

Declaration of Dr. Mark P. Mahon

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

ERICSSON INC.
NOKIA OF AMERICA CORPORATION
Petitioners,

v.

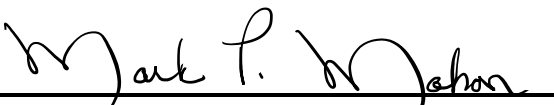
XR COMMUNICATIONS LLC
Patent Owner.

U.S. PATENT NO. 10,715,235
Title: DIRECTED WIRELESS COMMUNICATION

Inter Partes Review No.: IPR2024-00613

**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

TABLE OF CONTENTS

I.	INTRODUCTION	7
II.	BACKGROUND AND QUALIFICATIONS.....	7
III.	MATERIALS REVIEWED	14
IV.	LEGAL STANDARDS	14
V.	LEVEL OF ORDINARY SKILL.....	19
VI.	TECHNICAL BACKGROUND AND STATE OF THE ART	21
A.	Cellular And Wireless Technology.....	22
B.	Digital Communications and Packet Switched Networks	23
C.	Local Area Networks (LANs).....	25
D.	An Overview of 802.11 Local Area Networks	28
E.	Cellular Networking Technology.....	31
1.	The Radio Access Network	32
2.	The Core Network.....	33
3.	First Generation Cellular Telephony	34
4.	2nd Generation Cellular Telephony.....	34
5.	GPRS and Data Calls	38
6.	3rd Generation Cellular Systems	40
F.	Mobile Devices / Smartphones	45
G.	MIMO.....	48
H.	General Related Knowledge.....	72
1.	Prior Art MIMO Antenna Systems.....	72
2.	The Use Of Beamforming With MIMO Antennas	74

VII.	OVERVIEW OF THE CHALLENGED PATENT.....	75
A.	Priority Date	75
B.	Overview Of The Content Of The Challenged Patent	75
C.	Prosecution History	77
D.	Previous Petitions for Inter Partes Review.....	98
VIII.	OVERVIEW OF THE PRIOR ART	103
A.	Agee.....	103
B.	Butler	143
IX.	CLAIM CONSTRUCTION	161
X.	THE CHALLENGED CLAIMS OF THE ‘235 PATENT ARE OBVIOUS OVER AGEE ALONE OR IN COMBINATION WITH BUTLER.....	162
A.	The Motivation to Combine Agee With Butler With A Reasonable Expectation of Success.	162
B.	Challenged Claims.	164
1.	Detailed Application of Agee alone or in combination with Butler.....	164
a.	Claim 1	164
	[1.0] A receiver for use in a wireless communications system, the receiver comprising: an antenna, wherein the antenna comprises a first antenna element and a second antenna element;.....	164
	[1.1] a transceiver operatively coupled to the antenna and configured to transmit and receive electromagnetic signals using the antenna;	171
	[1.2] a processor operatively coupled to the transceiver, the processor configured to:	176

[1.3] receive a first signal transmission from a remote station via the first antenna element and a second signal transmission from the remote station via the second antenna element simultaneously; 186

[1.4] determine first signal information for the first signal transmission;.....224

[1.5] determine second signal information for the second signal transmission, wherein the second signal information is different than the first signal information; 224

[1.6] determine a set of weighting values based on the first signal information and the second signal information; 230

[1.7] wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals;.....248

[1.8] cause the transceiver to transmit a third signal to the remote station via the antenna, the third signal comprising content based on the set of weighting values.....255

b. Claim 2..... 257

[2] The receiver as recited in claim 1, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.....258

c. Claim 3..... 260

[3] The receiver as recited in claim 2, wherein the first signal transmission and the second signal transmission are directional transmissions. 260

d. Claim 4..... 263

[4] The receiver as recited in claim 1, wherein the content comprises data configured to be used by the remote station to modify the placement of one or more transmission peaks and one or more transmission nulls in a subsequent signal transmission.....263

e. Claim 5..... 264

[5] The receiver as recited in claim 4, wherein the set of weighting values is further based on one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data. 264

f. Claim 8..... 264

[8] 8. A method in a wireless communications system, the method comprising.....264

 [8.1] receiving a first signal transmission from a remote station via a first antenna element of an antenna and a second signal transmission from the remote station via a second antenna element of the antenna simultaneously, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls;.....264

 [8.2] determining first signal information for the first signal transmission;.....265

 [8.3] determining second signal information for the second signal transmission, wherein the second signal information is different than the first signal information;.....265

 [8.4] determining a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the remote station to construct one or more beam-formed transmission signals; and;.....265

 [8.5] transmitting to the remote station a third signal comprising content based on the set of weighting values.....269

g. Claim 9..... 269

[9] The method as recited in claim 8, further comprising: transmitting the third signal to the remote station via the antenna. 269

h. Claim 10. The method as recited in claim 8 wherein the first signal transmission and the second signal transmission are directional transmissions..... 270

Declaration of Dr. Mark P. Mahon

i.	Claim 11. The method as recited in claim 8, wherein the set of weighting values is further based on one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data.....	270
j.	Claim 12.....	270
[12]	The method as recited in claim 11, wherein the content comprises data configured to be used by the remote station to modify the placement of one or more transmission peaks and one or more transmission nulls in a subsequent signal transmission.	270
k.	Claim 15.....	271
[15]	15. An apparatus for use in a wireless communications system, the apparatus comprising: an antenna.....	271
[15.1]	a transceiver operatively coupled to the antenna;	271
[15.2]	a processor operatively coupled to the transceiver, the processor configured to:	271
[15.3]	receive a first signal transmission from a remote station via the antenna;	271
[15.4]	the first signal transmission comprising first signal information, wherein the first signal information comprises one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data;.....	271
[15.5]	receive a second signal transmission from the remote station via the antenna, the second signal transmission comprising second signal information;.....	271
[15.6]	determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals;	272
[15.7]	cause the transceiver to generate a third signal comprising content based on the set of weighting values.....	272

Declaration of Dr. Mark P. Mahon

1.	Claim 16.....	272
[16]	The apparatus as recited in claim 15, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.	272
m.	Claim 17.....	272
n.	Claim 18.....	276
o.	Claim 19.....	279
XI.	SECONDARY CONSIDERATIONS DO NOT REBUT THE PRIMA FACIE CASE OF OBVIOUSNESS.....	280
XII.	CONCLUSION AND DECLARATION	281
	APPENDIX A – MATERIALS RELIED UPON.....	283
	APPENDIX B – RÉSUMÉ	285

Declaration of Dr. Mark P. Mahon

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. 10,715,235 (“‘235 patent”) which I reference as the “challenged patent” in this declaration as discussed in detail below. My opinions are set forth below.
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. In my analysis below, I generally refer to the ‘235 patent for citations unless otherwise noted.
4. Unless otherwise indicated, the emphasis in quotations has been added.

II. BACKGROUND AND QUALIFICATIONS

5. 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.

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.

Declaration of Dr. Mark P. Mahon

6. The following is a brief summary of my relevant qualifications and professional experience
7. 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.
8. 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.
9. 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 at the CIA involved designing and testing systems to automatically capture and characterize telecommunication signals and emissions from various wireless and computer networking devices.
10. 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

Declaration of Dr. Mark P. Mahon

radio frequency and acoustic sensor systems including wireless communications and small wireless networks for acoustic tracking, source localization, and feature extraction.

11. 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 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.

12. 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

Declaration of Dr. Mark P. Mahon

communication signals for wideband characterization and remote sensing of propagation channels.

13. 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.

14. 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 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.

15.. 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

Declaration of Dr. Mark P. Mahon

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 seven refereed papers as listed in my curriculum vitae (CV) (attached as Exhibit A).

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

17. 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

Declaration of Dr. Mark P. Mahon

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.

18.. 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 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.

19.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

Declaration of Dr. Mark P. Mahon

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.

20. 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 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

Declaration of Dr. Mark P. Mahon

distributed processing algorithms, implementation of block chain coding techniques to improve handover security, and edge computing resource allocation in 4G (LTE)/5G (NR) networks.

21. 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

22. 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.

23. 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

24. 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

Declaration of Dr. Mark P. Mahon

understand that certain legal standards are to be applied by technical experts in forming opinions regarding the meaning and validity of patent claims.

25. 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.

26. 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

Declaration of Dr. Mark P. Mahon

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.

27. 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.

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

29. 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.

30. 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

Declaration of Dr. Mark P. Mahon

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.

31. 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 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.

32. 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.

Declaration of Dr. Mark P. Mahon

33. 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.

34. 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.

35. 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.

36. 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

37. 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

Declaration of Dr. Mark P. Mahon

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.

38. 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.

39. 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

Declaration of Dr. Mark P. Mahon

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.

40. 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.

41. 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.

42. 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.

43. This paragraph intentionally left blank.

44. This paragraph intentionally left blank.

VI. TECHNICAL BACKGROUND AND STATE OF THE ART

45. 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

46. 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.”

47. 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.

48. 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

49. 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 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

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.

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

50. 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.

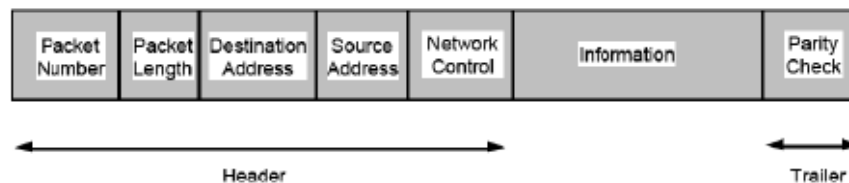


Figure A: A Generic Packet

51. 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.

52. 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 take different routes between source and destination. More importantly, packets from

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.

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.

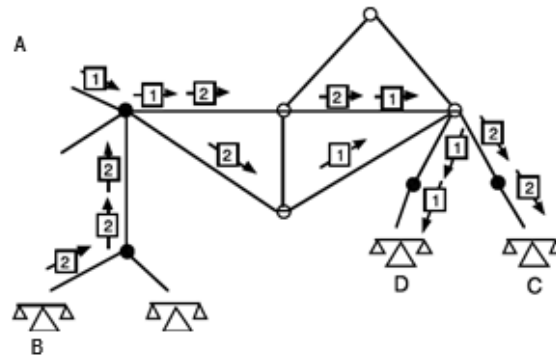


Figure B: A Packet-Switched Network

C. Local Area Networks (LANs)

53. 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.

54. 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.

55. 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.

56. 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.

57. 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.

58. 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

59.802.11 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.

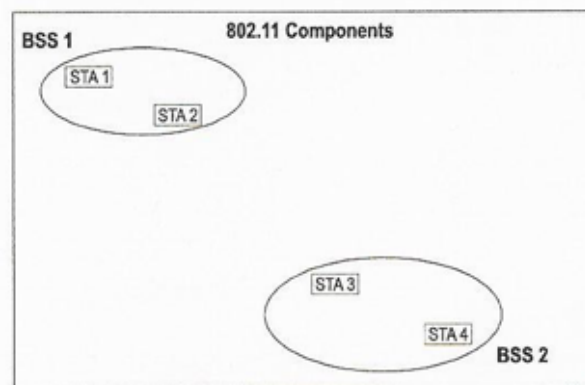


Figure C: 802.11 Independent Basic Service Set

60.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

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

62. 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.

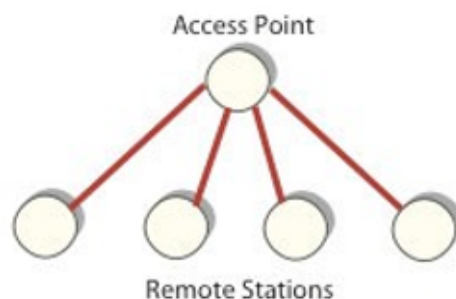


Figure E: 802.11 Infrastructure Network

63. 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

64. 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*

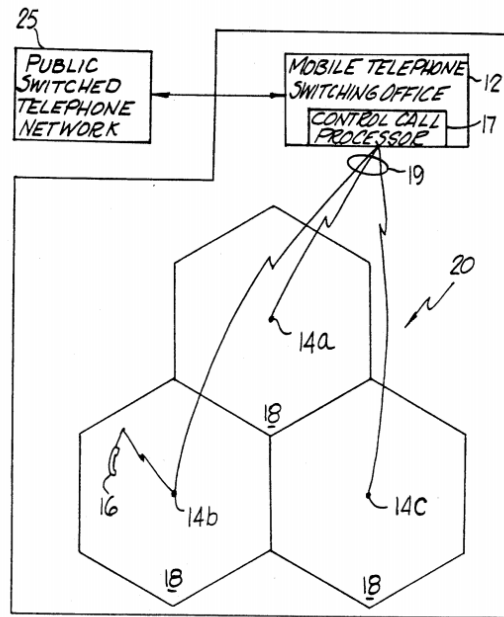
ANSI/IEEE Std 802.11, 1999 Edition, pg. 25

65. This paragraph left intentionally blank.

E. Cellular Networking Technology

66. 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

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



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

1. The Radio Access Network

68.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

Declaration of Dr. Mark P. Mahon

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.

69. 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.

70. 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

71. 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

72. 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

73. 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

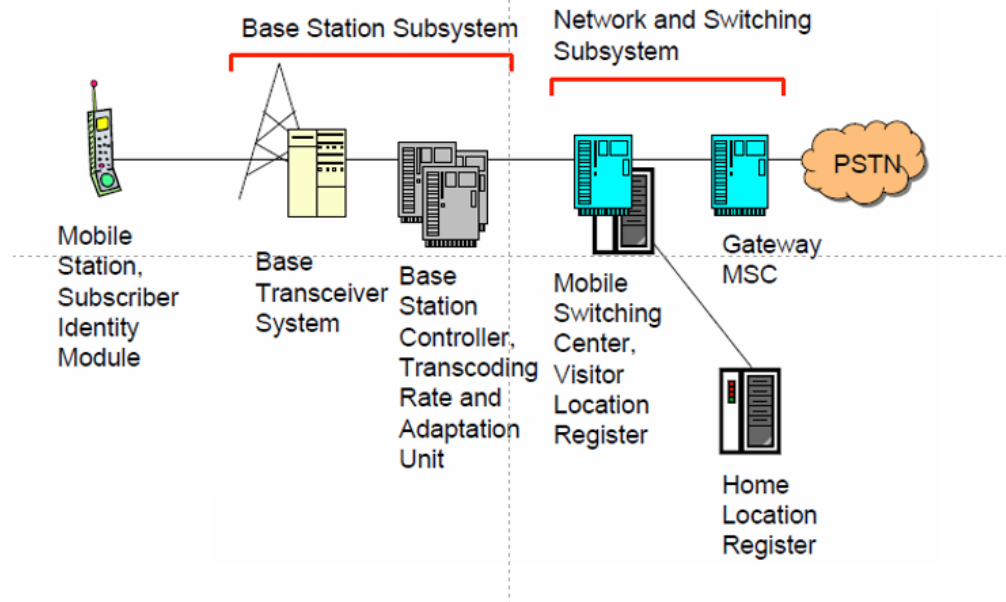
communications and established user authorization and authentication procedures.

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.

74. 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

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.

