsible for the design, development, and testing of telephony and data networking systems and testbeds. As a research faculty member, I oversaw engineers and computer scientists that executed many joint projects with development organizations. These interactions exposed me to a wide range of computer scientists and engineers working on telecommunication network technologies. Since 2011, I have been teaching undergraduate and graduate classes in communication and mobile networking and am familiar with the curricula being taught to electrical engineers and computer scientists. The interactions with a wide range of computer scientists and engineers working on telecommunication network technologies and the familiarity with the classes taught to electrical engineers and computer scientists have allowed me to have a good understanding of the level of skills possessed by a person of ordinary skill in the field of cellular technology.

19. I have extensive experience with mobile networks in general and LTE and 5G specifically. While most of my research efforts between 1998 and 2015 were highly classified, I can state that they included detailed investigation of network architectures, signaling, and functional behavior. A typical research effort would involve studying 3GPP, 3GPP2, IEEE, and other protocol standards to fully

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comprehend all aspects of L1, L2, and L3 requirements including timing, bit-level construction of the control and user plane messages, and timing characteristics for a given standard as well as functional behavior of network components and user equipment.

20. From 2006 through 2015 my research focused specifically on LTE. My research continues to this day, although I am no longer operating in a classified environment. During this time, I investigated the performance and functional differences of many varied network and handset devices to see how differing signaling and hardware configurations (including MIMO) and environmental factors influenced the behavior of user equipment in a given network environment. This included how diversity techniques (transmit and receive), synchronization, timing, and signal to interference plus noise ratio (SINR) for a given device would affect specific functional aspects including elements of the receiver structure, decoding and demodulation performance, calculation of parameters used by the device for making decisions and deriving parameters reported to the network.

21. As part of my research work, I built several custom CDMA, GSM, UMTS, and LTE platforms that implemented specific network-side and user equipment-side functionality including custom signal generation and processing structures, particularly the signal processing chains on both the transmit and receive sides. This equipment was developed using network simulation hardware in a laboratory

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environment and was later tested with corresponding networks in both controlled and fully operational environments. Implementing the transmit and receive chains for custom built protocol-enabled equipment required me to gain an intimate understanding of the relevant 3GPP protocol specifications and the underlying structures. Since 2015, I have been primarily focused on guiding graduate students pursuing research including using code domain non-orthogonal multiple access (NOMA) combined with MIMO sparse coding multiple access to minimize latency and maximize user density in grant free Internet of Things (IoT) environments. Additionally, I am guiding my graduate students in pursuing research in optimized distributed processing algorithms, implementation of block chain coding techniques to improve handover security, and edge computing resource allocation in 4G (LTE)/5G (NR) networks.

22. Much of the classified research work I performed also led to similar approaches for other wireless protocols including IEEE 802.11 and 802.15 (e.g., Zigbee, Bluetooth, and UWB), HART, and other short-range standards as well as HF radio and Wi-MAX.

III. MATERIALS REVIEWED

23. The opinions contained in this Declaration are based on the documents I reviewed, my professional judgment, as well as my education, experience, and knowledge regarding cellular networking systems.

24. I have reviewed all of the documents referenced in this Declaration. I have reviewed the challenged patent and its prosecution history. I have listed the reviewed materials in in Appendix A to this Declaration.

IV. LEGAL STANDARDS

25. I am not an attorney and offer no legal opinions. My analysis and opinions are based on my expertise in this technical field and on the instructions that counsel has given me for the legal standards relating to patentability as outlined in the rest of this section. I have applied these principles in reaching the opinions set forth herein do not provide any legal opinions in this Declaration. I have been informed and understand that certain legal standards are to be applied by technical experts in forming opinions regarding the meaning and validity of patent claims.

26. I understand and the standard that I have used throughout my declaration is that, in this proceeding, a patent claim may be deemed unpatentable as “anticipated” if it is shown by a preponderance of the evidence that each and every feature of the claim is found in a single prior art reference or rendered “obvious” if, in view of a prior art reference or a combination of prior art references, it would have been obvious to a person of ordinary skill in the art (“POSITA”) at the time of the invention, taking into account the following four issues: (1) the scope and intent of the prior art, (2) the differences between the prior art and the claim under consideration, (3) the level of ordinary skill in the art, and (4) any secondary evidence bearing on obviousness.

27. Counsel has informed me that legal principles regarding unpatentability of a claim due to obviousness have been addressed by the U.S. Supreme Court and that, while not absolute, the principles relating to a “motivation,” “suggestion,” or “teaching” in the prior art to combine references are useful in analyzing whether an invention is obvious. Counsel has also informed me that the suggestion or motivation may be either explicit or implicit and may come from knowledge generally available to a POSITA, from the nature of the problem to be solved, or from a combination of these factors. The test for an implicit motivation, suggestion, or teaching is what the combined teachings, knowledge of a POSITA, and the nature of the problem to be solved as a whole would have suggested to those of ordinary skill in the art. The analysis is not focused on the specific problem solved by the invention, but the general problem that confronted the inventor prior to the invention.

28. Counsel has further informed me that the U.S. Supreme Court has clarified that additional principles may also be applied in such an analysis. Some of those principles are set forth below.

29. I have been informed by counsel that it is no longer always required to present evidence of an explicit teaching, suggestion, or motivation to combine prior art references for purposes of determining whether an invention is obvious. Prior art can be combined based on several factors including: an express teaching, suggestion, or

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motivation from the prior art itself, or from a reasoned explanation of an expert or other witness.

30. I have been informed that a patent claim composed of several elements is not proved obvious merely by demonstrating that each of its elements was independently known in the prior art. In evaluating whether such a claim would have been obvious, I may consider whether there is a reason that would have prompted a person of ordinary skill in the field to combine the elements or concepts from the prior art in the same way as in the claimed invention.

31. To determine whether there was an apparent reason to combine the known elements in the way a patent claims, it will often be necessary to look to interrelated teachings of multiple pieces of prior art, to the effects of demands known to the design community or present in the marketplace, and to the background knowledge possessed by a POSITA. Also, in determining obviousness, one must be aware of the distortion caused by hindsight bias and be cautious of arguments relying upon hindsight reasoning. An obviousness argument cannot be sustained by mere conclusory statements. Instead, it must be some articulated reasoning with some rational underpinnings to support the legal conclusion of obviousness.

32. In an obviousness analysis, it is my understanding that there are “secondary considerations” that should be analyzed if they apply. I am told that these considerations include (a) whether the prior art teaches away from the claimed

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invention, (b) whether there was a long felt but unresolved need for the claimed invention, (c) whether others tried but failed to make the claimed invention, (d) skepticism of experts, (e) whether the claimed invention was commercially successful, (f) whether the claimed invention was praised by others, and (g) whether the claimed invention was copied by others.

33.I have also been informed that in order for evidence of secondary considerations to be significant, there must be a sufficient relationship between the claimed invention and the evidence of secondary considerations. I understand that this relationship serves to provide a link between the merits of the claimed invention and the evidence of secondary considerations provided.

34.I have been informed by counsel that the Board construes claims according to the so-called “Phillips” standard. Under the Phillips standard, terms in a claim are given their ordinary and customary meaning, consistent with the patent’s specification, as understood by a POSITA. I have been informed by counsel that what is to be considered includes the claims, the patent specifications and drawings, and the prosecution history, including any art listed by the examiner or the Applicant. I have been informed by counsel that information external to the patent, including expert and inventor testimony and unlisted prior art, are to be considered if ambiguities remain. However, expert testimony may be useful in helping to explain the technology.

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35. I have been informed and understand that a patent claim is not patentable as obvious if the differences between the patent claim and the prior art are such that the claimed subject matter as a whole would have been obvious at the time the claimed invention was made to a person having ordinary skill in the relevant art.

36. In analyzing the relevance of the differences between the claimed invention and the prior art, I have been informed that I must consider the impact of such differences on the obviousness or non-obviousness of the invention as a whole, not merely some portion of it. The person of ordinary skill faced with a problem is able to apply their experience and ability to solve the problem and also look to any available prior art to help solve the problem.

37. I have been informed and understand that there are recognized, exemplary rationales for combining or modifying references to show the obviousness of claimed subject matter. Some of the rationales include the following: combining prior art elements according to known methods to yield predictable results; simple substitution of one known element for another to yield predictable results; use of a known technique to improve a similar device (method or product) in the same way; applying a known technique to a known device (method or product) ready for improvement to yield predictable results; choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; known work in one field of endeavor may prompt variations of it for use in either the same field or a different one based on

design incentives or other market forces if the variations are predictable to one of ordinary skill in the art; and some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art teachings to arrive at the claimed invention.

V. LEVEL OF ORDINARY SKILL

38. It is my understanding that a person of ordinary skill in the art (“POSA” or “POSITA”) is a hypothetical person who is used to analyze the prior art without the benefit of hindsight. I have been instructed that the level of ordinary skill may be reflected by the prior art of record, and that a person of ordinary skill in the art to which the claimed subject matter pertains would have the capability of understanding the scientific and engineering principles applicable to the pertinent art. I have been instructed that there are multiple factors that may be considered in determining the level of ordinary skill in the art may include: 1) type of problems encountered in the prior art; 2) prior art solutions to those problems; 3) rapidity with which innovations are made; 4) sophistication of the technology; and 5) educational level of active workers in the field. I also understand that a POSITA is also a person of ordinary creativity, not an automaton. They would be able to fit the teachings of multiple patents together like a puzzle and have the capability of understanding the scientific and engineering principles applicable to the pertinent art.

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39. I have been asked to provide a definition for the level of ordinary skill in the art in the field of the challenged at the time the priority application was filed. As stated in the challenged '960 patent, "Embodiments of the present invention relate to wireless communication using Multiple Input Multiple Output ("MIMO") antennas and methods of operation." EX-1001, 1:24-26.

40. In my opinion, a POSITA as of the claimed priority date of the challenged patent would have had (1) the equivalent of an undergraduate degree in Electrical Engineering or a related field; and (2) at least four years of experience in design, development, and/or testing of telecommunication systems. In a similar vein, a POSITA would also have familiarity with the wireless standards and protocols related to data transmission and network management. It is also my opinion that more education could supplement practical experience or vice versa. For example, such knowledge could be acquired by a mixture of training and work experience such as a Master's degree in Electrical Engineering with less work experience.

41. I have also been advised that, to determine the appropriate level of a POSITA, the following factors may be considered: (1) the types of problems encountered by those working in the field and prior art solutions thereto; (2) the sophistication of the technology in question, and the rapidity with which innovations occur in the field; (3) the educational level of active workers in the field; and (4) the educational level

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of the inventor. When forming my opinions herein, I analyzed and applied the prior art and claim constructions from a POSITA's perspective at the invention's time.

42. I understand that a POSITA is presumed to have knowledge of all references that are sufficiently related to one another and to the pertinent art and to have knowledge of all arts reasonably pertinent to the particular problem that the claimed invention addresses.

43. All of my opinions in this declaration are from the perspective of a POSITA, as I have defined it above and during the relevant time frame, *i.e.*, on or around date of the priority application. During this time frame, I possessed at least the qualifications of a person of ordinary skill in the art, as defined above, and I am capable of addressing the issues from the perspective of such a person. My opinions in this declaration reflect how a POSITA would have understood the claims and the specification of the challenged patent, the prior art to the patent, and the state of the art on or around the priority date.

44. This paragraph intentionally left blank.

45. This paragraph intentionally left blank.

VI. TECHNICAL BACKGROUND AND STATE OF THE ART

46. The following section describes aspects of the state of the art for wireless systems as of the date of the priority application. This description is in addition to the description of the specific prior art references discussed in the “Overview of the Prior Art” section below.

A. Cellular And Wireless Technology

47. Mobile communications were originally developed for military purposes. The idea transitioned to the commercial world primarily through the development of cellular communication systems which were deployed beginning in the early 1980s. In mobile cellular telecommunications systems, user equipment (often abbreviated “UE”) transmit signals to and receive signals from a network of base stations. Over the past 40 years, mobile communication technologies have advanced tremendously with significant new developments appearing approximately every 10 years. To distinguish among the significant evolutions that have occurred over time, mobile communication technologies are generally divided into generations via industry consensus and is typically associated with a new air interface and network architecture. The first generation (1G) analog transmission technology emerged in the 1980s, followed by second generation (2G) digital systems in the early 1990s, which were followed by third generation (3G) networks and fourth generation (4G)

systems, culminating with the most recent fifth-generation (5G) of cellular technology, which is also called new radio or “NR.”

48. In 1998, the Third-Generation Partnership Project (3GPP) was formed as a consortium of several national and regional standardization organizations, manufacturers, operators, and market organizations. Since its formation, 3GPP has prepared the technical specifications for 3G Wideband Code Division Multiple Access or “WCDMA,” 4G Long Term Evolution or “LTE,” and 5G NR.

49. In what follows, I will provide an overview of digital communications and packet switched networks, wireless LANs and cellular telephony. These technologies are relevant to the accused system and the asserted claims.

B. Digital Communications and Packet Switched Networks

50. A digital communication system supports the transmission and reception of information that has been represented using binary signals - strings of zeros and ones.² If the original information is analog - a voice or an image, for example - then the transmitter will first have to digitize the image. In order to reproduce the transmitted information at the receiving end, the receiver must know how to interpret

² I note that some systems, such as FAX machines, use signal sets with hundreds to thousands of possible values, as opposed to just zeros and ones. Such systems are digital in that they have discrete signals, as opposed to the continuously varying analog systems.

the received bits. In the case of digitized voice, for example, the receiver must know how to break up the stream of bits into 8-bit blocks, so that those blocks can be used to create a signal with the appropriate amplitude at the appropriate time. Digital systems make this possible by organizing the transmitted bits into "packets."³

51. Packets are contiguous collections of bits in which the position of the bit within the packet indicates how the bit is to be interpreted. Figure A below shows a generic packet that has been divided up into "fields." If one knows the packet format, one can partition a string of bits into the appropriate fields and interpret the bits accordingly.

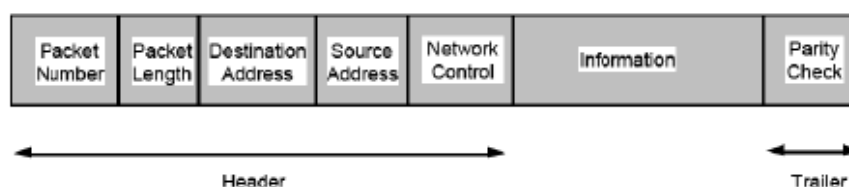


Figure A: A Generic Packet

52. The "Information" field in the packet in Figure A represents the actual message - the voice or image that is being transmitted. The rest of the fields of the packet constitute "overhead" - additional information that the network uses to reliably transfer the packet from its source to its destination.

53. Packets are self-contained in that they contain all of the information that is needed to get the packet through the network. The packets that make up a message may thus

³ Some systems use the term "frames," while others use "cells." There are distinctions than can be drawn between frames, cells, and packets, but they are not necessary here. I will use the term "packet" in a general sense.

take different routes between source and destination. More importantly, packets from different messages may share the same wire. In the network in Figure B, packets being sent from A and D are labeled "1", while those from B to C are labeled "2". Note that 1's and 2's can share the same path. The switches in this network must thus switch from packet to packet, as opposed to creating a circuit and leaving it in place for an entire conversation. Such networks are called "packet-switched" networks. The Internet consists of many interconnected packet-switched networks.

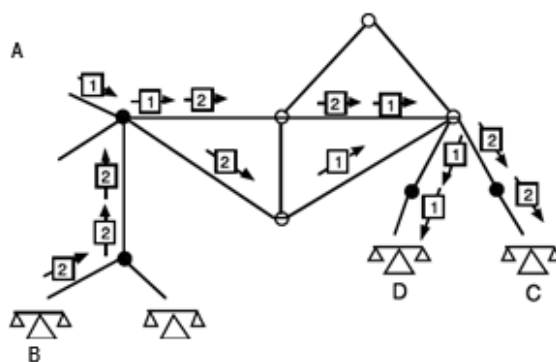


Figure B: A Packet-Switched Network

C. Local Area Networks (LANs)

54. A local area network generally consists of a group of communication nodes in a given, geographically confined, area that share a common communication medium. The nodes (i.e. "computers and/or devices") may be remote terminals, computers, printers, sensors, or some other, similar device, while the communication medium may consist of a single wire, a collection of wires, or one or more radio channels. Given the restrictions of LAN technology, a given LAN may interconnect the

computers on the floor of a building or possibly several floors; to cover larger distances requires switching and, potentially, wide area networking technologies.

55. One of the principal problems arising with local area networks is the need to share the common communication resource. Scheduling is one means of doing so, but this can be extremely inefficient if it isn't known when or how often each user will need to transmit. Polling is a second means. Polling is a protocol in which nodes may only transmit when expressly asked to do so by a controlling node. "Random access" algorithms provide yet another option. In random access systems, individual users request and use network resources as needed. A small network can thus support a very large number of users as long as those users only need the resources a small percentage of the time.

56. There have been a variety of random access algorithms developed over the years, beginning with the ALOHA system, developed at the University of Hawaii in the late 1960's and early 1970's. In the ALOHA system users transmit whenever they wish. If two users transmit at the same time, they are said to have "collided." Both users then wait a random amount of time and then retransmit. The "random" element is important, as the goal is to have the two users select different retransmission times, thus avoiding another collision.

57. In the mid 1970's a more sophisticated approach, Carrier Sense Multiple Access (CSMA) was developed. In CSMA, the network users listen to the medium before

transmitting. If the medium is in use, then the users wait and transmit at a later time.

The simple act of listening before talking greatly improves the performance of the random access system.

58. Perhaps the best known of the CSMA system is Ethernet (often referred to by the name of the associated standard, 802.3). In Ethernet local area networks, the users share a common collection of wires. The users may transmit whenever they wish, but before each transmission, the users must listen to the channel. Ethernet also uses collision detection (CD), and is generally referred to as a CSMA/CD technology. Even with carrier sensing, there may still be collisions due to time delays on the channel. In CSMA/CD protocols, once the users realize that they have collided, they stop transmitting immediately. This allows other users to use the channel. Ethernet is now standardized, though there are many versions. The most important version is the IEEE 802.3 standard for local area networks.

59. There are many other networking technologies available for the creation of local area networks. While it is possible to join a pair of Ethernet networks, for example, to form a larger network, it is generally not possible to simply connect two networks that use different networking technologies and have them function properly. A given networking technology is like a mono-lingual speaker. If two different networks are to communicate, some form of translation is necessary. For example, 802.11 uses a

different packet structure than a 3G cellular network. The two cannot communicate directly.

D. An Overview of 802.11 Local Area Networks

802.11 is a wireless LAN standard that was developed by the Institute of Electrical and Electronic Engineers (IEEE) in the 1990's. 802.11 allows for two different types of networks: independent and infrastructure. In independent networks, wireless terminals, or stations, communicate directly with each other. Figure C (taken from the 802.11 specification) shows two independent networks, or Basic Service Sets (BSSs). In the figure, each BSS consists of a pair of stations (STAs), though in general a BSS can consist of dozens or even hundreds of stations.

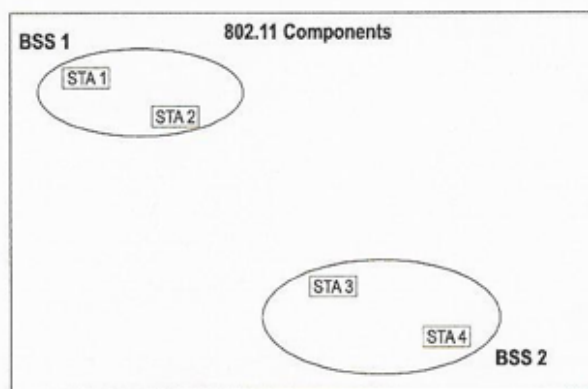


Figure C: 802.11 Independent Basic Service Set

61. The specification notes that independent networks are often referred to as ad hoc networks.

Figure 1 shows two IBSSs. This mode of operation is possible when IEEE 802.11 stations are able to communicate directly. Because this type of IEEE 802.11 LAN is often formed without pre-planning, for only as long

as the LAN is needed, this type of operation is often referred to as an ad hoc network.

802.11 Specification, 1999, pg. 10

62. Ad hoc networks are distinguished from infrastructure networks which use relatively permanent access points as the basis for wireless communication.

63. The access points (APs) can connect remote users to gateways for access to other networks. In an 802.11 infrastructure, the remote stations must associate with an access point before they can communicate with any other remote station (or, through the access point, to other networks). Remote stations may still communicate with each other, but all traffic has to be routed through the access point with which the transmitting station has associated. An exemplary infrastructure network is shown below in Figure C. The lines indicate the only paths over which communication can take place.

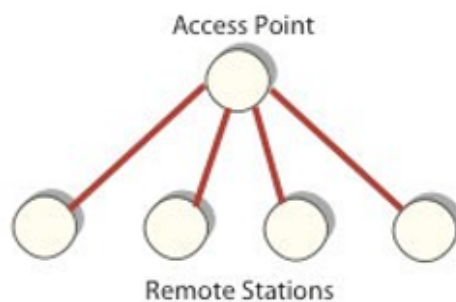


Figure E: 802.11 Infrastructure Network

64. When entering an infrastructure network, a station will first listen for a beacon in an attempt to determine which APs are present. Once an AP has been identified and selected, the station will initiate the “association service.”

A STA learns what APs are present and then requests to establish an association by invoking the association service.

ANSI/IEEE Std 802.11, 1999 Edition, pg. 19

65. The association service consists of the exchange of a pair of packets; these particular packets are examples of management frames. The station sends an “association request” frame to the AP, and the AP responds with an “association response” frame.

5.7.2 Association

For a STA to associate, the association service causes the following messages to occur:

Association request

— *Message type: Management*

— *Message subtype: Association request*

— *Information items:*

- *IEEE address of the STA initiating the association*
- *IEEE address of the AP with which the initiating station will associate*
- *ESS ID*

— *Direction of message:*

From STA to AP Association response

— *Message type: Management*

— *Message subtype: Association response*

— *Information items:*

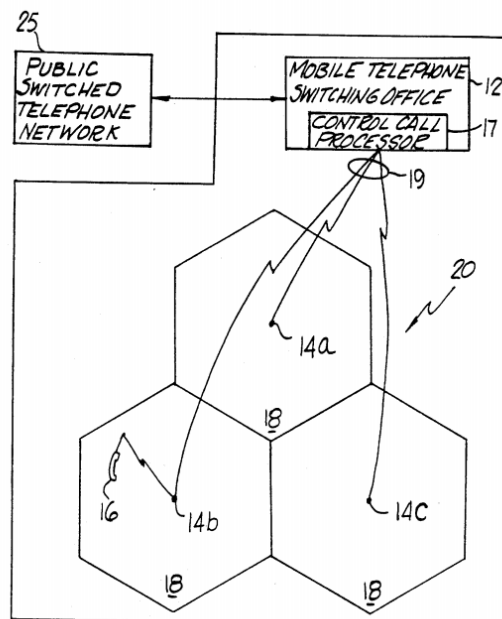
- *Result of the requested association. This is an item with values “successful” and “unsuccessful.”*
- *If the association is successful, the response shall include the association identifier (AID).*
- *Direction of message: From AP to STA*

ANSI/IEEE Std 802.11, 1999 Edition, pg. 25

66. This paragraph left intentionally blank.

E. Cellular Networking Technology

67. A cellular network is a mobile network that provides services by using a large number of transceiver base stations with limited power, each covering only a limited area. This limited area is called a cell. In this way a large geographic area, like a coast-to-coast network in the U.S., can be covered by a number of cells with a general structure like the below:⁴



68. A typical cellular network includes many components that facilitate end-to-end communications between subscribers and between subscribers and callers on other networks including landlines. At a high level, a cellular network can be divided into

⁴ U.S. Patent No. 5,295,180 to Vendetti, et al ("Vendetti"), 1:10-29, Fig. 1.

two main parts: the Radio Access Network, or “RAN,” to which wireless devices connect, and the Core Network.

1. The Radio Access Network

69. As the name implies, the Radio Access Network is the wireless portion of the cellular network and includes the base stations and mobile/cell phones. The size of each cell radius and its transmission power range is typically predetermined by the cellular carrier as part of its network radio plan and is based on a number of different factors that include the geographic area to be covered, the typical number of cell (mobile) phone users, and the type of voice and data to be supported.

70. One important characteristic of a cellular network is the control of the base station and mobile phone transmittal power. The basic concept for efficient network operation is that the base stations and the mobile phones not transmit at a power level greater than what is needed for efficient communication.

71. When a U.S. cellular network operator’s radio plan is complete, it typically includes hundreds of cells that are of many different sizes. Each cell is given a unique identity and is configured with various information by the cellular operator. One piece of important information for each cell includes the list of its neighbor cells. This information is critical for a mobile to use when it is moving out of the range of a cell that it is using and needs to switch to another cell.

2. The Core Network

72. The Core Network connects to the base stations and has many different types of network elements (computer systems) that perform the many different functions that are necessary for a cellular network to operate correctly. The Core Network also provides the voice and data connections between the mobile phones and other voice and data networks. The base stations in the RAN are connected to the Core Network using trusted private network type connections that are managed by the cellular network operator.

3. First Generation Cellular Telephony

73. Mobile communications were originally developed for military purposes. The idea transitioned to the commercial world primarily through the development of cellular communication systems which were deployed beginning in the early 1980s. Some of the first- generation (1G) cellular systems were Advanced Mobile Phone System (AMPS), Nordic Mobile Telephone (NMT), and the British Total Access Communication System (TACS). These analog systems were based upon Frequency Modulated (FM) radio channels and only carried user's voice signals. The 1G systems did not provide user information confidentiality since the signals could be easily listened to by using standard commercial radio receivers tuned to the correct frequency carrying the user's voice signal. Additionally, device credentials such as the telephone number could be copied due to the utilization of this non-protected radio interface and Signaling System (SS7) messages in the core network. These and

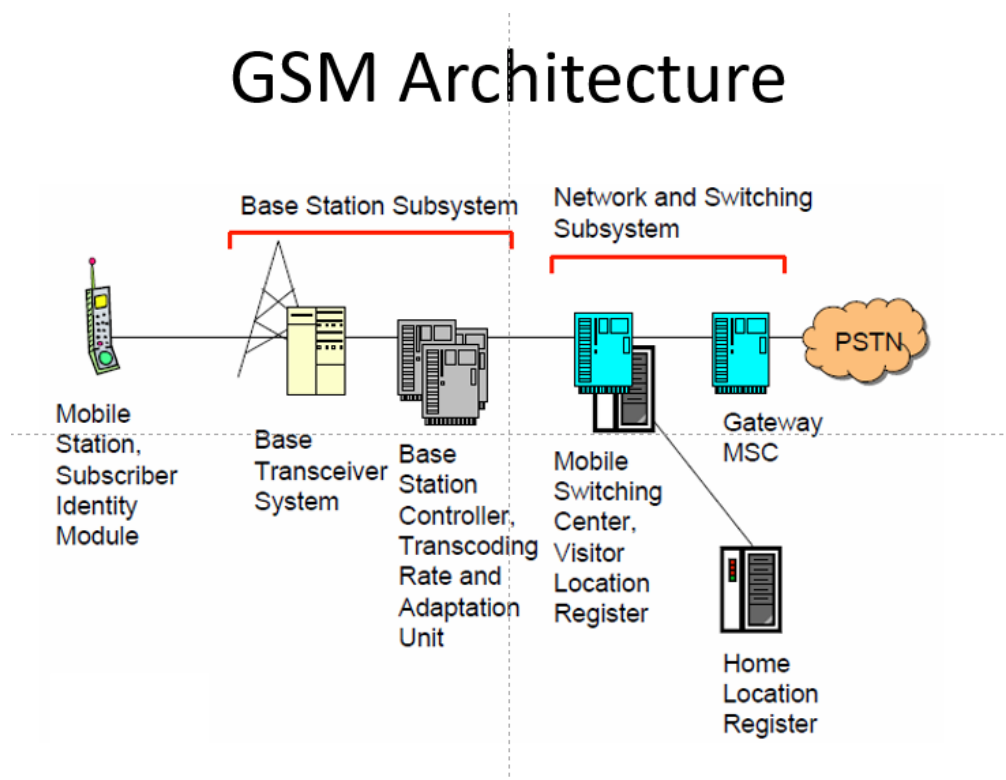
other security vulnerabilities were addressed in subsequent generation mobile communication systems.

4. 2nd Generation Cellular Telephony

74. Second-generation (2G) systems such as the Global System for Mobile communications (GSM) were deployed beginning in the early 1990s and were designed, in part, to address the obvious security flaws of the 1G systems. 2G systems introduced digital modulation techniques, encryption of signals and voice communications and established user authorization and authentication procedures. The European Telecommunications Standards Institute (ETSI) was the primary entity responsible for developing the first GSM standards. As part of this development work the idea of using a Subscriber Identity Module (SIM) card to protect important user and network information was introduced. A SIM is a smart card consisting of an integrated circuit chip and memory embedded into a plastic card. The first GSM SIM cards were commercially available in 1991 and they are used to store network and user-specific information used as part of the ETSI-defined security procedures.

75. Second generation GSM networks generally consist of four basic subsystems – the Mobile Station (MS), the Base Station Subsystem (BSS), the Network and Switching Subsystem (NSS), and the Home Location Register (HLR). The MS communicates over one or more wireless links with the BSS. The BSS consists of one or more Base

Transceiver Stations (BTSs – the cell towers and radio transceivers) and a Base Station Controller, as shown below.⁵



6

76. The figure below is taken from an early draft of the GSM standard, GSM 03.02, Version 3.1.4, February 1992. The figure depicts the interaction between the SS7 signaling network and the telephone network. A mobile handset is shown on the

⁵ See Xuan, Ohio State Course Materials concerning “Mobile Handset Cellular Network,” available at web.cse.ohio-state.edu/~xuan/courses/694/694_CELLULAR_NETWORK.ppt.

⁶ See web.cse.ohio-state.edu/~xuan/courses/694/694_CELLULAR_NETWORK.ppt at Slide 16.

bottom right of the diagram, interfacing with the Mobile Switching Center (MSC) through the Base Station Subsystem (BSS). The Home Location Register (HLR) and Visitor Location Register (VLR) are interrogated through switching points (SP) that provide the information needed for call setup and roaming. The VLR is a database that is part of the MSC, and which contains the location of the active mobile stations.

77. The backbone of a GSM network is a telephone network with additional cellular network capabilities. The GSM network could provide location updates to mobile stations. More specifically, the GSM network cells overlapped, and usually a mobile station could see several transceivers. The mobile station would monitor the identifier for the BSC controlling the cells. When the mobile station reached a new BSC's area, it would request a location update. The update would then be forwarded to the MSC, entered in the VLR, the old BSC is notified and an acknowledgement is passed back.

5. GPRS and Data Calls

78. The original ("phase one") GSM standard provided for 9.6 kbps data services. These data services were provided through circuit-switched traffic channels, in much the same way that a modem uses the PSTN to create a data connection. As the demand for Internet connectivity grew, service providers realized that 9.6 kbps was far too slow. The first significant attempt to increase data rates focused on combining

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multiple traffic channels. The result was “high-speed circuit switched data” (HSCSD), which supported data rates of 40 - 50 kbps, depending on the coding used.