GSM Architecture



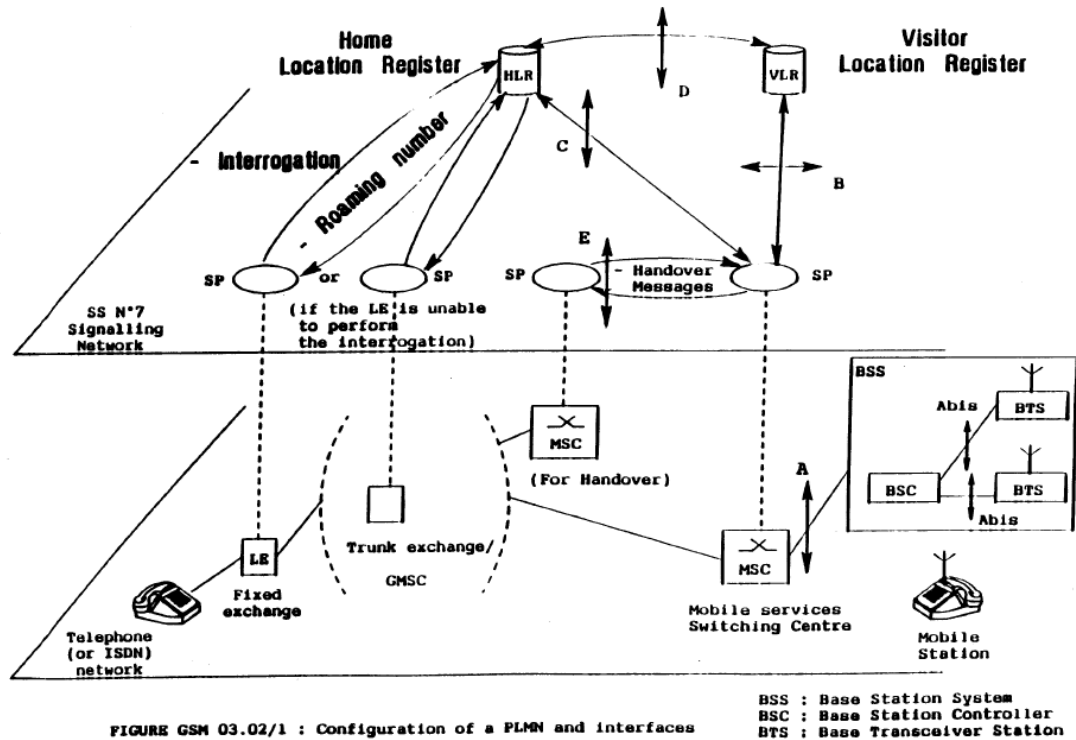
6

75. 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 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

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

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.

7



76. 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

⁷ See web.cse.ohio-state.edu/~xuan/courses/694/694_CELLULAR_NETWORK.ppt at Slides 12-25.

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.⁸

5. GPRS and Data Calls

77. 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 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.

78. 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

⁸ See web.cse.ohio-state.edu/~xuan/courses/694/694_CELLULAR_NETWORK.ppt at Slide 23.

Declaration of Dr. Mark P. Mahon

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.

79. 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.

80. 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 13.⁹

⁹ Available at https://www.etsi.org/deliver/etsi_en/301300_301399/301344/07.04.01_60/en_301344v070401p.pdf.

81. 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

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

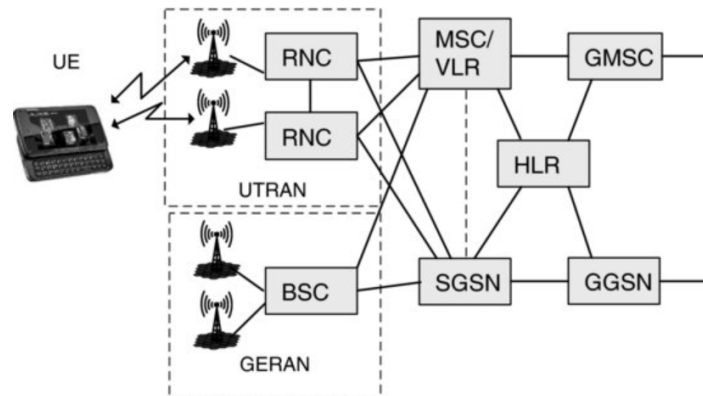


Figure 1. The 3G Release 99 system architecture.

Forsberg, “LTE Security” (2nd ed.).

83. 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

Declaration of Dr. Mark P. Mahon

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.

84. 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.

85. 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.

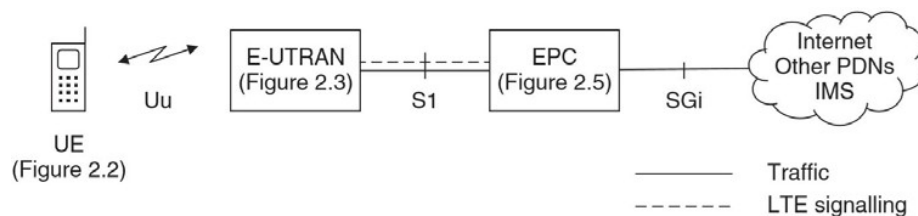


Figure 2.1 High-level architecture of LTE

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

86. 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.

87. 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.

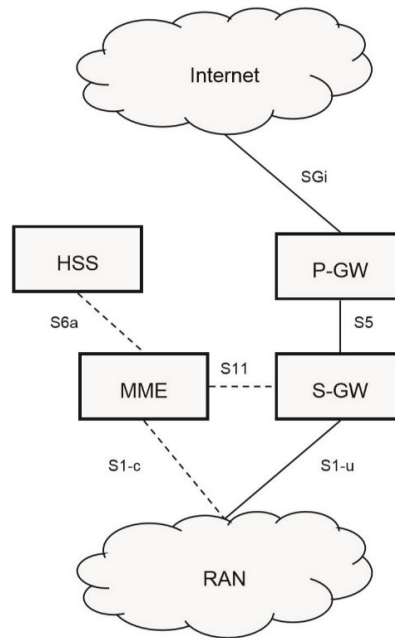


Figure 4.1 Core Network Architecture

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

F. Mobile Devices / Smartphones

88.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.

89.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

Declaration of Dr. Mark P. Mahon

(transmitter) and vice versa (receiver).¹⁰ 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.¹¹

90. 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.

91. Motorola was the first company to produce a handheld mobile phone in 1973, the Motorola DynaTAC.¹²

92. 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.¹³

93. 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

¹⁰ Rong Wang, PhD, “How Do Cell Phones Work?,” *Pong Pulse* (December 20, 2014) (available at <https://pongcase.com/blog/cell-phones-work/>).

¹¹ U.S. Patent No. 6,912,376 to Smith et al. (filed December 27, 1999).

¹² 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).

¹³ *Id.*

Declaration of Dr. Mark P. Mahon

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).

94.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.

95.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.

96.“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.

97. This paragraph left intentionally blank.

98. This paragraph left intentionally blank.

G. MIMO

99. 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.

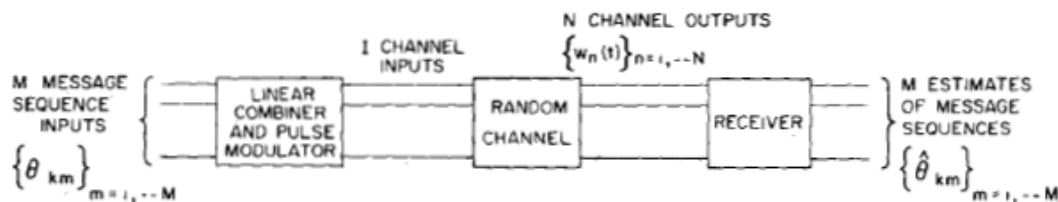


Fig. 2. General form of communication system.

100.

101. *Id.* at pp. 521.

102. 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.

103. 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,

Declaration of Dr. Mark P. Mahon

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).

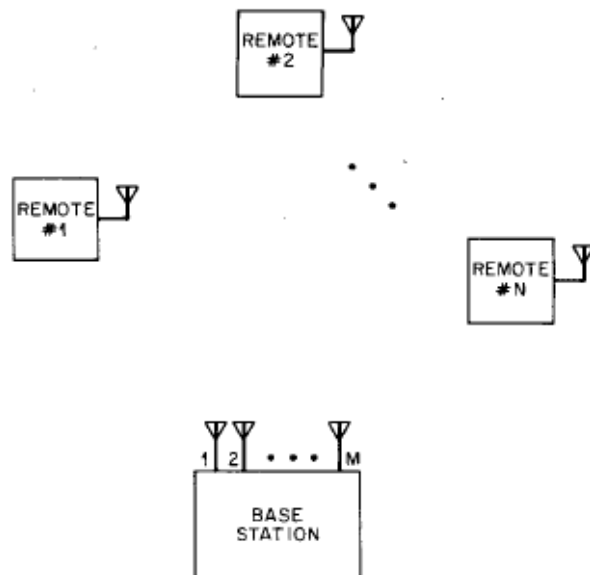


Fig. 1. Radio system consisting of a base station with M antennas and N remotes, each with one antenna.

104.

105. *Id.* at pp. 872.

106. 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).

107. 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

Declaration of Dr. Mark P. Mahon

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.

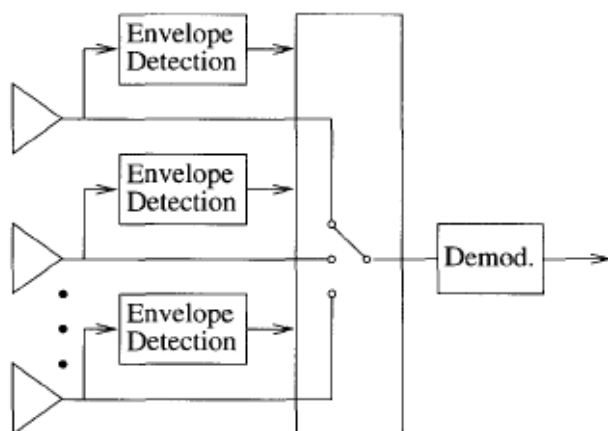


Figure 3.5: Selective-diversity combining.

108.

109. *Id.* at pp. 128.

110. 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 '235 patent.

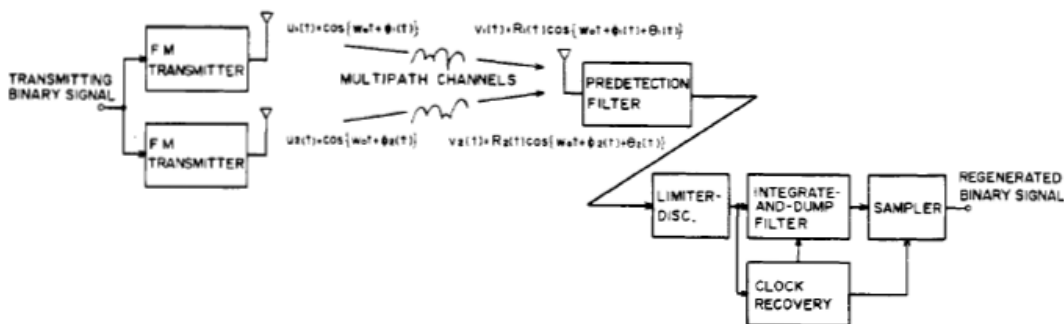


Fig. 1. Transmitter diversity system model.

111.

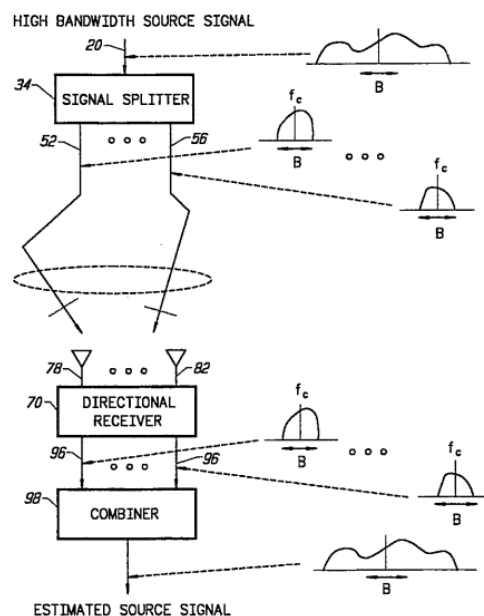
112. Adachi at pp. 334.

113. 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*.
114. 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

Declaration of Dr. Mark P. Mahon

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.

115.



116.

117. See US005345599 at face.

118. 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.

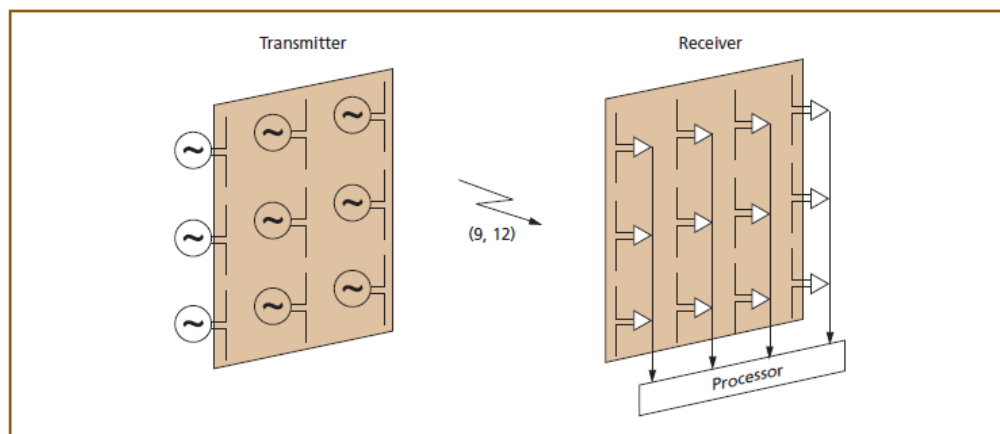


Figure 1.
Shorthand notation (n_T, n_R) for the number of transmit antennas n_T and receive antennas n_R (dipole antennas shown).

119.

120. Id at pp. 43.

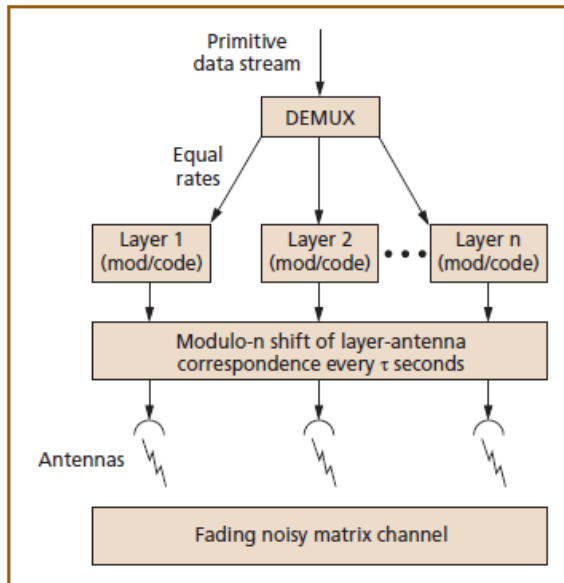


Figure 4.
Transmission process using space-time layering.

121.

122. Id at pp. 46.

123. 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.

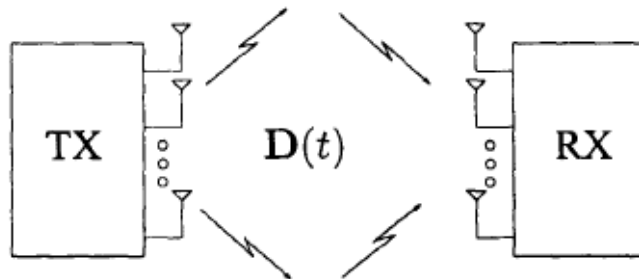


Fig. 1. Space-time coding modem.

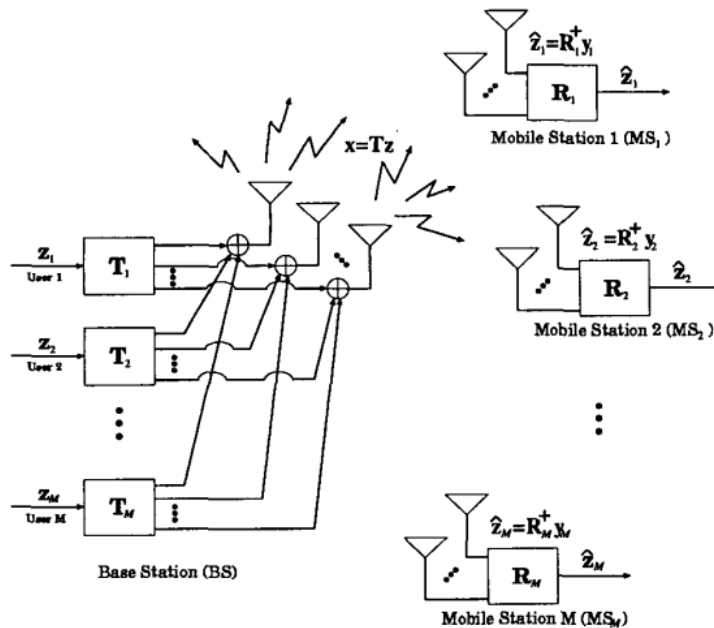
124.

125. Id at pp. 1128.

126. 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.

127. 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.



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

129. Id. at pp. 430.

130. Likewise, Rousseaux, et al., published "A Blind Multi-User MIMO Transceiver using Code Modulation in a Multiplath 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.

131. 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.

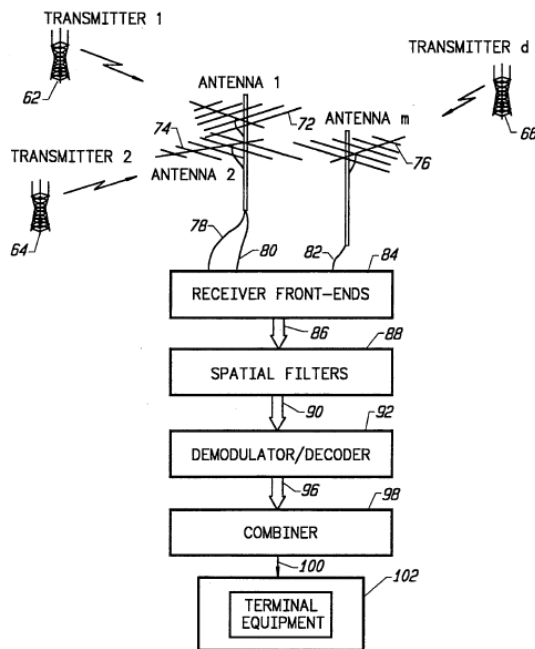


FIG. 5

132.

133. 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.

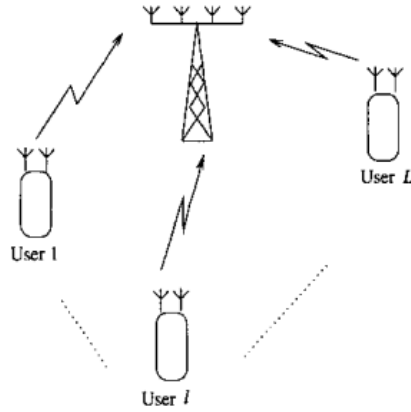


Fig. 1. Multiuser MIMO system in which users and the base station are equipped with antenna arrays for transmission/reception.

134.

135. 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.

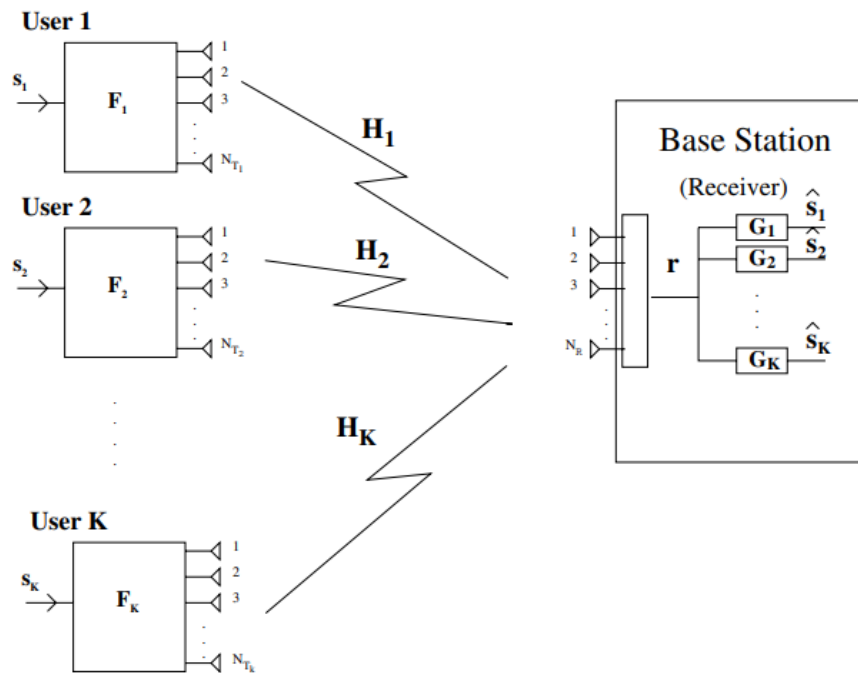


Fig. 1. System model of multiuser MIMO system.

136.

137. 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.

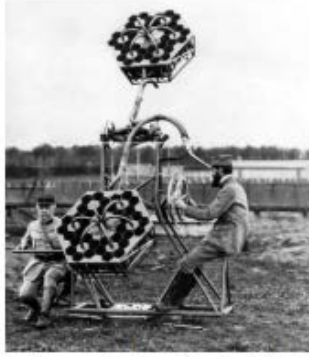


Figure 1: Acoustic array developed by Sergeant Jean Perrin (right) and used by the French Army during WWI to detect enemy aircraft.

138.

139. Heilman, et al.

140. 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.

141. “*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).

142. 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.

143. 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.

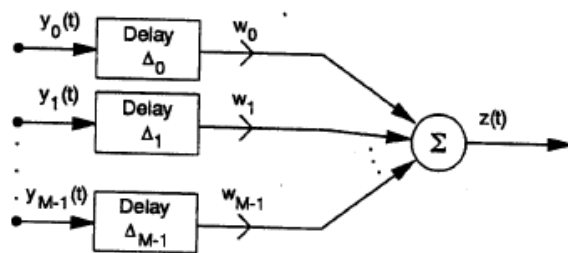


Figure 4.2 The beamformer's output $z(t)$ consists of adding together the sensors' outputs after a delay (and an amplitude weight) has been applied to each. The delays can be chosen to maximize the array's sensitivity to waves propagating from a particular direction or location in space.

144.

145. Id.

146. 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.

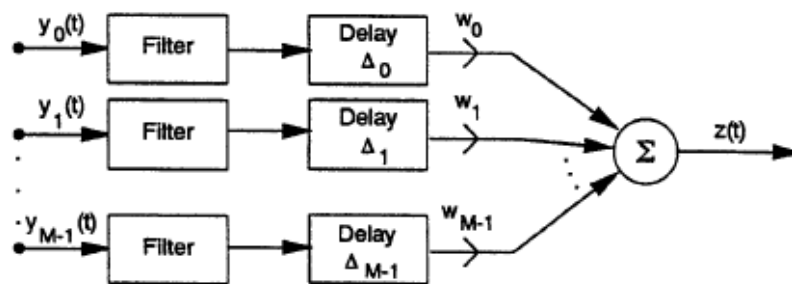


Figure 4.8 The configuration of the filter-and-sum beamformer consists of linear filters preceding the delay-and-sum beamforming stage. The transfer functions of these filters are usually identical and select the range of frequencies corresponding to the signal of interest.

147.

148. Id.

149. 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).

150. 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.”

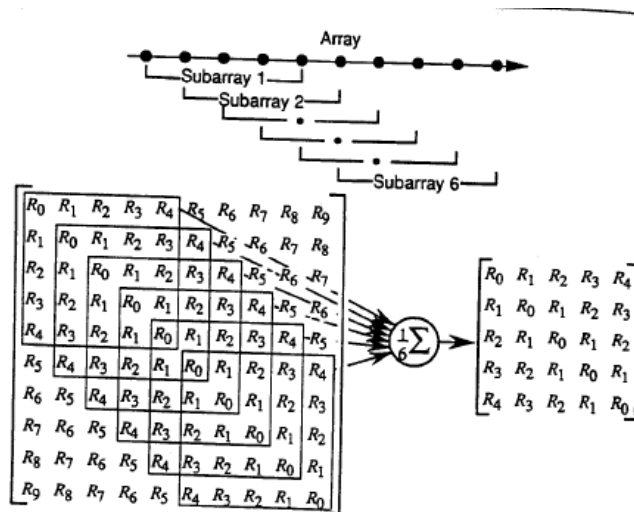


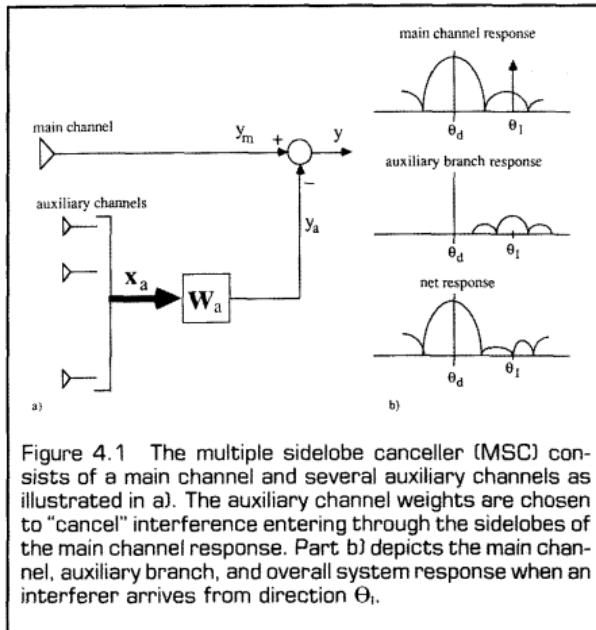
Figure 4.35 A regular linear array of M sensors can be conceptually decomposed into $M - M_s + 1$ subarrays each having M_s sensors. Here, spatial correlation matrices are computed for each of the six subarrays formed from a ten-sensor array. These matrices, which are submatrices of the array's spatial 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.

151.

152. Id. at pp. 188.

153. 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.

154. 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).



155.

156. Id.

157. 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.

158. Additionally, a POSITA at the priority date of the '235 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.

159.

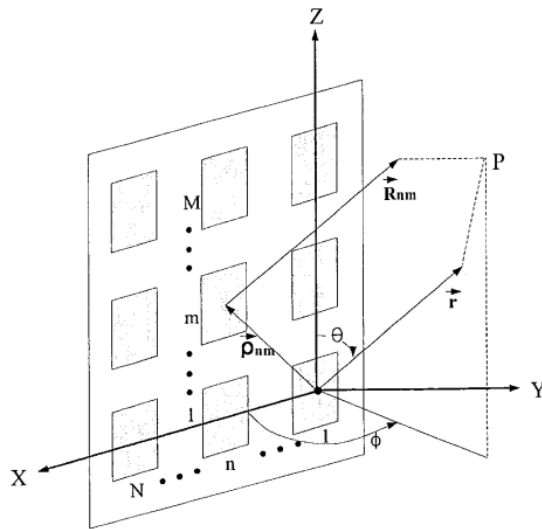


Figure 2. A planar array, consisting of N vertical linear subarrays of M patch radiators. The subarrays are placed in one plane, and are equally spaced.

160.

161. Id. at pp. 146-147.

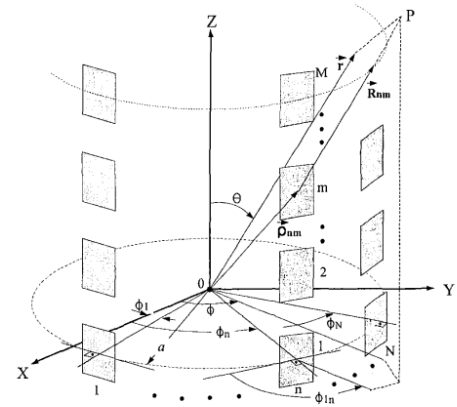


Figure 1. A circular array, consisting of N vertical linear subarrays of M patch radiators. The subarrays are situated along a circular arc of radius a , and have azimuth coordinates ϕ_n , $n = 1, \dots, N$.

Declaration of Dr. Mark P. Mahon

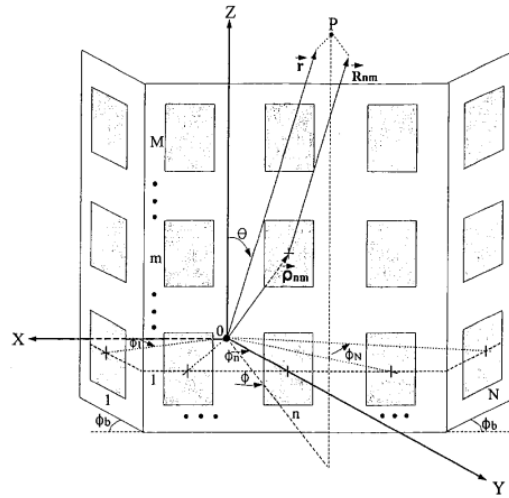


Figure 3a. A three-segment array, consisting of N vertical subarrays of M patch radiators.

162.