79. Once again, however, it was found that these services were simply too slow. Part of the problem lay in the mismatch between data applications and circuit-switched transport mechanisms. The economy of scale in packet switching was not available in a circuit-switched system, as once a circuit was dedicated to a user session, it could not be used by another party regardless of the activity level. The next step in providing high-speed data services was a step away from circuit switching to focus on packet switch transport – General Packet Radio Service (GPRS) was the result.

80. GPRS was developed to provide packet switched data communication services within GSM cellular networks. GPRS is often referred to as “2.5 generation cellular,” acknowledging its advance over the circuit-switched data systems provided by 2nd generation GSM networks. GPRS was added to the GSM standard in 1997, and has remained a part of the standard through the transition to third generation systems.

81. GPRS requires that two additional nodes – the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN) – be added to the original GSM network architecture. These two new nodes are described as follows in the GSM specification.

The Serving GPRS Support Node (SGSN), which is at the same hierarchical level as the MSC, keeps track of the individual MSs’ location and performs security functions and access control. The SGSN is connected to the base station system with Frame Relay. The Gateway GSN (GGSN) provides

interworking with external packet switched networks, and is connected with SGSNs via an IP-based GPRS backbone network.

GSM 03.60, version 7.4.1, 1998, at 13.⁷

82. In addition to the two new network nodes, GPRS requires modifications to several of the pre-existing 2nd generation GSM network elements. A Packet Control Unit (PCU) is added to the base station controller (BSC). GPRS subscriber information is added to the HLR. The SMS-GMSCs and the SMS-IW MSCs are upgraded to support packet switched transport through the SGSN. The MSC/VLR may be upgraded to better support GPRS and non-GPRS services, such as SGSN-supported paging of packet switched calls, and combined voice and data location updates. The packet control unit in the BSC is connected to one or more SGSNs using frame relay; as discussed above, frame relay is a transport technology for wide area networks. The GGSN is connected to one or more SGSNs through an IP backbone network. The GPRS Tunneling Protocol (GTP) has been designed for routing packets between the SGSNs and the GGSNs.

6. 3rd Generation Cellular Systems

83. Beginning in 1999, third generation (3G) cellular network technology protocol standards were published by 3GPP, Release 99. The 3G network technology was

⁷ Available at https://www.etsi.org/deliver/etsi_en/301300_301399/301344/07.04.01_60/en_301344v070401p.pdf.

known as Universal Mobile Telecommunications Service (UMTS) and was built upon a Wideband Code Division Multiple Access (WCDMA) air interface. A major design goal of 3G technology was enabling and ensuring comprehensive global roaming which made it possible for a user to utilize the global system anywhere in the world. A simplified version of the 3GPP Release 99 architecture is shown below:

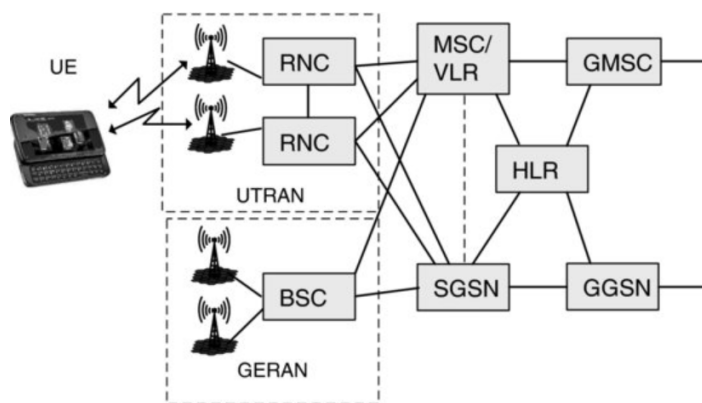


Figure 1. The 3G Release 99 system architecture.

Forsberg, “LTE Security” (2nd ed.).

84. The 3G network architecture has three main components: User Equipment (UE), the UMTS Terrestrial Radio Access Network (UTRAN), and the Core Network (CN). The UE is actually composed of two components: the Mobile Equipment (ME) and the Universal SIM (USIM). The ME is the hardware and software that make up what the average consumer thinks of as a ‘cell phone’ – the screen, the battery, antennas, processor chips, etc., however the USIM is an application running on the Universal Integrated Circuit Card (UICC) which is ‘plugged into’ the UE and was referred to

as the 'SIM card' in 2G systems. In the figure above, the network elements labeled 'MSC/VLR' and 'SGSN' are two important components of the global roaming network architecture. The Mobile Switch Center (MSC) controls the location area around the cell tower for circuit switched connections while the Visitor Location Register (VLR) holds a list of users in that area. The Serving GPRS Support Node (SGSN) performs an equivalent function of the combined MSC/VLR for packet switched connections. Additionally, the Home Location Register (HLR) is typically deployed as an integrated element with the Authentication Center (AuC). The HLR maintains a list of subscribers for the home serving network and the AuC holds the permanent security information associated with those same subscribers as well as performing other security related functions.

85. Beginning in 2004, the Third Generation Partnership Project (3GPP) commenced a study into the long-term evolution of UMTS (the current cellular network architecture at the time) which resulted in LTE. The goals were primarily high data rates, low latency, and an architecture that could evolve and adapt with developments in technology and built upon an all packet-based network. LTE (Long-Term Evolution) is a term that refers to the 4th Generation (4G) of the cellular network architecture. As the name suggests, LTE evolved from the 3G network architecture and represented a significant departure in design, functionality, and performance from its predecessor.

86. At a high-level the LTE network architecture, like UMTS, consists of three main components: the UE, the RAN which is the interface over which the UE and the main network communicate, and the evolved packet core (EPC) which communicates with other networks and the broader electronic world. The latter two components (RAN and EPC) are referred to as the evolved packet system (EPS). Additionally, the LTE RAN, since it represents an evolution of the previous generation's radio access network (UMTS – RAN), is also called the Evolved-UMTS RAN (E-UTRAN). A high-level architecture diagram of LTE is presented below.

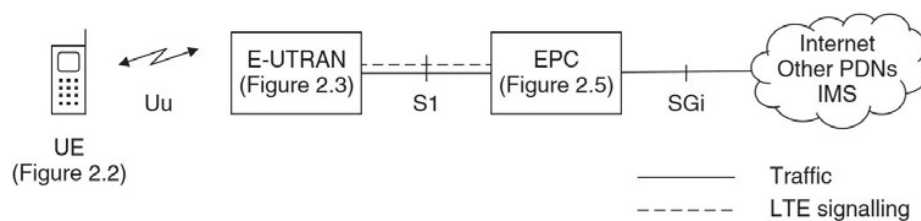


Figure 2.1 High-level architecture of LTE

Cox, "An Introduction to LTE: LTE, LTE-Advanced, SAE, VoLTE, and 4G Mobile Communications" (2nd ed.) at p. 22.

87. The first release of the 3GPP protocol standards defining LTE was termed Release 8 (R8). This release provides the foundation for LTE and introduces all of the major requirements and specifications that network operators, network equipment, chip set, and handset manufacturers use to design, develop, test, and deploy their products. The features and requirements in R8 address key enablers for LTE: signaling efficiency,

spectrum flexibility and efficiency, capacity enhancements, and multi-antenna techniques. R8 also provides the basis for subsequent releases which followed.

88. LTE's core network (CN) consists of several types of nodes (devices to provide the functionality and packet-switching required to operate the network). The mobility management entity (MME) is a key control plane (carries LTE signaling) node and is responsible for establishing and releasing a service connection to a UE or other end users, signaling, mobility (users moving from cell to cell), and security. The serving gateway (S-GW) is a user-plane (carries user data) node that connects the EPC to the RAN and serves as the mobility anchor (as a UE moves from cell to cell the S-GW keeps track of the data connection between multiple cells and is responsible for the smooth handoff when switching service areas). Two other main nodes are the home subscriber system (HSS) which contains subscriber information and the packet data network (PDN) gateway (P-GW) which connects the EPC to the internet or other networks. A few of the LTE architecture CN nodes are pictured below.

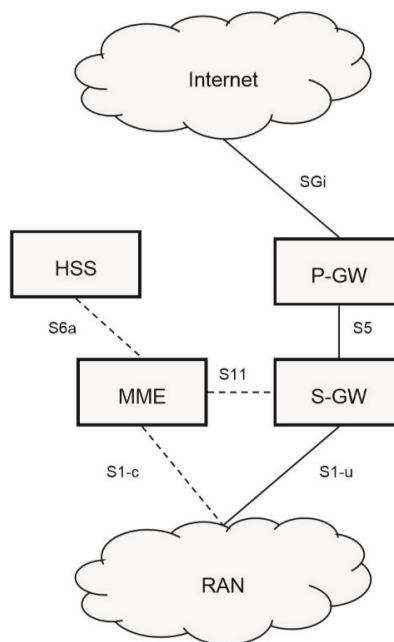


Figure 4.1 Core Network Architecture

Dahlman, "4G, LTE-Advanced Pro and The Road to 5G", (3rd ed.).

F. Mobile Devices / Smartphones

89.A mobile phone or cellular phone is a portable telephone which makes or receives calls through a cell site base station or other transmitting tower. Radio waves at specific frequencies (or “radio frequencies”) are used to transfer signals in analog or digital form to and from the cell phone.

90.In order to be able to communicate with a cellular network using radio frequency transmissions, a mobile device needs, at a minimum, a transceiver and an antenna to which it is connected. An antenna converts an electric signal to the radio wave

(transmitter) and vice versa (receiver).⁸ A transceiver is a combination of a transceiver and a receiver and it generates a reference signal in both receive mode and transmit mode for various frequency bands.⁹

91. While there existed before the advent of cellular service devices that have been called “mobile phones” or similar, it was really the introduction of the cellular technology described above that made widespread adoption of mobile telephones economically feasible.

92. Motorola was the first company to produce a handheld mobile phone in 1973, the Motorola DynaTAC.¹⁰

93. Subsequently in the 1980s, with the introduction of the first analog cellular systems (including AMPS, discussed above), the first commercially available mobile phone in the U.S., the DynaTAC 8000X, launched.¹¹

94. With the introduction of the second generation of cellular networks occurring in the United States in the 1990s, advances in mobile telephone technologies occurred as well. While the traditional first generation analog cellular networks had provided

⁸ Rong Wang, PhD, “How Do Cell Phones Work?,” *Pong Pulse* (December 20, 2014) (available at <https://pongcase.com/blog/cell-phones-work/>).

⁹ U.S. Patent No. 6,912,376 to Smith et al. (filed December 27, 1999).

¹⁰ Peter Ha, “Motorola DynaTAC 8000x,” *Time* (October 25, 2010) (available at http://content.time.com/time/specials/packages/article/0,28804,2023689_2023708_2023656,00.html).

¹¹ *Id.*

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more extensive coverage than the new, second generation digital networks, the use of digital circuit switched transmissions enabled quicker network signaling, thereby decreasing the amount of dropped calls and increasing call quality. As a result, 2G networks experienced significant growth in mobile phone usage. Other improvements included increase battery life and computer chip technology which allowed for a shift away from the larger “brick” phones towards smaller, lighter handheld devices. This second generation of mobile phones also eventually included the ability to communicate via SMS or text messages and to access media content on mobile phones (such as ring tones).

95.The introduction of third generation cellular networks in the 2000s marked a significant advancement over 2G networks, providing a wider range of services, advanced network capacity, and increased information transfer rates. Due to increased network bandwidth, 3G devices could support transmission of voice and data.

96.Furthermore, the higher connection speeds of third generation technology also made web browsing and streaming of radio and television content possible. As of the mid-2000s, there was widespread availability of 3G cellular coverage, and accordingly a higher concentration of cellular phones.

97.“Smartphones” are a particular class of mobile phones and multi-purpose mobile computer devices. They are generally characterized by their hardware capabilities

and the fact that they have mobile operating systems that facilitate wider software, internet, and multimedia functionality, alongside core functions such as voice calls and text messaging. Smartphones typically include various sensors that can be leveraged by their software, such as a magnetometer, proximity sensors, barometer, gyroscope and accelerometer, and support wireless communications protocols such as Bluetooth, Wi-Fi (802.11), and satellite navigation.

98. This paragraph left intentionally blank.

99. This paragraph left intentionally blank.

G. MIMO

100. Analytical models for Multiple Input Multiple Output (MIMO) systems were first introduced in the context of multipair telephone cable systems in 1970 by Kaye and George in a paper published on the “Transmission of Multiplexed PAM Signals Over Multiple Channel and Diversity Systems”. See *IEEE Transactions on Communication Technology*, Vol. Com-18, No. 5, October 1970, pp. 520 – 526. This paper extended an optimum receiver design for pulse amplitude-modulated (PAM) signals over a single channel to a general case of M multiplexed PAM signals over random-time and frequency-dispersive multichannel systems with l inputs and N outputs (See Fig. 2 below). *Id.* at Abstract.

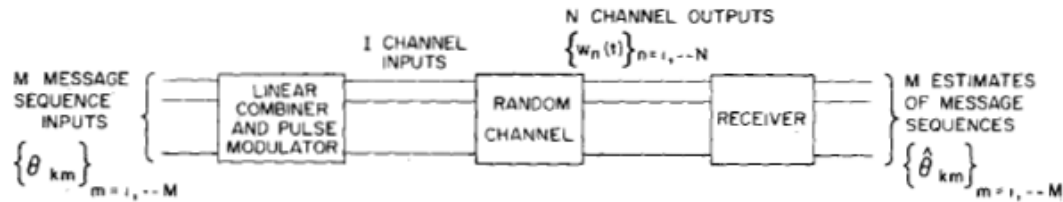


Fig. 2. General form of communication system.

101.

102. *Id.* at pp. 521.

103. Subsequently in 1974, a journal article which presented “[a] formula [] derived for the capacity of a multi-input, multi-output linear channel” describing an analytic expression for information capacity of MIMO channels with discrete-time signals and perfect channel state information was published. See Brandenburg and Wyner, *The Bell System Technical Journal*, Vol. 53, No. 5, May-June 1974. This led to several subsequent information theoretic papers dealing with optimizing channel capacity for MIMO systems.

104. An early reference to the application of MIMO techniques specifically in the context of cellular communications may be found in a 1987 paper on the capacity limits in systems with diversity in a Rayleigh fading environment. See Winters, *Journal on Selected Areas in Communications*, “On the Capacity of Radio Communications with Diversity in a Rayleigh Fading Environment”, Vol. SAC-5, No. 5, June 1987, pp. 871 – 878. Winters is specifically addressed to “radio communication system[s] ... such as a mobile radio or indoor wireless system, the communication channels between multiple transmit and/or receive antennas”. “Thus,

communication systems, with appropriate signal processing techniques, can use antenna diversity (e.g., space, direction, or polarization) to establish independent channels within the same bandwidth between the transmitters and receivers, thereby achieving large capacity”. *Id.* at pp. 871. The figure below from Winters shows a base station with multiple antennas (multiple input) to multiple remote devices which constitute multiple receive antennas (multiple output).

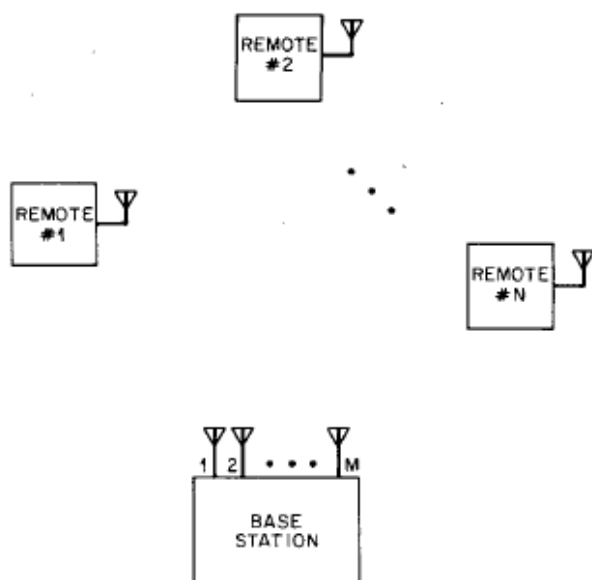


Fig. 1. Radio system consisting of a base station with M antennas and N remotes, each with one antenna.

105.

106. *Id.* at pp. 872.

107. Winters references spatial diversity in a paper he authored in 1984, “Optimum Combining in digital Mobile Radio with Cochannel Interference,” which appeared in the *IEEE Journal on Selected Areas in Communications*, Vol. SAC-2, No. 4, July 1984, pp. 528 – 539. This paper mainly focuses on receive diversity; “[p]revious studies of mobile radio systems [] have considered space diversity only for combating

multipath fading ... [h]owever, in most systems the same interfering signals are present at each of the receiving antennas. Thus, the received signals can be combined to suppress these interfering signals...”. *Id.* at pp. 528. Winters also mentions what a POSITA would understand as transmit diversity in the context of discussing multipath effects at the receive antennas: “Similarly, at the receive antennas, the signal phases from two different transmit antennas are independent when the transmit antennas are more than a half of a wavelength apart”. *Id.* at pp. 530. There is nothing novel about Winters’ reference to the effects of multipath fading in the context of transmit diversity in a MIMO system where the author is focused on an optimum receiver design. A POSITA would have been knowledgeable about space diversity (transmit and receive) to improve the quality and reliability of a wireless link. In discussing multiple antenna techniques, Cox states, “The most familiar is diversity processing, which increases the received signal power and reduces the amount of fading by using multiple antennas at the transmitter, the receiver or both. **Diversity processing has been used since the early days of mobile communications ...**”. See Cox at pp. 87 (emphasis added).

108. As a specific example of transmit diversity, Adachi published a paper in 1979 entitled, “Transmitter Diversity for Digital FM paging System”, IEEE Transactions on Vehicular Technology, Vol. VT-28, No. 4, November 1979, pp. 333 – 338. “Multipath fading is one of the most serious problems for the signal transmission in

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mobile radio. To combat this problem, the application of transmitter diversity to a digital paging system is described. The method is to transmit two digital FM paging signals with different modulation indices, each of which is modulated by an identical binary signal, from separate antennas.” *Id.* at Abstract. A POSITA would understand the transmission system disclosed in this paper to be a transmit diversity system where the same data (“identical binary signal”) is transmitted from two or more antennas (“separate antennas”) enabling an improved combined signal at the receive antenna. Referencing transmit diversity, Adachi states, “In Section II, it is shown that the same action obtained with the well-known selection diversity can be achieved ...”. *Id.* at pp. 333. And, “This is the same result with the well-known selection diversity which selects the branch with the higher received signal envelope.” *Id.* at pp. 334. “*Selection diversity* is a more sophisticated version of switched diversity, where the system can monitor the signal level on all of the antennae simultaneously, and select the specific branch exhibiting the highest SNR at any given time ... as seen in Figure 3.5.” Bloch and Hanzo, *Third-Generation Systems and Intelligent Wireless Networking*, pp. 127-128.

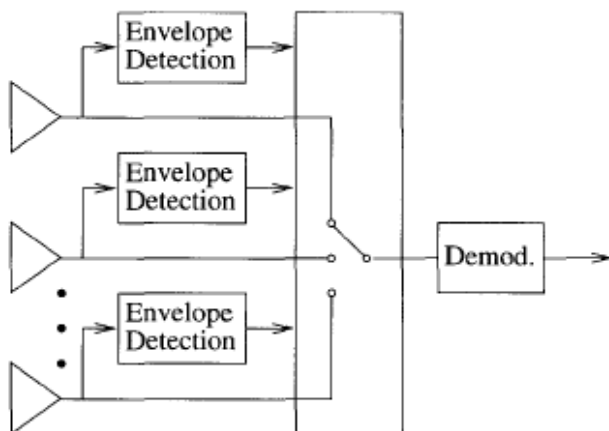


Figure 3.5: Selective-diversity combining.

109.

110. *Id.* at pp. 128.

111. It would be clear to a POSITA that Adachi is disclosing a transmit diversity system where the receiver optimizes received signal power by effectively selecting the received signal which propagated over the path (beam) that results in a maximum received signal power as shown in Fig. 1. Thus, both transmit diversity and receive diversity were well known for several decades preceding the priority date of the '930 patent.

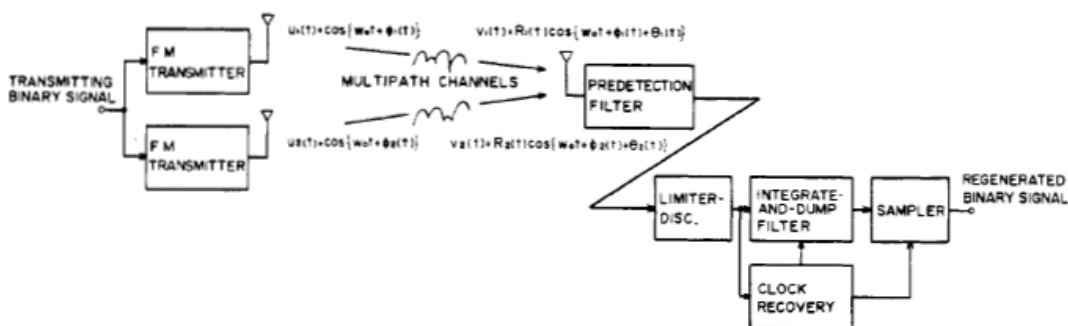


Fig. 1. Transmitter diversity system model.

112.

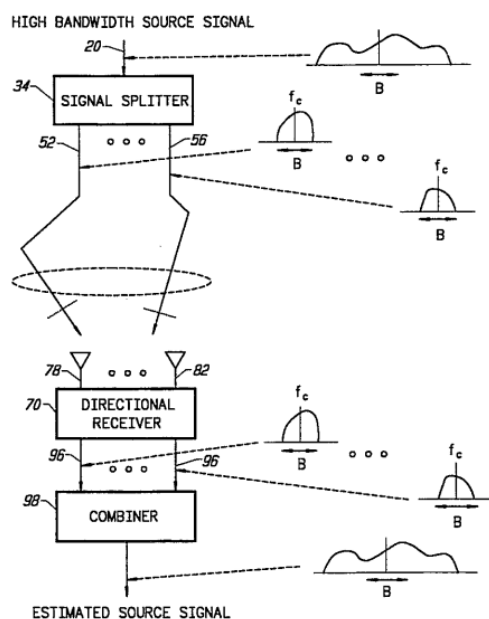
113. Adachi at pp. 334.

114. By the early 2000's, diversity techniques in mobile communication systems had become well entrenched. "*Diversity* is another technique used to compensate for fading channel impairments, and is usually implemented by using two or more receiving antennas. The evolving 3G common air interfaces also use transmit diversity, where base stations may transmit multiple replicas of the signal on spatially separated antennas or frequencies. As with an equalizer, diversity improves the quality of a wireless link without altering the common air interface, and without increasing the transmitted power or bandwidth [] [and] is usually employed at both the base station and mobile receivers." See Rappaport at Chapter 7, *Introduction*.
115. Spatial multiplexing which involves "Deploying multiple antennas at both the transmitter and the receiver of a wireless system" was known since the early 1990's when it was shown "to yield extraordinary bit rates []." See Bocskei, et al., *IEEE Conference Record of the Thirty-Third Asilomar Conference on Signals, Systems, and Computers*, 24-27b October, 1999, Vol. 2, pp. 1127 – 1132. In 1992 Paulraj and Kailath filed a provisional application for a patent entitled "Increasing Capacity in Wireless Systems Using Distributed Transmission/Directional Reception (DTDR)" which issued as US005345599 on September 6, 1994. The patent discloses "A method and apparatus for increasing the capacity of wireless broadcasts communications system for a central studio to a plurality of users in a service area ... Given a source signal whose information rate exceeds the practical information

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carrying capacity of the available broadcast channel bandwidth, the invention increases the effective capacity of the broadcast system to effectively communication such a source signal. The high-rate signal is split into several low-rate signals such that each can be accommodated within the allocated bandwidth. These low-rate signals are transmitted from spatially separated transmitters, all radiating into the service area in the same frequency channel. Each receiver uses a plurality of antennas to receive these multiple cochannel signals that arrive from different directions-of-arrival.” See US005345599 at Abstract. Thus this patent discloses a method and apparatus for a MIMO spatial multiplexing system.

116.



117.

118. See US005345599 at face.

119. In the fall of 1996, *Bell Labs Technical Journal* presented an article, “Layered Space-Time Architecture for Wireless Communication in a Fading Environment When Using Multi-Element Antennas”, Foschini, Autumn 1996. The paper discloses a MIMO system for increasing the capacity (throughput) in a Rayleigh fading environment, “[the system] use[s] (n_T, n_R) to express the number of antenna elements at the transmitter and receiver. An (n, n) analysis shows that despite the n received waves interfering randomly, capacity grows linearly with n and is enormous.” See *Bell Labs Technical Journal* at pg. 41. The paper presents a “new” architecture with an equal number of antennas at the transmitter and receiver (MIMO) and coined the term of art, “layered space-time architecture” which “targets application in future generations of fixed wireless systems, bringing high bit rates to the office and home. The architecture might also be used in future wireless local area networks (LAN) applications for which it promises extraordinarily high bit rates.” Id.

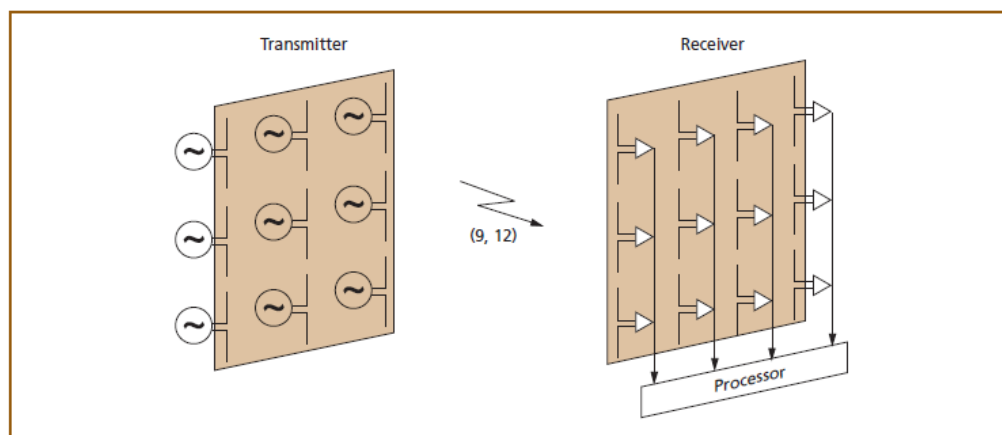


Figure 1.
Shorthand notation (n_T, n_R) for the number of transmit antennas n_T and receive antennas n_R (dipole antennas shown).

120.

121. Id at pp. 43.

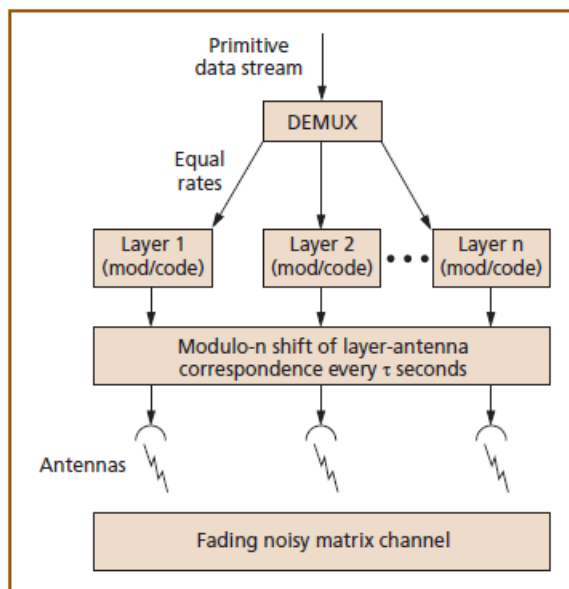


Figure 4.
Transmission process using space-time layering.

122.

123. Id at pp. 46.

124. By the late 1990's and early 2000's a POSITA would be very familiar with the concept of spatial multiplexing to transmit multiple data streams simultaneously in a MIMO system to significantly increase data throughput rates compared to single input single output and diversity systems. As presented in Bolcskei regarding spatial multiplexing systems "have been shown to have the potential of achieving extraordinary bit rates." "In the following M_T and M_R denote the number of transmit-and-receive antennas, respectively. Using single-carrier modulation, M_T different data streams are sent simultaneously from the M_T transmit antennas, pass through a

time-dispersive matrix channel, and arrive at the M_R receive antennas.” See Bolcskei at Abstract, pp. 1128.

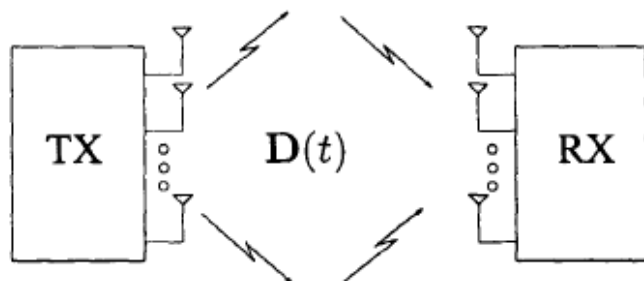


Fig. 1. Space-time coding modem.

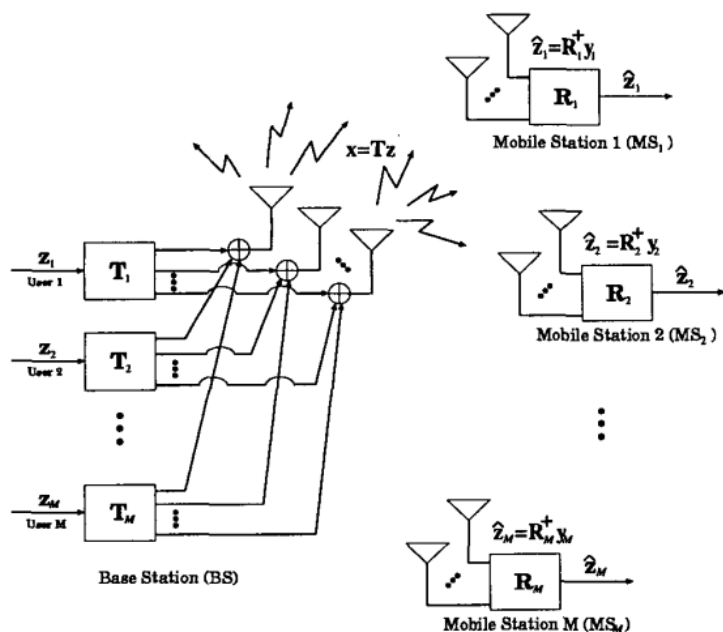
125.

126. Id at pp. 1128.

127. In addition to MIMO systems in which a transmitter and receiver both have multiple antennas (that is, one radio on each side controlling the transmit and receive signal processing) being well known to a POSITA by the early 2000’s, he/she would also be knowledgeable of so called, Multiuser MIMO systems (MU-MIMO). In MU-MIMO, multiple radios control multiple antennas.

128. In the *IEEE Wireless Communications and Networking Conference*, 23-28 September, 2000, Vol. 3, pp. 426 – 430, Wong, et al., published “Optimizing the Spectral Efficiency of Multiuser MIMO Smart Antenna Systems”. “In this paper, we consider the maximization of spectral efficiency of a multiuser MIMO system for downlink communications (one base to many mobiles) ... [e]ach mobile (user) in the system incorporates an array of n_R antennas and in general transmits $K_m \geq$ space-time subchannels, in the same frequency spectrum and time slot.” See Wong at Abstract.