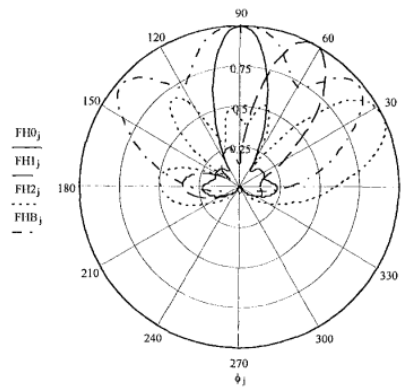


Figure 4a. The azimuth (H-plane) normalized patterns in polar (dimensionless) coordinates for the five-subarray circular array, with $a = 0.95\lambda$, $\Delta\phi = 30^\circ$: $\phi_0 = 90^\circ$ (solid line), $\phi_0 = 60^\circ$ (dashed line), and $\phi_0 = 15^\circ$ (dotted line). Also shown is the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

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

164. This paragraph left intentionally blank.

165. This paragraph left intentionally blank.

166. This paragraph left intentionally blank.

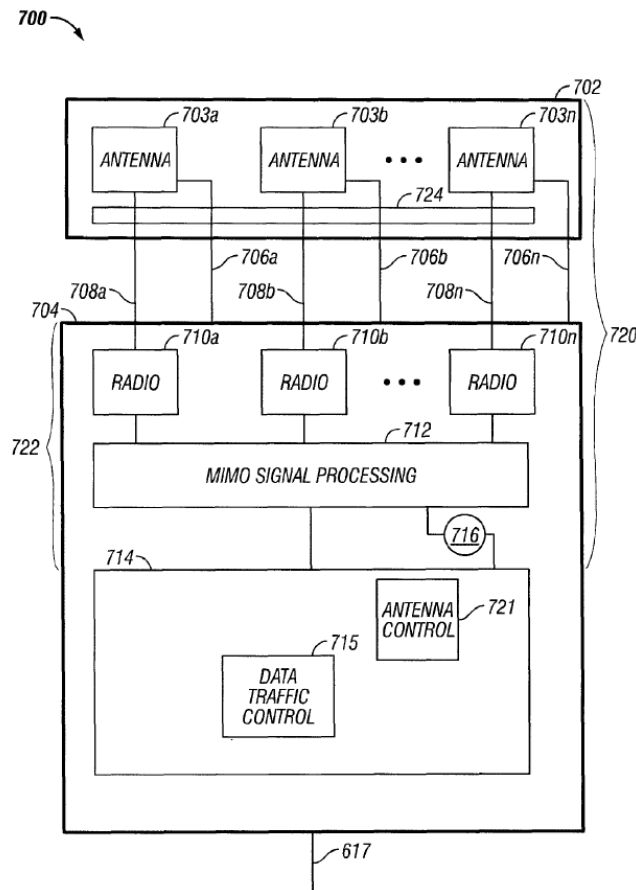
167. This paragraph left intentionally blank.

H. General Related Knowledge

168. 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

169. 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.

170. 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.
171. 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.
172. 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.

173. This paragraph left intentionally blank.

2. The Use Of Beamforming With MIMO Antennas

174. 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. However, the signal to interference and noise ratio (SINR) was enhanced within the area covered by the beams.

175. 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.

176. This paragraph left intentionally blank.

177. This paragraph left intentionally blank.

VII. OVERVIEW OF THE CHALLENGED PATENT

A. Priority Date

178. I have been instructed that for the purposes of this IPR, to assume the priority date for the challenged patent is November 4, 2002 (the filing date of Provisional Application No. 60/423,660 to which the challenged patent claims priority). I am also aware that the PO has asserted that the priority date could be as early as February 1, 2002 in prior IPR proceedings. E.g., IPR2022-00367, Patent Owner's Preliminary Response at p. 3 ("the challenged ['235] claims are entitled to a priority date at least as early as February 1, 2002.").

179. My analysis herein would not change for either of these two possible dates.

B. Overview Of The Content Of The Challenged Patent

180. The Challenged Claims are directed to receiving signals from a remote station and using signal information related to those signals to determine "weights" that can be used for beamforming. Some of the Challenged Claims recite that the received signals must be received simultaneously (e.g., Challenged Claims 1, 8 and their dependent claims).

Declaration of Dr. Mark P. Mahon

181. As I have noted in the discussion of the Crilly reference in my discussion of the prosecution history, the '235 patent shares a significant amount of its content with Crilly.
182. In the '235 specification, there is only a single embodiment that discusses the calculation of weights that are subsequently used specifically for beamforming. That embodiment is shown at 24:25-27:67.
183. While the Abstract mentions the calculation of weights, that content was added when the '235 patent application was filed in 2017 and does not appear in the priority non-provisional application filed in 2003. Similarly, Figure 12 (and its description) also show a "weighting matrix" but, as I have noted in the discussion of the prosecution history, Figure 12 was present in the prior art Crilly reference cited by the Examiner. Similarly, the "weighting information" was reference in the '235 patent at 15:47-48, but that same content was also present in the prior art Crilly reference.
184. The '235 patent discusses the use of a Butler matrix at 25:31-27:67 including Figures 13-15.
185. All of the concepts of using a Butler matrix with an array of antennas as described and claimed in the '235 Patent, including forming beams based on measurements made using antennas in the antenna array were known to a POSITA long prior to the '235 patent.

186. This paragraph left intentionally blank.

C. Prosecution History

187. The ‘235 Patent issued from U.S. Pat. App. No. 15/260,147 filed April 24, 2017 claiming priority through a series of continuation applications to U.S. Provisional Pat. App. No. 60/423,600 filed November 4, 2002.

188. I have reviewed the prosecution history related to the Challenged Claims. I discuss portions of it below.

189. During prosecution, the Examiner rejected the Challenged Claims and cited the Crilly reference (U.S. Pat. App. 2002/0158801) (EX-1008). As detailed below, Crilly shares at least two inventors with the Challenged Claims and Crilly’s disclosure is highly similar to the ‘235 patent.

190. The Examiner rejected the ‘235 claims over Crilly – finding that Crilly disclosed each element except the “simultaneously” aspect.

4. Claims 1-20 is/are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Crilly, Jr. et al. (US 2002/0158801 A1) in view of Ishii et al. (US 6,714,584).

191. EX-1002, 000202-0225.

192. The Examiner cited to Crilly’s Fig. 4 (copied in the ‘235 patent’s Fig. 12):

Declaration of Dr. Mark P. Mahon

As shown in FIGS. 1-24, Crilly discloses a receiver for use in a wireless communications system, the receiver comprising:

- an antenna (**see Crilly, FIG. 4, antenna array 110**);
- a transceiver operatively coupled to the antenna and configured to transmit and receive electromagnetic signals using the antenna (**see Crilly, FIG. 2, transmitter/receiver 114**); and
- a processor operatively coupled to the transceiver, (**see Crilly, FIG. 4, control logic 112**) the processor configured to:
 - receive a first signal transmission from a remote station via the antenna and a second signal transmission via the antenna (**see Crilly FIG. 4, paragraph [0091]; These signals, both desired and undesired, are collected by receiving elements within antenna array 110 and are eventually provided to control logic 110.**);
 - determine first signal information for the first signal transmission (**see Crilly, paragraph [0092]; Here, control logic 112 includes a search receiver 164 that is configured to update routing information 120 with regard to the received signals.**);
 - determine second signal information for the second signal transmission, wherein the second signal information is different than the first signal information (**see Crilly, paragraph [0092]; Here, control logic 112 includes a search receiver 164 that is configured to update routing information 120 with regard to the received signals.**);

- determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the remote station to construct one or more beam-formed transmission signals (**see Crilly, paragraph [0093]; The stored weighting values associated with each connection/source are utilized in a weighting matrix 166. Weighting matrix 166 operates so as to apply the latest weighting values to the received signals and also to transmitted signals. In this illustrative example, subsequently received signals will be processed using the most recent weighting values in the weighting matrix.**); and
- cause the transceiver to generate a third signal comprising content based on the set of weighting values (**see Crilly, paragraph [0093]; The stored weighting values associated with each connection/source are utilized in a weighting matrix 166. Weighting matrix 166 operates so as to apply the latest weighting values to the received signals and also to transmitted signals. In this illustrative example, subsequently received signals will be processed using the most recent weighting values in the weighting matrix.**)

193. EX-1002, 000203-205. However, the Examiner concluded:

Crilly does not specifically disclose “receive a first signal transmission from a remote station via the antenna and a second signal transmission from the remote station via the antenna simultaneously.”

Declaration of Dr. Mark P. Mahon

194. EX-1002, 000205. The Examiner cited a secondary reference (Ishii) for “simultaneously.” EX-1002, 000206.

195. The PO did not challenge the Examiner’s determination the Crilly disclosed all elements except “from the remote station ... simultaneously” but instead (unsuccessfully) challenged the secondary reference, Ishii.

However, the cited portions of Ishii do not disclose or suggest receiving signal components from the same transmitter. In fact, Ishii discloses that the “present invention relates to CDMA (Code Division Multiple Access) adaptive antenna . . . for separating and synthesizing

11

a plural of desired signal components incoming at a plural of different timings and from a *plural of different directions at each timing.*” *Id.*, column 1, lines 8-13 (emphasis added). In Ishii, signal components come from a plurality of different directions, and are thus associated with *different* transmitters. In contrast, claim 1 recites “receive a first signal transmission from *a* remote station via the antenna and a second signal transmission from *the* remote station” (emphasis added).

For at least these reasons, Applicant respectfully submits that Crilly in combination with Ishii does not disclose or suggest claim 1 and respectfully requests withdrawal of the rejection.

196. EX-1002, 000190-0192.

197. In a Final Rejection, the Examiner held again that Crilly disclosed all claim elements except the “simultaneously.”

Crilly does not specifically disclose “receive a first signal transmission from a remote station via the antenna and a second signal transmission from the remote station via the antenna simultaneously.”

198. EX-1002, 000148-0150.

199. As shown below, the only substantive difference between Crilly (which the Examiner held does not show the “receiving simultaneously” elements) and the ‘235 patent portions that disclose using calculated weights for beamforming (which presumptively discloses those “simultaneously” elements) is that the ‘235 patent includes a Butler matrix which is not in Crilly.

200. Below is a copy of a table in EX-1014 that contains a side-by-side comparison of relevant Crilly passages and the passages in the ‘235 Weight Embodiment which is the only embodiment in the ‘235 specification describing the use of calculated weights to form beams.

‘235 Weight Embodiment (EX-1001, 24:24-25:30)	Crilly Largely Verbatim Language (EX-1008, ¶¶87-94)
Fig. 12: <i>Fig. 12</i>	Fig. 4 <i>Fig. 4</i>
EX-1001, 24:25-33:	Crilly, ¶90 [0090]

FIG. 12 illustrates an exemplary implementation 1200 of the multi-beam directed signal system 206 that weighs signals received via antenna array 302. Communication and/or data transfer signals are received from sources 1202 (e.g., sources A and B). The signals received from sources 1202 are considered desired signals because they are from nodes within the wireless routing network. Further, signals such as noise and WLAN interference associated with another external wireless system 1204 are not desired.	Reference is now made to FIG. 4, which illustratively depicts signals received by a wireless routing device 102 from different sources. Here, for example, it is assumed that signals received from sources 160 are desired signals as they are from other nodes within wireless routing network 100 and that signals such as the noise and WLAN interference associated with another external wireless system 162, are not desired.
EX-1001, 24:34-38 These signals, both desired and undesired, are received via antenna array 302 and are provided to the signal control and coordination logic 304 (shown in FIG. 3) from the receiver/transmitters (Rx/Tx) 824(0), 824(1), . . . , 824(N) (also shown in FIG. 8B).	Crilly, ¶91 [0091] These signals, both desired and undesired, are collected by receiving elements within antenna array 110 and are eventually provided to control logic 110. Note, while not important for the purposes illustrated in this example, receivers 114 actually provide the received signals to control logic 110.
EX-1001, 24:38-53: In this example, the signal control and coordination logic 304 includes the scanning receiver 822 that is configured to update routing information 1206 with regard to the received signals. For example, scanning receiver 822 may identify information about different classes of interferers (e.g., known and unknown types) within the routing information 1206. In this example, routing information 1206 includes connection indexed routing table(s) based on identification information, such as address	Crilly, ¶92 [0092] Here, control logic 112 includes a search receiver 164 that is configured to update routing information 120 with regard to the received signals. For example, search receiver 164 may identify information about different classes of interferers (e.g., known and unknown types) within routing information 120. In this example, routing information 120 includes a connection indexed routing table(s) based on identification

information, CID, and the like. The routing table includes identifiers of the desired sources and other identifiers for the interferers (“Int”). Further, the routing table includes stored weighting values (w) each associated with a particular signal source 1202 (e.g., sources A and B). Other information such as “keep out” identifiers may also be included in this exemplary routing table.	information, such as, e.g., address information, CID, etc. The routing table(s) includes identifiers of the desired sources and other identifiers for the interferers (Int). Further included in the routing table(s) are stored weighting values (w). Other information such as “keep out” identifiers, which are described in later sections, are also included in this exemplary routing table(s).
EX-1001, 24:54-67: A description of the received signal(s) can be stored in the routing table in the form of the pattern or weighting of the signal(s). In this example, a polynomial expansion in z, $w(z)=w_0+w_1z+w_2z^2+w_3z^3+w_4z^4+\dots+w_iz^i$ can be utilized to establish the values of the weights (w_i) to be applied to a weight vector. The routing table(s) may store such weighing patterns as a function of θ, or the zeroes of the polynomial, for example. One advantage of zero storage is that the zeros represent directions for communication that should be nulled out to prevent self-interference or interfering with other nodes or possibly other known wireless communication systems, such as WLAN 1204 that is not part of the wireless routing network, but is operating within at least a portion of a potential coverage area 1208 and frequency bands.	Crilly, ¶87 [0087] Each of these illustrations represents a description of the form of the pattern or weighting that may be stored in the routing table(s). In the example shown here, the polynomial expansion in z, $w(z)=w_0+w_1z+w_2z^2+w_3z^3+w_4z^4+\dots+w_iz^i$ establishes the values of the weights (w_i) to be applied to the weight vector. The routing table(s) may store such weighing patterns as a function of θ, or the zeroes of the polynomial, for example. One advantage of zero storage is that the zeros represent directions that should be nulled out to prevent self-interference or possibly interfering with other nodes or possibly other known wireless communication systems, such as, e.g., a WLAN that is not part of wireless routing network 100 but is operating within at least a portion of potential coverage area 132 and frequency bands.
EX-1001, 25:1-15: The polynomial expansion in z, $w(z)$, and the zeroes may be calculated from	Crilly, ¶88 [0088] The polynomial expansion in z, $w(z)$ and the zeroes may be calculated from

each other and each may be stored. Updates can be generated frequently (e.g., in certain implementations, about every millisecond), and a zero storage system may be more advantageous in most wireless network environments because only a few values will change at a given time. Storing the weighting values will in general require changes to all of the weighting values $w(i)$ when any change in the pattern occurs. Note that $w(i)$ and $A(\theta)$ may be expressed as Fourier transform pairs (discrete due to the finite antenna element space). The $w(i)$ is equivalent to a time domain impulse response (e.g., a time domain unit sample response) and the $A(\theta)$ is equivalent to the frequency response (e.g., an evaluation of $w(z)$ sampled along a unit circle).	each other; therefore, each may be stored. Updates preferably occur fairly frequently (e.g., in certain implementations, about every millisecond), so a zero storage system may be more advantageous as it is expected that in most environments only a few values will change at a given time. Storing the weighting values will in general require changes to all of the weighting values $w(i)$ when any change in the pattern occurs. Note that $w(i)$ and $A(\theta)$ may be expressed as Fourier transform pairs (discrete due to the finite antenna element space). The $w(i)$ is equivalent to a time domain impulse response (e.g., a time domain unit sample response) and the $A(\theta)$ the frequency response (e.g., an evaluation of $w(z)$ sampled along a unit circle).
EX-1001, 25:16-22: The stored weighting values associated with each connection, data signal, and/or source are utilized in a weighting matrix 1210 which operates to apply the latest weighting values to the received signals and also to transmitted signals. In this illustrative example, subsequently received signals will be processed using the most recent weighting values in the weighting matrix 1210.	Crilly, ¶93 [0093] The stored weighting values associated with each connection/source are utilized in a weighting matrix 166. Weighting matrix 166 operates so as to apply the latest weighting values to the received signals and also to transmitted signals. In this illustrative example, subsequently received signals will be processed using the most recent weighting values in the weighting matrix.
EX-1001, 25:22-30. Thus, as described herein, the multi-beam directed signal system 206 is configured to control the transmission	Crilly, ¶94 [0094] Thus, as described above and in subsequent sections, wireless routing device 102 is essentially configured to

Declaration of Dr. Mark P. Mahon

amplitude frequency band and directionality of data packets to other nodes and assist in reducing the effects associated with received noise and interference (e.g., self interference and/or external interference). This is accomplished with the signal control and coordination logic 304 within the multi-beam directed signal system 206.	control the transmission amplitude frequency band and directionality of data packets to other nodes and assist in reducing the effects associated with received noise and interference (e.g., self interference and/or external interference). This is accomplished with control logic 112 within wireless routing device 102.
EX-1001, 25:31-27:67, Figs. 13-15 (describing Butler matrix operation)	Not found in Crilly.

201. As is plainly apparent from the side-by-side comparison above, Crilly largely has all of the content from the ‘235 Weight Embodiment with the exception of the Butler matrix.

202. The intrinsic record (the exchanges between the applicant and the Examiner) would indicate to a POSITA that the Butler matrix is the only component within the ‘235 Weight Embodiment that is not in Crilly.

203. Thus, (a) the Examiner determined (twice) that Crilly disclosed all claim elements except “simultaneously”; (b) PO did not challenge the Examiner’s conclusions on Crilly, and (c) the ‘235 patent added only the Butler matrix to Crilly’s disclosure. Based on this (and consistent with my analysis of the Butler matrix above), a POSITA would reasonably conclude that the scope of the “simultaneously” elements is disclosed by the known operation of a Butler matrix.

Declaration of Dr. Mark P. Mahon

204. This conclusion is further bolstered by the applicant's citations to the Littlejoe priority document during prosecution to pre-date Crilly after the applicant was unsuccessful in challenging Ishii.

205. In response to the Final Rejection above, the applicant sought to pre-date Crilly by asserting that the '235 priority documents predated the effective date of the Crilly reference:

The present application claims priority to US Provisional Application No. 62/423,660, which was filed November 4, 2002. The Provisional application includes a compilation of several documents, labeled Appendices A-L on page 2. These documents describe aspects and embodiments of Applicant's invention existing at the time the particular document was written.

Document A, at page A-71, lists several "References" used in compiling Document A. Included in the References list is "[2] Ed Casas, 'Beamforming for LittleJoe', VIVATO Technical Report, Feb 1, 2002", which is Document C of the Provisional. At least Document C describes aspects of Applicant's invention that had been invented at least as early as February, 2002, which is well before Crilly was published (October 31, 2002). As such, at least the disclosure in Document C was invented before Crilly was published, and Crilly is not prior art to such disclosure.

As demonstrated by Document C, at least the limitations that the Office Action contends are taught by Crilly were invented by Applicant prior to Crilly's publication.

206. EX-1002, 000130-0134.

207. The Littlejoe priority document cited by the applicant describes a system that uses the outputs of a Butler matrix to calculate the weights for performing beamforming:

Little Joe ... us[es] a 16-element linear antenna array to increase range and performance.

It uses two separate RF beamformers. The first beamformer, the "searcher," is for receiving only and uses a 16-port Butler matrix whose outputs are connected to

Declaration of Dr. Mark P. Mahon

16 standard WLAN cards installed in a PC. An application on the PC obtains the received signal levels for each received packet.

This signal level information is used to compute the complex weights for a second RF beam former.

208. EX-1009, 0134. Figure 1 in Littlejoe depicts the “Butler Matrix BF”

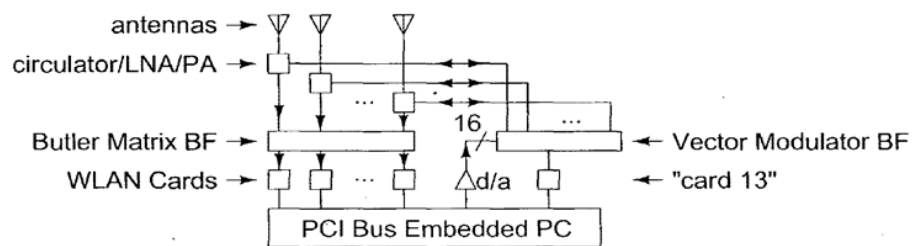


Figure 1: *Little Joe* block diagram.

209. EX-1009, 0135. The inputs to the “Butler Matrix BF” are the signals received from the 16 antennas in the “16-element linear antenna array.” EX-1009, 0134.

210. Littlejoe’s “Butler Matrix BF” has 16 outputs to “WLAN Cards.” Each output represents the composite signal strength levels for multiple antennas connected to that output as explained in the section herein describing the operation of the well-known Butler matrix.

211. As noted above, the ‘235 applicant sought to overcome Crilly by citing to Littlejoe (and thus trying to establish an earlier priority date before Crilly).

Declaration of Dr. Mark P. Mahon

212. The PO specifically argued that the operation of a Butler Matrix BF corresponded to multiple claim elements in the following passages. For example, the applicant cited to the following:

For example, with respect to independent Claim 1 (and OA at pp.6-7) Doc C describes:

- an antenna
 - see C-2, section 1.2.
- a transceiver operatively coupled to the antenna and configured to transmit and receive electromagnetic signals using the antenna
 - see C-1 – C-2, C-4 (“each array element [can] generate the receive and transmit beams”) and throughout Document C.
- a processor operatively coupled to the transceiver, the processor configured to:
 - C-1 and C-2, including Fig. 1 disclose a PC
- receive a first signal transmission for a remote station via the antenna and a second signal transmission from the remote station via the antenna

213. EX-1002, 000130-0131. The passages above are citing to the antenna array and the associated components in Littlejoe.

214. For the “receive a first signal transmission element...”, PO argued it was disclosed by passages from Littlejoe describing the operation of the antenna array and the Butler matrix:

- receive a first signal transmission for a remote station via the antenna and a second signal transmission from the remote station via the antenna
 - C-3: “The signal received by the array elements will be the vector sum of signals arriving by many paths.” C-3 also refers to the “arrival of signals from the desired and undesired users”.

215. EX-1002, 000130-0131.

216. I note that the Examiner cited Crilly's similar statement for this "receiving element." EX-1002, 000146, 000204 (both rejections citing to "0091 These signals, both desired and undesired, are collected by the receiving elements....")

217. For the "determine first signal information" and "determine second signal information" elements, PO argued they were both disclosed by merely using the signal strength in a beamforming application (as Agee does below):

- determine first signal information for the first signal transmission
 - C-4: "The beamforming application uses the signal strength information derived from packet receptions by the 'searcher' receivers."
- determine second signal information for the second signal transmission, wherein the second signal information is different than the first signal information
 - C-4: "The beamforming application uses the signal strength information derived from packet receptions by the 'searcher' receivers. However, not all of these receivers will correctly receive each packet." Also, "Each beam points in a different direction"

218. EX-1002, 000130-0131.

219. The applicant mirrored these arguments for the other claims. EX-1002, 000132-0134. The Examiner accepted these arguments. EX-1002, 000091.

220. Thus, Littlejoe used the Butler matrix to "sum" the "signals" arriving on each antenna – reflecting how a Butler matrix works. Littlejoe used the known Butler matrix beamformer for its intended and known purpose of combining multiple different transmissions (of different phases and amplitudes) received simultaneously – just as such Butler matrix beamformers had been known and used since 1960 as I have described herein..

Declaration of Dr. Mark P. Mahon

221. Based on these arguments, a POSITA would understand the intrinsic record such that the scope of elements 1.3-1.7 below encompasses the operation of a Butler matrix beamformer or, at a minimum, is rendered obvious by that operation because that operation is what was cited by the applicant to overcome prior art during prosecution.
222. I have discussed some of the passages from the other IPRs filed against the ‘235 patent elsewhere in this declaration. I have been advised that the interactions during IPRs constitute the intrinsic record that a POSITA should consider.
223. The PO statements during the previous IPRs confirm that the operation of a Butler matrix disclosures, including rendering obvious, the claim elements related to receiving signal transmissions from a remote unit simultaneously.
224. During the previous IPRs, PO has repeatedly argued that the Butler matrix beamformer in Littlejoe disclosed claim elements 1.3 – 1.7.
225. For example, the PO stated to the PTAB that: “Patent Owner respectfully submits that Document C [Littlejoe] discloses each of the challenged claim elements of Challenged Claim 8, as shown in the following table.” EX-1010 at 000012 (IPR2022-00367, “Preliminary Patent Owners Response” (“POPR”)). That table then presented various quotations regarding the operation of the antenna array and the associated Butler matrix components.
226. The PO then further cited to the operation of the Butler matrix. See EX-1010, IPR2022-00367, POPR at 000016-000017 (“The first beamformer, the ‘searcher,’ is

Declaration of Dr. Mark P. Mahon

for receiving only and uses a 16-port Butler matrix whose outputs are connected to 16 standard WLAN cards installed in a PC. An application on the PC obtains the received signal levels for each received packet. The signal level information is used to compute the complex weights for a second RF beamformer....”).

227. The PO then presented detailed arguments that Littlejoe’s “Butler matrix” corresponded to the claim elements reciting reception of signal information. EX-1010 at 000017-000021.

228. PO argued that the Littlejoe document disclosed the aspects of the claims challenged by the prior petitioners (“Petitioner argues that there are ‘two limitations recited in claim 8 that are not supported in Document C.’ Pet. at 15. But **Patent Owner respectfully submits that the two challenged claim elements are clearly disclosed in Document C.**”). EX-1010 at 000017.

229. PO repeatedly argued that the (known) Butler matrix disclosed the claimed receiving actions:

Document C [Littlejoe] describes that the “searcher” receivers **use a “Butler matrix”** with “N = 16 array elements to form N beams.” EX-1009, 137. ... **This design enables the searcher receiver to receive multiple signals simultaneously via the receive beams.**

230. EX-1010 at 000019. Indeed, the POPR spent pages arguing that the known operation of a Butler matrix disclosed the claim elements:

Declaration of Dr. Mark P. Mahon

Petitioner only disputes the portion of this element requiring “simultaneous” receipt of a first and second signal transmission from the same remote station. ... However, these elements are disclosed in Document C [Littlejoe]. As Petitioners note, the “searcher” “comprises a 16-port Butler matrix coupled to 16 different WLAN wireless cards.” *Id.* As will be shown below, Document C describes methods by which multiple signals are received simultaneously. EX-1009, 134 [C-1] (“The first beamformer, the ‘searcher,’ is for receiving only and uses a 16-port Butler matrix”)....

231. EX-1010, 000018.

232. PO reiterated these arguments. EX-1011, 000006-000008 (IPR2022-00365, PO’s sur-reply to the POPR). In particular, PO argued that:

Petitioners dispute Doc. C discloses “simultaneous” reception. But Doc. C discloses a “16-element linear antenna array” ... with “a Butler matrix to support the beamforming function”

Petitioners dispute the Examiner’s understanding that sixteen antenna elements coupled to sixteen “searcher” receivers (i.e., WLAN radios) will receive signals simultaneously. But an ordinary artisan would recognize that each WLAN radio on each **Butler matrix port** will “listen simultaneously,” It would be clear to an

ordinary artisan from Document C alone that Little Joe's sixteen antenna elements with sixteen receivers results in simultaneous reception.

233. EX-1011 at 000007-000008.

234. Again, PO argued that it was the known Butler matrix operation that was “clear to an ordinary artisan.” PO did not argue to the Board that the Littlejoe Butler matrix operated in any different fashion than had been known since 1960 as I have described herein.

235. Thus, the PO's arguments in the IPR2022-00367 proceeding show that the operation of a Butler matrix teaches the disputed elements or, at a very minimum, a POSITA would understand those elements to be obvious over the known use of a Butler matrix.

236. I understand that the specification of the '235 patent also forms part of its intrinsic record.

237. I note that the specification does not expressly teach these receiving elements.

238. The '235 specification includes only one example of creating “weights” for beamforming – the '235 Weight Embodiment. EX-1001, 24:25-27:67, Figs 12-14.

239. As I have identified above, much of the relevant language in the '235 Weight Embodiment is virtually identical to the language in Crilly cited by the Examiner – including substantively the same Figure. But, as detailed above, the Examiner

determined that Crilly did not disclose the “receiving ... simultaneously” elements.

Thus, that language in Crilly would not support the “simultaneously” elements.

240. The ‘235 specification does not ever explicitly discuss two signals being received simultaneously from the same remote unit. At most, the ‘235 patent states:

FIG. 12 illustrates an exemplary implementation 1200 of the multi-beam directed signal system 206 that weighs signals received via antenna array 302. Communication and/or data transfer signals are received from sources 1202 (e.g., sources A and B). The signals received from sources 1202 are considered desired signals because they are from nodes within the wireless routing network. Further, signals such as noise and WLAN interference associated with another external wireless system 1204 are not desired.

241. EX-1001, 24:25-33. This paragraph discusses “signals are received from sources” twice – both in the plural. It does not discuss signals received simultaneously from the same source.

242. I also note that Crilly discloses substantively the same language as above:

Reference is now made to FIG. 4, which illustratively depicts signals received by a wireless routing device 102 from different sources. Here, for example, it is assumed that signals received from sources 160 are desired signals as they are from other nodes within wireless routing network 100 and that signals such as the noise and WLAN

Declaration of Dr. Mark P. Mahon

interference associated with another external wireless system 162, are not desired.

243. EX-1008, ¶0090 (Crilly).

244. Thus, because Crilly has this same discussion of “desired” signals as the ‘235 patent contains and because the Examiner determined that Crilly did not disclose “simultaneously” the intrinsic record would indicate that this passage cannot be said to disclose the “simultaneously” claim aspects.

245. The ‘235 Weight Embodiment then discusses the calculation of “weights.” EX-1001, 24:35-25:30. This does not discuss any receiving “simultaneously” and was present largely in Crilly as I have noted above.

246. After the weights, the ‘235 specification describes using a Butler matrix. EX-1001, 25:31-27:67. As the plain language shows, the ‘235 does not ever in this Butler matrix discussion explicitly describe a “receiver” that receives two signals simultaneously from the same remote unit.

247. Rather, the ‘235 specification uses the already-known operation of a Butler matrix – using language similar to Butler’s 1960 patent discussed in Section V.E.

Exemplary Butler matrix 1300 is a passive device that forms, in conjunction with antenna array 302, communication beams 214 using signal combiners, signal splitters, and/or signal phase shifters. Butler matrix 1300 includes a first side with multiple antenna ports

(designated by “A”) and a second side with multiple transmit and/or receive signal processor ports (designated by “Tx/Rx”).

Although Butler matrix 1300 is so illustrated, the antenna ports and transmit/receive ports need not be distributed on separate, much less opposite, sides of a Butler matrix. Also, although not necessary, Butler matrices typically have an equal number of antenna ports and transmit and/or receive signal processor ports. Furthermore, although Butler matrices are typically of an order that is a power of two (e.g., 2, 4, 8, 16, 32, 64, . . . , $2n$), they may alternatively be implemented with any number of ports.