In this paper the authors presented a technique that maximizes the spectral efficiency of the system in the context of the downlink. "...we consider the downlink (base station to many mobiles) communications for wireless systems where smart antennas are employed at both the BS and all MS." Id. at pp.426. The presented MU-MIMO system consists of a single base station with multiple antennas transmitting to multiple mobile stations, each with multiple antennas as shown in Fig. 1 below. A POSITA would understand that the proposed system is a downlink MU-MIMO system where the receivers are all separate radios controlling their own multiple antennas.



129. Fig. 1. System configuration of a multiuser MIMO system.

130. Id. at pp. 430.

131. Likewise, Rousseaux, et al., published "A Blind Multi-User MIMO Transceiver using Code Modulation in a Multipath Context," in the 14th International Conference

on Digital Signal Processing Proceedings, 1-3 July, 2002, Vol. 2, pp. 267 – 270. This paper was also focused on “... multi-user systems where both the base station and the users have multiple antennas” in a “wideband context” using “OFDM ... and related block transmission techniques that use a cyclic prefix.” *Id.* at pp. 267.

132. In US005345599 discussed above, a POSITA would also understand that the disclosed system where “The high-rate signal is split into several low-rate signals ... [and] [t]hese low-rate signals are transmitted from spatially separated transmitters, all radiating into the service area in the same frequency channel. Each receiver uses a plurality of antennas to receive these multiple cochannel signals”, discloses a downlink MU-MIMO system where multiple data streams are transmitted by separate radios (base stations) to be received by a device using multiple antennas. See US005345599 at Abstract. “Fig. 5 shows operation of a representative receiving station. A receiving station located within the service area will receive all signals in the same frequency channel. Receiving stations use a receive array that contains *m* subarrays (or elements)”. See US005345599 7:49-53.

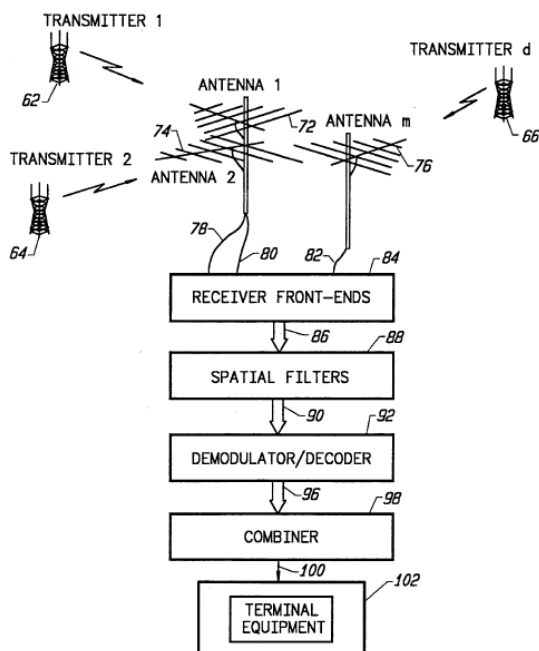
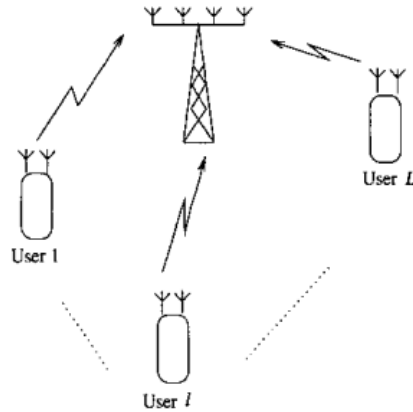


FIG. 5

133.

134. Other papers presented uplink MU-MIMO systems where mobile stations with multiple antennas transmit data up to the base station which uses multiple antennas to receive the spatially multiplexed data from the multiple mobile stations. In the paper, “Multiuser MIMO Systems and Interference Avoidance”, *IEEE International Conference on Acoustics, Speech, and Signal Processing*, 6-10 April, 2003, pp. 828 – 831, Popescu and Rose present “A general signal space formulation” used to make “the approach applicable to any MIMO system model regardless of the choice of basis functions.” They further state, “We also note that the approach is general and applicable to any MIMO system model.” See Popescu and Rose at Abstract, pp. 828. The authors present an application of interference avoidance techniques “to multiuser

MIMO systems such as those associated with the uplink of a wireless system in which users and the base station are equipped with multiple antennas.” Id. at pp. 828.



135. **Fig. 1.** Multiuser MIMO system in which users and the base station are equipped with antenna arrays for transmission/reception.

136. By 2004, many papers discussing uplink MU-MIMO were known to a POSITA, such as “Transceiver Optimization for Multiuser MIMO Systems”, Serbetli and Yener, *IEEE Transactions on Signal Processing*, Vol. 52, No. 1, January 2004, pp. 214 – 226.. “We consider the uplink of a multiuser system where the transmitters as well as the receiver are equipped with multiple antennas. Each user multiplexes its symbols”. See Serbatli and Yener at Abstract. “We consider the uplink of a single cell synchronous system with K users. The receiver employs N_R antennas. We assume that the i th user multiplexes a fixed numver of data streams M_i through its N_T transmit antennas emplying an $N_T \times M_i$ linear transmitter $\mathbf{F}_i$ in one symbol period (Fig. 1).” Id. at pp. 215.

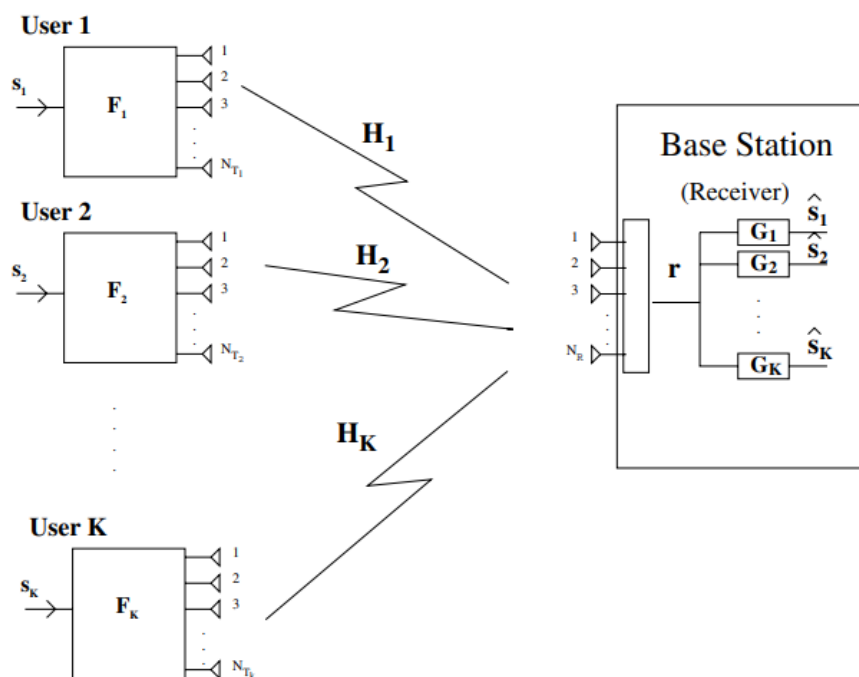


Fig. 1. System model of multiuser MIMO system.

137.

138. Beamforming or spatial filtering has been an active topic of research and application since the late 19th century. An early version of a beamformer was the Perrin array (designed by and named after Sergeant Jean Perrin) deployed during WWI. This was an acoustic array used by the French army to detect enemy aircraft using two subarrays of six hexagonal sensors in each subarray. The picture below shows Perrin's array. The two main receivers (equivalent to acoustic antennas) were separated by a fixed distance which provided the operators with the ability to spatially filter signals arriving at the sensor based upon the overlap of the receiver's sensitivity patterns (i.e., the spatial responsiveness to a given direction of arrival) to determine the elevation angle of the enemy plane.



Figure 1: Acoustic array developed by Sergeant Jean Perrin (right) and used by the French Army during WWI to detect enemy aircraft.

139.

140. Heilman, et al.

141. The early days of beamforming were dominated by acoustic (in air and underwater) applications primarily until the mid-20th century when radio antennas came on to the scene during WWII.

142. “*Beamforming* is the name given to a wide variety of array processing algorithms that, by some means, focus the array’s signal-capturing abilities in a given direction. Based on the analogy of a flashlight, the mainlobe of an array’s directivity pattern is called a *beam*[]. Just as one might point a telescope or a radar dish, a beamforming algorithm ‘points’ the array’s spatial filter toward desired directions but algorithmically rather than physically...**the signal processing algorithms developed for these conventional beamforming algorithms date from the early days of array processing and are well understood.**” See Johnson and Dudgeon pp. 112 (emphasis added).

143. The fundamental concepts of using multiple antenna elements (acoustic or RF) to form an array which are used to spatially focus the transmit signal (transmit beam) or spatially filter the received signal (receive beam) have not changed significantly because it was the well-understood physics that permitted the original construction of the arrays. For example, the basic idea of using two subarrays (as in Perrin's array) with overlapping receive sensitivity patterns to combine the arriving signal in a way that permitted higher resolution spatial filtering than could be obtained if the subarrays were used individually was well understood during the early part of the 20th century.

144. The simplest and oldest form of a beamforming algorithm is the so called, delay-and-sum beamforming. "The underlying idea is quite simple: If a propagating signal is present in an array's aperture, the sensor outputs, delayd by appopriate amounts and added together, reinforce the signal with respect to noise or waves propagating in different directions." Id.

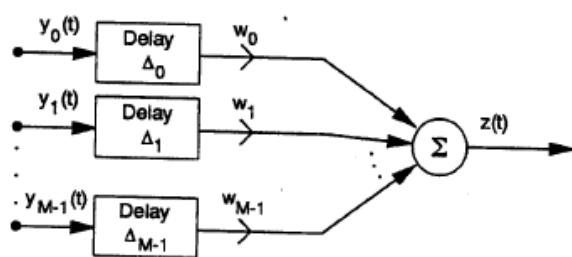


Figure 4.2 The beamformer's output $z(t)$ consists of adding together the sensors' outputs after a delay (and an amplitude weight) has been applied to each. The delays can be chosen to maximize the array's sensitivity to waves propagating from a particular direction or location in space.

145.

146. Id.

147. In array signal processing, the simple delay-and-sum beamforming is, in reality modified by characteristics of the sensors themselves and by various filtering operations that may be performed on the received signals. “For all these reasons, we must consider each sensor’s output to be a filtered version of the local wavefield. Combining these filtered outputs to form a beam is known as *filter-and-sum beamforming*.” Id. at pp. 128.

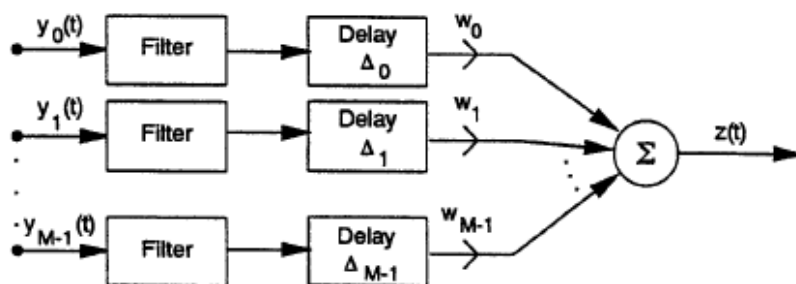


Figure 4.8 The configuration of the filter-and-sum beamformer consists of linear filters preceding the delay-and-sum beamforming stage. The transfer functions of these filters are usually identical and select the range of frequencies corresponding to the signal of interest.

148.

149. Id.

150. Combining and using subarrays has also been known (as illustrated above) since the early days of the beamforming and they have been used to provide higher sensitivity (i.e., increased spatial filtering) as well as to perform averaging, cancellation, and other array functionality. “The simple concept of the filter-and-sum beamformer can be generalized to include spatial filtering of sensor signals. This filtering occurs when the sensors are **not omnidirectional**, having greater sensitivity to waves propagating in certain directions. We find this solution when the sensors are continuous apertures, as in the case of telescopes[] or World War I

listening devices[], or consist of small subarrays, as in the case of some sonar and seismic arrays.” Id. at 131 (emphasis added).

151. Additionally, using subarrays (as in the Perrin beamformer) has been a method used to obtain high resolution (as above) or to form other desired outcomes, such as averaging data statistics. One example is spatial averaging. In this case “a regular linear array of M sensors can be decomposed into component regular linear subarrays having M_S sensors. If the subarrays are spatially disjoint, then we can average over nonoverlapping subapertures... The trick is to *overlap* the subarrays, compute the spatial correlation matrix for each, and average these to form a spatial correlation matrix that uses the data provided by the entire array.”

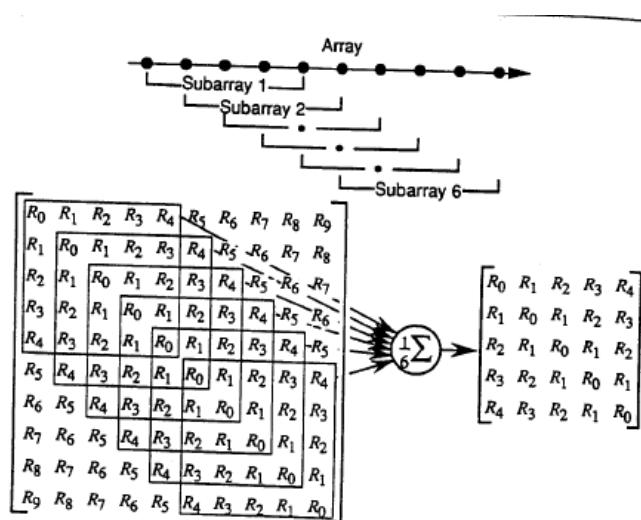


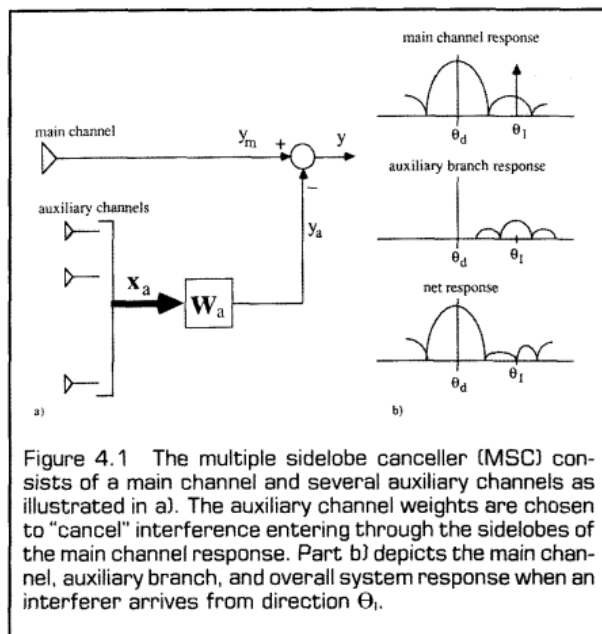
Figure 4.35 A regular linear array of M sensors can be conceptually decomposed into $M - M_S + 1$ subarrays each having M_S sensors. Here, spatial correlation matrices are computed for each of the six subarrays formed from a ten-sensor array. These matrices, which are submatrices of the array's spatial correlation matrix, are then averaged to form a smaller spatial correlation matrix. In this way, time-bandwidth product is gained at the expense of aperture.

152.

153. Id. at pp. 188.

154. The above illustrates that a single array is separated into six logical subarrays which together create nine combinations of subarray overlapped regions. This concept has been used throughout the history of beamforming. The same concepts may be applied to circular arrays or arrays covering 360 degrees. If, for example, the array depicted above was reshaped into a circular array, each subarray would cover approximately 160 degrees with 120 degrees of overlap in each sector associated with each subarray of one or more subarrays. The figure above also indicates that it was well known that the overlap could be handled by processing the data of the subarrays in various ways to obtain the high resolution or specific desired performance behavior of the overall array.

155. Another example of using subarrays to obtain specific behavior from a set of arrays is the well-known multiple sidelobe canceller (MSC). "The multiple sidelobe canceller (MSC) is perhaps the earliest statistically optimum beamformer. An MSC consists of a 'main channel' and one or more 'auxillary channels'". See Veen and Buckley, "Beamforming: A Versatile Approach to Spatial Filtering", *IEEE Signal Processing Magazine*, April 1988 at pp. 13-14. The main channel can be a high gain antenna (as in a single highly directional antenna covering a sector of a cell) or an array whose output is processed to achieve the same angular coverage. In the MSC it is the sidelobes of the two subarrays that overlap and the resulting signals are processed in such a way to perform a specific function (sidelobe cancellation).



156.

157. *Id.*

158. The MSC uses multiple subarrays or a combination of a highly directional antenna and an array to combine the outputs of the two arrays to obtain improved spatial performance for the overall system.

159. Additionally, a POSITA at the priority date of the '930 patent would be knowledgeable about various antenna configurations and sectorized designs for used for wireless communication systems. An example of various antenna design considerations can be found in Kalinichev, "Analysis of Beam-Steering and Directive Characteristics of Adaptive Antenna Arrays for Mobile Communications", IEEE Antennas and Propagation Magazine, Vol. 43, No. 3, June 2001, pp. 145-152.

160.

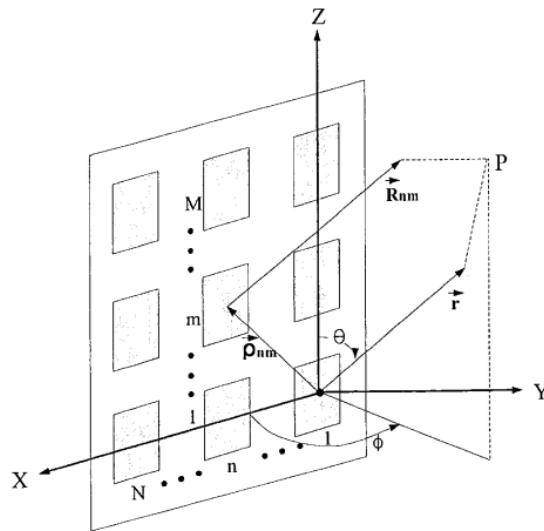


Figure 2. A planar array, consisting of N vertical linear subarrays of M patch radiators. The subarrays are placed in one plane, and are equally spaced.

161.

162. Id. at pp. 146-147.

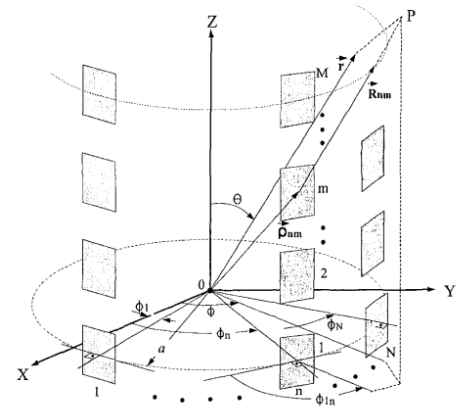


Figure 1. A circular array, consisting of N vertical linear subarrays of M patch radiators. The subarrays are situated along a circular arc of radius a , and have azimuth coordinates ϕ_n , $n = 1, \dots, N$.

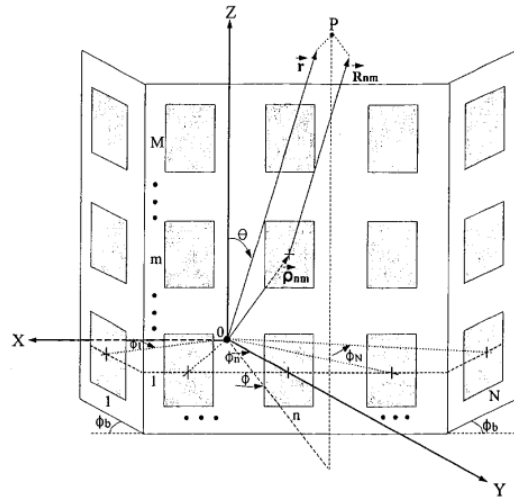


Figure 3a. A three-segment array, consisting of N vertical subarrays of M patch radiators.

163.

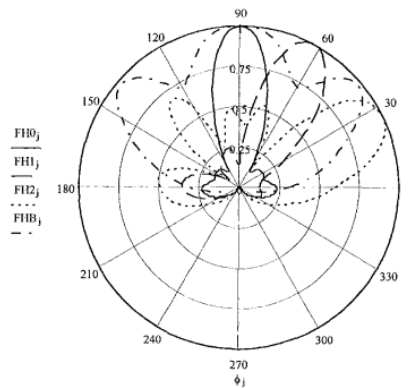


Figure 4a. The azimuth (H-plane) normalized patterns in polar (dimensionless) coordinates for the five-subarray circular array, with $a = 0.95\lambda$, $\Delta\phi = 30^\circ$: $\phi_0 = 90^\circ$ (solid line), $\phi_0 = 60^\circ$ (dashed line), and $\phi_0 = 15^\circ$ (dotted line). Also shown is the synthesized broad-beam pattern (dash-dotted line) with a 136° 3 dB beamwidth.

164. *Id.* at pp. 148 and 149.

165. This paragraph left intentionally blank.

166. This paragraph left intentionally blank.

167. This paragraph left intentionally blank.

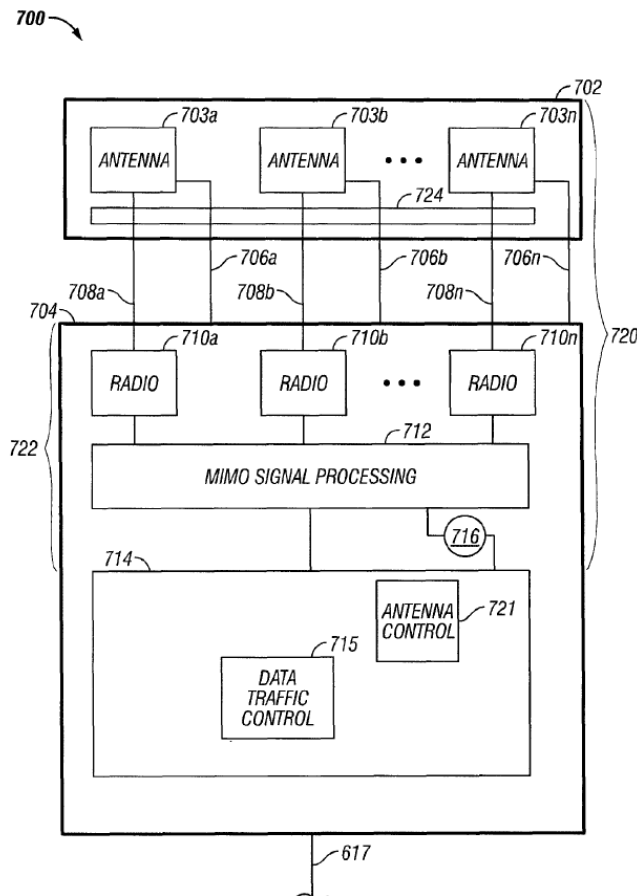
168. This paragraph left intentionally blank.

H. General Related Knowledge

169. The following section further describes the state of the art for wireless systems as of the priority date as known to a POSITA.

1. Prior Art MIMO Antenna Systems

170. It was known to use MIMO antennas at an access point in a wireless communication system. For example the prior art system illustrated below is directed to a wireless access point having a configurable antenna system:



EX-1005 FIG. 7.

171. Figure 7 illustrates a wireless communication device 700 that can be a mobile access point or other type of wireless communication device that employs multiple-in multiple-out (MIMO) technology. The communication device 700 includes a configurable antenna system 702 which is in communication with a radio system 704. The antenna system includes a plurality of configurable antennas 703a-n, wherein each of the configurable antennas 703a-n each includes one or more directional antennas which allows the antenna system to direct or steer the gain of each of the configurable antennas (as well as the overall antenna system) (for both transmitting and receiving) in more than one direction or pattern. EX-1005 13:26-50.
172. The configurable antenna system 702 can be selectively configured in response to control signals to create different antenna configurations which can include different antenna patterns and/or polarizations. EX-1005 13:51-54.
173. The radio system 704 includes a plurality of radios 710a-n and a MIMO signal processing module 712. EX-1005 14:6-10. The signal processing module 712 implements the MIMO processing. MIMO processing is well known in the art and includes the processing to send information out over two or more radio channels on two or more antennas and to receive information via multiple radio channels and antennas as well. The signal processing module can combine the information received via the multiple antenna into a single data stream. EX-1005 14:21-27.

2. Selection Of MIMO Antennas Based On Environmental Measurements

174. It was widely and pervasively known in the prior art that measurements of channel conditions could control the selection of MIMO antennas for transmissions to particular devices. For example, as noted above, Gore extensively taught transmissions were altered based on “channel quality indicators” that included “signal to interference noise ratio” or the “supportable rate over the channel.” EX-1006 7:51-60; Abstract, claims 1-36. Gore teaches “sectorization” which includes the selection of specific antennas to use for transmission and beamforming. EX-1006, 1:17-26, 5:13-6:34, 7:6-26.

175. As a further example, in Salo, the antenna control module 721 determines the desired configuration for each of the antenna 703a-n and generates the control signals to be sent to the antenna system 702. EX-1005 14:48-53. The antenna control module 721 is provided with or has access to a signal quality metric for each received signal and/or transmitted signal on a communication link. EX-1005 15:7:11. The signal quality metric, such as received signal strength, can also be supplied from the radios 710a-n. The signal quality metric is used to determine or select the antenna configurations. EX-1005 15:22-26. Various signal quality metrics or a combination of signal quality metrics can be used. For example, the strength of the signal from a station received at the access point can be used, the signal to noise ratio of the signal, error rates and the forward error correction value used by the radios can also be used.

The signal quality metric can be measured or determined at the radio with that information being transmitted to the access point. EX-1005 5:16-24. A POSITA understood that many factors can affect the signal quality metrics. For example, factors such as distance, reflectance, path, multi-path, interference, weather, moving objects, and fixed objects can all affect the signal quality. EX-1005 5:12-17.

176. The use of channel information to alter transmission characteristics was well-known to a POSITA. EX-1012 2:12-16 (U.S. Pat. No. 8,649,322); EX-1019 7:35-8:16 (U.S. Pat. No. 7,590,078); EX-1017 5:9-67 (U.S. Pat. No. 9,178,577).

3. The Use Of Beamforming With MIMO Antennas

177. A POSITA understood that performance for a wireless communication system would be enhanced by using beamformed transmissions to communicate from the base station to the mobile devices. Multiple transmit antennas located at a base station were used to create beamformed transmissions. Beamformed transmissions, also referred to as beams, typically covered a narrower area than transmissions using a single transmit antenna. A beam would be considered a virtual sector and thus would allow a virtual six-sector system to be generated from a conventional three-sector system. However, the signal to interference and noise ratio (SINR) was enhanced within the area covered by the beams. The communication system utilized a fixed or predetermined set of beams. Although the fixed beam pattern would be updated or adapted, in contrast to a beam steering system, the beams in a fixed beam

system were not dynamically updated based on individual user devices. EX-1006 2:1-16.

178. A POSITA understood that a wireless communication system included one or more base stations in contact with one or more user devices. Each base station provided coverage for a plurality of sectors and could use MIMO capable antennas. In communication with a user device, the transmitting antennas of a base station can utilize beamforming techniques in order to improve the signal-to-noise ratio of forward links for the different mobile devices. Additionally, a base station used beamforming to transmit to mobile devices scattered randomly through its coverage area caused less interference to mobile devices in neighboring cells/sectors than a base station transmitting through a single antenna to all mobile devices in its coverage area. Generally, beams generated by multiple transmit antennas are narrower than the coverage area of a single antenna. User devices in the areas covered by beams experienced an enhanced SINR. EX-1006 5:42-63.

179. A POSITA understood that channel quality indicators (CQI) were used to determine an improved beamforming performance. For example, CQI would be used to select a MIMO transmission and opportunistic beamforming for one or more user devices. In addition, the CQI would be used to determine the appropriate beam assignment or to update the beam pattern. EX-1006 2:38-48. One known method included generating a first pilot, transmitting the first pilot and receiving at least one

channel quality indicator (CQI) based at least in part upon the first pilot. The method also included scheduling at least one user device based on the CQI. Additionally, the method included assigning a user device to a beam based upon the CQI. The method also included generating a second pilot, transmitting the second pilot on a second beam and receiving a second CQI based on the second pilot. Thus, a POSITA understood that multiple CQIs could be used to determine appropriate beam patterns and assignments. EX-1006 2:42-63.

4. The Use Of 802.11 Protocols

180. The ‘895 claims recite the “802.11n protocol” and “another 802.11 protocol.” The ‘895 specification (as filed in 2006) contains only a single reference to 802.11n. EX-1001 7:14-15 (“Radios 18-22 use the 802.11a/b/g/n communication protocols.”).¹² The ‘895 does not contain any other teaching regarding 802.11, and thus treats all 802.11 protocols as equivalent.

181. The IEEE established the 802.11n working group called “TGn” in 2003. The 802.11n protocol was not adopted until 2009 – 3 years after the 2006 filing of the ‘895 priority application. *Id.* However, before the ‘895 priority date, draft IEEE 802.11n standards were publicly available from the IEEE. EX-1007 (May 2005);

¹² The ‘895 application filed in 2018 included reference to 802.11n in the newly-added Abstract and Summary of the Invention.

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EX-1008 (January 2006). One of the primary improvements added in 802.11n was MIMO. EX-1007 at Sections 1, 11.

182. By May 2005, the draft IEEE 802.11n standards contained extensive specifications regarding MIMO, beamforming, and feedback regarding channel state conditions used to adjust the MIMO transmission. EX-1007 at Sections 11 (“MIMO-OFDM PHY specification”); 11.2.1.2.3 (“Transmit Beamforming”); 11.2.2 (“Transmit Beamforming... One method of improving the SNR at the receiver... is to apply transmit beamforming. A basic requirement for transmit beamforming is the availability of channel state information (CSI).”); 11.1.1.6 (“Feedback Mechanisms”); 7.1.5.2 (“Closed-loop MIMO training”).

183. Moreover, the draft 802.11n specification required support of prior “legacy” 802.11 variants (such as 802.11a/b/g). EX-1007 at Section 1 (“The TGn Sync proposal also offers seamless interoperability with 802.11 legacy devices.”). Such support is described as being in “mixed mode” in which “there are co-channel legacy devices present.” EX-1007, Section 3 (definitions); 6.2.2 (“Operating Mode”); 8.1.1 (“Operating Modes”); 8.1.3.2; 8.1.3.3 (“Managed Mixed Mode Operation”); 8.1.3.4.

184. Numerous prior art patents expressly referenced the draft 802.11n standard including its teachings of MIMO, beamforming and feedback. EX-1011 1:8-24; 3:14-32; 4:8-5:5; EX-1012 3:1-31, 4:66-5:24, 6:1-7:16, 9:55-57; claims 6-12

(claiming a “MU-MIMO receiver”); Figures 1, 3; EX-1005 FIG.1, 1:20-25, 3:16-20, 4:66-5:10, 5:25-33, 2:18-27.

185. This paragraph left intentionally blank.

186. This paragraph left intentionally blank.

VII. OVERVIEW OF THE CHALLENGED PATENT

A. Priority Date

187. I have been instructed that for the purposes of this IPR, to assume the priority date for the challenged patent is February 28, 2006 (the filing date of Provisional Application No. 60/743,376 to which the challenged patent claims priority).

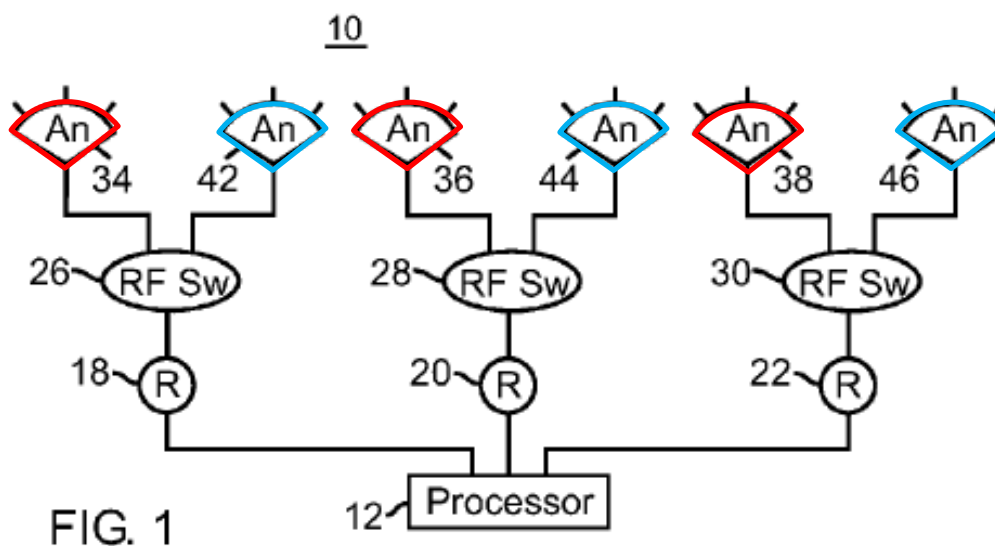
B. Overview Of The Content Of The Challenged Patent

188. The '930 Patent is directed to wireless systems with MIMO capability. It describes that one problem associated with wireless communications is that the antennas are subject to noise sources which may interfere with wireless communications. Prior art solutions included many techniques to reduce the detrimental effect of noise. For example, dividing the area of wireless coverage into sectors, using directional antennas, and using multiple antennas to provide redundancy and spatial diversity were well-known solutions improved the wireless communications. EX-1001 2:47-55.

189. The '930 Patent proposed as a solution, a wireless system which includes directional antennas positioned in such a way that the physical sectors of the antennas of the wireless device overlap and the antennas selected for communication are the

antennas whose physical sectors overlap in an area in a manner that permits the antennas to operate as a MIMO. EX-1001 2:56-63.

190. The '930 Patent describes that an exemplary device is shown in FIG. 1¹³, and the wireless device can include a wireless cell, access point, wireless client, mobile computer and handheld devices:



EX-1001 FIG. 2, 3:3-7.

191. Wireless device 10 comprises processor 12, radios 18, 20 and 22, RF switches 26, 28 and 30, and antennas 34, 36, 38, 42, 44 and 46 where two antennas interfacing with each one RF switch respectively. One antenna 34, 36 and 38 for each radio 18,

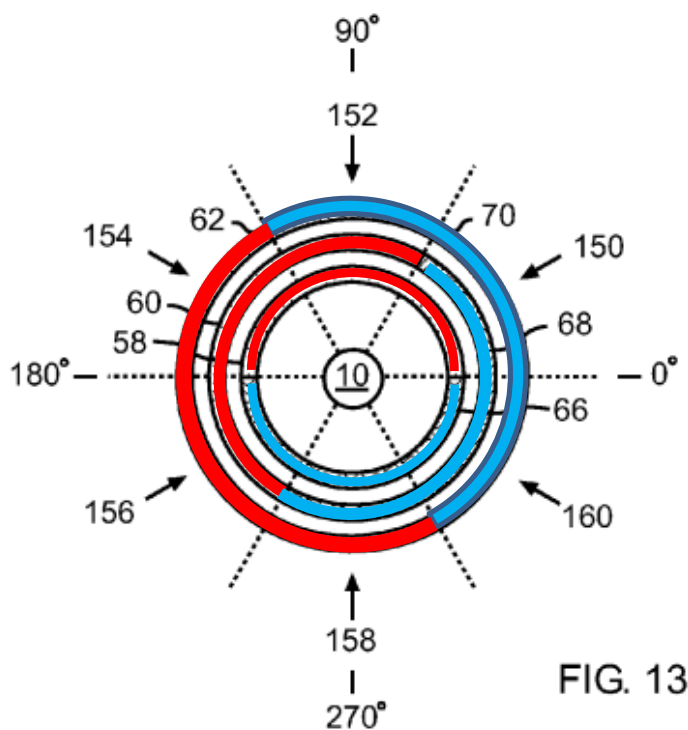
¹³ All color annotations of the figures, and all emphasis of any text herein has been added otherwise noted.

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20 and 22 operate as a first MIMO antenna and the other antenna 42, 44 and 46 for each radio operates as a second MIMO antenna. EX-1001 7:6-39.

192. The '930 Patent uses MIMO techniques long known in the prior art. The '930 Patent describes that "MIMO antenna" means at least two antennas that each transmits and/or receives signals that can be combined. Antennas may be positioned in such a way that their physical sectors overlap. Antennas whose physical sectors overlap in the same area may be configured to operate as a MIMO antenna in that area. Each individual antenna of a MIMO antenna operates on the same channel (*e.g.*, frequency, encoding, or other method of dividing the radio spectrum for communication). A MIMO antenna provides spatial diversity between the antennas, redundancy, and temporal diversity to reduce the effects of noise on transmission and reception. Reducing the effects of noise permits a wireless device to communicate more reliability. EX-1001 3:20-34. Known algorithms may be used to process the signal received by each antenna that form the MIMO antenna to construct a resultant receive signal that contains as much of the receive signal information as can be extracted. EX-1001 6:17-42.

193. For example, using the architecture of FIG. 1 three radios each having two antennas, the patterns for overlapping physical sectors in FIG. 13 is shown below. Each antenna has a 180° physical sector which causes overlap of three antennas (red and blue) for each virtual sector.



194. The term “virtual sector” means the area where the physical sectors of antennas overlap. Referring to FIG. 13, physical sectors 58, 60, 62, 66, 68 and 70 each have an angle of coverage of about 180 degrees respectively. The antennas associated with physical sectors 58, 60, 62, 66, 68 and 70 are positioned in such a way that in area 150, physical sectors 58, 68, and 70 overlap. In area 152, physical sectors 58, 60, and 70 overlap and so forth for areas 154-160. Each one area 150-160 comprises a virtual sector because the antennas whose physical sectors overlap in the area may operate as a MIMO antenna.

195. The '930 Patent describes that the wireless device, according to the various aspects of the present invention may select for communication any suitable combination of directional antennas that operate as a MIMO antenna and are oriented in a desired direction of communication. Furthermore, the wireless device may assign any available channel to the antennas to improve performance. EX-1001 2:64-3:3
196. The '930 Patent describes that the antennas that form a MIMO antenna may be used in any manner to transmit and/or receive signals for example, any number of antennas that operate as the MIMO antenna may transmit only, receive only, and transmit and receive signals. EX-1006 6:12-16.
197. The '930 Patent describes that antennas may be selected for communication according to any criteria, such as data throughput, signal strength, signal quality, signal-to-noise ratio, reduced signal error, reduced data errors, reduced retransmission requests, reduced interference, rejection of multipath signals, and higher transmission rates. EX-1001 5:28-32; 5:67-6:3.
198. The '930 Patent includes a description of the benefits of using MIMO antennas, but these "improvements" are merely the known benefits provided by conventional MIMO systems. EX-1001 5:3-14.
199. Likewise the '930 Patent includes a basic description of the operation of a conventional MIMO antenna and the benefits it provides. For example, the '930

Patent describes that MIMO permits a wireless device to communicate with increased performance. MIMO virtual sectors permits a wireless device to select an area to transmit and receive in accordance with the MIMO virtual sector that provides a desired level of performance. A wireless device having multiple MIMO virtual sectors may select between the various MIMO virtual sectors. A wireless device may select the MIMO virtual sector that provides an increased level of performance. Positioning the antennas of a wireless device to form MIMO virtual sectors that are oriented in different directions permits the wireless device to select a MIMO physical sector based on the orientation of the virtual sector with relation to the position of noise sources. EX-1001 5:14-27.

200. All of the concepts of using MIMO antennas as described and claimed in the '930 Patent, including selecting MIMO antennas based on measurements made by a mobile device in communication with the antennas were known to a POSITA as demonstrated by the PO's previous patent publication (EX-1004) by the same inventors.

201. This paragraph left intentionally blank.

C. Prosecution History

202. The '930 Patent issued from U.S. Pat. App. No. 14/952,850 filed November 25, 2015 claiming priority to U.S. Provisional Pat. App. No. 60/743,376 filed February 28, 2006. In the first Office Action, all claims were rejected for double patenting

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over U.S. Pat Nos. 9,525,468, 9,496,931 and 9,584,197 (all then pending). In response, the applicant filed terminal disclaimers and the '930 Patent was allowed and subsequently issued.

203. The '930 Patent issued from U.S. Pat. App. No. 16/120,258 filed September 18, 2018 claiming priority to U.S. Provisional Pat. App. No. 60/743,376, filed on Feb. 28, 2006 through a string of continuation applications. In the first Office Action, pending claims were rejected for double patenting over U.S. Pat Nos. 10,068,548; 9,859,963; and 10,063,297. In response, the applicant filed terminal disclaimers and the '930 Patent was allowed.

VIII. OVERVIEW OF THE PRIOR ART

A. Lastinger

204. U.S. Patent Application Publication No. 2005/0003865 ("Lastinger") published on January 6, 2005 from an application filed June 15, 2004. Although Lastinger is incorporated by reference in the specification of the '930 Patent, the '930 Patent does not claim priority to it. I have been advised that Lastinger qualifies as prior art under §102(b) which is consistent with my understanding of how certain references qualify as "prior art" for purposes of invalidity analyses. Lastinger was provided by the applicant during the prosecution of the family patents, but it was not applied or otherwise mentioned by the examiner.

205. Lastinger has identical inventors as the '930 Patent and describes the identical concepts described and claimed in the '930 Patent but uses slightly different terminology. For example, the abstract describes wireless cells as an access point for a cellular telephone system, where the wireless cells are equipped with multiple radios to increase the amount of throughput available through a single wireless cell. In addition, multiple antennas are attached to the radios through RF switches to enable the wireless cell to service multiple clients simultaneously. The physical sectors of the antennas may overlapped to form virtual sectors that provide greater flexibility in client load management and in simultaneously servicing multiple clients. EX-1004 Abstract.

206. This described architecture is illustrated in FIG. 22 of Lastinger:

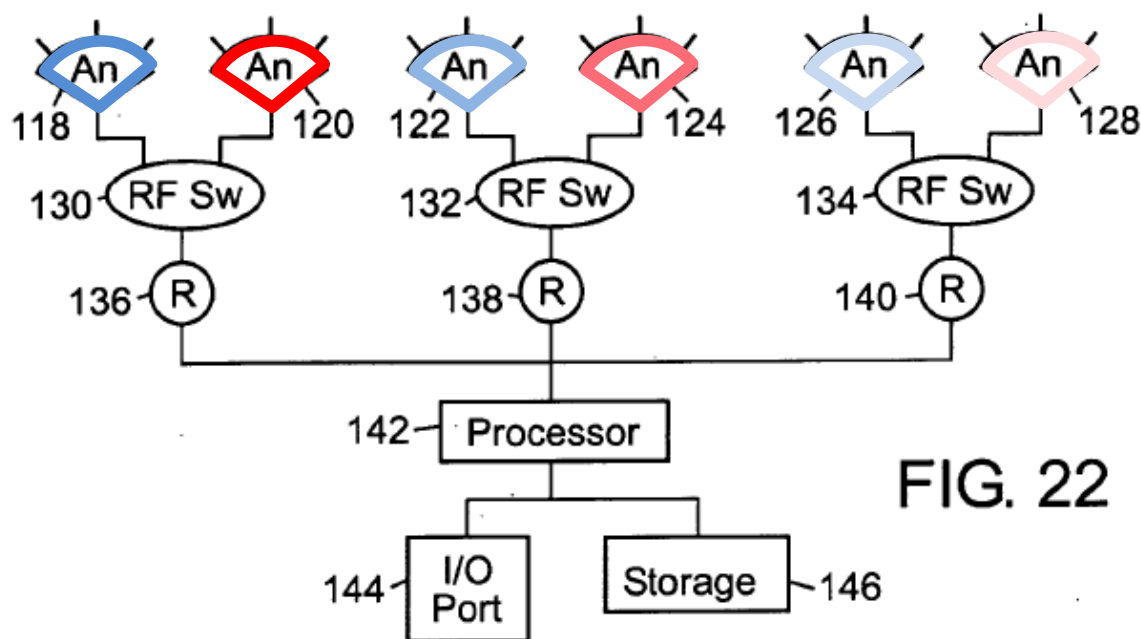




Exhibit 1003
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Page 000084

in FIG. 13, which causes overlap of two antennas for each virtual sector in FIG 14, and overlap of three antennas for each virtual sector in FIG. 13 of the '930 Patent. However, Lastinger makes clear that “the number of physical sectors that overlap to form a virtual sector is not limited. Wireless cell coverage depends on the characteristics of the individual physical sectors and how they combine. There are no requirements or limitations on size or method of combination.” EX-1004 [0092].

209. Lastinger discloses that a wireless cell communicates with a client. A client may be any type of wireless apparatus that communicates or cooperates with a wireless cell. EX-1004 [0097]. Like the wireless cell, clients may have one or more radios and one or more antennas. A client can send control information to the cell, including signal quality, desired antenna, error rate, number of dropped frames, desired throughput, throughput delivered, wireless cells detected, and/or any other conceivable information. A client may also request information or action from the cell, including retransmission, channel change, throughput demands, authentication, variation in transmit power, and/or a request to modify any communication factor. EX-1004 [0098].

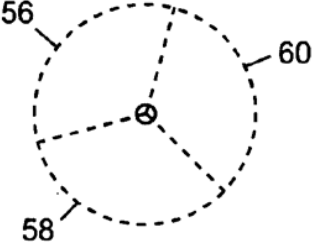
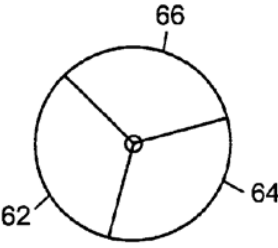
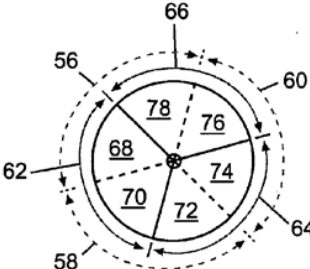
210. Lastinger discloses that the communications between the cell and clients may be MIMO transmissions using known existing MIMO techniques. EX-1004 [0103-0105], claims 5, 15, 25, 34, 41, 48, 53, 62, 71, 96, 122 (all reciting MIMO). Known

MIMO techniques included transmitting the same data from multiple antennas. *E.g.*, '930 patent at 3:20-23 (“The term “MIMO antenna” is understood to mean at least two antennas that each transmits and/or receives signals on the same channel in the area where the physical sectors of the antennas overlap.”).

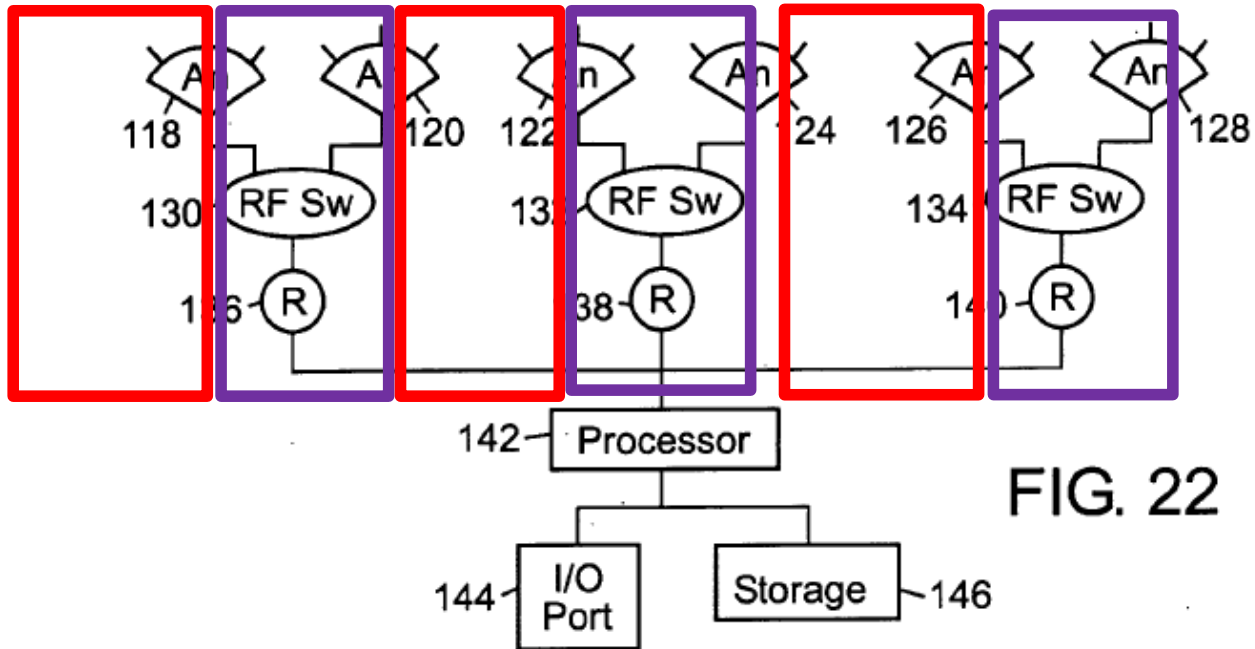
211. Lastinger teaches that the MIMO transmission encompasses transmitting from more than one set of antennas/radios using, for example, the same channel. For example, Lastinger’s claim 104 teaches two different groups of antennas in which the different groups overlap with the other group:

104. A method for facilitating the assignment of channels to at least partially **overlapping** physical sectors, said method comprising:
- selecting a wireless cell having a first group of non-overlapping physical sectors and a second group of non-overlapping physical sectors superimposed such that **each physical sector of said second group at least partially overlaps at least one physical sector of said first group;**
 - assigning a channel to each physical sector of said first group; and,
 - assigning a channel to each physical sector of said second group.

212. EX-1004, claim 104. Lastinger taught this arrangement using FIG. 12 (first group of antennas), FIG. 13 (second group of antennas), and FIG. 14 (result). EX-1004 0091 (“If the antennas from FIG. 12 were combined with the antennas of FIG. 13 into the same wireless cell while preserving their orientation, the wireless cell may have the coverage shown in FIG. 14.”)

First group		Second group		Result showing overlap
 FIG. 12	+	 FIG. 13	=	 FIG. 14

213. The “groups” of antennas in Lastinger’s claim 104 include a single antenna associated with each of the radios in FIG. 22 above. EX-1004 [0111] (“One exemplary antenna assignment is to assign the physical sectors of antennas 118, 120, 122, 124, 126, and 128 to substantially correspond to 56, 64, 58, 66, 60, and 62 respectively.”). Thus, for example, the “first group” would correspond to the red rectangles in FIG. 22 below (with antennas 118, 122, and 126 that service sectors 56, 58, and 60, respectively) and the second group would correspond to the purple rectangles (with antennas 120, 124, 128 that service sectors 64, 66, and 62 respectively).



214. Further, Lastinger’s claim 106 teaches that the two groups of antennas recited in claim 104 may use the same channel:

106. The method of claim 104, wherein each physical sector of said first group and said second group **is assigned a same channel**.

EX-1004, claim 106.

215. Lastinger also teaches that, in the overlapping physical sector scenario, “multiple antennas ... may be simultaneously active.” EX-1004 [0110]. The “collection of antennas, radios, and potentially other devices (e.g., attenuators, RF switches, etc.) under the common control of a processor....” EX-1004 0090.

216. Thus, in looking at FIG. 14, virtual sector 78 is serviced by antennas 118 (which services sector 56 and uses radio 136) and antenna 124 (which services sector 66 and uses radio 138).

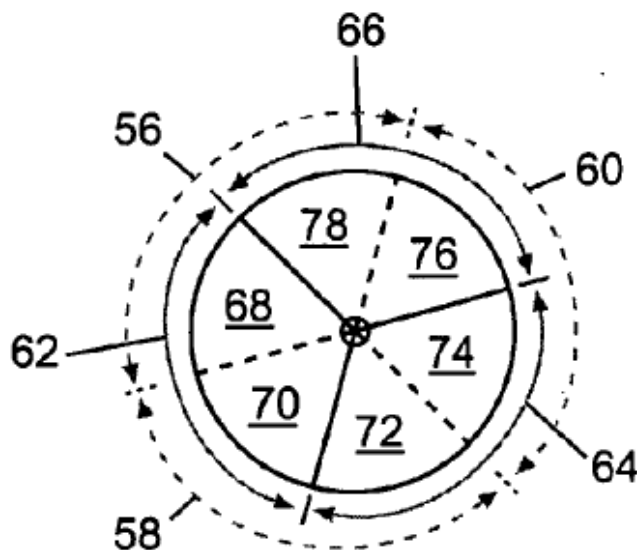


FIG. 14

217. A POSITA understood that one example of MIMO transmissions may use the same channel with different antennas. Lastinger's system can use this concept known as spatial diversity. EX-1004 [0103] ("MIMO antennas may use any combination of spatial, polarization, or angle antenna diversity."). Thus, a POSITA understood Lastinger taught forming a MIMO transmission for sector 78 by transmitting from antenna 118 (using radio 136) and antenna 124 (using radio 138) using the same channel (as noted in Lastinger's claim 106).

218. Thus, given that Lastinger teaches

- using the known MIMO techniques,
- that the different antenna groups are commonly controlled by the same processor,

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- that the antenna groups can be simultaneously transmitting,
- that the antenna groups can all use the same channel,

219. Lastinger teaches that the different antenna groups (using different radios) can be used for the same MIMO transmissions. Lastinger further teaches that the type and selection of antennas was broad and well-known. Lastinger discloses that the antennas used by the cell or the client may be MIMO antennas using use any combination of spatial, polarization, or angle antenna diversity. The MIMO may use any type of encoding including, for example, OFDM, space-time-codes, or weighting of the antenna signals in the array to accomplish beam steering. During transmission or reception, all or any subset of antennas in the MIMO array may be used or selection diversity may be used to limit the number of antennas used. EX-1004 [0103]. Adaptive arrays may use adaptive array weights to transmit directional beams within the angle and area of coverage to send a stronger signal to a desired client. During reception, an adaptive array may use array weights to direct a beam substantially towards the transmitting client and substantially null out any sources of interference. EX-1004 [0105].

220. Lastinger discloses that the selection of antenna(s) can be based on information provided by a client. For example, a client may send information that helps the wireless cell manage its communication with the clients it serves, including desired

through put, buffer fullness, signal quality, and/or other relevant information. EX-1004 [0100].

221. Although FIG. 2 shows two antennas per virtual sector, Lastinger makes clear that there is essentially no limitation on the number of antennas per virtual Sector. EX-1004 [0110].

222. Lastinger further discloses that wireless communication typically cannot take place between a wireless cell and a client until a relationship is established. In the simplest setting, a client requests to associate with a wireless cell, and if the wireless cell grants the association, a relationship is established and communication may occur. A client may not only associate with the wireless cell, but also with a specific physical sector of the wireless cell. The client detects radio signals from physical sectors and makes a request to associate with one of the physical sectors generally based on the quality of the signal the client receives from each sector. The wireless cell tracks the clients serviced by each physical sector. EX-1004 [0170].

223. Lastinger discloses that signal quality is a term used to describe radio signals wherein higher quality signals typically more accurately transmit and receive information, and provide higher data transfer rates (i.e., throughput). In contrast, lower quality signals potentially suffer losses in transmission and reception; thereby resulting in low throughput. Signal quality is a measure of, for example, signal level,

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noise level, error rate, and other operational and environmental factors from a radio's perspective. EX-1004 [0167].

224. Lastinger discloses that a radio at the wireless cell or the client may measure signal quality by listening to receive signals and ranking them by their signal quality. Radios may be capable of using more than one channel scan and ranking all signals received on all channels. EX-1004 [0168]. A wireless cell may perform a traffic load scan by setting its radios into the receive mode and counting the number of frames or the amount of traffic sent by foreign wireless cells on all possible channels. A traffic scan reveals the traffic load on each channel and the signal quality of the channels used by the detected foreign wireless cells. Traffic load information may be used when assigning channels to physical sectors. EX-1004 [0169]. A wireless cell may dynamically balance its load by disassociating a particular client with a particular physical sector and accepting an association with a different sector, or the wireless cell may use control commands to move an advanced client to a different physical sector and different channel without requiring the client to repeat the association process. A client may disassociate with its current physical sector and request association with another physical sector of the same wireless cell. EX-1004 [0175].

225. This paragraph left intentionally blank.

B. Sadowsky

226. U.S. Pat. No. 7,881,390 (“Sadowsky”) was filed November 30, 2005. I have been advised that Sadowsky qualifies as prior art under §102(e) which is consistent with my understanding of how certain references qualify as “prior art” for purposes of invalidity analyses. It was not cited nor applied by the examiner during prosecution of the challenged patent.

227. Sadowsky teaches techniques for the simultaneous use of “existing Wi-Fi” systems (such as 802.11a/b/g systems) with the “next-generation Wi-Fi” identified as the “proposal IEEE P802.11n, May 2005” which is found in EX-1007. EX-1009 1:17-60, 2:33-52. Sadowsky’s “architecture of system 100 may be identical or similar to that described in IEEE P802.11n, section 11 ‘MIMO-OFDM HT PHY Specification.’” EX-1009 3:31-33. Sadowsky repeatedly expressly references the May 2005 802.11n draft standard. EX-1009 Abstract, 1:27-29; 2:40-53; 5:1-3; 5:30-31. Indeed, Sadowsky submitted the May 2005 draft standard to the PTO on January 30, 2006. EX-1010; *see also* EX-1009, Other Publications.

228. Sadowsky references the draft 802.11n standard as the “HT” or “High Throughput” version of Wi-Fi (corresponding to Sadowsky’s citation to a specific 802.11n section of “IEEE P802.11n, section 11 ‘MIMO-OFDM **HT** PHY Specification.’” EX-1009, 3:31-33, 5:20-36.

229. Sadowsky expressly teaches support for simultaneous transmissions to 802.11n devices and other 802.11 legacy variants. EX-1009 1:30-59; 2:33-3:25; claims 1-20

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(frame includes “legacy portions” and “high throughput portions”). Sadowsky teaches the 802.11n use of MIMO using any form of antenna including arrays. EX-1009 4:9-47.

230. Sadowsky contains extensive teachings on allowing different channels for different 802.11 transmissions including “lower bandwidth channel and a lower throughput (e.g., 802.11a/g systems)” as opposed to higher throughput systems using the draft 802.11n proposal. EX-1009 5:3-36.

231. This paragraph left intentionally blank.

C. Gore

232. U.S. Pat. No. 9,408,220 (“Gore”) was filed on October 27, 2005. I have been advised that Gore qualifies as prior art under at least §102(a)/(e)/(g) which is consistent with my understanding of how certain references qualify as “prior art” for purposes of invalidity analyses. Gore claims priority to Provisional Application Nos. 60/672,575 and 60/710,419 filed April 19, 2005 and August 22, 2005, respectively. I have reviewed these Provisional Applications and if the patent owner seeks to pre-date Gore’s October 27, 2005 filing date, at least Provisional 60/710,419 would support one or more of Gore’s claims and serve to establish an earlier priority date for the Gore disclosure.

233. Like Lastinger, Gore teaches multi-sector base stations that adapt transmissions (including MIMO) based on feedback information from wireless client devices. Gore teaches that:

... the channel quality is monitored. Channel quality indicators can be used to select a scheduling technique, such as space division multiplexing (SDM), multiple-input multiple output (MIMO) transmission and opportunistic beamforming for one or more user devices. In addition, the CQI can be used to determine the appropriate beam assignment or to update the beam pattern.

EX-1006 Abstract.

234. Gore teaches a base station with an exemplary MIMO wireless configuration that is essentially identical to Lastinger's FIG. 22 above:

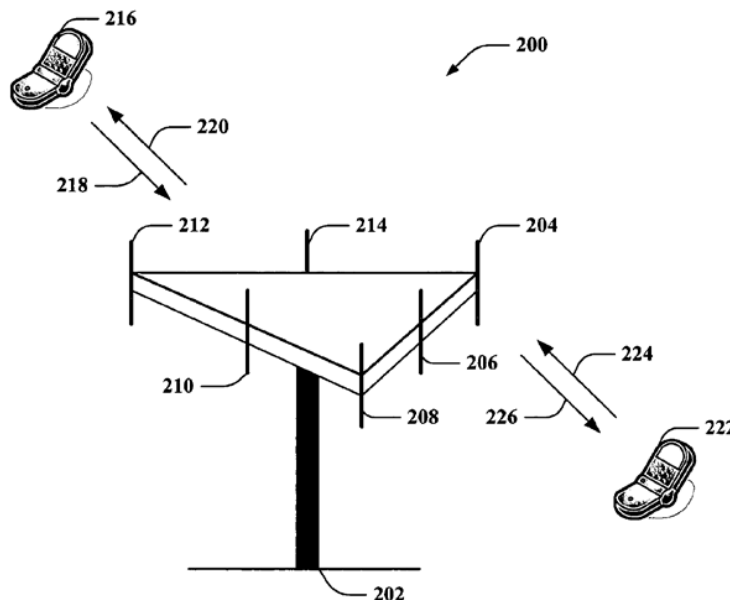


FIG. 2

EX-1006 FIG. 2. FIG. 2 shows:

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A 3-sector base station 202 includes multiple antenna groups, one including antennas 204 and 206, another including antennas 208 and 210, and a third including antennas 212 and 214. According to the figure, only two antennas are shown for each antenna group, however, more or fewer antennas may be utilized for each antenna group.

235. EX-1006, 5:13-21. Each antenna group is part of a “transmitter chain” which “comprise a plurality of components associated with signal transmission and reception (e.g., processors, modulators, multiplexers, demodulators, demultiplexers, antennas, etc.)...” that constitute radios. EX-1006, 4:61-67. These various radio elements are under the common control of a processor which performs the processing for the various functions on the base station. EX-1006, FIG. 8, 22-58.
236. Gore teaches the extensive use of beamformed transmissions for different techniques including SDM, MIMO, and opportunistic beamforming. EX-1006, 6:35-7:26. Exemplary beams are shown in FIG. 3:

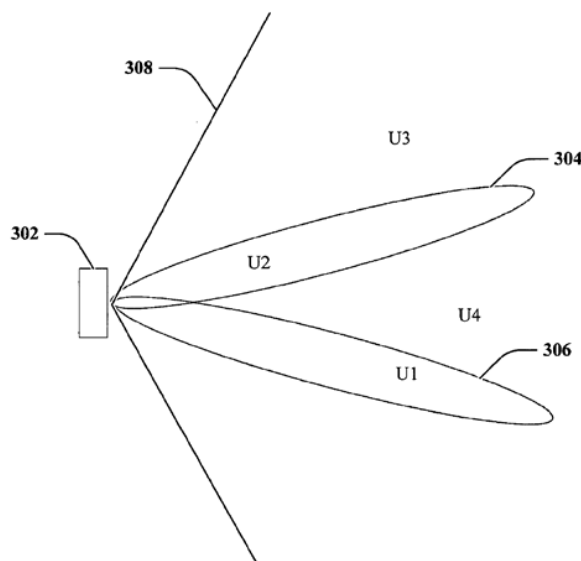


FIG. 3

EX-1006 FIG. 3.