The sixteen antenna ports of Butler matrix 1300 are identified or otherwise numbered from $A(0, 1, \dots, 15)$. Similarly, the sixteen transmit/receive ports are numbered from $Tx/Rx(0, 1, \dots, 15)$. Antenna ports $A(0-15)$ are coupled to and populated with sixteen antenna elements 400(0), 400(1), . . . , 400(15), respectively. Likewise, transmit/receive ports $Tx/Rx(0-15)$ are coupled to and populated with sixteen signal processors 1302(0), 1302(1), . . . , 1302(15), respectively. These signal processors 1302 are also directly or indirectly coupled to baseband processors 902. It should be noted that one or more active components (e.g., a power amplifier (PA), a low-noise amplifier (LNA), etc.) may also be coupled on the antenna port side of Butler matrix 1300.

Declaration of Dr. Mark P. Mahon

In an exemplary transmission operation, communication signals are provided from baseband processors 902 to the multiple transmit and/or receive signal processors 1302. The multiple signal processors 1302 forward the communication signals to the transmit/receive ports Tx/Rx(0-15) of Butler matrix 1300. After signal processing (e.g., signal combination, signal splitting, signal phase shifting, and the like), Butler matrix 1300 outputs communication signals on the antenna ports A(0-15). Individual antenna elements 400 wirelessly transmit the communication signals, as altered by Butler matrix 1300, from the antenna ports A(0-15) in predetermined communication beam patterns. The communication beam patterns are predetermined by the shape, orientation, constituency, etc. of antenna array 302 and by the Butler matrix 1300 signal processing. In addition to transmissions, wireless signals such as wireless communications 106 (FIG. 1) are received responsive to the communication beams 214 formed by antenna array 302 in conjunction with Butler matrix 1300 in an inverse process.

248. EX-1001, 25:46-26:31. As I noted above, there is not any express statement regarding the simultaneously receiving elements that the PO has repeatedly cited for evidence of distinction over prior art references.

249. Thus, based on this intrinsic record as discussed above, a POSITA would understand that the the only support for the “receiving ... simultaneously” elements in the ‘235 specification, as argued by the applicant and PO, is that “an ordinary artisan” would recognize the “receiving ... simultaneously” elements to be disclosed by the known operation of a Butler matrix – which is consistent with my discussion herein (particularly in light of the OFDM usage in Agee as discussed below). A POSITA would have this knowledge of “an ordinary artisan” that PO applies to the specification and Littlejoe and it would apply to the Butler matrix used in the prior art (Agee) herein as detailed below.

250. This paragraph left intentionally blank.

D. Previous Petitions for Inter Partes Review

251. I understand that other entities (not the present Petitioners) filed Petitions for Inter Partes Review against the ‘235 patent as I have discussed in part above.

252. I am aware of five other different Petitions for IPR filed against claims of the ‘235 patent which I separate into two sets. In the first set, the lead IPR was IPR2022-00367 which asserted that claims 8-14 of the ‘235 Patent were obvious over certain prior art. I understand that 3 other IPRs (IPR2022-01398, IPR2022-01362, and IPR2022-01353) were filed by different Petitioners asserting the same prior art against the same set of claims (8-14) and were joined with IPR2022-00367.

Declaration of Dr. Mark P. Mahon

253. In the second set, IPR2022-01155, the Petition challenged claims 1-7 and 15-16 of the ‘235 patent using a different set of prior art from the art asserted in IPR2022-00367.

254. Neither set of prior IPR Petitions included the prior art or arguments that I discuss herein for invalidity. However, as noted below, my arguments herein reference the arguments made by the PO in some of its filings in those prior IPR proceedings.

255. In IPR2022-00367, PO submitted numerous arguments regarding the scope of the disputed claim terms in its Patent Owner’s Preliminary Response (“POPR”) (EX-1010) and sur-reply to the POPR (EX-1011) as I have discussed elsewhere in my declaration.

256. Primarily, the PO in IPR2022-00367 argued that the prior art (a reference named “Burke”) did not disclose receiving two signals “simultaneously.” For example, the Patent Owner’s Response stated

But Burke’s mobile station uses an antenna with only a single antenna element—not two antenna elements, as required by the challenged claims. Likewise, Burke does not teach or suggest receiving a first / second signal transmission at the first / second antenna elements, respectively. Nor does Burke teach or suggest that the reception occurs simultaneously.

257. Patent Owner's Response, at 2. Patent owner repeated this response throughout its various briefings and at the oral argument. For example, the PO started its arguments by stating:

Each challenged claim of the '235 patent requires "receiving a first signal transmission from a remote station via the first antenna element and a second signal transmission from the remote station via the second antenna element simultaneously" (Limitation [8a]), "determining second signal information for the second signal transmission, wherein the second signal information is different than the first signal information" (Limitation [8d]), and "determining a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the remote station to construct one or more beam-formed transmission signals" (Limitation [8e]). The Petition admits that Burke's mobile station does not perform Limitations [8a], [8d], and [8e]. The Petition provides insufficient evidence that that Burke renders these limitations obvious to a POSITA.

258. Patent Owner's Response at pp. 14-15. The PO's response then focused on these arguments. See Patent Owner's Response at pp. 15-33; Patent Owner's Sur-Reply, at pp. 2-15.

259. The parties submitted various arguments regarding these claim limitations. After all of the various briefing and an oral argument, PO settled with the petitioners and IPR2022-00367 (along with joined IPR2022-01398, IPR2022-01362, and IPR2022-01353) were all dismissed without the Board having ruled on these arguments.¹⁴

260. In IPR2022-01155, the Board declined to institute review. In that IPR, the PO again argued that the asserted prior art did not show the the beam-forming weights were calculated based upon signals from the same remote station.

Each of the challenged claims requires determining a set of weighting values from two different signals received from the same remote station, wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals. See, e.g., '235 Patent, limitations [1c-4], [6c-4], [15c-4]. The Petition fails to identify any teaching in the combined Saunders-Hottinen system (or the combined Saunders-Hottinen-Shull system) that renders this limitation obvious.

261. IPR2022-01155, Patent Owner's Preliminary Response at 7-8. The PO further argued:

¹⁴ IPR2022-01398, IPR2022-01362, IPR-01353 were "me-too" IPRs that were joined with IPR00367 using substantially the same arguments.

Declaration of Dr. Mark P. Mahon

Notably, Petitioners do not identify any disclosure in Saunders that indicates that “x” refers to two different signals from the same remote station. Nor do Petitioners identify any disclosure in Saunders that indicates that “x” refers to two different signals received simultaneously from the same remote station.

262. IPR2022-01155, Patent Owner’s Preliminary Response at 8-9.

263. The Board accepted PO’s arguments that the prior art in IPR2022-01155 did not disclose two simultaneous signal transmissions received from the same remote station. See IPR2022-01155, Institution Decision at 27-32.

264. In addition to not evaluating the prior art discussed herein, in IPR2022-01155, the Board was not presented with, and did not analyze, the following analysis presented herein:

- the known operation of a Butler matrix discloses the “simultaneously” receiving elements;
- PO extensively relied upon the known operation of a Butler matrix during prosecution and in IPR2022-00367 to disclose the “simultaneously” receiving elements;

Declaration of Dr. Mark P. Mahon

- the Butler matrix recited in the ‘235 specification is the only difference over the prior art cited by the Examiner (that has very similar, if not verbatim, content) for all elements except the “simultaneously” receiving elements; and
- that the claim language regarding different “signal informations” includes different “signal strengths” on the different antennas and not just the content of signals as was apparently argued by the Petitioner in IPR2022-01155.
- The discussion of the simultaneous OFDM transmissions and receptions presented below.

265. The technology and discussions regarding “simultaneously” receiving that I present herein were not presented or considering in IPR2022-01155.

VIII. OVERVIEW OF THE PRIOR ART

A. Agee

266. U.S. Patent No.7,248,841 (“Agee”) issued on July 24, 2007 from an application filed June 10, 2001. I have been advised that Agee qualifies as prior art under §102(a) and (e) which is consistent with my understanding of how certain references qualify as “prior art” for purposes of invalidity analyses. Agee was not cited nor applied by the Examiner during prosecution of the challenged patent.

267. Agee teaches a wireless system in which base stations (“BS”) communicate with other BS’s and subscriber units (“SU”) using beam-formed transmissions and

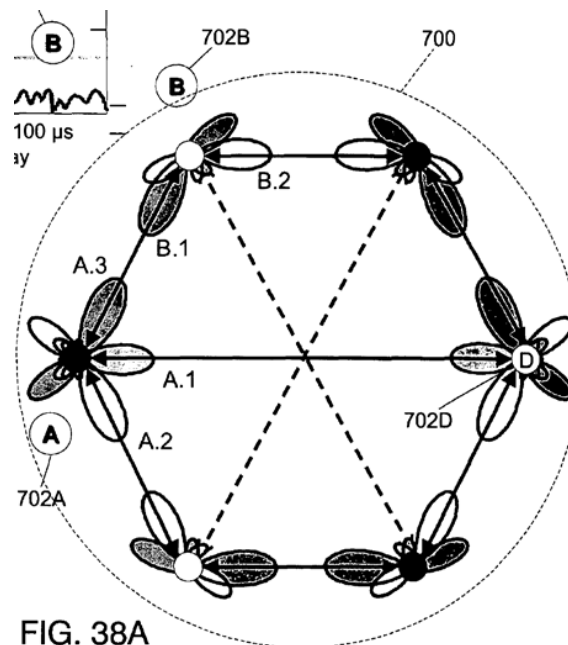
receptions (which I will call “communications” collectively). Agee references these beams-formed using various terms including nulls, peaks, steering, and various references to “beam” and derivatives of that word such as beamformer as well as concepts such as “spatial separation.” E.g., EX-1004, 10:16-11:46, 13:61-14:29, 19:49-20:11, 20:23-22:17, 32:17-27, 33:48-67, 34:19-23, 45:55-47:5, 50:49-51:60, 63:5-64:26, 4:1-5, Figs. 4, 5, 38A. Agee’s claims reflect this usage also. E.g., EX-1004 at claims 3, 4, 5, 40, 58, 68, 72-78, 98, 106, 110, 180.

268. Agee’s beams are formed by calculating weights based upon received information such as known pilot tones. For example, Agee’s Abstract states:

Exploiting the substantive reciprocity of internode channel responses through dynamic, adaptive modification of receive and transmit weights, enables locally enabled global optimization of a multipoint, wireless electromagnetic communications network of communication nodes. Each diversity-channel-capable node uses computationally efficient exploitation of pilot tone data and diversity-adaptive signal processing of the weightings and the signal to further convey optimization and channel information which promote local and thereby network-global efficiency. The preferred embodiment performs complex digital signal manipulation that includes a linear combining and linear distribution of the transmit and receive weights, the generation of piloting signals containing origination and destination node information, as well as interference-avoiding pseudorandom delay timing, and both symbol and multitone encoding, to gain the benefit of

substantive orthogonality at the physical level without requiring actual substantive orthogonality at the physical level.

269. An example of these beam-formed transmissions is depicted Agee in Figure 38A:



270. “FIGS. 38A and 38B illustrate a MIMO network with null-steering and pilot-tone transmissions, with the overall transmission shown as the Extraction SINR, and the mask-fitted transmissions perceived at 702A and 702B which correctly account through the imposed pilot pseudodelay for the intended transmission peaks.” EX-1004, 36:59-64.

271. Agee’s BSs include an antenna array.

Each node of the network incorporates a MIMO transceiver. FIG. 24 displays a functional representation of such, and the hardware and processing is detailed over the next several paragraphs.

Declaration of Dr. Mark P. Mahon

Each MIMO transceiver possesses an antennae array where the antennae are spatially separated and the antennae array itself is preferentially circularly symmetric (FIG. 15, Item **110**). This provides 1-to-M modes (RF feeds) for the signals to be transmitted or received over, maximizes the separability of transmission links, enables a scalable DSP backend, and renders the MIMO transceiver fault-tolerant to LNA failures.

EX-1004, 45:43-54, Fig. 24.

The preferred embodiment uses a substantively null-steering network wherein each node transmits baseband data (complex symbols provided by a multirate codec) through the multiplicity of reciprocal linear matrix operations prior to transmission into the antenna array during transmit operations, and after reception by the antenna array during receive operations, in a manner that physically separates messages intended for separate recipients. This is accomplished by

(1) forming uplink and downlink transmit signals using the matrix formula

$$s_1(k,l;n_1)=G_1(k,l;n_1)d_1(k,l;n_1) \quad \text{EQ. 40}$$

$$s_2(k,l;n_1)=G_2(k,l;n_2)d_2(k,l;n_2)$$

where

$d_1(k,l;n_1)=[d_1(k,l;n_2(1),n_1) \dots d_1(k,l;n_2(N_2),n_1)]^T$ represents the vector of complex data symbols transmitted from node n_1 and intended for each of nodes $\{n_2(q)\}$, respectively, within uplink channel (k,l) ;

$d_2(k,l;n_2)=[d_2(k,l;n_1(1),n_2) \dots d_2(k,l;n_1(N_1),n_2)]^T$ represents the vector of complex data symbols transmitted from node n_2 and intended for each of nodes $\{n_1(q)\}$, respectively, within downlink channel (k,l) ;

$G1(k,l;n1)=[g1(k,l;n2(1),n1) \dots g1(k,l;n2(N2),n1)]$ represents the complex distribution weights used to redundantly distribute symbol vector $d1(k,l;n1)$ onto each diversity channel employed at node $n1$ within uplink channel (k,l) ; and

$G2(k,l;n2)=[g2(k,l;n1(1),n2) \dots g2(k,l;n1(N1),n2)]$ represents the complex distribution weights used to redundantly distribute symbol vector $d2(k,l;n2)$ onto each diversity channel employed at node $n2$ within downlink channel (k,l) ;

(2) reconstructing the data intended for each receive node using the matrix formula

$$\begin{aligned} y1(k,l;n1) &= W H 1(k,l;n1) x 1(k,l;n1) \\ y2(k,l;n2) &= W H 2(k,l;n2) x 2(k,l;n2) \end{aligned} \quad \text{EQ. 41}$$

where $(\cdot)^H$ denotes the conjugate-transpose (Hermitian transpose) operation, and where

$y1(k,l;n1)=[y1(k,l;n2(1),n1) \dots y1(k,l;n2(N2),n1)]^T$ represents the vector of complex data symbols intended for node $n1$ and transmitted from each of nodes $\{n2(q)\}$, respectively, within downlink channel (k,l) ;

$y2(k,l;n2)=[y2(k,l;n1(1),n2) \dots y2(k,l;n1(N1),n2)]^T$ represents the vector of complex data symbols intended for node $n2$ and transmitted from each of nodes $\{n1(p)\}$, respectively, within uplink channel (k,l) ;

$W1(k,l;n1)=[w1(k,l;n2(1),n1) \dots w1(k,l;n2(N2),n1)]$ represents the complex combiner weights used at node $n1$ to recover symbol symbols $\{d1(k,l;n2(q),n1)\}$ intended for node $n1$ and transmitted from nodes $\{n2(q)\}$ within uplink channel (k,l) ; and

$W2(k,l;n2)=[w2(k,l;n1(1),n2) \dots w2(k,l;n1(N),n2)]$ represents the complex combiner weights used at node $n2$ to recover symbol symbols

$\{d_2(k,l;n_1(p),n_2)\}$ intended for node n_2 and transmitted from nodes $\{n_1(p)\}$ within uplink channel (k,l) .

(3) developing combiner weights that $\{w_1(k,l;n_2,n_1)\}$ and $\{w_2(k,l;n_1,n_2)\}$ that substantively null data intended for recipients during the symbol recovery operation, such that for $n_1 \neq n_2$:

$$|w_{H1}(k,l;n_2,n_1)a_1(f_{12}(k),t_{12}(l);n_2,n_1)| \ll |w_{H1}(k,l;n_1,n_1)a_1(f_{12}(k),t_{12}(l);n_1,n_1)| \quad \text{EQ. 42}$$

and

$$|w_{H2}(k,l;n_1,n_2)a_2(f_{21}(k),t_{21}(l);n_1,n_2)| \ll |w_{H2}(k,l;n_2,n_2)a_2(f_{21}(k),t_{21}(l);n_2,n_2)| \quad \text{EQ. 43}$$

(4) developing distribution weights $\{g_1(k,l;n_2,n_1)\}$ and $\{g_2(k,l;n_1,n_2)\}$ that perform equivalent substantive nulling operations during transmit signal formation operations;

(5) scaling distribution weights to optimize network capacity and/or power criteria, as appropriate for the specific node topology and application addressed by the network;

272. EX-1004, 63:4-64:19.

273. Agee's BS includes radios that receive signals on the antennas in the arrays and uses those signals to calculate adaptive "weights" to form a "receive beam."

As stated in the summary, each node preferentially has an antennae array; multiple, multitone, transceivers (one per antenna); and constrains itself to reciprocal uplinks and downlinks (FIGS. 13 A and 13B). The antennae array is spatially and/or polarization diverse and transmits and receives signal energy during alternating time slots (or sequences of time slots in TDD-TDMA systems). Each transceiver

Declaration of Dr. Mark P. Mahon

is a vector OFDM transceiver, with digital signal processing elements, that downconverts, A/D converts, and frequency channelizes data induced on each antenna (or other diversity channel) during receive time slots, and inverse channelizes, D/A converts, and upconverts data intended for each antenna (or diversity channel) during transmit time slots; linearly combines data received over each diversity channel, on each frequency channel and receive time slot; redundantly distributes data intended for each diversity channel, on each frequency channel and transmit time slots; and computes combiner and distributor weights that exploit the, narrowband, MIMO channels response on each frequency channel and time slot (FIG. 15). Although the preferred embodiment of the invention allows individual nodes to vary greatly in their capacities, a set of nodes preferentially will incorporate the hardware capabilities detailed in the following paragraphs.

274. EX-1004, 45:4-28.

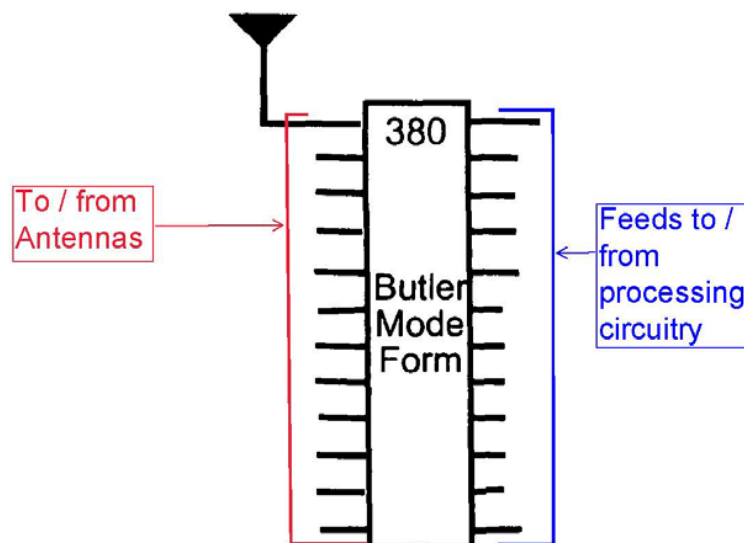
275. Using the principle of reciprocity, Agee's BS then uses the "receive weights" to form "transmit weights."

Exploiting the substantive reciprocity of internode channel responses through dynamic, adaptive modification of receive and transmit weights, enables locally enabled global optimization of a multipoint, wireless electromagnetic communications network of communication nodes. Each diversity-channel-capable node uses computationally efficient exploitation of pilot tone data and diversity-adaptive signal processing of the

weightings and the signal to further convey optimization and channel information which promote local and thereby network-global efficiency. The preferred embodiment performs complex digital signal manipulation that includes a linear combining and linear distribution of the transmit and receive weights, the generation of piloting signals containing origination and destination node information, as well as interference-avoiding pseudorandom delay timing, and both symbol and multitone encoding, to gain the benefit of substantive orthogonality at the physical level without requiring actual substantive orthogonality at the physical level.

276. EX-1004, Abstract.

277. Agee's BS uses a "Butler" matrix to simultaneously receive different signals on the different antennas in the array and output those signals received on the feeds to the BS processing units. Agee references the Butler matrix as the "Butler Mode Form" in Fig. 25:



278. EX-1004, Fig. 25.

279. Agee repeatedly references the Butler matrix:

Each MIMO transceiver possesses an antennae array where the antennae are spatially separated and the antennae array itself is preferentially circularly symmetric (FIG. 15, Item 110). This provides 1-to-M modes (RF feeds) for the signals to be transmitted or received over, maximizes the separability of transmission links, enables a scalable DSP backend, and renders the MIMO transceiver fault-tolerant to LNA failures.

In an alternative embodiment the transceiver sends the transmission signal through Butler Mode Forming circuitry (FIG. 25, Item 380), which includes in a further embodiment a Band Pass Filter (FIG. 25, Item 382) where the transmission is reciprocally formed with the shared Receiver feeds, and the number of modes out equals the numbers of antennae, established as an ordered set with decreasing energy. The Butler Mode Forming circuitry also provides the spatial signal

separation adaptation, preferentially with a FFT-LS algorithm that integrates the link separation operation with the pilot/data sorting, link detection, multilink combination, and equalizer weight calculation operations. This Butler Mode Forming approach means that the transmission forming is readily reciprocal with the receiver feeds (also shared), makes the transmission fault tolerant for PA (Phase-Amplitude) failures, and enables a readily scalable DSP front end; it also enables the transceiver to ratchet the number of antennae used for a particular transmission or reception up or down.

Having passed through the Butler Mode Forming circuitry, the transmission is then sent through the transmission switch (FIG. 15, Item 112), with the uplink frequencies being processed by the LNA bank (FIG. 15, Item 113), moderated by an AGC (FIG. 15, Item 114), and the downlink frequencies being processed by a PA bank (FIG. 15, Item 124). The LNA bank also instantiates the low noise characteristics for the outgoing signal and communicates the characteristics to the PA bank to properly manage the power amplification of the incoming signals to moderate the transmission overlap.

Further transmission switch processing then hands off the transmission to the frequency translator (FIG. 15, Item 115), which is itself governed in part by the Los circuit (FIG. 15, Item 116). The transmission switch throughout is controlled by a controller (FIG. 15, Item 120) such that baseband link distribution of the outgoing signals takes place such that energy is distributed over the multiple RF feeds on each channel, steering up to Kfeed beams and nulls independently on each FDMA channel in order to enhance node and network capacity and coverage.

Declaration of Dr. Mark P. Mahon

This control further greatly reduces the link fade margin and that node's PA requirements.

From the transmission switch the transmission goes to an ADC bank (FIG. 15, Item 117), while a received signal will come from a DAC bank (FIG. 15, Item 123), the complexity of the analog/digital/analog conversion determining the circuit mix within the banks.

Then from the ADC bank the transmission flows through a Multitone Demodulator Bank (FIG. 15, Item 118), which splits it into 1 through K FDMA channels, where K is the number of feeds. The now separated tones (1 through M for each channel) in aggregate forms the entire baseband for the transmission, which combines spatial, polarization, either, or both, feeds across the FDMA channels or even combines up to K FDMA channels as transmission data density requires. This combination enables steering a greater number of beams and nulls than the RF feeds, up to the number of feeds times the number of FDMA channels. It also separates up to [K]feed links per FDMA channel, improves overall transmission link error and/or retransmission rates, improves overall network capacity and coverage, and reduces the link fade margins, reduces the PA cost, and reduces battery consumption at the other ends of the link.

From the Multitone Demodulator Bank the Rx data is passed to circuitry for mapping the received broadband multitone signal into separated, narrowband frequency channels and time slots (FIG. 15, Item 119).

An outgoing transmission signal experiences the reverse of the above process; having been mapped to tones and RF feeds (FIG. 15, Item 121), it passes into a Multitone Modulator bank (FIG. 15, Item 122), an

Declaration of Dr. Mark P. Mahon

DAC bank (FIG. 15 Item 123), the transceiver switch, the Frequency Translator, the transceiver switch, the PA bank element (FIG. 15, Item 124), the transceiver switch, and thence in the preferred embodiment through the Butler Mode Form and on to the RF T/R feeds (FIG. 24, Item 130) and to the antennae array and the particular transmission antennae therein (FIG. 15, Item 125)

The transmission switch throughout is controlled such that baseband link distribution of the outgoing signals takes place such that energy is distributed over the multiple RF feeds on each channel, steering up to Kfeed beams and nulls independently on each FDMA channel in order to enhance node and network capacity and coverage. This control further greatly reduces the link fade margin and that node's PA requirements.

The particular Multitone MOD and DEMOD elements (FIG. 15, Item 118 and 119) in a node vary according to whether it will be handling Fixed, Portable, Low-Mobility, and/or High-Mobility Nodes. Generally, a signal passing into the MT DEMOD may be passed through a comb filter, where a 128-bit sample is run through a 2:1 comb; then passed through an FFT element, preferably with a 1,024 real-IF function; and then mapped to the data using 426 active receive 'bins'. Each bin covers a bandwidth of 5.75 MHz with an inner 4.26 MHz passband, so each of the 426 bins has 10 MHz. The middle frequency, bin 256, will be at 2.56 MHz, leaving a buffer of 745 kHz on either side of the content envelope. Within the transmission, when it passes through the MT MOD, presuming each link is 100 μ s, 12.5 μ s at each end of the transmission is added as a cyclic prefix buffer and cyclic suffix buffer, to allow for timing error. (FIG. 22, Items 314, 3181, 322.)

In an alternative embodiment, presuming that only a cyclic prefix is needed, the system can either double the size of the prefix (FIG. 22, Item 310) or add the suffix to the signal time. The reverse processing as appropriate (i.e. stripping off the cyclic prefix and suffix buffers) is not shown but is well known to the art.

The 426 bins form 13 channels and 426 tones, (FIG. 26, Item 430), with each Channel forming 320 kHz and 32 tons (FIG. 26, Item 432), being further organized with an upper and lower guard tone (FIG. 26, Items 438 and 436, respectively) and 30 information bearing tones (FIG. 26, Item 440). An alternative embodiment for a high-mobility environment halves the numbers of tones and doubles the MHz, so there are only 213 bins (and tones) for 4.26 MHz (FIG. 27, Item 442), and each channel only carries 16 tones (FIG. 27, Item 446), with 1 being an guard tone (FIG. 27, Item 448) and fifteen being information-carrying tones (FIG. 27, Item 450).

For non-fixed embodiments, the timing modifications may be varied. The signal being processed is handed first to a MUX where an element-multiply with a Tx or Rx (for transmit or receive, respectively) window is performed. The guard time is retained to serve as dead time between signals, effectively punctuating them. The high-mobility embodiment halves the number of bins, doubling the average bin size, and uses duplication to increase QoS within the multitone. (FIG. 26.)

The next stage through the MIMO transceiver is the incorporation (on the transmission side) or interpretation (on the reception side) of the QAM/PSK symbols, prior to the signal's passing through the MIMO transceiver exits (if being transmitted) or enters (if being received) through a Link codec. Each FDMA channel will separate through the

codec into 1 through M links, and each Link codec will incorporate tone equalization and ITI remove as necessary. The Link codec also includes SOVA bit recovery, error coding and error detection, and package fragment retransmission methodologies.

An optional alternative embodiment would at this point further include tone/slot interleaving (for the reception) or delevaing (for the transmission). A [further] optional alternative embodiment would replace the TCM codec and SOVA decoder with a Turbo codec.

Another optional alternative will incorporate dual-polarization. (See FIG. 25.) Fundamentally, this halves the modes and complexity of the transmissions and receptions, while doubling the capacity for any particular link/PA power constraint. In this alternative embodiment, the antennae array provides 1-to-(M/2) modes (RF feeds) for downconversion and demodularization. The Butler Mode Forming splits the modes into positive and negative polarities, where the negative polarization has the opposite, and normally orthogonal, polarization to the positive path. Preferentially the Butler Mode Forming works with circular polarizations. This alternative embodiment enables scalable DSP transmission and reception paths and renders the entirety fault tolerant to LNA/PA failures. At the last stage (for transmission; the first stage, for reception) the signal passes through a dual-polarized Link codec. That links the nodes over the dual polarizations, doubles the capacity under any particular link/PA power constraint, greatly reduces the codec complexity (and thus cost), and the link/PA power requirement for any particular link rate constant.

The Transceiver DSP backend for the preferred embodiment is detailed in FIG. 15. The Butler Mode Forming element with its RF transmission

and reception leads, is controlled by the T/R switch control, which in turn is subject to the system clock and synchronization subsystem. An transmission signal (which can be continuous, periodic, triggered, human-determined, reactive, context-sensitive, data quality or quantity sensitive) that forms a Tx link message passes through a symbol encoder bank and into the circuitry where Delay/ITI/pilot gating are imposed, said circuitry being linked to its reciprocal for received signals. The transmission data symbols, over k channels, now pass through the multilink diversity distribution circuitry, where for each channel k transmission gains $G(k)$ are adapted to the proper weighting, as determined by the multilink, LEGO gain adaptation element (with both algorithms and circuitry). From the multilink diversity distribution the transmission next is mapped over diversity modes and FFT bins, then handed to the transmission/reception compensation bank. Here, according to the perceived environment of transmissions and reception and the particular Transmission/Reception compensation algorithm used, the transmission is passed to the inverse frequency channel bank and, finally, into the Butler Mode Forming element. This Transceiver DSP backend also passes the information about the transmission signal from the compensation bank element to the synchronization subsystem

280. EX-1004, 45:47-48:46.

From the Butler Mode Forming element received signals are first passed through the frequency channel bank, then mapped to the FDMA channels. The received data on channel k will be passed through both the Multilink Receive weight adaptation algorithm and the Multilink diversity combining, Receive weights $W(k)$ element, which in turn both

feed into the Multilink LEGO gain adaptation algorithm and thus feed-back into the multilink diversity distribution element for outgoing transmissions. The Multilink Receive weight adaptation algorithm passes the adapted data from channel k over to the Multilink Diversity combining, Receive Weights $W(k)$ element passes on the signal to both the circuits for the Equalization algorithm and the Delay/ITI/pilot-gating removal bank, that strips out the channel-coordinating information and passes the now combined signal to the symbol decoder bank to be turned into the information which had been sent out from the originating transceiver, the inverse process, generally, from the symbol encoding at the transmission end.