237. Gore uses known MIMO techniques. EX-1006 6:57-7:26. Various “channel quality indicators” (“CQI”) are used to coordinate and alter the “transmitter chain” transmissions in at least three different ways (1) to “select a scheduling technique, such as space division multiplexing (SDM), multiple-input multiple output (MIMO) transmission and opportunistic beamforming”; (2) to “select” / “assign” or “reassign” particular beams for a client device and (3) to “update” beam patterns. EX-1006 Abstract, 2:42-48, 6:3-5 8:35-51, 8:55-9:17, 9:20-22, 9:47-54, 10:15-17, 13:1-4, claims 1-36.

238. Gore’s CQI includes “signal to interference and noise ratio” and “supportable rate” received from the wireless clients. EX-1006 7:53-55. Gore’s beamforming

techniques included altering beam weights based on the CQI. EX-1006 8:22-54, claim 8.

239. As with Lastinger, Gore teaches that a base station with three physical sectors (as shown in FIG.2 above) and “beam patterns may provide multiple transmit directions in the sectors of a 3-sector base station, resulting in a virtual 6-sector base station.” EX-1006, 6:28-34. *See also* EX-1006 2:1-16, 7:6-26..

IX. CLAIM CONSTRUCTION

240. I have been instructed solely for purposes of this IPR, that each claim term in the Challenged Claims be given its plain and ordinary meaning in this proceeding and that no specific construction of any claim term is required because the prior art relied on in this Petition meets each of the claim terms under any reasonable construction.

X. CLAIMS 1-14 AND 16-19 OF THE '930 PATENT ARE OBVIOUS OVER LASTINGER ALONE OR IN COMBINATION WITH GORE.

A. The Motivation to Combine

241. The '930 Patent, Lastinger and Gore are all directed to wireless communication including wireless base stations (also referenced as access points or wireless cells) that use sectorization and optionally use MIMO techniques. All three provide examples of multiple mobile devices communicating with a shared base station.

242. Lastinger and Gore are directed to the same problems of increasing system capacity and performance (including overcoming interferences) at wireless base stations communicating to clients. See EX-1004 at [0006] (“the current generation

of wireless access points and devices are limited in that they use omni-directional antennas assigned to a single channel. The demand for wireless access has increased the demand for higher wireless throughput per wireless access point, the reduction of interference between wireless cells, and the ability to use off-the-self components to deliver higher performance at lower cost.”), EX-1006 at 1:62-67 (Prior art “devices can be degraded due to channel variations and/or interference power variations”), 6:32-34 (Gore’s “ability to subdivide sectors when combined with various scheduling techniques results in increased system capacity”); 11:22-24 (Gore “facilitates increasing system capacity or performance in a communication environment”).

243. Both Lastinger and Gore offer improvements through the uses of “sectorized” radios that are not “omni-directional”. E.g., EX-1004 Title (“Method and apparatus for high throughput multiple radio sectorized wireless cell”); Abstract, [0006], EX-1006 Title (“Channel quality reporting for adaptive sectorization”); Abstract, 5:34-41, 8:22-54, 11:53-58.

244. Both Lastinger and Gore cite the use of techniques such as beamforming to overcome the prior art problems. E.g, EX-1004 at [0103] (“Although MIMO antennas are arrays of antennas, any antenna array may be used as a single antenna or a MIMO antenna may be used. For example, a directional antenna with about 120-degree angle of coverage may be replaced by an antenna array that provides similar coverage. The array may be fixed or adaptive. Adaptive arrays may use adaptive array

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weights to transmit directional beams within the angle and area of coverage to send a stronger signal to a desired client. During reception, an adaptive array may use array weights to direct a beam substantially towards the transmitting client and substantially null out any sources of interference.”); EX-1006 at 2:17-26 (“user devices should be assigned to appropriate beams to optimize channel performance. In addition, the beamforming system can utilize a variety of scheduling techniques based upon spatial, frequency or time divisions. The system should select the technique or combination of techniques to optimize channel performance, and consequently system performance. Thus, there exists a need in the art for a system and/or methodology for monitoring channel quality to optimize selection of beams and transmission techniques”).

245. Both Lastinger and Gore use known techniques for MIMO and non-MIMO transmissions to help overcome interference and increase throughput. For example, Lastinger states:

An enhanced antenna system may include one or more antennas of various types such as, for example, omni-directional, directional, patch, parabolic, beam, yagi, MIMO, antenna arrays, adaptive antenna arrays, or similar devices. In one embodiment, an antenna for an enhanced antenna system may be a directional antenna with about 5 to 8 dB attenuation in signal strength from the operation center to the edge of the physical sector and at least about 15 dB signal rejection from behind the antenna. The attenuation from operation center to physical sector edge may range from about 3 dB to 20 dB. The amount of attenuation from the operation center to the physical sector edge and the signal rejection from behind the antenna may be modified by use of a horn (as described below) or similar reflective element

such as a parabolic reflector, a four-corner reflector, or any reflector capable of producing a desired area of coverage. A horn, or a reflective element, also allows omni-directional and other types of antennas to be adapted to provide desired characteristics and angle of coverage. The desired antenna may be used with or without the horn.

A Multiple Input Multiple Output (MIMO) antenna is not a single antenna, but many antennas. In this invention, a MIMO antenna array may be used as any other single antenna type may be used. Just as a single antenna services a physical sector of a certain angle and area of coverage, a MIMO antenna array may provide a desired angle and area of coverage. For example, if four 90-degree, directional antennas provide about 360 degrees of non-overlapping coverage, each directional antenna may be replaced by a MIMO antenna array to provide similar coverage. The MIMO antenna may be used in both wireless cells and clients. MIMO antennas may use any combination of spatial, polarization, or angle antenna diversity. The MIMO antenna array may be fixed or adaptive for either transmit, receive, or both. When receiving, the MIMO antenna may use, for example, a maximum ratio combiner, an optimal linear combiner, selection diversity, or any combination of these methods or other methods for combining the signals from multiple antennas into a single signal. When transmitting, the MIMO antenna may use any type of encoding including, for example, OFDM, space-time-codes, or weighting of the antenna signals in the array to accomplish beam steering. During transmission or reception, all or any subset of antennas in the MIMO array may be used or selection diversity may be used to limit the number of antennas used. Antenna diversity may be used in the transmit path, in the receive path, or in both transmit and receive paths. The signal from each antenna, transmitted or received, may or may not be weighted.

Servicing a physical sector with a MIMO antenna means that all antennas in the MIMO array use the channel (discussed below) assigned to the physical sector. Signal attenuation may be added after each antenna, after the signal combiner, or in the signal processor that manipulates the incoming signals.

Although MIMO antennas are arrays of antennas, any antenna array may be used as a single antenna or a MIMO antenna may be used. For example, a directional antenna with about 120-degree angle of coverage may be replaced by an antenna array that provides similar coverage. The array may be fixed or adaptive. Adaptive arrays may use adaptive array weights to

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transmit directional beams within the angle and area of coverage to send a stronger signal to a desired client. During reception, an adaptive array may use array weights to direct a beam substantially towards the transmitting client and substantially null out any sources of interference.

246. EX-1004, [0102-0105] whereas Gore contains extensive teachings related to selecting and using MIMO and non-MIMO techniques. EX-1006 6:44-7:26.
247. Lastinger and Gore teach an embodiment with a common architecture in which a base station has, for example, three physical sectors each with their own antenna groups and radios with the physical sector transmissions combine to form “virtual” sectors. EX-1004, FIGS. 22, 12, 13, 14 and associated specification descriptions; EX-1006 FIG. 2, 4:58-5:41.
248. Lastinger and Gore provide extensive overlapping details regarding altering their transmissions to wireless devices based upon feedback information measured by, and transmitted from, those devices regarding channel conditions (such as interference / signal to noise ratios) to reduce interference and increase throughput. EX-1004 at [0098 -0101]; EX-1006 Abstract, 2:42-62, 3:15-32, 6:3-5, 8:22-51, 8:55-9:17, 9:20-22, 9:47-54, 10:15-17, 13:1-4, claims 1-36. Gore’s CQI are based upon measurements, including interference, done at the client devices. EX-1006, FIG. 6, 8:33-37, 8:59-63, 9:18-46, 10:35-37, 12:29-31. Gore’s alterations are done to reduce interference, increase the signal-to-noise ratio, and increase system capacity. EX-1006, 2: 10-12, 5:44-52, 6:32-34, 7:11-13.

249. Both Lastinger and Gore recite, in their claims, specific embodiments that use MIMO and non-MIMO techniques to transmit data to devices in overlapping physical sectors. *Compare* EX-1006 claims 1, 6 with EX-1004, claim 1.

250. As noted above, a POSITA would have been motivated to augment the teachings of Lastinger to include the specific related teachings of Gore. For example, Gore provides additional details of known MIMO techniques that Lastinger references. Similarly, Gore provides details of using channel condition information (referenced as CSI in Gore) to coordinate its transmissions and alter the transmissions of its various transmitter chain – a teaching that augments Lastinger’s own teachings of using such channel feedback information to coordinate and alter the transmissions of its various transmission point collections of antennas and radios.

251. A POSITA would have known that Gore’s techniques correspond to the techniques referenced in Lastinger – particular techniques related to MIMO transmissions, beamforming for both MIMO and non-MIMO transmissions, and using channel information to adapt and alter the radio transmissions sent from different antennas and antenna groups.

252. A POSITA would have understood that there are only a few finite MIMO techniques and that Lastinger’s broad reference to MIMO in both its specification and claims would encompass Gore’s MIMO techniques and be augmented and enhanced by Gore’s additional details regarding both MIMO and the ability to use

beamforming in both MIMO and non-MIMO transmissions (as noted in Lastinger above).

253. Moreover, a POSITA would have had a reasonable expectation of success in the combination of Lastinger and Gore. The references both teach complementary wireless base stations with similar (or identical) components and architecture as noted above and herein. Both references teach the same type of transmissions using known wireless techniques (such as MIMO, non-MIMO, beamforming, and sectorized transmissions) using known wireless protocols (such as OFDMA, 802.11, CDMA). Both references rely upon known techniques at the lower layers (such as protocols) for returning channel condition information from the mobile device to base stations. The two references fit like a glove.

254. This paragraph left intentionally blank.

B. '930 Patent Claims

1. Detailed Application of Lastinger alone or in combination with Gore.

a. Claim 1

[1.0] A system comprising:

255. Lastinger discloses and claims an enhanced antennas system. EX-1004; FIG 2, Claims 1-72. As noted above, embodiments of Lastinger's architecture are substantively identical to that disclosed in the '930 and recited in the claims of the '930.

[1.1] a single wireless station configured to operate in a packet-switched cellular network, the single wireless station including:

a first transmission point with a multiple-input-multiple-output (MIMO) capability, the first transmission point having:

a plurality of first directional antennas,

at least one first radio in communication with the first directional antennas, and

first circuitry in communication with the at least one first radio;

256. Lastinger discloses a single wireless station configured to operate in a packet switched cellular network as illustrated in annotated FIG. 22:

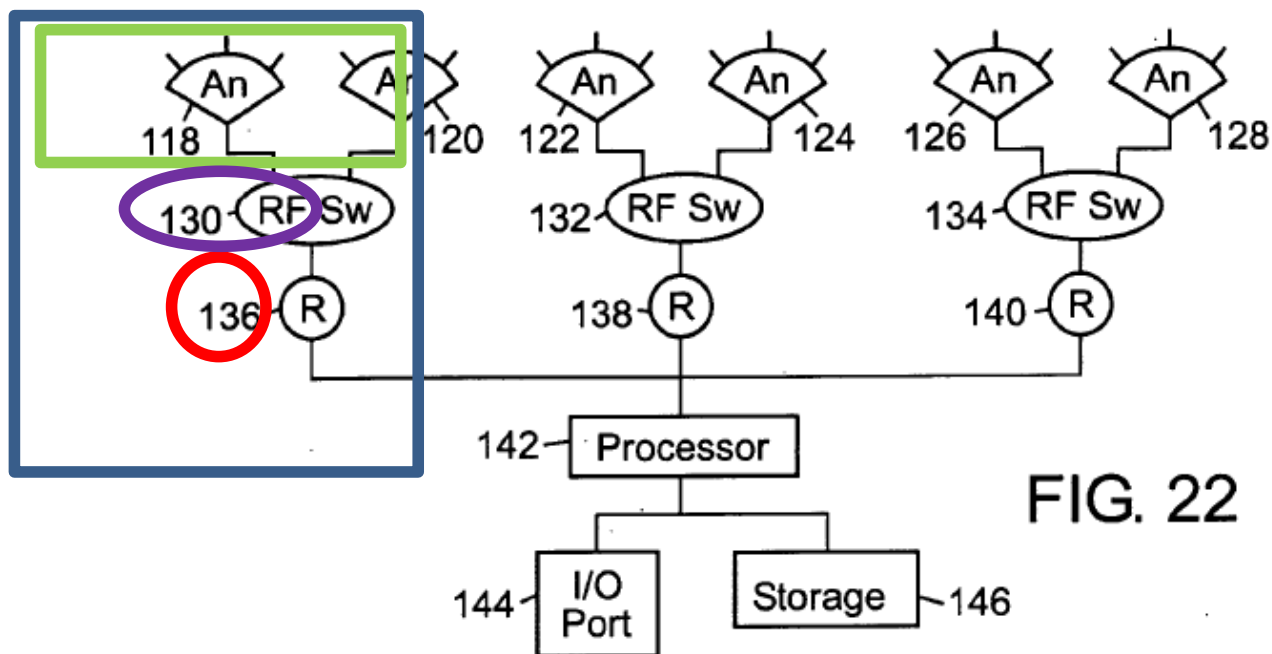


FIG. 22

EX-1004 FIG. 22. I note further that Lastinger's claim 1 recites effectively the same architecture as is claimed in '930 claim 1 with a "plurality" (e.g., at least 2) sets of radios, RF circuitry and antennas. Lastinger's claim 5 expressly recites MIMO. Thus, Lastinger's claims 1, 5 recite elements 1.0, 1.1., 1.2, 1.3 in the '930.

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I further note that the priority application specification (as filed at the time of the priority date) did not include the term “transmission point.” This term was added into the Abstract and Summary of the Invention for the '930 in the filing of the '930 application on November 25, 2015. I note that Lastinger provides “directional” antennas. EX-1004, [0106]. The “directional” antennas is also taught or would be known to a POSITA by the reference to “sectors” or “sectorized wireless cell” including in Lastinger’s Title and throughout the disclosure.

257. Lastinger discloses that FIG. 22 is an exemplary six antenna, three-radio wireless cell and that the wireless cell does packet switching (*a single wireless station configured to operate in a packet-switched cellular network*). EX-1004 [0031];

Radios are an additional, indispensable part of a wireless cell. Other components of a wireless cell may include, for example, at least one of RF switches, ASDS, processors, I/O ports, storage, attenuators in addition to those used in the enhanced antenna system, **packet switches**, horns, base band processors, digital signal processors, and other analog or digital electronic components, or connections, and busses. No limitation is placed on the number of radios, antennas, other components, or the organization of the components in a wireless cell.

EX-1004 [0130]. *See also* EX-1004, FIGS. 22-31 (showing various component configurations). “Exemplary communication protocols may use packets....” EX-

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1004, [0179]. Moreover, Lastinger cites a variety of known protocols that are used in packet-switched networks including such protocols as “802.11a, 802.11b, 802.11g, 802.15, 802.16, Bluetooth...” EX-1004, [0134]. Lastinger notes that its base station may use “Ethernet” connections and Ethernet is a packet / frame protocol. EX-1004, [0133].

258. A POSITA understood that Lastinger’s “wireless cell” is a shorthand for “wireless cellular station” that may use any protocol to communicate including 802.11, 802.15, 802.16, Bluetooth, and ultra-wideband. EX-1004 [0134]. I note that the ’930 patent does not recite “wireless station” (or even “station”) in its specification and this is a term present only in the ’930 claims. Lastinger’s “wireless cell” is defined broadly and in a similar manner to the definitions in the ’930 patent of the same term “wireless cell” and “wireless device.”

Lastinger (EX-1004)	’930 Patent (EX-1001)
“A wireless cell includes, for example, a collection of antennas, radios, and potentially other devices (e.g., attenuators, RF switches, etc.) under the common control of a processor or multiple processors. An exemplary wireless cell communicates with other wireless cells, wireless clients, or other wireless devices. One	“A wireless device, according to the various aspects of the present invention includes, for example, wireless cells, access points, wireless clients, mobile

embodiment of a wireless cell is an access point, which combines wireless communication with an I/O port connected to a wired network thereby allowing communication between wired and wireless devices. ...” [0090].	computers, and handheld devices.” 3:4-7
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The *first transmission point* (outlined in blue) includes:

- *a plurality of first directional antennas having MIMO capability*
(yellow) EX-1004 [0102]-[0105]; Claim 5.
- *at least one radio in communication with the first directional antenna*
(red), EX-1004 [0110]-[0111], [0135], Claim 1,
- *first circuitry in communication with the at least one first radio*
(purple) EX-1004 [0110]-[0111], [0135], Claim 1.

See also EX-1004, [0145-0146], [0135-0138], [0090-0098] (all disclosing various permutations of components used in Lastinger’s wireless cells).

259. As noted my discussion of Gore above, Gore teaches multiple different directional antenna groups that include their own radio and other circuitry as part of “transmission chains.” For example, Gore states “Each base station 102 can comprise multiple transmitter chains and receiver chains, e.g. one for each transmit and receive antenna, each of which can in turn comprise a plurality of components associated

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with signal transmission and reception (e.g., processors, modulators, multiplexers, demodulators, demultiplexers, antennas, etc.). ... A 3-sector base station 202 includes multiple antenna groups, one including antennas 204 and 206, another including antennas 208 and 210, and a third including antennas 212 and 214. According to the figure, only two antennas are shown for each antenna group, however, more or fewer antennas may be utilized for each antenna group. Typically, beamforming techniques require multiple transmit antennas to transmit beams.” EX-1006, 4:62-5:23. The “directional” aspect of Gore’s antennas is shown through the different sectors throughout the specification and the reference to “adaptive sectorization” in the Title of Gore. E.g., EX-1006, 8:24-25 (“[t]he transmit antennas can be trained in several directions.”), FIGs. 1, 2, 3. I note that Gore’s description of “modulators, multiplexers, demodulators, demultiplexers” describes the components of a radio and, in the context of Gore being a wireless base station, would teach the claimed “radio.” This is shown in Gore’s FIG.8 below. Gore’s “radio” is also taught by the combination of the components in FIG. 9 below including the RCVR (receiver), TMTR (transmitter), symbol modulator/demodulator and other components. E.g., EX-1006 12:4-13:6.

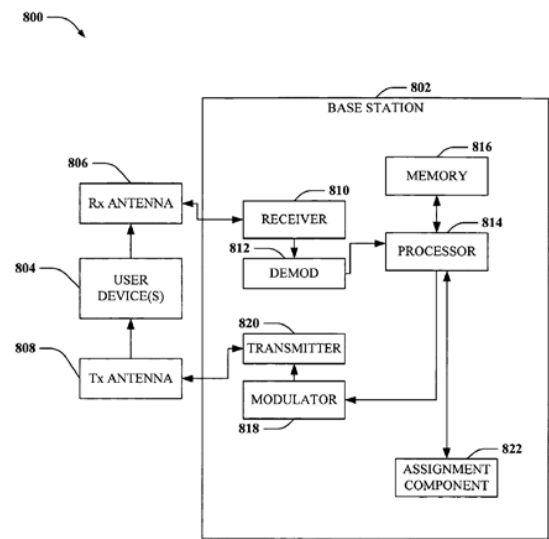


FIG. 8

260.

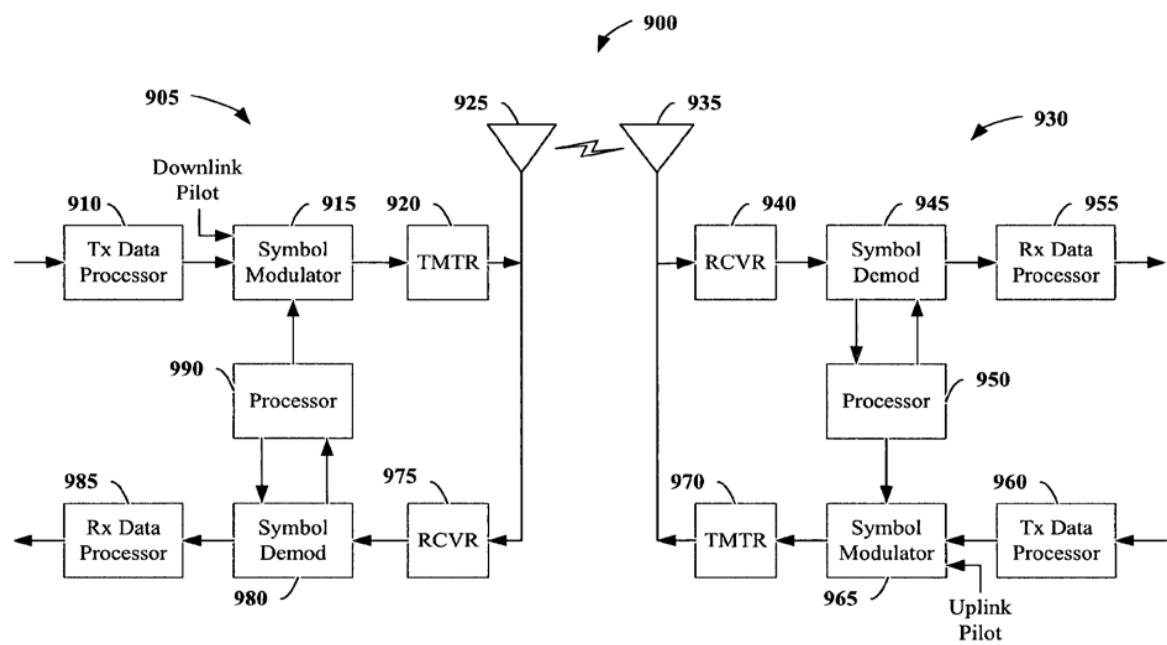


FIG. 9

261.

262. This paragraph left intentionally blank.

263. This paragraph left intentionally blank.

264. This paragraph left intentionally blank.

265. This paragraph left intentionally blank.

[1.2] a second transmission point with a multiple-input-multiple-output (MIMO) capability, the second transmission point having:

a plurality of second directional antennas, at least one second radio in communication with the second directional antennas, and second circuitry in communication with the at least one second radio;

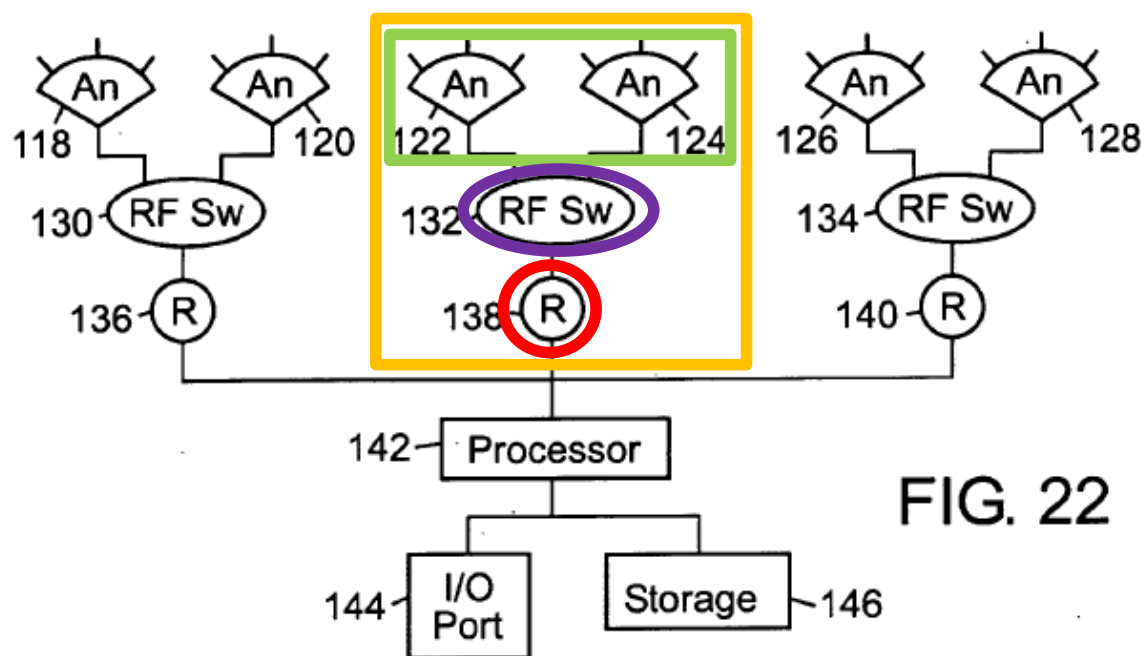
266. Lastinger discloses this limitation for the reasons cited for limitation 1.1.

Lastinger discloses a *second transmission point* (outlined in gold) that includes:

- *a plurality of second directional antennas having MIMO capability* (gold) EX-1004 [0102]-[0105]; Claim 5.
- *at least one second radio in communication with the first directional antenna* (red), EX-1004 [0110]-[0111], [0135]
- *second circuitry in communication with the at least one first radio* (purple) EX-1004 [0110]-[0111], [0135].

I note also that both Lastinger and Gore expressly recite that their wireless cells / base stations / access points can include any number of the collections of radios, antennas, and related circuitries. E.g., EX-1006 [“however, the embodiments may include any number of antennas available, any number of antennas in simultaneous use, any number of radios, overlapping or non-overlapping physical sectors,

physical sector positioning, and/or communication protocols used.”); EX-1006, 4:62-5:23. Thus, merely reciting multiple copies of a particular hardware component (the “transmission point”) is neither new over the prior art nor would a POSITA recognize this as some type of patentable improvement.



EX-1004 FIG. 2.

[1.3] third circuitry in communication with the first circuitry of the first transmission point with the multiple-input-multiple-output (MIMO) capability and the second circuitry of the second transmission point with the multiple-input-multiple-output (MIMO) capability;

267. Lastinger discloses a processor (*third circuitry*) (yellow) in communication with the RF switches (*first circuitry and second circuitry*) (purple) of the *first and second transmission points* (blue and gold respectively). As I noted for element 1.1 above,

Lastinger's claim 1 (and claim 5) recite an architecture disclosing the components recited in elements 1.1, 1.2, and 1.3.

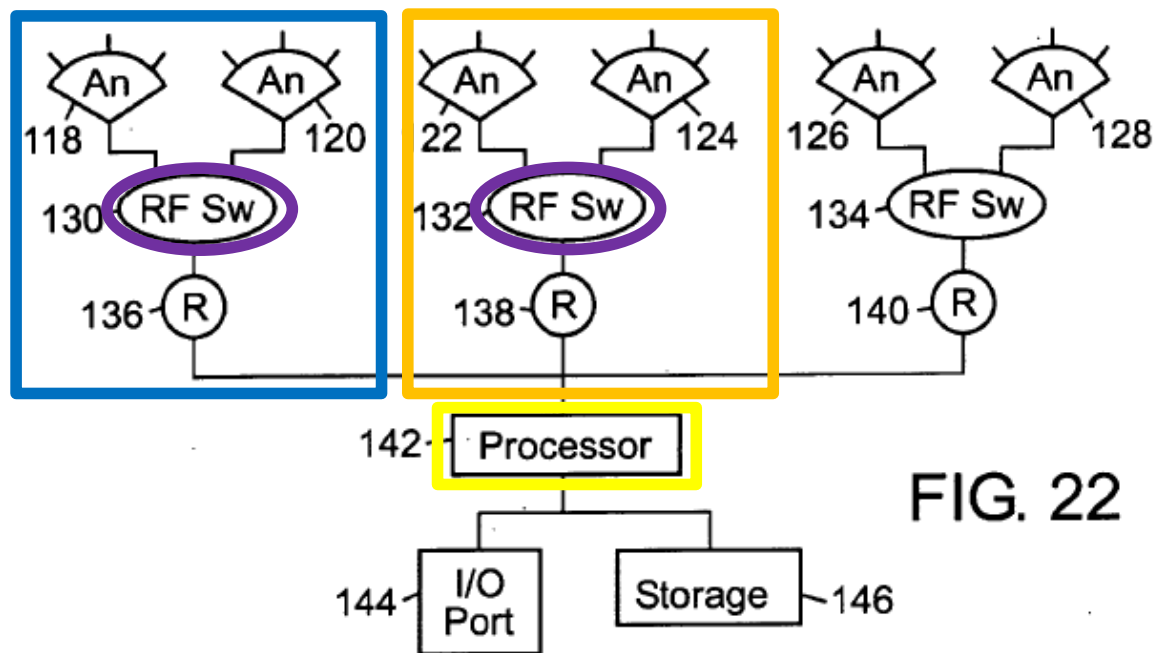


FIG. 22

EX-1004 FIG. 2.

268. Lastinger discloses that the processor (yellow) controls the RF switches (purple) to adjust the physical sector attached to the radio to increase efficiency, increase performance and decrease interference. EX-1004 [0132]. Lastinger's processon controls the various components in its radio. EX-1004 [0090]. Lastinger provides for a processor to process the MIMO signals. EX-1004 [0104]. Lastinger's processor connects to the radio through a wide variety of industry standard interfaces. EX-1004 [0152] ("The radio board then couples to the processor board and to the antennas. Components such as I/O port and local memory may be incorporated into the processor board. The interface between the processor board and the radio PCB is

generally not timing critical or sensitive to noise because the processor connects to the radios using an industry standard bus such as PCI, USB, PC Card, or IEEE 1394 depending on the radio interface bus.”);

269. As noted in my discussion of Gore above, Gore teaches a processor that controls the base station’s functions including processing radio signals received from the transmission chains. EX-1006, 10:38-59, 11:48-58, 12:4-13:7. *See also* EX-1006 2:1-16, 7:6-26. Gore teaches that the processors are part of the “plurality of components associated with signal transmission and reception” 4:52-67. Gore’s processor(s) are in communication with the various components. E.g., EX-1006 FIGS.7-9, 10:38-59, 11:48-58, 12:4-13:7 including the broad disclosure at 12:64-13:7 (“Processors 990 and 950 direct (e.g., control, coordinate, manage, etc.) operation at access point 905 and user device 930, respectively. Respective processors 990 and 950 can be associated with memory units (not shown) that store program codes and data. Processors 990 and 950 can utilize any of the methodologies described herein, including those illustrated in FIGS. 4-6 to select a scheduling technique or beam assignment for the user device 930. Respective Processors 990 and 950 can also perform computations to derive frequency and impulse response estimates for the uplink and downlink, respectively.”).

[1.4] said single wireless station configured such that the first transmission point with the multiple-input-multiple-output (MIMO) capability cooperates with the second transmission point with the multiple-input-multiple-output (MIMO) capability in

connection with a first transmission to a first multiple-input-multiple-output (MIMO)-capable portable wireless device, for improving the first transmission;

270. Lastinger discloses that the wireless cell (*first and second transmission site*) and the client device (*portable wireless device*) are *MIMO capable*, which improves the communications between the wireless cell and the client device (*improving the first transmission*).¹⁴ For example, Lastinger discloses that the antennas used by the cell or the client may be MIMO antennas. EX-1004 [0103][0105]. Lastinger also repeatedly recites in its claims that its antennas are MIMO antennas. EX-1004, claims 5, 15, 25, 35, 41, 48, 53, 62, 71, 96, and 122. Lastinger cites to known MIMO techniques in “servicing a physical sector.” EX-1004 [0104]. Lastinger also states that “[a] wireless cell may use any or all of the techniques” disclosed in Lastinger in servicing the clients. EX-1004 [0193]. Lastinger also repeatedly states that its disclosure should be considered broadly and is not limited by specific examples. EX-1004 [0199], [0078] (“Thus, the detailed description herein is presented for purposes of illustration only and not of limitation. For example, the steps recited in any of the method or process descriptions may be executed in any order and are not limited to

¹⁴ The ‘930 specification does not include the word “cooperate” nor does it explain any particular meaning for this term. The ‘930 Abstract and Summary of the Invention recite “cooperate” but both the Abstract and Summary of the Invention were not present in the priority document and were added on November 25, 2015 in the filing of the ‘930 application.

the order presented.”), [0094], [0098], [0106] (“one skilled in the art will appreciate that enhanced antenna systems are not limited to the embodiments described.”), [0115] (“the arrangement is mentioned to emphasize that the enhanced antenna system embodiments disclosed are not limitations, but specific examples of possible approaches.”), [0130-0131] (“No limitation is placed on the number of radios, antennas, other components, or the organization of the components in a wireless cell. [0131] Various wireless cell hardware embodiments are presented in this application. Wherever possible, the hardware embodiments are described in terms of a previously described enhanced antenna system embodiment plus other components. The wireless cell hardware embodiments are specific, non-limiting examples”), [0145]. In light of the express disclosure of MIMO techniques, the recitation in the claims, and the broad disclosure of Lastinger, a POSITA would have understood Lastinger’s teachings to include MIMO transmissions (in their known and various forms) between the wireless cell and the client devices.

271. Lastinger discloses the claimed cooperation in multiple different ways. First, Lastinger discloses that the MIMO antennas can be used during transmission to the client by forming an array of at least one antenna from the first transmission site and one antenna from the second transmission site (*the first transmission point ... cooperates with the second transmission point*) thus forming a MIMO array that transmits directional beams within the angle and area of coverage to send a stronger

signal to a desired client, which a POSITA understood would *improve the first transmission*. EX-1004 [0105]. This MIMO cooperation between Lastinger's transmission points is detailed in the section above discussing Lastinger. As I have detailed above in the discussion of Lastinger, Gore, and the State of the Art for MIMO, known MIMO techniques included transmissions from multiple different antennas controlled by multiple different radios.

272. Second, Lastinger expressly discloses that adjusting the physical sectors associated with the MIMO antennas of the first and second transmission site will "increase efficiency, increase performance and decrease interference." EX-1004 [0132]. Such an adjustment is disclosed in Lastinger in multiple ways. Lastinger teaches "adjusting radio transmission power" and "adjusting attenuation" can be used for "facilitating adjustment of physical sector size". EX-1004 claim 79. This is also taught in EX-1004 [0088-0089] ("Adjusting the transmit power of an off-the-self radio changes the area of coverage, or size, of the antenna's physical sector. The physical sector 34 and distance 36 shown in FIG. 7 represents the size of the physical sector when the radio transmits at maximum power. As radio transmission power decreases, physical sector size 38 and distance 40, as shown in FIG. 8, also decrease. [0089] The same variation in size occurs for receive signals if an attenuator is placed in the radio receive path. An attenuator with zero attenuation allows the maximum receive physical sector 42 and receive distance 44 as shown in FIG. 9. As the

attenuation increases, the size of the receive physical sector 46 and receive distance 48 decrease as shown in FIG. 10. Clearly, the size of the transmit physical sector may also be adjusted by using an attenuator in the transmit path. In other embodiments, the size of the receive sector may be adjusted using variable gain. Both transmit and receive physical sector sizes may be simultaneously adjusted if an attenuator is placed between the radio and the antenna thereby affecting both the transmit and receive paths substantially equally. Obviously, the size of the transmit and receive physical sectors may be adjusted independently.”). By adjusting the physical sectors serviced by each transmission point, Lastinger’s transmission points are cooperating to ensure that there is adequate coverage.

273. Third, Lastinger teaches cooperation in an embodiment in which there is a determination of which transmission point is selected for a particular client. For example, Lastinger teaches that the “physical sectors of the antennas may overlapped to form virtual sectors.” EX-1004 Abstract. *See also* EX-1004 [0085]. The “physical sectors” are created by each radio/antenna grouping as shown in FIG. 22 above (claimed “transmission point”). EX-1004, [0111]. Thus, each “virtual sector” may be serviced by multiple different transmission points. EX-1004 [0085] (“If antennas 14 and 20 are attached to different radios, then the virtual sectors are serviced by two radios instead of the single radio that services either physical sector.”). The selection of a “radio” (transmission point) also includes the selection of a channel used by that

radio. EX-1004 [0111] (“since a radio uses a single channel...”). Lastinger’s enhanced antennas allows for one or more of the different physical sectors to be selected for servicing the clients that are within the particular virtual sector which shows cooperation by the transmissions points measuring information which can be used by the processor to select an appropriate antenna.

274. Lastinger teaches that the transmission points for a “virtual sector” can cooperate to select the “best” radio/antenna (“transmission point”) for a particular client device.

Lastinger expressly teaches this in FIG. 58:

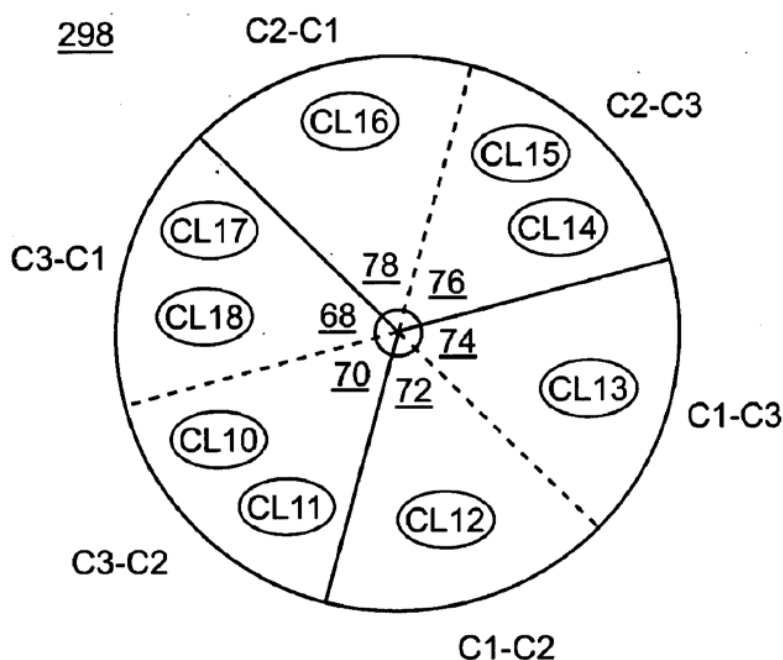


FIG. 58

275. EX-1004, FIG. 58. FIG. 58 shows six different “virtual sectors” (68, 70, 72, 74, 76, 78). Each “virtual sector” is serviced by two physical sectors. EX-1004, [0181].

Lastinger then explains how a particular client (denoted by “CL”) may be serviced by either of two different radios/antennas (“transmission points”).

In the scenario of FIG. 58 and when the hardware of FIG. 22 is used, each client of wireless cell 298 may associate with one of two radios that service each virtual sector. For example, assume client CL10 associates with radio 138 using channel C2...

EX-1004, [0182]. Lastinger’s teaching that the multiple transmission points can service different clients shows that those transmission points are cooperating (including under the control of the common processor disclosed in Lastinger).

276. Lastinger also explains that, when using the virtual sectors, the “best” of the two transmission points is chosen for a particular device:

A second embodiment of an enhanced antenna system uses multiple directional antennas arranged such that the antenna physical sectors overlap....The exemplary antennas and hardware shown in FIG. 22, FIG. 25, FIG. 28, or FIG. 29 may be adapted to provide overlapping coverage and to implement the second embodiment of an enhanced antenna system. The coverage of two antennas in each virtual sector may allow the second embodiment of an enhanced antenna system to use the best antenna of two antennas to communicate with a device in the virtual sector.

EX-1004 [0110]. A determination of “best” can include many different factors such as the coverage for a particular client, but it can also include the overall coverage and needs of multiple clients in the cell. For example, Lastinger teaches that a “client may provide the wireless cell with a prioritized list of optimal channels from the clients' perspective. The wireless cell then determines the optimal way to meet all client needs using the available resource.” EX-1004,

[0190]. Lastinger teaches that the cell can alter sector assignments and associations to address the overall needs of the cell and its various transmission points. E.g., EX-1004 [0191-0198]. For example, “Some of the options for Client X may include, for example, at least one of transcoding to a lower bit rate, displaying a message to the user, prioritizing desired throughput for multiple clients, redistributing client load among available radios and/or antennas, or continuing to operate with degraded performance.” EX-1004 [0198]. These forms of cooperation allow for different factors to be used to select the particular transmission points.

277. Lastinger teaches a different form of “cooperation” when the physical sectors (created by each transmission point) are not overlapping. In that situation, the two transmission points “cooperate” to determine which of the transmission points should service a particular client. In one example, the “best reception” is used as the criteria for the cooperation between the transmission points:

A first embodiment of an enhanced antenna system uses multiple directional antennas arranged such that the antenna's physical sectors are adjacent, but non-overlapping. During communication, only one antenna is active at a time. The antenna used to communicate is selected by measuring the signal strength of the desired receive signal through each antenna. The antenna that detects the strongest receive signal is used and the other antennas are either disabled or ignored. The first embodiment of an enhanced antenna system provides increased performance by using the antenna that provides the best reception.

278. EX-1004, [0107]. See also EX-1004, [0109] (showing different criteria for selecting the transmission point). See also EX-1004, FIG. 57, [0170-0171]. Lastinger teaches that the “environmental conditions” (which are reported to the wireless cell by the clients as in 1.5 and 1.6) “may affect the association and servicing of clients....” EX-1004, [0171]. See also EX-1004, claims 44-49 (selecting only transmission point with highest incoming signal quality); claims 73-78; claims 120-123. This cooperation is performed under the common control of the processor that performs the assignments in Lastinger because, for example, it is the component that sits in the processing path of all transmission points and provides an ability to ensure consistent operation between the multiple transmission points.

279. Thus, Lastinger also teaches the claimed “cooperation” also in the selection of the transmission point(s) used to provide service to a particular client. This is discussed above for the overlapping scenario and the cooperation provides largely the same functionality in the non-overlapping sector case.

280. Gore confirms Lastinger’s teachings of cooperation and fills any gaps that the PO might allege exist in Lastinger. First, Gore confirms that two separate transmission points (Gore’s “transmitter chains”) transmit to the same mobile device using beamforming techniques to create virtual sectors. For example, “a virtual six-sector system” is “generated from a conventional three-sector system” by using the beams formed by different sectors. This use of different sectors to transmit to individual

devices matches Lastinger's teachings (discussed above) and meets the "cooperates" element. This form of "cooperates" is shown by the "SDM" and MIMO techniques. E.g., EX-1006 6:35-43 (SDM), 6:44-51 ("In a MIMO system, multiple data streams corresponding to a single user device are scheduled at the same time and frequency on different beams."). Gore teaches that the transmissions from the different physical sectors can be used to form beams that create virtual sectors. Thus, for example, in Gore's MIMO scenario, multiple beams could be formed from the antennas in different physical sectors to transmit data to a single device on the multiple beams. The beams could carry either the same data (called transmit diversity) or different data (called spatial multiplexing). I have discussed these in detail above in the section explaining known MIMO techniques. Gore's techniques are referenced in Lastinger in its discussion in [0103-0105] of using known MIMO diversity techniques.

281. Gore also teaches Lastinger's form of cooperation in which a single transmission point is selected to serve the device. EX-1006, 6:35-43 ("in opportunistic beamforming, also referred to as beam selection, the base station transmits to a single user device over a given set of frequencies and time using a single beam."). Gore's discussion of "opportunistic beamforming" references the ability of a base station to use beams to transmit data without using MIMO techniques. This is similar to Lastinger's discussion in EX-1004 [0105].

282. Gore confirms that “multiple antennas at a base station” are used to “emit beams.”

6:5-10. *See also* EX-1006, 5:21-23 (beamforming requires multiple transmit antennas to transmit beams).

283. In both types of cooperation, Gore’s base station “assigns” or “reassigns” user devices to one or more beams with the assignment being a form of cooperation. EX-1006, 9:47-55, 11:52-57, 13:1-4, 2:17-25, 6:35-7:4, claims 15, 31. This teaching from Gore complements Lastinger’s teachings of using the information from multiple different devices to assign, or re-assign, devices to particular transmissions to increase the overall throughput of the system. For example, Gore teaches that “After the CQI is determined, it can be communicated to the base station at 406. At 408, the CQI can be used to determine scheduling technique and/or the beam assignment for one or more user devices. Using CQI in scheduling and assignment determination can optimize individual channel and overall system performance.” EX-1006 7:55-60, FIG 4. *See also* EX-1006 9:47-56 (“User devices can be reassigned to beams or the entire beam pattern can be modified depending upon the CQI values. In general, user devices are capable of relocating or being relocated during voice or data transmission, and may move into or out of the coverage area provided by the beam to which they area assigned. User devices should be reassigned as they move through the sector from the coverage area of one beam to another. In addition, based upon the CQIs reported by multiple users, the base station can adjust the beam pattern to better

service the group of user devices.”). The transmission chains are cooperating (under the control of the processor) to ensure that the user devices are being efficiently served as those devices move through the different physical sectors (and through the virtual sectors).

284. Thus, Lastinger, alone or in combination with Gore, teaches this element.

[1.5] said single wireless station configured for: receiving first information from the first multiple-input-multiple-output (MIMO)-capable portable wireless device that is based on a measurement performed by the first multiple-input-multiple-output (MIMO)-capable portable wireless device;

285. Lastinger discloses several examples of this limitation. Lastinger discloses that “[a]n advanced client may report, for example, at least one of its desired minimum and maximum throughput needs, desired channel, signal quality for all channels, all detectable wireless cells and physical sectors, physical distance to all wireless cells....” EX-1004 [0173]; *see also* EX-1004 [0189]. To report these metrics, the client device “may measure receive signal strength, or signal quality....” EX-1004 [0146]. Lastinger further discloses:

- That its “client also uses extensions to the 802.11 protocols to communicate control information and requests to the wireless cell to improve data throughput, transmission signal strengths, noise suppression, and other performance factors.” EX-1004 [0147].

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- That signal quality is a measure of signal level, noise level, error rate, and other operational and environmental factors from a radio's perspective, and that a radio may perform a signal quality scan by listening to receive signals and ranking them by their signal quality. EX-[0167-0168].
- That a client can send control information to the wireless cell, including signal quality, desired antenna, error rate, number of dropped frames, desired throughput, throughput delivered, wireless cells detected, and/or any other conceivable information (*first information.. based on a first measurement performed by the first portable wireless device*). EX-1004 [0097-0100];
- That the AP receives environment, performance or any other information measured by the client (*receiving first information.. based on a first measurement performed by the first portable wireless device*). EX-1004 [0193].
- That the communication of control or environmental information between a wireless cell and advanced clients may occur at association, during active or passive scans, or at any time allowed by the communication protocol. EX-1004 [0189].

See also EX-1006 [0173-0175], claims 126, 73, 76. Lastinger's teaching merely reflects the well-known (before the priority date) techniques of using channel conditions to adjust transmission parameters. Such techniques had long been known in the wireless communication arts prior to 2006. Indeed, Lastinger (as well as the '930 patent) relies upon the known techniques and protocols for returning such feedback information measured by mobile devices to the base station. This information was referenced in the art as channel state information (CSI) or channel conditions or similar names. As noted above in the General Related Knowledge section, it was also well known to use this information to adapt MIMO transmissions.

286. Lastinger also discloses that a client may also request information or action from the cell, including retransmission, channel change, throughput demands, authentication, variation in transmit power, and/or a request to modify any communication factor (*first information.. based on a first measurement performed by the first portable wireless device*). EX-1004 [0098]. Such requests are from the client are based on measurements made at the client and reflect the client seeking alterations in the transmitted data on the downlink.

287. Further, Lastinger expressly recites that this first information received by the wireless cell "helps the wireless cell manage its communication with the clients it serves", including desired throughput, buffer fullness, signal quality, and/or other

relevant information. EX-1004 [0100]. Lastinger provides extensive details throughout its disclosure (as noted above) regarding the functionality of the wireless cell to alter the transmission characteristics on the downlink to different mobile devices to accommodate both the needs of a single mobile device and the needs across the entire set of devices to potentially increase the overall throughput or the throughput requests of a particular client device.

288. Thus, the information would include environment, performance, “control information,” or any other information measured by the client, including a signal quality measurement and other measurements discussed above. Lastinger’s broad definition of “control information” gives several specific examples that meet the limitation of “first information” as well as confirm that a POSITA would understand the “control information” to encompass any form of such information, including all of the examples provided in the challenged patent’s claims and specification. The challenged patent did not teach any form of new measurement or new information but rather relied upon what was already known in the industry as examples of the type of information that could be used to alter or adjust the transmission parameters and characteristics.

289. Gore mirrors Lastinger in teaching that Gore’s access points receiving “channel quality information” (“CQI”) that includes “signal to interference and noise ratio” and “supportable rate” received from the wireless clients. EX-1006 7:53-55, 9:4-6

(“user device can report CQIs ... such that the base station receives CQIs continually...”); 9:19-46, claims 3, 4, 16. The term “CQI” / “channel quality information” is a well-known term in the wireless industry. Gore gives several examples of CQI, but this term is known to encompass many different forms of “channel quality information” such as the “environmental conditions” of the channel that are referenced in Lastinger. E.g., EX-1004, [0167], [0171], [0189], [0193], [0194].

[1.6] receiving second information from the first multiple-input-multiple-output (MIMO)-capable portable wireless device that is based on another measurement performed by the first multiple-input-multiple-output (MIMO)-capable portable wireless device;

290. Lastinger alone or in combination with Gore discloses this limitation for the same reason as discussed with respect to claim limitation [1.5]. The various environmental conditions would potentially be different for each of the transmission points due to factors such as different antenna placement and different channels.

[1.7] altering at least one aspect of the first transmission in connection with at least one of: multiple of the first directional antennas of the first transmission point with the multiple-input-multiple-output (MIMO) capability, or multiple of the second directional antennas of the second transmission point with the multiple-input-multiple-output (MIMO) capability, based on the first information and the second information;

291. Lastinger alone or in combination with Gore discloses several examples of this limitation.¹⁵ For example, assigning (or re-assigning/changing) channels is *altering one aspect of the first transmission*, and Lastinger discloses that the “signal quality collected from each radio may be used to determine potential channel assignments for each radio to substantially comply with throughput, or loading specifications” (*altering at least one aspect of the first transmission... based on the first information and the second information*). EX-1004 [0176]. Another example is that Lastinger discloses changing the channels used for transmission based on signal quality information from the clients:

The channel used between the wireless cell and the client may also be established at association. The wireless cell **may change the channels assigned to its physical sectors in response to, for example, interference, loading, throughput demands, or other factors**. In one embodiment, when the wireless cell **changes the channel** used in a physical sector, all clients associated with the physical sector detected, and **follow to the new channel**. Advanced clients may be capable of either negotiating the use of a different channel, or **providing the wireless cell with signal quality**

¹⁵ I note that the ‘930 patent specification as filed on the priority date does not reference the term “aspect” of a transmission. “Aspect” is used only in the context of several statements regarding “aspects of the invention.” In the ‘930 non-provisional application, the term “aspect” was used in the Abstract and Summary of the Invention (and claims) that were added in November 2015.

information from each client's perspective to assist the wireless cell in determining the best channels to use.

EX-1004 [0174]. See also EX-1004, [0196-0199] (describing specific example of changing channels to reduce interference based on information from clients), [0189] (“changing channels, changing protocols, ..., moving a client to another physical sector, and/or any other type of action” in response to information from the client). Changing the channels is “altering” an aspect of the transmission. It is based on the first and second information because, as noted in the elements above (regarding receiving the information), Lastinger teaches receiving information from the various transmission points and then using that collective information to, for example, assign channels.

292. By way of another example, changing physical sectors to a client is *altering one aspect of the first transmission*, and Lastinger discloses this change may be done for load balancing purposes which a POSITA understood to be based on the “throughput demand” received from the clients (*altering at least one aspect of the first transmission... based on the first information and the second information*):

A wireless cell may **dynamically balance its load by disassociating a particular client with a particular physical sector and accepting an association with a different sector**, or the wireless cell may use control commands to move an advanced client to a different physical sector and different channel without requiring the client to repeat the association process. **A client may disassociate**

with its current physical sector and request association with another physical sector of the same wireless cell, but in one embodiment, the wireless cell approves the new association request.

EX-1004 [0175][0190]. The change of physical sector(s) changes the antenna/radio grouping used to service the client. The antenna selection may depend on the feedback information from the clients. *E.g.*, EX-1004, [0146], [0110], [0185-0188], [0196-0198]. Because the physical sectors in Lastinger generally correspond to specific transmission points (e.g., collection of radios and antennas), changing the physical sectors changes the aspect of the invention that relates to the specific hardware (e.g., antennas) being used to emit the RF signals that represent the channel.

293. Lastinger's option to change physical sectors is highlighted by FIG. 53 (showing physical sectors overlapping to create virtual sectors served by at least two physical sectors). EX-1004 [0153-0164]. As Lastinger teaches, when the physical sectors overlap, the device may be serviced by one (or more as described above for Lastinger) of the overlapping physical sectors. This allows the processor to base a physical sector assignment on the information that is received from the client devices. Such assignments can change (as noted herein) according to Lastinger.

294. In yet another example, changing priority of a transmission to a client is *altering one aspect of the first* transmission, and Lastinger discloses changing priority of a

transmission to a high throughput client (*altering at least one aspect of the first transmission... based on the first information and the second information.*) EX-1004 [0191][0192].

295. A further example in Lastinger is its teaching of “[a]n exemplary client also uses extensions to the 802.11 protocols to communicate control information and requests to the wireless cell to improve data throughput, transmission signal strengths, noise suppression, and other performance factors.” EX-1004 [0147]; see also EX-1004 [0098-0100]. Lastinger teaches altering the power or transmit attenuation of its transmissions based on the information returned from the devices. EX-1004, [0088-0089], [0125] (adjustable attenuation). Changing the power and attenuation is changing an aspect of the transmission because they both impact the ability of the RF waves forming the transmission to convey information over different distances between two components involved in the transmission (e.g., the base station antenna(s) and the client devices). Furthermore, Lastinger’s reference to “control information” from protocols such as 802.11 would also include alterations in the various transmission aspects that are specific to those protocols such as the encoding and modulation parameters for the transmission as well as adjusting the assignments across the entire set of devices attached to the base station / access point. E.g., EX-1004, [0006], [0153], [0191]-[0198].

296. Lastinger also teaches that various MIMO characteristics may be altered based on the feedback information from the clients. EX-1004 [0103-0105]. This includes the selection of different antenna and/or transmission points for a particular transmission. E.g., EX-1004, [0103] (“During transmission or reception, all or any subset of antennas in the MIMO array may be used or selection diversity may be used to limit the number of antennas used.”). This alteration would include selecting whether to even use the MIMO capability. E.g., EX-1004, [0105] (“any antenna array may be used as a single antenna or a MIMO antenna may be used.”). Because Lastinger merely relies on the known MIMO capabilities, a POSITA would understand that MIMO parameters such as number of horizontal and vertical elements (spacing and aperture/beam width), azimuth and elevation angle (steering angle), phase, and gain would be altered to accommodate different changing conditions. Moreover, as noted in Gore, the access point has the capability to choose either MIMO or non-MIMO transmissions and can switch back and forth as appropriate.

297. Lastinger’s claims recite altering various aspects of the transmission to reduce interference. EX-1004 claim 76 (“adjusting attenuation...”); claim 12, claim 66; claim 79 (“adjusting radio transmission power...”); claim 79 (“adjustment of physical sector size”); claims 83-86; claim 87 (adjusting “transmission range and reception range”); 91 (“adjusting a size of the physical sectors...”); 120-126; 130-141 (all changing channels); 126. Moreover, Lastinger teaches that may use “a

combination of techniques” which alter transmission characteristics “to improve performance” which would include reducing interference and that “all or any of the techniques” may be used to increase performance. EX-1004, [0101], [0193]. Lastinger’s references to increasing performance encompass the claimed efforts to reduce interference. For example, “performance” can be a measure of different factors such as overall throughput for the device, or for the entire cell to all devices. It can also encompass the amount of power necessary to apply to a signal to ensure reception. Factors such as the “signal-to-noise ratio” reflect interference because the “noise” aspect is generally considered to be, or include, interference and the “signal” aspect is heavily influenced by the amount of power applied at the RF transmission point to generate the RF waves carrying the data signal.

298. As noted in section VII.A.2 supra, Gore teaches several forms of alteration that are all based upon the CQI information received from the various client devices. First, Gore teaches to select different “select a scheduling technique, such as space division multiplexing (SDM), multiple-input multiple output (MIMO) transmission and opportunistic beamforming” This teaching supplements Lastinger’s teaching on selecting whether to use MIMO or not. Selecting one of “Gore’s scheduling techniques” alters a transmission characteristic because it can change the number of antennas or specific antenna(s) used for the RF transmission and it can/will change the specific encoding of the data signals on the RF transmission.

299. Second, Gore teaches the base station may to “select” particular beams for a client device. This supplements Lastinger’s teaching that the base station may assign (or re-assign) clients to the transmissions from particular sectors / antennas. Changing the beam(s) used for the transmission changes an aspect of the RF transmission because it changes the specific characteristics of the RF waves used for transmission as well as potentially changes the antenna(s) used to generate the transmission and it would change the coverage patterns of the RF waves to alter the specific reception at the client device.

300. Third, Gore teaches the base station may “update” one or more of the beam patterns – including though applying weights to form/alter the beams. This supplements Lastinger’s teaching of using weights to update beamforming. Updating the beams alters the transmission because it changes the coverage patterns of the RF waves, it would change the reception ability at the client device, and it changes the specific emissions generated by the antenna(s).

301. Each of Gore’s alterations are done based on CQI. EX-1006 Abstract, 2:42-62, 3:15-32, 6:3-5, 8:22-51, 8:55-9:17, 9:20-22, 9:47-54, 10:15-17, 13:1-4, claims 1-36. Gore’s CQI are based upon measurements, including interference, done at the client devices. EX-1006, FIG. 6, 8:33-37, 8:59-63, 9:18-46, 10:35-37, 12:29-31. Gore’s alterations are done to reduce interference, increase the signal-to-noise ratio, and increase system capacity. EX-1006, 2: 10-12, 5:44-52, 6:32-34, 7:11-13. Gore’s

teaching is essentially that the transmission characteristics can/should be altered as appropriate based on the feedback information from one or more devices to adapt the access point transmissions to provide better coverage for a particular device or more generally for devices attached to the base station / access point.

302. Thus, Lastinger, alone or in combination with Gore, teaches this limitation.

[1.8] transmitting data in connection with the first transmission to the first multiple-input-multiple-output (MIMO)-capable portable wireless device, utilizing at least one of: the multiple first directional antennas of the first transmission point with the multiple-input-multiple-output (MIMO) capability, or the multiple second directional antennas of the second transmission point with the multiple-input-multiple-output (MIMO) capability.

303. Lastinger alone or in combination with Gore discloses transmitting to clients by one or more transmission points. See elements 1.5, 1.6 *supra* discussing coordinating and altering transmissions to clients. As shown in FIG. 14 of Lastinger, each virtual sector is serviced by two antennas, *one of the multiple first directional antennas of the first transmission point with the multiple-input-multiple-output (MIMO) capability* (shades of red) *or the multiple second directional antennas of the second transmission point with the multiple-input-multiple-output (MIMO) capability* (shades of blue). The entire point of Lastinger is to adapt transmission from a base station to the wireless devices being served by the base station.

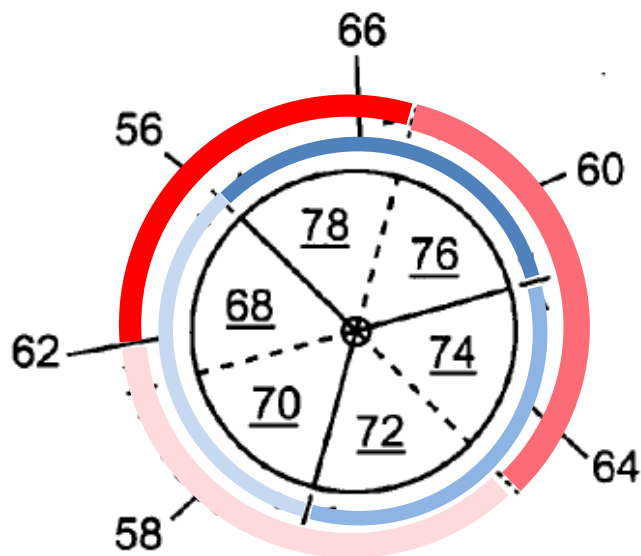


FIG. 14

304. Lastinger discloses that Lastinger discloses that the antennas used by the cell or the client may be MIMO antennas using any of many well-known MIMO techniques. EX-1004 [0103-0105]. As detailed above, Lastinger teaches that its transmissions can use MIMO (or not use MIMO) as appropriate.

305. Gore teaches that its access points use one or more of the “transmitter chains” to transmit data to mobile devices using techniques such as MIMO. EX-1006, 4:58-67, 5:13-55, 6:36-7:26. As with Lastinger, the purpose of Gore’s invention is to provide an access point / base station that allows for different transmission to associated client devices. Gore uses different collections of components that it references as

“transmitter chains” to perform the actual transmission (and reception) of data under the control of a processor. .

306. Thus, Lastinger, alone or in combination with Gore, discloses this claim limitation.

b. Claim 2

[2] The system of claim 1, wherein the system is configured such that the first directional antennas and the second directional antennas include multiple-input-multiple-output (MIMO) antennas.

307. This limitation is disclosed by Lastinger, alone or in combination with Gore, for the same reasons as discussed with respect to Claim 1. As I have noted above for claim 1, both Lastinger and Gore expressly teach that their equipment and transmissions include MIMO capabilities.

c. Claim 3

[3] The system of claim 1, wherein the system is configured such that the first information is identified by enabling at least one of the first directional antennas of the first transmission point with the multiple-input-multiple-output (MIMO) capability, and measuring an ability of the at least one first directional antenna of the first transmission point with the multiple-input-multiple-output (MIMO) capability to communicate with the first multiple-input-multiple-output (MIMO)-capable portable wireless device.

308. Lastinger alone, or in combination with Gore, discloses this limitation in several respects. See element 1.5 discussing Lastinger’s client measuring and reporting information to the wireless cell from clients. “Control information from a client may include, for example, signal quality, desired antenna, error rate, number of dropped

frames, desired throughput, throughput delivered, wireless cells detected, and/or any other conceivable information.” EX-1004, [0098]. Of these types of information, at least signal quality, error rate, number of dropped frames, throughput delivered, and wireless cells detected are measured and identified by enabling the transmission point antennas and measuring an ability to communicate. This element appears to reflect that the “information” in the claims is “identified”¹⁶ by a measurement by the client device of a transmission made by one of the transmissions. As noted in the citations above, Lastinger teaches this through various measurements – particularly of the factors that reflect the channel or “environmental conditions” including those identified above.

309. For example, Lastinger teaches how radios (including clients) measure signal quality including by active or passive scans including signal quality for each channel available. EX-1004 [0167-0168]. For example, “the radio may measure receive signal strength, or signal quality, through each available antenna” and may be measured and reported “periodically by fixed or random interval, after each transmission, after each frame, as commanded by the wireless cell, when the signal strength of the receive signal decreases below a predetermined threshold, or any at any other time.” EX-1004, [0146]. These factors and the scanning all reflect the

¹⁶ I note that the ‘930 specification does not use the term “identified” (or any variant of “identify.”

Lastinger teaching of this element because they are measuring transmissions from the transmission point.

310. Gore teaches that its CQI information is reported in response to the base station sending a pilot signal (*enabling one of the transmission points*) which is then measured for an ability to communicate (such as for interference and the signal-to-noise ratio and to estimate the CQI). EX-1006, 2:49-62, 3:2-5, 7:46-8:67, 10:26-37, 12:6-42, claims 1-36. Moreover, Gore's identified CQI is reflective of the "channel quality" which is generally understood to be a measurement of the ability of the transmitter to successfully transmit RF waves conveying information to the receiver.
311. Thus, Lastinger, alone or in combination with Gore, discloses this limitation.

d. Claim 4

[4] The system of claim 1, wherein the system is configured such that at least one of the first information or the second information is a function of at least one of: a data throughput, a signal-to-noise ratio, a reduced signal error, a reduced data error, a reduced retransmission request, a reduced interference, a rejection of multipath signal, a higher transmission rate, or a signal strength, in connection with the first multiple-input-multiple-output (MIMO)-capable portable wireless device.

312. As discussed with respect to claim limitation [1.5, 1.6, and 3], Lastinger, alone or in combination with Gore, discloses that the first and second information can be *signal quality*, *error rate*, *desired throughput*, *throughput* delivered, "and/or any other conceivable information." EX-1004 [0098]. *See also* EX-1004, [0167] (exemplifying "signal quality."), [0125], [0147]; EX-1006 7:53-55. Lastinger's

teachings largely mirror the factors identified and claimed in the '930. Gore's CQI's would be understood by a POSITA to encompass any or all of the claimed factors as these factors are all well-known factors that are used to characterize the quality of a channel. For Lastinger and Gore, each of the references allows for one or more of the identified types of information to be used in the determination. For example, as is noted in Lastinger, many radio manufacturers might have their own measurement of signal quality that is measured by a combination of different types of information. E.g., EX-1006 [0167] ("Signal quality is a term used to describe radio signals wherein higher quality signals typically more accurately transmit and receive information, and provide higher data transfer rates (i.e., throughput). In contrast, lower quality signals potentially suffer losses in transmission and reception; thereby resulting in low throughput. Signal quality is a measure of, for example, signal level, noise level, error rate, and other operational and environmental factors from a radio's perspective. Each radio manufacturer determines a proprietary measure of signal quality and assigns a relative number. Most manufacturers determine signal quality in a different way, so the quality numbers from different radio manufacturers often cannot be meaningfully compared to each other. The signal quality of radios from the same manufacturer may be compared to determine which radio receives the highest or lowest quality signal, wherein such signal quality may be determined for each channel available."). Similarly, Gore's reference to CQI reflects a calculation that

often involves many different measurements of different factors (such as identified above in Lastinger) in an attempt to reduce the characterization of the “channel quality” to a single number or just a few numbers that can be meaningfully compared across the different channels so the transmitter (and receiver) can make decisions about channel usage.

e. **Claim 5**

[5] The system of claim 1, wherein the system is configured such that the first transmission point with the multiple-input-multiple-output (MIMO) capability and the second transmission point with the multiple-input-multiple-output (MIMO) capability are capable of communicating with the first multiple-input-multiple-output (MIMO)-capable portable wireless device utilizing the same channel with at least one different channel characteristic.

313. As discussed with respect to Claim 1, Lastinger discloses that each of the antennas in the first transmission point and the second transmission point illustrated in FIG. 22 can be a MIMO capable antenna. As detailed in the section above discussing Lastinger’s teachings, the antennas in one or more transmission points have the ability to communicate with a MIMO capable portable device in a physical sector utilizing the same channel. For example, Lastinger discloses that each physical sector of a first group of antennas and a second group is assigned a same channel. EX-1004 Claim 106. As I have explained above in the sections related to MIMO transmissions, the well known (by the priority date) MIMO transmissions included that multiple different sets of radios/antennas could be used together to form MIMO transmissions.

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For example, in “transmit diversity,” the MIMO antennas (and their associated radios) would transmit the same data on the same channel to increase the possibility of reliable and receivable transmissions. In “spatial multiplexing,” different data streams would be transmitted by the different antennas to increase potential data rates. The different antenna groups (antennas/radios) would have different channel characteristics – that is the reason that the channel characteristics (such as the various factors referenced above for claim 4) would be measured for each transmission point (in both Lastinger and Gore). Different interference points would impact differently situated antennas even using the same channel because some of the factors related the channel characteristics might be different for the two different transmission points (antenna groups).

314. The '930 specification does not define or use the term “channel characteristic.”

Moreover, the specification does not use the term “characteristic” (or any variant) in a manner in which that term is associated with a channel. Dependent claims 6-9 below use “channel characteristics” to describe the factors measured and reported by clients (also as recited in claim 4 *supra*). *See also* EX-1001 at 5:28-33. I am guided by the usage of “channel characteristics” in the dependent claims although I would note that these factors are not specific to a “channel” particularly in light of the '930 identification of a “channel” as being “frequency, encoding, or other method of dividing the radio spectrum for communication.” EX-1004, 3:27-29. Rather, the

factors seemingly identified as “channel characteristics” in the claim relate in large part on the distance between the transmitter and receiver (as well as other factors) and not merely on the particular “channel” which could be common among many different client devices which might have vastly different measurements of the factors identified in the claims.

315. As discussed with respect to claim limitations [1.5, 1.6, 3, and 4], Lastinger discloses that a portable device can measure and provide to the wireless cell environment, performance or any other information, including signal strength, signal quality, signal level, noise level, error rate, desired antenna, error rate, number of dropped frames, desired throughput, throughput delivered, wireless cells detected, minimum and maximum throughput needs, desired channel, signal quality for all channels, all detectable wireless cells and physical sectors, physical distance to all wireless cells, local storage capacity, additional available communication protocols, ability to physically move, and/or any other conceivable information (*different channel characteristics*). EX-1004 [0098], [0146], [00167], [0168], [0173], [0193]. Lastinger’s lists of characteristics appear to match the lists provided in the other claims.

316. A POSITA understood that two transmission points communicating with a portable wireless device on the same channel can have different channel characteristics even using the same channel because, for example, the two

transmission points would be physically located in different locations and would likely be oriented in different directions. This would result in different channel characteristics. I have explained above that the channel characteristics (as used in these claims) can be (and would likely be) different for different transmission points even if those transmission points are using the same “channel” (as the ’930 patent appears to define that term at 3:27-29).

317. Moreover, Lastinger teaches that the different transmission points can use different transmissions characteristics for the channels. These include different “encoding including, for example, OFDM, space-time-codes, or weighting of the antenna signals in the array to accomplish beam steering.” EX-1004, [0103]. It might also include different “encoding and decoding schemes, modulating and demodulating schemes, and other methods to enable a channel to send and receive information.” EX-1004 [0153]. These various transmission characteristics would all relate to factors such as throughput, signal-to-noise ratio, signal strength, and multipath because, for example, choosing different transmission characteristics would impact how these factors are measured at the client for the different transmissions. These different characteristics of the transmission and how the channel is used for a particular transmitter can change, for example the throughput (by using an encoding with more symbols that reflect a greater ability to transmit a number of bits/symbol) or can be related to the interference (by using beam steering

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to direct particular beams) or signal strength and signal-to-noise ratio (for the same reasons) or multipath (which can be addressed by different encoding techniques).

318. As detailed in section VII.A.2 and in [1.4] and [1.7], Gore teaches that one or more of the transmitter chains (“*transmission points*”) can communicate with the client devices using the same channel. *E.g.*, EX-1006 6:35-43 (SDM), 6:44-51 (“In a MIMO system, multiple data streams corresponding to a single user device are scheduled at the same time and frequency on different beams.”). Gore also teaches that any of its scheduling techniques can use different forms of multiplexing that may use the same channel from multiple transmitters. EX-1006, 7:30-33; 13:8-13. Gore teaches that the CQI is measured for each beam because it will be different for different beams. EX-1006, 7:64-66 (“CQI for each beam to be determined”). The clients measure and calculate the devices even for other beams that are not specifically being used. EX-1006, 8:59-67. Gore’s teachings are consistent with my discussions of the various well-known MIMO techniques above. The MIMO transmissions (including through the use of particular beams) would have the characteristics of the channel be different for the reasons discussed above. For example, one purpose of “transmit diversity” form of MIMO is that there might be better or worse channel conditions (characteristics) from the different antennas such that the receiving device will get a “better” signal from one or the other of the

antennas (and their associated antenna groups / transmitter chains / transmission points).

f. Claim 6

[6] The system of claim 5, wherein the system is configured such that the at least one different channel characteristic includes at least one of: a channel characteristic that is throughput-related, a channel characteristic that is signal-to-noise ratio-related, a channel characteristic that is signal strength-related, or a channel characteristic that is multipath signal-related, in connection with the same channel.

319. This limitation is disclosed by Lastinger, alone or in combination with Gore, for the same reasons as discussed with respect to Claims 4 and 5. As I noted for claim 4, Lastinger expressly states that the “Signal quality is a measure of, for example, signal level, noise level, error rate, and other operational and environmental factors from a radio's perspective.” EX-1006 [0167]. This expressly teaches this element. Moreover, as I have discussed in claim 4, POSITA would understand that the channel quality information known and used in the industry is and can be based on multiple different known facts (which the '930 recites) because one of the challenges / issues to address is how to take many different measurements of the channel quality / conditions and combine them in a single value that can be used to compare across different channels (and also so that the amount of information that is transmitted back to the base station / access point is smaller rather than the entire set of measured

information such that the feedback information takes less of the uplink bandwidth and can also be more reliably sent in a shorter transmission).

g. Claim 7

[7] The system of claim 5, wherein the system is configured such that the at least one different channel characteristic includes at least two of: [reciting same characteristics as claim 6].

320. This limitation is disclosed by Lastinger, alone or in combination with Gore, for the same reasons as discussed with respect to Claims 4 and 5. A POSITA understood that Lastinger does not limit the number of different channel characteristics between transmission points communicating with a portable wireless device on the same channel can have. I have addressed this with the discussion above for claims 4 and 6.

h. Claim 8

[8] The system of claim 5, wherein the system is configured such that the at least one different channel characteristic includes at least three of: [reciting same characteristics as claim 6].

321. This limitation is disclosed by Lastinger, alone or in combination with Gore, for the same reasons as discussed with respect to Claims 4 and 5. A POSITA understood that Lastinger does not limit the number of different channel characteristics between transmission points communicating with a portable wireless device on the same channel can have different characteristics. I have addressed this with the discussion above for claims 4 and 6.

i. Claim 9

[9] The system of claim 5, wherein the system is configured such that the at least one different channel characteristic includes at least four of: [reciting same characteristics as claim 6].

322. This limitation is disclosed by Lastinger, alone or in combination with Gore, for the same reasons as discussed with respect to Claims 4 and 5. A POSITA understood that Lastinger does not limit the number of different channel characteristics between transmission points communicating with a portable wireless device on the same channel can have. I have addressed this with the discussion above for claims 4 and 6.

323.

j. Claim 10

[10] The system of claim 1, wherein the system is configured such that the altering the at least one aspect includes selecting both the multiple first directional antennas of the first transmission point with the multiple-input-multiple-output (MIMO) capability and the multiple second directional antennas of the second transmission point with the multiple-input-multiple-output (MIMO) capability in connection with the first transmission to the first multiple-input-multiple-output (MIMO)-capable portable wireless device, and the same data is transmitted in connection with the first transmission to the first multiple-input-multiple-output (MIMO)-capable portable wireless device via a same channel, utilizing both the multiple first directional antennas of the first transmission point with the multiple-input-multiple-output (MIMO) capability and the multiple second directional antennas of the second transmission point with the multiple-input-multiple-output (MIMO) capability.

324. As discussed in [1.7], Lastinger discloses many forms of “altering” including the selection of different transmission points (such as physical sectors or antennas), as well as the option to use MIMO, to service a client.
325. As discussed in the section above discussing Lastinger’s teachings, Lastinger discloses that multiple transmission points can be selected (as part of the selection process) to transmit the same data using the same channel to a client.
326. Furthermore, Lastinger discloses the use of known MIMO techniques including “antenna diversity” / “spatial diversity” in the transmit path.

MIMO antennas may use any combination of **spatial**, polarization, or angle antenna **diversity**. The MIMO antenna array may be fixed or adaptive for either transmit, receive, or both. When receiving, the MIMO antenna may use, for example, a maximum ratio combiner, an optimal linear combiner, selection diversity, or any combination of these methods or other methods for combining the signals from multiple antennas into a single signal. When transmitting, the MIMO antenna may use any type of encoding including, for example, OFDM, space-time-codes, or weighting of the antenna signals in the array to accomplish beam steering. **During transmission or reception, all or any subset of antennas in the MIMO array may be used** or selection diversity may be used to limit the number of antennas used. **Antenna diversity may be used in the transmit path, in the receive path, or in both transmit and receive paths.** The signal from each antenna, transmitted or received, may or may not be weighted.

EX-1004 [0103].

327. Lastinger's disclosure is essentially identical to the disclosure of the '930 Patent regarding MIMO antennas:

MIMO antennas may use any combination of spatial, polarization, or angle antenna diversity. The MIMO antenna array may be fixed or adaptive for either transmit, receive, or both. When receiving, the MIMO antenna may use, for example, a maximum ratio combiner, an optimal linear combiner, selection diversity, or any combination of these methods or other methods for combining the signals from multiple antennas into a single signal. When transmitting, the MIMO antenna may use any type of encoding including, for example, OFDM, space-time-codes, or weighting of the antenna signals in the array to accomplish beam steering.

During transmission or reception, all or any subset of antennas in the MIMO array may be used or selection diversity may be used to limit the number of antennas used. **Antenna diversity may be used in the transmit path, in the receive path, or in both transmit and receive paths.** The signal from each antenna, transmitted or received, may or may not be weighted.

EX-1001 12:47-64.

328. Antenna diversity includes using multiple MIMO antennas to transmit the same data (signals) to a client using the same channel at the same time.
329. Thus, a POSITA understood that Lastinger's selection of the transmission points including an "altering" would include selecting the specific antenna(s) for

transmission. This includes selecting the first transmission point and the second transmission point antennas to achieve antenna diversity. “During transmission ..., all or any subset of antennas in the MIMO array may be used or selection diversity may be used to limit the number of antennas used.” EX-1004, [0103]. *See also* EX-1004, [0145-0146] (“the embodiments may include any number of antennas available, any number of antennas in simultaneous use, any number of radios, overlapping or non-overlapping physical sectors, physical sector positioning, and/or communication protocols used.”), [0085], [0110].

330. As detailed in section VII.A.2 and in [1.4], [1.7] and [5], Gore teaches that one or more of the transmitter chains (“*transmission points*”) can communicate with the client devices using the same channel at the same time. *E.g.*, EX-1006 6:44-51 (“In a MIMO system, multiple data streams corresponding to a single user device are scheduled at the same time and frequency on different beams.”). Gore also teaches that any of its scheduling techniques can use different forms of multiplexing that may use the same channel from multiple transmitters. EX-1006, 7:30-33; 13:8-13.

331. Thus, when Gore alters its transmission to “select” the MIMO scheduling technique, the limitation is met for the two distinct reasons that there is an “altering” to select MIMO and that there is an altering to select the beam(s) (using two (or more) specific transmitter chains (transmission points) that are combined to form the beam) on which the MIMO transmission is used to transmit the data at the same time on the

same channel/frequency. This matches Lastinger teachings that multiple transmitter points combine to transmit on the same channel as discussed above.

332. Thus, Lastinger, alone or in combination with Gore, teaches this limitation.

k. Claim 11

[11] The system of claim 1, wherein the system is configured such that the altering the at least one aspect includes selecting only one of: the multiple first directional antennas of the first transmission point with the multiple-input-multiple-output (MIMO) capability, or the multiple second directional antennas of the second transmission point with the multiple-input-multiple-output (MIMO) capability in connection with the first transmission to the first multiple-input-multiple-output (MIMO)-capable portable wireless device, and the data is transmitted in connection with the first transmission to the first multiple-input-multiple-output (MIMO)-capable portable wireless device, utilizing only the selected one of: the multiple first directional antennas of the first transmission point with the multiple-input-multiple-output (MIMO) capability, or the multiple second directional antennas of the second transmission point with the multiple-input-multiple-output (MIMO) capability.

333. Lastinger, alone or in combination with Gore, discloses this limitation for the reasons in limitations 1.7 and 11. Essentially, this claim describes altering that results in transmission by a single antenna of a single transmission point – which has been known and used since the earliest wireless systems.

334. Lastinger discloses that “[d]uring transmission or reception, all or any subset of antennas in the MIMO array may be used.” EX-1004 [0103]. A POSITA understood

that utilizing only the selected one of the multiple first directional antennas of the first transmission point or the multiple second directional antennas of the second transmission point is utilizing only a subset of the antennas in the MIMO array. See also EX-1004, [0146] (“the embodiments may include any number of antennas available, any number of antennas in simultaneous use, any number of radios...”).

335. As detailed in section VII.A.2 and in [1.4], [1.7] and [5], Gore teaches that a single antenna from one of the transmitter chains (“*transmission points*”) can communicate with the client devices. *E.g.*, EX-1006 5:18-21 (each sector can contain 1 antenna); 5:44-46 (beamforming is optional because it “can” be used); 1:50-67 (describing system without beams).

I. Claim 12

[12] The system of claim 1, wherein the system is configured such that coordination is performed for selectively directing a beam associated with the first transmission to improve the transmission of the data by overcoming interference.

336. Lastinger, alone or in combination with Gore, discloses that the MIMO array can use beamforming to improve the transmission by overcoming interference:

When transmitting, the MIMO antenna may use any type of encoding including, ... weighting of the antenna signals in the array to accomplish beam steering... The signal from each antenna, transmitted or received, may or may not be weighted.

Ex-1004 [0103]. See also EX01004, [0105] (“Adaptive arrays may use adaptive array weights to transmit directional beams within the angle and area of coverage to send a stronger signal to a desired client. During reception, an adaptive array may use array weights to direct a beam substantially towards the transmitting client and substantially null out any sources of interference.”).

337. As detailed in section VII.A.2 and in [1.4], [1.7] and [5], Gore teaches directing beams to specific devices to overcome interference. Gore’s alterations are done to reduce interference, and increase the signal-to-noise ratio EX-1006, 2:10-12, 2:17-18 (“appropriate beams to optimize performance”); 5:44-58, 7:58-60, 11:22-55, claims 136 (“improving performance”). A POSITA would understand Gore’s teaching to “improve” or “enhance” performance to include overcoming interference. As detailed in [1.4, 1.7], the beam patterns can coordinate by directing the beams to improve the transmissions. EX-1006 Abstract, 2:46-58, 6:3-5, 8:22-51, 9:47-54, 10:15-17, claims 13, 29.

m. Claim 13

[13] The system of claim 1, wherein the system is configured such that the altering the at least one aspect includes altering beamforming in connection with at least one of: the multiple first directional antennas of the first transmission point with the multiple-input-multiple-output (MIMO) capability, or the multiple second directional antennas of the second transmission point with the multiple-input-multiple-output (MIMO) capability in connection with the first transmission to the first multiple-input-multiple-

output (MIMO)-capable portable wireless device, and the data is transmitted in connection with the first transmission to the first multiple-input-multiple-output (MIMO)-capable portable wireless device, utilizing the beamforming in connection with the at least one of: the multiple first directional antennas of the first transmission point with the multiple-input-multiple-output (MIMO) capability, or the multiple second directional antennas of the second transmission point with the multiple-input-multiple-output (MIMO) capability.

338. Lastinger, alone or in combination with Gore, discloses this limitation for the same reason with respect to limitations [1.4], [1.7], 5 and 12.

339. As detailed in section VII.A.2 and in [1.4], [1.7] and [5], Gore teaches that its alterations (including both selecting beams and altering beams) are done based on the CQI. For example, as detailed in [1.4, 1.7], selection and modification of beams are all based on CSI. EX-1006 Abstract, 9:47-54 (“User devices can be reassigned to beams or the entire beam pattern can be modified depending on the CQI values...”), 2:46-58, 6:3-5, 8:22-51, 10:15-17, claims 13, 29.

n. Claim 14

[14] The system of claim 13, wherein the system is configured such that the beamforming involves weighting and the altering is performed to improve the first transmission independent of a handoff.

340. Lastinger, alone or in combination with Gore, discloses this limitation for the same reason as discussed with respect to Claims 12 and 13. Further Lastinger discloses that “adaptive arrays may use adaptive array weights to transmit directional

beams within the angle and area of coverage to send a stronger signal to a desired client.” EX-1004 [0130]. Further, Lastinger disclose that “the signal from each antenna, transmitted or received, may or may not be weighted.” Ex-1004 [0103].

341. Gore’s teaching provide details regarding the weights used to form beams. EX-1006 8:38-39 (“beams are formed using a set of weights ... if the beam pattern is updated, the base station should ... send/signal the updated set of beam weights...”); 8:22-54; claims 8, 20.

342. Neither Lastinger nor Gore restricts beamforming to during handoff.

o. Claim 16

[16.0] A system, comprising:

343. Lastinger disclose this limitation for the same reasons as discussed with respect to claim limitation [1.0].

[16.1] a single wireless station configured to operate in a packet-switched cellular network, the single wireless station including:

a first portion

16.2] a second portion...

[16.3] third circuitry...

[16.4] said single wireless station configured...

344. These limitations are identical to limitations [1.1]-[1.4], with the only difference being that use of a “first portion” substituted for “a first transmission point” recited in [1.1]-[1.4].

345. Lastinger, alone or in combination with Gore, discloses this limitation for the same reasons discussed in [1.1] through [1.4]

[16.4] said single wireless station configured such that the first portion with the multiple-input-multiple-output (MIMO) capability cooperates with the second portion with the multiple-input-multiple-output (MIMO) capability to support a first transmission to a first multiple-input-multiple-output (MIMO)-capable portable wireless device, for improving the first transmission to address interference, by:

346. Lastinger, alone or in combination with Gore, discloses this limitation for the same reasons discussed with respect to claim limitation [1.4].

[16.5] in response to at least one first signal sent by the single wireless station, receiving first information from the first multiple-input-multiple-output (MIMO)-capable portable wireless device that is based on an interference-based measurement performed by the first multiple-input-multiple-output (MIMO)-capable portable wireless device;

347. Lastinger, alone or in combination with Gore, discloses this limitation for the same reasons discussed with respect to claim limitations [1.5, 3]. As discussed in claim 3, many of Lastinger's different types of information measured by the client and reported to the wireless cell are in response to one or more signal(s) sent by the wireless cell.

348. Further, Lastinger discloses that the wireless cell can send commands (*first signal sent by the wireless station*) to the client requesting signal quality information from the client's perspective (*in response to ... receiving first information*) or any other

type of action, and can do so at any time allowed by the communication protocol.

EX-1004 [0189].

[16.6] in response to at least one second signal sent by the single wireless station, receiving second information from the first multiple-input-multiple-output (MIMO)-capable portable wireless device that is based on another interference-based measurement performed by the first multiple-input-multiple-output (MIMO)-capable portable wireless device;

349. Lastinger, alone or in combination with Gore, discloses this limitation for the same reasons discussed with respect to claim limitation [16.5].

[16.7] performing beamforming to support the first transmission utilizing at least one of: multiple of the first directional antennas of the first portion with the multiple-input-multiple-output (MIMO) capability, or multiple of the second directional antennas of the second portion with the multiple-input-multiple-output (MIMO) capability, based on the first information and the second information; and

350. Lastinger, alone or in combination with Gore, disclose this limitation for the same reasons discussed with respect to claim limitations [1.4], [1.7] and Claims 12-14. Limitations [1.4], [1.7], 10 and 11 detail Lastinger and Gore's ability to utilize one or more of the transmission points.

[16.8] transmitting data during the first transmission to the first multiple-input-multiple-output (MIMO)-capable portable wireless device, utilizing the beamforming with at least one of: the multiple first directional antennas of the first portion with the multiple-input-multiple-output (MIMO) capability, or the multiple second directional antennas of the second portion with the multiple-input-multiple-output (MIMO) capability.

351. Lastinger disclose this limitation for the same reasons discussed with respect to claim limitations [1.8, 16.7] and Claims 12-14.

p. Claim 17

[17] The system of claim 16, wherein the system is configured such that a channel between the first portion and the first multiple-input-multiple-output (MIMO)-capable portable wireless device differs from another channel between the second portion and the first multiple-input-multiple-output (MIMO)-capable portable wireless device in terms of at least one channel characteristic that includes at least one of: a channel characteristic that is throughput-related, a channel characteristic that is signal-to-noise ratio-related, a channel characteristic that is signal strength-related, or a channel characteristic that is multipath signal-related.

352. Lastinger, alone or in combination with Gore, disclose this limitation for the same reasons discussed with respect to Claim 5. This claim recites that the channel between the two transmission points (“portions”) differ in at least one characteristic. I have explained in claim 5 above the reasons that Lastinger teaches that the “channels” would differ in at least one characteristic. If they did not differ, then there would be no reason to measure all of the channels for feedback information and yet Lastinger teaches measurement and reporting of each of the channels.

q. Claim 18

[18] A system, comprising

353. Lastinger discloses this limitation for the same reasons discussed with respect to claim limitation [1.0].

[18.1] a packet-switched cellular network including a plurality of wireless stations including a particular wireless station including:

a first group ...

[18.2] a second group...

[18.3] third circuitry in communication with...

[18.4] said particular wireless station configured such...

[18.5] receiving first information...

[18.6] receiving second information ...

354. These elements recited the same limitations as in 1.1 through 1.6 except with replacing “transmission point” with “group.” Lastinger, alone or in combination with Gore, discloses this limitation for the same reasons discussed with respect to claim limitations 1.1-1.6. As I noted for claim 1, the ’930 patent does not use the term “transmission point” in the specification as filed on the priority date.

[18.7] coordinating utilization of at least one of multiple of the first directional antennas of the first group with the multiple-input-multiple-output (MIMO) capability, or multiple of the second directional antennas of the second group with the multiple-input-multiple-output (MIMO) capability, based on the first information and the second information; and

355. Lastinger, alone or in combination with Gore, discloses this limitation for the same reasons discussed with respect to claim limitation [1.7] and Claims 11-13. In element 1.7, I explained the different forms of coordinate in the cited prior art. This claim appears to recite merely the utilization of a single antenna from one of the groups. The claim is somewhat ambiguous about what exactly is being coordinated when there is only a single antenna transmitting. But, nonetheless, because the claim

recites “at least one” of the two different transmission point/group antennas, the prior art discloses it for the same reasons as cited in 1.7.

[18.8] transmitting data with the first transmission to the first multiple-input multiple-output (MIMO)-capable portable wireless device, utilizing at least one of: the multiple first directional antennas of the first group with the multiple-input-multiple-output (MIMO) capability, or the multiple second directional antennas of the second group with the multiple-input-multiple-output (MIMO) capability.

356. Lastinger, alone or in combination with Gore, discloses this limitation for the same reasons discussed with respect to claim limitation [1.8] and Claims 11-13. This claim recites using “at least one” of the various antennas. The prior art as cited in [1.8] and claims 11-13 encompass this concept.

r. Claim 19

[19] The system of claim 18, [reciting same language as claim 17 except replacing “portion” with “group”].

357. Lastinger, alone or in combination with Gore, discloses this limitation for the same reasons discussed with respect to Claims 4, 5, 6, and 17. I have discussed this with respect to the claims 4-6 and 17 above.

s. Claim 20

[20] The system of claim 18, wherein the system is configured

358. This claim recites the same limitation as claim 19 except this claim recites “at least two channel characteristics” rather than “at least one.” Lastinger, alone or in

combination with Gore, discloses this limitation for the same reasons discussed with respect to Claims 4, 5, 6, 7, and 17.

CONCLUSION AND DECLARATION

359. My findings and opinions set forth in this Declaration are based on my work and examination to date. I may continue my examinations in view of additional documents or other factual evidence over the course of this proceeding that may necessitate supplementing and/or refining my opinions. I reserve the right to add to, alter, or delete my opinions and my Declaration upon discovery of additional information. I reserve the right to make such changes as necessary.

360. In signing this Declaration, I understand that the Declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I acknowledge that I may be subject to cross-examination in this case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

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

Declaration of Dr. Mark P. Mahon

[SIGNATURE ON COVER PAGE]

October 15, 2024

APPENDIX A – MATERIALS RELIED UPON

Exhibit #	Description
1001	U.S. Patent No. 9,496,930 (the “’930 Patent”)
1002	Select portions of prosecution history of the ’930 Patent (“File History”)
1003	Declaration of Petitioner’s Expert Dr. Mark Mahon
1004	U.S. Patent Application Publication 2005/0003865 (“Lastinger”)
1005	U.S. Pat. No. 7,907,971 (“Salo”)
1006	U.S. Pat. No. 9,408,220 (“Gore”)
1007	May 2005 IEEE Draft Specification
1008	January 2006 IEEE Draft Specification (MAC layer)
1009	U.S. Pat. No. 7,881,390 (“Sadowsky”)
1010	U.S. Pat. No. 7,881,390 Prosecution History Excerpts including IDS from January 30, 2006.
1011	U.S. Pat. 7,596,355 (“Li”)
1012	U.S. Pat. No. 8,649,322 (“Grandhi”)
1013	U.S. Patent No 8,498,346 (“Biswas”)
1014	WO20071088885
1015	January 2006 IEEE Draft Specification (PHY layer)
1016	Related Patents
1017	U.S. Pat. No. 9,178,577
1018	[This Exhibit Intentionally Omitted From This Petition]
1019	U.S. Pat. No. 7,590,078

Declaration of Dr. Mark P. Mahon

APPENDIX B – RÉSUMÉ

Mark P. Mahon, Ph.D.
Teaching Professor
Pennsylvania State University
School of Electrical Engineering and Computer Science
W209A Westgate Bldg.
University Park, PA

Highlights

Teaching faculty experienced in research and systems development in cellular and mobile wireless networks, wireless local area networks, wireless network security, mobility management, mobile data systems including networks, protocols, and applications, wideband signal processing, modulation theory, algorithms, mathematical/analytical modeling, communication, detection and estimation, and control systems. Pursues funding for and conducts advanced research in computer and mobile networks, theoretical and experimental analysis of communication systems, cellular, wireless, and mobile systems, wideband signal processing, sensors, tracking, localization, and data fusion. Experienced in hardware/software development, data acquisition, integration, and testing, field test planning, preparation, and execution. Extensive programming experience including UI, analysis tools, real-time object-oriented programming, and embedded systems code development in C, C++, python, java, Verilog, RTL, VHDL, HDL, and assembly.

Education

PhD. Acoustics, The Pennsylvania State University, University Park, PA 16802, 2001
M.S. Electrical Engineering, The Pennsylvania State University, University Park, PA, 16802, 1991
B. S. Electronics Engineering, The University of Scranton, Scranton, PA, 18510, 1987

Employment

July 2021 – Present: *Teaching Professor, School of Electrical Engineering and Computer Science, The Pennsylvania State University, University Park, PA 16801*

June 2018 – June 2021: *Associate Teaching Professor*

Aug. 2015 – June 2018: *Assistant Teaching Professor*

Teach graduate and undergraduate courses in computer science and electrical engineering such as communication networks, mobile networks, neural networks, programming, mathematics, and wireless security. Advise and direct graduate students' MS and PhD research in the areas of wireless and computer networks, data pipelining, network resource allocation and optimization techniques, ultrawide band systems, multiple antenna applications, and wireless security. Guide Schreyer Honors College students' honors theses. HackPSU and BlockChain@PSU faculty adviser, member of graduate advising committees, member of Computer Science Undergraduate Curriculum Committee, member of School of EECS Management Committee, advise undergraduate electrical engineering, computer science, computer engineering, and data science students.

2003 – Aug. 2015: *Associate Research Professor, Applied Research Laboratory, Communications, Information, and Navigation Office, The Applied Research Laboratory, The Pennsylvania State University, State College, PA* Principal Investigator, Co-Principal Investigator, Technical lead conducting research on multi-Int data fusion and UI design to support intelligence analysts in Combat Operation Centers, cellular and mobile networks, computer network security, mobile communication systems, and wideband signals and image processing with total funding over \$12M.

2002 – 2003: *Sr. Systems Engineer, Klein & Stump, Inc., 2120 Washington Blvd. #400, Arlington, VA 22204* Researcher and technical consultant working on wireless communications projects for US Special Operations Command (SOCOM) and Naval Information Warfare Activity (NIWA). Awarded \$150k SBIR for SOCOM advanced signal simulator.

1991 – 2002: *Assistant Research Professor, Applied Research Laboratory, Communication Sciences and Technology Division, The Applied Research Laboratory, The Pennsylvania State University, State College, PA 16804* Principal Investigator and researcher conducting research on cellular and mobile networks, wideband signals, tracking and localization, adaptive signal processing, acoustic propagation, sensor systems, remote sensing, and active noise control. Awarded \$750k for development of novel wavelet based wideband signal detection for high altitude sensors.

1988 – 1989: *Program Engineer, Central Intelligence Agency, Langley, VA 22101*

Assisted in the development of algorithms and signal processing systems for novel applications in the areas of RF communications and signal modulation techniques.

Detailed Research Experience:

Current ongoing research:

Resource allocation and scheduling improvements in NG networks and edge computing; Multiple Input Multiple Output antenna techniques for increased capacity in NG systems; Fast handover techniques using blockchains to reduce mobility interruption times in 5G networks; AI/NN techniques applied to network scheduling and optimization, and mobile robotics for localization and mapping; Automated object detection and 3D mapping using sonar array data. Security vulnerabilities in UWB ranging.

2015 – Present

Lead graduate and undergraduate student research in wireless communication networks, distributed video processing in cellular systems, UWB ranging, communication systems and security, software defined network security, application of game theory to cyber resiliency, wireless, machine learning, big data analytics, and artificial intelligence for mobile and computer network security and automated detection in acoustic and sonar systems.

2014 – 2015

Leading internal research and development effort on deep packet inspection for zero day and predictive detection for data networks. Technical performer developing novel deformable wavelet-based contour matching technique for automated object detection in satellite images. Acoustic tracking and identification of drones for area defense system.

2014

Developed real-time scanner for 802.15.4 (LR-WPAN) protocol deployed on software defined radio platform.

2013-2014

Technical lead on developing novel mathematical model for analyzing torpedo acoustic threat surrogate systems for US Navy. Experimental lead on disposable, adaptive, high bandwidth fiber-optic undersea communication system for US Navy.

2013

Implemented a novel matched filter receiver for a unique OFDM signal of interest to facilitate signal detection in a high co-channel interference environment of a wide field of view high altitude receiver and wideband signal set design in highly complex propagation environments for Department of Defense (DoD).

2012-2013

Technical lead for design and implementation of a real-time transmitter/receiver on a software defined radio platform for maritime communication systems (Automatic Information System/Maritime Security).

2012

Communications/signal processing technical consultant on Maritime Domain Operations and Unmanned Surface Ship Interdiction study effort for US Navy.

2011-2012

Principal Investigator, technical and experimental lead on fiber optic undersea communication system for Advanced Submarine System Development effort for US Navy.

2011

Technical lead on mathematical analysis, algorithm development, and implementation of pattern of life signal to noise ratio analysis in high co-channel interference environment for DoD.

Trusted agent for Army Research Lab to review and critically analyze work associated with wideband signaling and passive emissions collection from cell phones. Reviewed contractor data analysis and technical briefings for scientific accuracy and rigor. Advised the sponsor on contractor testing methodologies, procedures, and analysis techniques. Technical lead implementing unique wideband acoustic communication system and specialized signal processing hardware for an acoustic system being utilized in a complex maritime environment for the DoD.

2009 – 2010

Tiger team lead for large unmanned undersea vehicle (UUV) assigned to identify platform induced electromagnetic interference with electronic payload system in the HF and acoustic regimes for the US Navy.

Developed and implemented a novel algorithm to calculate the effective force charge based on muzzle sensor data utilizing MEMS transducers and PIC controller on a portable howitzer for the US Army.

Conducted study and authored Intelligence, Surveillance, and Reconnaissance (ISR) for Unmanned/Minimally Manned Undersea Vehicle (UMUV) report presented to Defense Advanced Research Projects Agency (DARPA).

2006 – 2009

Principal Investigator for a multi-year research and FPGA-based engineering prototype development effort in the area of 3G/4G (UMTS/LTE) cellular and wireless (IEEE 802.16 and 802.11) communication systems; Effort consisted of three phases: theoretical and analytical study, proof-of-concept development, and testing, and prototype development for DoD.

2005-2006

Technical lead on Information Fusion engine integration into a sandbox enclave at Joint Interagency Task Force South (JIATF-S) to support multi-int data fusion.

2003 – 2006

Principal Investigator for multi-year Office of Secretary of Defense sponsored research program in the area of multi-intelligence data fusion (fusion engine and UI interface) as part of the overall initiative of Force Transformation; worked extensively with NGA, DIA, DISA, OSD, all military services, and some coalition components. Led team of software engineers to develop scalable user-facing application and backend data fusion engines.

2002 – 2003

Pursued funding for research interests in the areas of wireless/wideband communications, wideband systems, source detection/localization, intelligent system of systems design, and data fusion; Awarded Phase I, Small Business Innovative Research contract for Portable Signal Training System by SOCOM (02-013); Technical consultant for Naval Information Warfare Center on Common for High Performance Computing Software Support Initiative's (CHSSI) Electronic Battlefield Environment (EBE) portfolio (Electromagnetic Environmental Effects Toolkit), SBIR, MERIT/TENCAP, TST programs

1998 – 2002

Researcher and principal investigator performed research in large time-bandwidth product (wavelets) source detection and localization – theoretical, analytical, and field testing; CDMA IS-95A/3G cellular communications; Developed mathematical analytical models and included code development of the CDMA air interface physical layer implementing major aspects of the CDMA protocol for test and analysis purposes; Built real-time hardware platform for deploying developed CDMA physical layer code.

1997 – 1998

Principal Investigator in charge of signal processing algorithm and code development, image acquisition and compression, telephony, and user interface design for an experimental remote, autonomous, acoustic rockslide detection for Conrail. Work included algorithm and code development utilizing embedded digital signal processing (DSP) board and development of unique algorithms for real-time monitoring of transducers to create an event detection system.

1991 – 1997

Performed fundamental research in the areas of signal processing algorithm development, acoustic atmospheric propagation, detection, source localization, beamforming, system identification, and active control; Main responsibilities include real-time code development (C, Visual C++, assembly) for signal processing systems, adaptive beamforming, and embedded processing for eight major projects during this time. Multiple DSP platform development; Active Noise Control, feature extraction, data logging and fusion, passive acoustic tracking, beamforming, and analysis for these projects

1988-1989

Assisted in the development of algorithms and signal processing systems for novel applications in the areas of RF communications and signal modulation techniques.

Case History:

May 2024 – Present, Merchant & Gould

Apex Beam Technologies LLC v. TCT Mobile International Ltd. Case No. 2:21-cv-438 (EDTX)

Consulting for defendant TCT. Technology related to signaling in 5G cellular networks. Wrote submitted claim construction declaration. Deposed 7/31/24 on claim construction declaration.

March 2024 – June 2024, Duane Morris

Ericsson and Nokia v. Active Wireless IPR2024-00886, -00951, -00985, -00986

Consulted for petitioners Ericsson and Nokia. Technology related to signaling in 4G and 5G cellular networks. Wrote four declarations.

March 2024 – May 2024, Quinn Emanuel, LLP

Samsung Electronics Co., Ltd. v. Datang Mobile Communications Equipment Co., Ltd.

Consulted for petitioner Samsung. Technology related to random access in 4G/5G cellular networks. Wrote declaration in support of claim construction. Case stayed.

October 2023 – April 2024, Erise IP; Finnegan, DLA Piper, Husch Blackwell

BNR v. ASUSTek/Media Tek/Laird/NXP Inc. Inv. No. 337-TA-1367 (USITC). Consulting for defendant ASUS on ASUS (Qualcomm-based products) non-infringement and JDG (ASUS/Media Tek/ Laird/ NXP) on Tech DI non-infringement on WiFi wireless devices and semiconductor chips with wireless capabilities related to wireless transmission technologies. Wrote rebuttal report. BNR settled with ASUS and Media Tek; BNR withdrew complaint for NXP.

September 2023 – April 2024, McKool Smith

Daingean Technologies Ltd. v. AT&T, et al, Case No. IPR2024-00309. Consulting for petitioner AT&T. Technology related to 5G wireless transmissions. Wrote declarations. Case settled.

August 2023 – December 2023, Greenberg Traurig

Atlas Global Technologies, LLC v. Acer Incorporated, No. 2:22-cv-00259 WDTX. Consulting for defendant Acer. Technology related to wireless transmissions in WiFi networks. No reports. Settled.

August 2023 – July 2024, McKool Smith

Ericsson v. Lenovo/Motorola, In the Matter of Certain Mobile Phones, Components Thereof, and Products Containing Same, Inv. No. 337-TA-1375 (USITC)

Consulting for Complainant Ericsson on technology related to 5G cellular signaling technology. Wrote infringement and invalidity rebuttal.

August 2023 – Present, Caldwell, Cassady and Curry

Neo Wireless, LLC v. Ford, et al., Case No. 2:22-MD-03034. Consulting for plaintiff on technology related to 4G cellular radio access. Wrote infringement and invalidity rebuttal reports.

June 2023 – November 2023, Duane Morris

Ericsson, Inc., and Celco Partnership D/B/A Verizon Wireless v. Woodbury Wireless LLC., IPR 2023-01364. Consulted for petitioner Verizon. IPR. Technology related to MIMO and minimization of interference. Declaration filed 10/10/23. Case settled.

January 2023 – April 2023, McKool Smith

Ericsson v. Koninklijke KPN N.V., Case No. IPR2023-00582. Consulting for Petitioner Ericsson. IPR. Technology related to neighbor cell lists in wireless systems. Declaration filed 2/17/23.

November 2022 – April 2023, Finnegan, Henderson, Farabow, Garrett & Dunner, LLP

Qualcomm, Inc. vs. FedEx, Inc., IPR 2022-00585

Consulting for patent owner FedEx. Wrote IPR declaration. Deposed 4/19/23. Technology related to sensor information collected by tracking devices.

October 2022 – November 2023, BC Law Group, P.C.

Lionra Technologies Limited v. Apple, Inc. Case No. 6:22-cv-00351-ADA, WDTX

Consulting for patent owner Lionra. Case dismissed 11/18/23.

September 2022 – June 2023, Quinn Emanuel, LLP

Google LLC v. Sonos, Inc., Inv. No. 337-TA-1330 (USITC)

Consulting for patent owner Google. Wrote infringement and validity rebuttal reports.

Technology related to voice assistants and smart devices. Deposed 4/14/23. Testified at trial 6/20/23 and 6/23/23.

September 2022 – August 2023, BC Law Group, P.C.

Apple, Inc. vs. Speir Technologies Limited, IPR2022-01512 and -00151

Consulted for patent owner Speir on UWB localization technology. Wrote IPR declarations. Deposed 10/25/23. Case dismissed 11/18/23.

August 2022 – July 2024, Venable, LLP

VoIP-Pal.com, Inc. v. Verizon Communications Inc. Case No. 6:21-cv-00672, WDTX

Consulting for defendant Verizon. Wrote non-infringement report. Deposed 5/17/23.

Technology relates to VoIP in cellular networks. Summary judgement of non-infringement.

July 2022 – November 2023, Quinn Emanuel Urquhart & Sullivan, LLP

Evolved Wireless LLC v. Samsung Electronics Co., Ltd., and Samsung Electronics America, Inc., Case No. 2:21-cv-00033, EDTX. Technology related to handovers in 4G networks.

Consulting for defendant Samsung. Wrote non-infringement and validity rebuttal report. Deposed 7/5/23; Testified at trial 11/14/23.

March 2022 – Dec. 2022, Knobbe, Martens, Olson & Bear, LLP

Jawbone Innovations, LLC v. Amazon.com, Inc., et al.

Consulting for petitioner Amazon (IPR). Technology related to tracking using acoustic arrays. Case stayed. No reports.

May 2022 – Dec. 2022, McKool Smith; Alston Bird

Ericsson Inc. and Telefonaktiebolaget LM Ericsson vs. Apple Inc., Case No. 2:21-cv-376, EDTX

Consulted for plaintiff and counter-defendant Ericsson.

Report on Essentiality and Rebuttal report (FRAND). Deposed 10/4/2022. Testified 12/7/2022. Case settled during trial.

Broad spectrum of technology related to cellular networks (core network and mobile device)

March 2022 – Dec. 2022, McKool Smith

Ericsson Inc. and Telefonaktiebolaget LM Ericsson vs. Apple Inc., Inv. No. 337-TA-1299, ITC

Consulted for Ericsson. Opening and Rebuttal report. Deposed 10/7/2022. Case settled.

Technology related to security in cellular systems.

January 2022 – March 2023, Duane Morris

Telecom Network Solutions v. AT&T Inc., et al, Case No. 2:21-cv-415 and Verizon Communications Inc., et al, Case No 2:21-cv-416, EDTX

Consulted for defendants AT&T and Verizon on Invalidity. Case settled; no reports filed.

Technology related to QoS in cellular networks.

September 2021 – December 2021, Duane Morris, LLP

KAIFI LLC v. Verizon Wireless, Case No. 2:20-cv-280-JRG, EDTX

Consulted for defendant Verizon. Wrote Non-Infringing Alternatives and Non-Infringement reports.

Deposed 12/15/21. Case settled. Technology related to cellular and WiFi enablement cellular systems.

September 2021 – December 2021, Quinn Emanuel, LLP

L2 Mobile Technologies, LLC v. Google, Case No. 6:21-cv-358, WDTX

Consulted for defendant Google. Wrote reply Claim Construction brief. Case settled.

Technology related to control signaling in cellular systems.

August 2021 – May 2022, McKool Smith

Godok Kaisha IP Bridge 1 v. Ericsson, Case No. 2:21-cv-00213-JRG, EDTX

Consulted for defendant Ericsson. IPR and Claim Construction declarations.
Technology related to signaling in OFDM systems.

July 2021 – August 2021, Quinn Emanuel, LLP

Finesse Wireless, LLC v. Nokia, et al., Case No. 2:21-CV-00063-JRG, EDTX

Consulted for defendant Nokia on claim construction. Wrote declaration and deposed on 8/17/21.
Technology related to coding techniques in wireless systems.

June 2021 – Dec 2021, Knobbe, Martens, Olson & Bear, LLP

Vocalife LLC v. Amazon.com, Inc., et al., Case No. 2:20-cv-00401-JRG-RSP, EDTX

Consulted for defendant Amazon on claim construction. Stayed pending sister case outcome.
Technology related to echo cancelation and signal enhancement in acoustic systems.

March 2021 – Sept 2021, Wilson Sonsini

Lenovo Holding Co, Inc., et al. v. InterDigital Technology Corp.

IPR. Consulted for InterDigital. Wrote three declarations. Deposed 7/27/21.
Technology related to control signaling in cellular systems.

January 2021 – May 2021, Winston & Strawn, LLP

Ericsson, Inc. v. Samsung Electronics, Ltd., ITC

Consulted for plaintiff. Settled May 2021. No deposition. No declaration filed.
Patents dealt with antenna arrays for 5G/4G base stations, access point signaling, bearer handling.

November 2020 – June 2021, Sheppard Mullin

Hong Kong uCloudlink v. SIMO Holdings, Inc. and Skyroam, Inc., Case No. 18-cv-05031-EMC, NDCA. Consulted for plaintiff uCloudlink on infringement and validity. Deposed (3/26/21). Case settled. Virtual SIM technology.

August 2019 – August 2020; June 2021 – Sept 2021 McKool Smith/Irell & Manella

Optis Wireless Technology, LLC et al. v. Apple, Inc., EDTX, Civ No. 2:19-cv-66

Consulted for plaintiff Optis. Infringement and validity analysis/reports, IPR. Deposed 06/01/20 and testified at trial 8/3/20 – 8/9/20. Re-trial for damages 8/10/21 – 8/16/21.

March 2019 – May 2020 Gibson, Dunn, & Crutcher, LLP

Sol IP v. AT&T, Ericsson, Nokia, Verizon, and Sprint, EDTX, Case No. 2:18-cv-526

Consulted for defendants on patents involving LTE downlink cell search and synchronization signaling. Invalidity, non-infringement analysis/reports, claim construction. No deposition, case settled.

2016 – March 2019 Sidley Austin, LLP

Huawei v. Samsung, NDCA

Case No. 3:16-cv-02787-WHO

Consulted for plaintiff Huawei on original complaint and for defendant Huawei on counterclaims on patents involving control channel signaling, network access, and security. Assisted claim construction, IPR petition and preliminary response, wrote validity and non-infringement reports. Deposed 6/20/18, 7/19/18. Case settled.

2016 Russ, August & Kabat

Core Wireless v. Apple, Court of Northern California, Case No. 6:14-cv-752-JDL

Consulted for plaintiff on patents associated with core network signaling. Wrote infringement and validity reports and rebuttals. Performed source code review and conformance testing. Deposed

(8/12/2016). Patent was dropped during down-select before trial.

2015 - 2016 Hueston & Hennigan

Core Wireless v. LG Electronics, Court of Eastern Texas, Case No. 2:14-cv-911-JRG-RSP (lead case), Case No. 2:14-cv-912-JRG-RSP (consolidated)

Consulted for plaintiff on patents on cellular user interface. Present at jury trial (3/2016) and participated in mock jury trial (2/10/2016). Wrote rebuttal expert report on validity and deposed (12/11/2015). Wrote infringement report regarding cellular protocols. Performed source code review and conformance testing. Core Wireless prevailed.

2015 Bunsow De Mory Smith & Allison

Core Wireless v. LG Electronics, Court of Eastern Texas, Case No. 2:14-cv-911-JRG-RSP (lead case), Case No. 2:14-cv-912-JRG-RSP (consolidated) and Core Wireless v. Apple, Case No. 6:14-cv-752-JDL

Consulted for plaintiff on patents associated with core network signaling. Wrote declarations on claim construction. Prepared tutorial to be presented to court. Case handed off to Hueston & Hennigan.

Case Testimony History:

May 2024 – Present, Merchant & Gould

Apex Beam Technologies LLC v. TCT Mobile International Ltd. Case No. 2:21-cv-438 (EDTX)

Consulting for defendant TCT. Technology related to signaling in 5G cellular networks. Submitted claim construction declaration. Deposed 7/31/24 on claim construction declaration.

October 2023 – April 2024, Erise IP; Finnegan, DLA Piper, Husch Blackwell

BNR v. ASUSTek/Media Tek/Laird/NXP Inc. Inv. No. 337-TA-1367 (USITC). Consulting for defendant ASUS on ASUS (Qualcomm-based products) non-infringement and JDG (ASUS/Media Tek/ Laird/ NXP) on Tech DI non-infringement. Wrote on WiFi wireless devices and semiconductor chips with wireless capabilities related to wireless transmission technologies. Wrote rebuttal report. Deposed 2/8/24. BNR settled with ASUS and Media Tek; BNR withdrew complaint before hearing.

August 2023 – July 2024, McKool Smith

Ericsson v. Lenovo/Motorola, In the Matter of Certain Mobile Phones, Components Thereof, and Products Containing Same, Inv. No. 337-TA-1375 (USITC)

Consulting for Complainant Ericsson on technology related to 5G cellular signaling technology. Wrote infringement and invalidity rebuttal. Deposed 5/23/24. Testified 7/16/24.

August 2023 – Present, Caldwell, Cassady and Curry

Neo Wireless, LLC v. Ford, et al., Case No. 2:22-MD-03034. Consulting for plaintiff on technology related to 4G cellular radio access. Wrote infringement and invalidity rebuttal reports. Deposed 5/16/24 and 5/17/24.

November 2022 – April 2023, Finnegan, Henderson, Farabow, Garrett & Dunner, LLP

Qualcomm, Inc. vs. FedEx, Inc., IPR 2022-00585

Consulting for patent owner FedEx. Wrote IPR declaration. Deposed 4/19/23. Technology related to sensor information collected by tracking devices.

September 2023 – June 2023, Quinn Emanuel, LLP

Google LLC v. Sonos, Inc., Inv. No. 337-TA-1330 (USITC)

Consulting for patent owner Google. Wrote infringement and validity rebuttal reports. Technology related to voice assistants and smart devices. Deposed 4/14/23. Testified 6/20-23/23.

September 2022 – November 2023, BC Law Group, P.C.

Apple, Inc., vs. Speir Technologies Limited, IPR2022-01512 and -00151

Consulted for patent owner Speir on UWB localization technology. Wrote IPR declarations. Deposed 10/25/23. Case dismissed 11/18/23.

August 2022 – July 2024, Venable, LLP

VoIP-Pal.com, Inc. v. Verizon Communications Inc. Case No. 6:21-cv-00672, WDTX

Consulting for defendant Verizon. Wrote non-infringement report. Deposed 5/17/23.

Technology relates to VoIP in cellular networks. Summary judgement of non-infringement.

July 2022 – November 2023, Quinn Emanuel Urquhart & Sullivan, LLP

Evolved Wireless LLC v. Samsung Electronics Co., Ltd., and Samsung Electronics America, Inc., Case No. 2:21-cv-00033, EDTX. Technology related to handovers in 4G networks.

Consulting for defendant Samsung. Wrote non-infringement and validity rebuttal report. Deposed 7/5/23; Testified at trial 11/14/23. Jury found for defendant on all counts.

March 2022 – December 2022, McKool Smith

Ericsson Inc. and Telefonaktiebolaget LM Ericsson vs. Apple Inc., Inv. No. 337-TA-1299, ITC

Consulting for Ericsson. Opening and Rebuttal report. Deposed 10/7/2022. Testified 12/7/2022. Case settled during trial.

May 2022 – December 2022, McKool Smith; Alston Bird

Ericsson Inc. and Telefonaktiebolaget LM Ericsson vs. Apple Inc., Case No. 2:21-cv-376, EDTX

Consulting for plaintiff and counter-defendant Ericsson.

Report on Essentiality and Rebuttal report. Deposed 10/4/2022. Case settled.

September 2021 – December 2021, Duane Morris, LLP

KAIFI LLC v. Verizon Wireless, Case No. 2:20-cv-280-JRG, EDTX

Consulted for defendant Verizon. Wrote Non-Infringing Alternatives and Non-Infringement reports. Deposed 12/15/21. Case settled.

July 2021 – August 2021, Quinn Emanuel, LLP

Finesse Wireless, LLC v. Nokia, et al., Case No. 2:21-CV-00063-JRG, EDTX

Consulted for defendant Nokia on claim construction. Technology related to noise in the front-end of receiver. Deposed on 8/17/21.

March 2021 – Sept 2021, Wilson Sonsini

Lenovo Holding Co, Inc., et al. v. InterDigital Technology Corp.

IPR. Consulted for InterDigital. Technology related to control signaling in cellular systems. Wrote three declarations. Deposed 7/27/21.

November 2020 – June 2021, Sheppard Mullin

Hong Kong uCloudlink v. SIMO Holdings, Inc. and Skyroam, Inc., Case No. 18-cv-05031-EMC,

NDCA. Consulted for plaintiff uCloudlink on infringement and validity. Technology related to virtual SIM. Deposed 3/26/21.

August 2019 – August 2020; June 2021 – Sept 2021 McKool Smith/Irell & Manella

Optis Wireless Technology, LLC et al. v. Apple, Inc., EDTX, Civ No. 2:19-cv-66

SEPs – Consulted for plaintiff Optis on control channel MIMO switching, control channel information fields. Infringement and validity analysis/reports, IPR. Deposed 06/01/20 and testified at trial 8/3/20 – 8/9/20. Testified at re-trial for damages 8/10/21 – 8/16/21.

2016 – March 2019 Sidley Austin, LLP

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2016 Russ, August & Kabat

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2015 - 2016 Hueston & Hennigan

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Teaching:

Courses:

- CSE 516 (Mobile Networks): Redesigned the course to integrate latest developments in mobile network architecture design. The course now includes signaling, control, and protocol issues unique to 4G/5G architectures addressing eMBB, mMTC, and URLLC use cases critical to IoT and future wireless network development and future NG networks.
- CSE 514 (Communication Networks)
- CSE 590 (Colloquium)
- CMPEN 462 (Wireless Communication Systems and Security): Created and designed this course to address a gap in the wireless communications area focusing on security. This course is included in the cybersecurity computational foundations minor.
- EE 456 (Introduction to Neural Networks): This course is intended to address the need for EE and CMPEN students to be exposed to the principles associated with artificial intelligence.
- CMPEN/EE 362 (Communication Networks)
- CMPSC 263 (Blockchains and Modern Web Development): This course is 'module' driven and designed to provide students with a broad range of academic backgrounds an opportunity to learn about blockchains and cryptography. Under supervision, students in the Distributed Ledger Society teach the modules including theory and practice in the areas of programming, math, and cryptography.
- ACS 505 (Experimental Techniques in Acoustics)
- MATH 141 (Calculus with Analytical Geometry II)
- CMPSC 101 (Programming in C++)

Publications:

Rublein, Mehmeti, Mahon, and LaPorta, "Impact of Client Choice on Distributed Resource Allocation in Edge Computing", *The 33rd International Conference on Computer Communications and Networks (ICCCN 2024)*, IEEE and IEEE Communication Society, July 29 – 31, 2024, Big Island, Hawaii, USA.

Rublein, Mehmeti, Mahon, and LaPorta, "Improved Methods of Task Assignment and Resource Allocation with Preemption in Edge Computing Systems", *IEEE Transactions on Parallel and Distributed Computing*. Submitted July 2023.

- Sorensen, Mahon, Mehmeti, and LaPorta, QoE-Analysis of 5G Network Resource Allocation Schemes for Competitive Multi-User Video Streaming Applications, *IEEE Conference on Vehicular Technology*, Florence, Italy, June 2023.
- Sorensen, Mehmeti, Mahon, LaPorta, and Cao, "EQMS: An Improved Energy-Aware and QOE-aware Video Streaming Policy across Multiple Competitive Mobile Devices", *Wireless Networks: The Journal of Mobile Communication, Computation and Information*, Dec. 2022.
- Sorensen, Mehmeti, Mahon, Qui, Chan, Qui, and LaPorta, "Optimal Resource Allocation for Crowdsourced Image Processing", *IEEE Transactions on Mobile Computing*. June 2022.
- Sorensen, Mehmeti, Mahon, LaPorta, Cao, "Multi-User Competitive Energy-Aware and QoE-Aware Video Streaming on Mobile Devices", *ACM Proceedings of the QoS and Security for Wireless and Mobile Networks (Q2SWinet) Symposium collocated with Modeling, Analysis, and Simulation of Wireless and Mobile Systems (MSWIM 2020)*, Alicante, Spain, Nov. 2020.
- Sorensen, Mehmeti, Mahon, Qui, Chan, and LaPorta, "Optimal Resource Allocation for Crowdsourced Image Processing", *IEEE International Conference on Sensing and Networking (IEEE SECON 2020)*, Como, Italy, June 2020.
- Swanson, Mahon, Norris, and Mast, "Atmospheric Multipath Resolution Using Spread Spectrum Acoustic Signals", *Proceedings of Meetings on Acoustics*, September 2017.
- Aquaviva, Mahon, Einfalt, and LaPorta, "Optimal Cyber-Defense Strategies for Advanced Persistent Threats: A Game Theoretic Approach," *2017 International Symposium on Reliable and Distributed Systems*, Hong Kong, China, September 27 – 29, 2017.
- Young, Mahon, and Wyckoff, "Automated Information Management," Chap. 12, *Mathematical Techniques in Multisensor Data Fusion*, Hall, David L., Artech House Inc., Mar 2004
- Mahon, Sonstebly, and Wenchel, "Application of Non-Orthogonal Waveletes for Geolocation," *Radiolocation and Direction Finding Symposium*, Southwest Research Institute, San Antonio, Texas, 2-4 Nov. 1999.
- Myers, Lovette, Kilgus, Giannini, Swanson, Reichard, Mahon, Mast, "A Java-based Information System for Wayside Sensing and Control," *Proc. of the 1998 ASME/IEEE Joint Railroad Conference*, 1998, pp. 135-147.
- Swanson, Mast, Mahon, "Atmospheric Multipath Resolution Using Spread Spectrum Acoustic Signals," *Proceedings of the 133rd Meeting of the ASA*, June 15-20, 1997.
- Mahon, Swanson, "Acoustic Holography as an Active Control Measurement Tool," *Proceedings of Active 95, The 1995 International Symposium on Active Control of Sound and Vibration*, Newport Beach, CA, July 1995, pp. 673-684.
- Mahon, Sibul, Valenzuela, "A Sliding Window Update for the Basis Matrix of the QR Decomposition," *IEEE Transactions on Signal Processing*, May 1993, pp. 1951-1953.
- Mahon, Sibul, Valenzuela, "An Alternative Updating Scheme for the QR Algorithm as Applied to Adaptive Beamforming," *Proc. 25th Annual Conf. on Info. Sciences and Systems*, Johns Hopkins University, Baltimore, MD, March 1991, pp. 193-199.

Awards/Honors:

Senior Member IEEE

2001 Formal citation letter from National Reconnaissance Office (NRO) for experimental work with mobile wireless systems

2001 Formal citation letter for excellence in software development from the NRO for work associated with mobile wireless systems.

2000 Formal citation letter from NRO for development of wavelet course presented at NRO Technology Symposium

1997 Invited session chair of "Signal Processing in Acoustics: General Signal Processing," Noise-Con '97, 133rd meeting of the ASA.

1996 Simowitz Citation Acoustics Department PSU for outstanding publication by a graduate student

1995 Invited co-chair of "Transducers for Active Control of Sound and Vibration," Active 95, Active Noise Control Conference

1993 Simowitz Award Acoustics Department PSU for outstanding publication by a graduate student

1987 Dr. A. J. Cawley Award for Excellence in Electronics Engineering by Physics/EE Department University of Scranton