281. EX-1004, 57:25-42.

A MIMO transceiver contains and uses simultaneously a multiple of single RF feeds. A signal passes between the Butler Mode Forming element and a Band Pass Filter, or preselection, element, and then between the Band Pass Filter element and the Transceiver switch. If the signal is being transmitted, it goes through a Low Noise Amplifier element and then back into the Transceiver switch; if the signal is being received, it goes through a Phase Amplifier and back into the Transceiver switch. The signal passes between the Transceiver switch and the Frequency translator, and then back into the Transceiver switch.

282. EX-1004, 59:23-33. See also Fig. 25, claims 40, 180.

283. A POSITA would recognize Agee's reference to a "Butler mode form" as implementing the long-known Butler matrix.

284. First, the Butler matrix is pervasively well known having been cited by at least 1600 patents and the use of “Butler” in this context would be recognized by a POSITA as the Butler matrix – particularly in the context of being used with an antenna array. To determine this information, I used Google Patents (patents.google.com) to search for all patents that referenced the term “butler matrix.” I then filtered this data by the date with an earliest date being June 15, 1960 (the date of filing for Butler’s patent as noted below) and a latest date of February 1, 2002 (the earliest priority date that the PO has asserted for the ‘235 challenged claims as discussed herein). This resulted in a URL of [https://patents.google.com/?q=\(%22butler+matrix%22\)&before=priority:20020201&after=priority:19600615&num=100](https://patents.google.com/?q=(%22butler+matrix%22)&before=priority:20020201&after=priority:19600615&num=100).

285. That search resulted in a reported 1697 results. I selected the option to “Deduplicate by Family” in an attempt to remove duplicate family patents such as continuations.

286. I then clicked the “Download” option which downloaded an Excel spreadsheet file.

287. I note that the spreadsheet downloaded shows only 684 entries (not 1697 as reported by the Google patents webpage). I also note that the spreadsheet shows entries from jurisdictions outside the United States such as Japanese, Chinese, and European patents and/or published applications.

288. I sorted the spreadsheet by various columns. For example, I sorted by the “Priority Date” column. In doing these various exemplary sorts, I did notice that there appeared to likely be rows that were the same disclosure because they had the same priority date and other common entries such as Title, Assignee and/or one or more Inventors.

289. Based on this analysis, it appears that there are at least several hundred unique patents / families that use the term “butler matrix.” While I did not review every patent, the titles of the patents were consistent with what a POSITA would expect uses a Butler matrix – generally including RF radio waves including, for example, RF communications as well as radar systems that would benefit from beamforming.

290. I then also filtered these results by “simultaneous” which resulted in a URL of [https://patents.google.com/?q=\(%22butler+matrix%22\)&q=\(%22simultaneous%22\)&before=priority:20020201&after=priority:19600615&num=100](https://patents.google.com/?q=(%22butler+matrix%22)&q=(%22simultaneous%22)&before=priority:20020201&after=priority:19600615&num=100). Google Patents reported about 190 results. E.g., U.S. Pat. No. 6,218,987 (Abstract (“One perceivable possibility of creating several simultaneous narrow beams is using a Butler matrix connected to an antenna array. A Butler matrix is a completely passive and reciprocal circuit comprising an interconnection of a number of hybrid couplers and either fixed phase shifting elements or transmission cables of varying lengths. A Butler matrix for an antenna of N elements, N being an integer number, usually a power of two, has N input ports and N output ports and therefore enables the generation of N narrow

beams. A signal on one of the input ports to the Butler matrix results in signals on the output ports of the matrix of substantially the same amplitude but different phases. Each input port corresponds to a certain combination of phases on the output ports. Each one of these combinations generates a narrow beam from the antenna array. Since the antenna and the Butler matrix are completely reciprocal the system works as well for reception as for transmission.”); U.S. Pat. No. 4,231,040 (1:35-45: “The present invention pertains to an antenna array matrix for simultaneously providing multiple beams including a Butler matrix...” (claim 1: “In a simultaneous multiple beam antenna array matrix including a Butler matrix”); U.S. Pat. No. 5,778,324 (4:23-33: “The first group of elements (and second if of a similar configuration) can be connected to a multiple beam former, such as a Butler matrix, which forms simultaneous multiple beams spanning the sector of interest. By detecting the relative amplitudes in the multiple beams, the angle of arrival of the uplink signal can be deduced, and this information used to derive the necessary phase slope to be applied to the close spaced array elements for the downlink signal. Uplink maximal ratio combining can be performed on the complex beam outputs plus the outlier element(s) output(s).”)); U.S. Pat. No. 4,408,205 (3:59-4:4: “Since the beam-forming network 107 is fully reciprocal, it operates to excite the array 100 to generate a beam in a predetermined direction for each first beam port 107A excited for both transmitting and receiving. Beam forming networks per se provide for discrete multiple excitation

Declaration of Dr. Mark P. Mahon

to form simultaneous plural beams, or conversely to separate receive signal energy into discrete corresponding signals at the first beam-forming network ports 107A in accordance with receiving beam angle. In a general sense, the beam-forming network 107 could be one of several known matrices which generally accomplish the objective. The so-called Butler matrix is capable of providing such a function”); US2005/0164664 (continuation of application filed July 21, 2000) (“[0061] FIG. 7 depicts a multiple beam antenna array 128. In this case signals provided on a plurality of inputs 130, 132, 134 and 136 are coupled to a Butler Matrix beam-forming network 138 to produce a set of simultaneous beams 140, 142, 144 and 146, which emanate from radiating elements 148, 150, 152 and 154”);

291. These are mere samples of the known usage of a Butler matrix – which largely correspond to how Agee uses its Butler circuitry.

292. As a further reason that a POSITA would understand Agee to refer to the known Butler matrix technology, Agee identifies the operations performed by the “Butler Mode Forming” as those operations that would be performed by the known Butler matrix. EX-1004, 45:55-46:50 quoted above, 48:19-46, claims 40, 180. For example, Agee states:

In an alternative embodiment the transceiver sends the transmission signal through Butler Mode Forming circuitry (FIG. 25, Item 380), which includes in a further embodiment a Band Pass Filter (FIG. 25. Item 382) where the **transmission is reciprocally formed with the**

shared Receiver feeds, and the number of modes out equals the numbers of antennae, established as an ordered set with decreasing energy. The Butler Mode Forming circuitry also provides the spatial signal separation adaptation, preferentially with a FFT-LS algorithm that integrates the link separation operation with the pilot/data sorting, link detection, multilink combination, and equalizer weight calculation operations. This Butler Mode Forming approach means that the transmission forming is **readily reciprocal with the receiver feeds (also shared)**, makes the transmission fault tolerant for PA (Phase-Amplitude) failures, and enables a readily scalable DSP front end; it also enables the transceiver to ratchet the number of antennae used for a particular transmission or reception up or down.

293. EX-1004, 45:55-46:6.

294.

295. The “transmission reciprocally formed with the shared Receiver feeds” reflects that Butler matrices form beams for both transmission and reception – which, as explained in the section discussing the Butler patent, is a known feature of the Butler matrix operation (as confirmed by the patents quoted above as well).

296. Agee’s reference to “spatial signal separation,” also reflect the type of beamforming that is known to be performed by Butler matrix. Agee discusses “Spatial Separation of Signals” at 20:22-21:28. That spatial separate involves, in part, the type of beamforming performed by Butler matrix operation. For example, Agee notes:

Spatial Separation of Signals

Spatial filtering techniques (separation of signals based on their observed spatial separation at transceivers) can be used to boost network capacity in a variety of manners. Approaches used in prior art include reuse enhancement, in which fixed (e.g., sectorized antenna arrays) or adaptive (e.g., adaptive array processing) spatial filtering is used to reduce or control interference between centralized transceivers (e.g., BS's) and edge nodes (e.g., SU's) using the frequency or time resource (e.g., time slot or frequency channel) in different cells of cellular PMP networks, thereby reducing the geographical separation between those cells and therefore the frequency reuse factor employed by the network; and space diversity multiple access (SDMA), in which a centralized transceiver uses spatial filtering to establish simultaneous links with multiple edge transceivers operating on the same frequency or time resource in PMP or cellular PMP networks.

The SDMA transmission protocol involves the formation of directed beams of energy, whose radiation patterns do not overlap with each other, to communicate with users at different locations. Adaptive antennae arrays can be driven in phased patterns to simultaneously steer energy in the direction of selected receivers. With such a transmission technique, the other multiplexing schemes can be reused in each of the separately directed beams. For example, in FDMA systems, the same frequency channel can be used to link to two spatially separated nodes, using two different spatially separated beams. Accordingly, if the beams do not overlap each other, different users can be assigned the same frequency channel as long as they can be uniquely identified by a specific beam/channel combination.

The SDMA receive protocol involves the use of multi-element adaptive antennae arrays to direct the receiving sensitivity of the array toward selected transmitting sources. Digital beamforming is used to process the signals received by the adaptive antennae array and to separate interference and noise from genuine signals received from any given direction. **For a receiving station, received RF signals at each antenna element in the array are sampled and digitized. The digital baseband signals then represent the amplitudes and phases of the RF signals received at each antenna element in the array. Digital signal processing (DSP) techniques are then applied to the digital stream from each antenna element in the array.** The process of beamforming involves the application of weight values to the digital signals from each antenna element ('transmit weights'), thereby adjusting the numerical representation of their amplitudes and phases such that, when added together, they form the desired beam—i.e. the desired directional receive sensitivity. The beam thus formed is a digital representation within the computer of the physical RF signals received by the antennae array from any given direction. The process of null steering at the transmitter is used to position the spatial direction of null regions in the pattern of the transmitted RF energy. The process of null steering at the receiver is a DSP technique to control the effective direction of nulls in the receiver's gain or sensitivity. Both processes are intended to minimize inter-beam spatial interference.

297. EX-1004, 20:22-21:15. The bolded passage is exactly how Agee uses its Butler matrix to sample each antenna and then apply DSP techniques to the stream from each antenna in the array and further confirms that Agee is referencing Butler matrix

operation. Agee specifically states that its Butler matrix (Mode Forming) “enables steering ... beams and nulls” which is what “spatial separation” is identified as performing in the passage above. EX-1004, 46:43-45. See also EX-1004, Fig. 38A (showing beams), 36:59-60, 46:65-47:3, 46:21-27, 48:19-46; Fig. 25.

298. Furthermore, Agee teaches that the BS will have “links” to other network nodes. The “link detection” is using the Butler matrix technology to detect the links on particular beams. The “link separation” allows for the beams to create nulls and peaks to separate the transmissions for each link to avoid interference—again, a functionality of the known Butler matrix.

299. Agee’s reference to “Mode Forming” reflects that its component with the Butler matrix is creating beams. The different “modes” as described in Agee reflect “spatial separation” of the different links. That “spatial separation” (as discussed above) is what Butler references as “beams.”

300. Agee’s reference to “1-to-M modes (RF feeds)” is referring to the separate spatial paths (modes) arriving/departing to/from the antenna array.

301. In the passage that Agee states that “the number of modes out equals the numbers of antennae” (as quoted above) is in the context of the Butler Mode Forming circuitry. So Agee’s statement is consistent with the concept that, in a typical butler matrix, circuitry connects each antenna to an input and in an NxN configuration, for M antennas, there are M input feeds, each feed corresponds to a given look direction or

mode (beam) associated with the antenna array. So in the receive direction, the signals arriving from various spatial directions would show up on the various electronic feeds (lines) on the output of the circuitry.

302.

303. The BS uses the “feeds” from the Butler matrix (with the different signal information from different antennas) to adaptively determine “weights” using Agee’s “Multilink Rx Weight Adaptation Algorithm” depicted in Fig. 24:

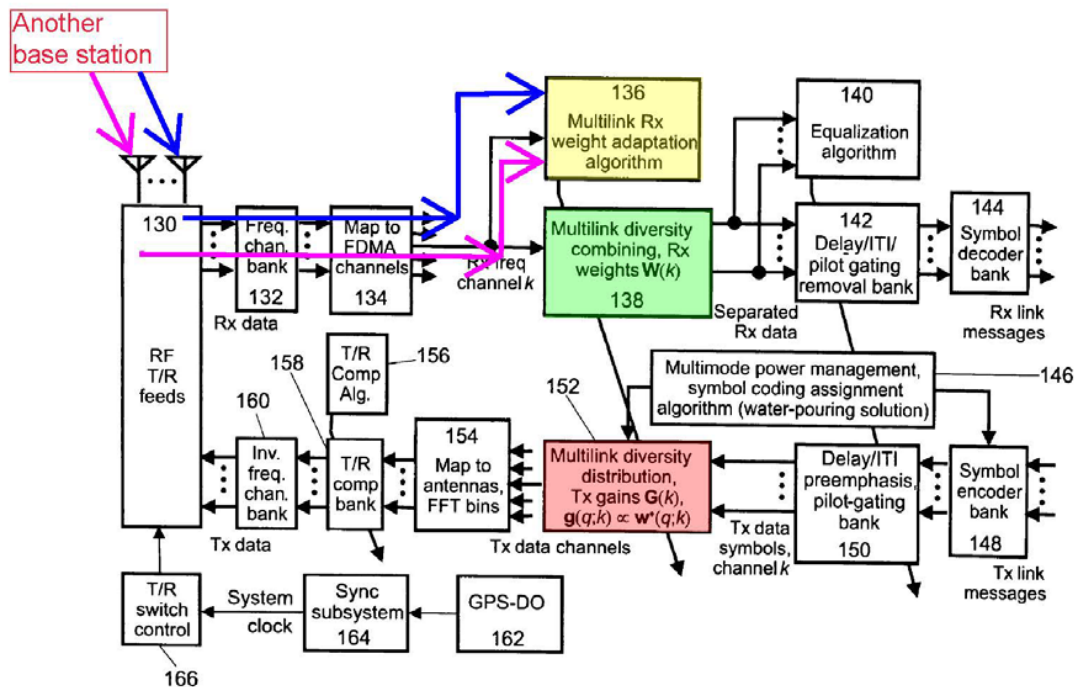


FIG. 24

304. EX-1004, Fig. 24. The “Multilink RX weight adaptation algorithm” adaptively calculates the “receiver weights” for each link:

Declaration of Dr. Mark P. Mahon

In the preferred embodiment, substantively nulling combiner weights are formed using an FFT-based least-squares algorithms that adapt $\{w_1(k,l;n_2,n_1)\}$ and $\{w_2(k,l;n_1,n_2)\}$ to values that minimize the mean-square error (MSE) between the combiner output data and a known segment of transmitted pilot data. Operations used to implement this technique during receive and transmit operations are shown in FIGS. 35 and 36, respectively. The preferred pilot data is applied to an entire OFDM symbol at the start of an adaptation frame comprising a single OFDM symbol containing pilot data followed by a stream of OFDM symbols containing information data. The pilot data transmitted over the pilot symbol is preferably given by

$$\begin{aligned} p_1(k; n_2, n_1) &= d_1(k, 1; n_2, n_1) \\ &= p_{01}(k)p_{21}(k; n_2)p_{11}(k; n_1) \end{aligned} \quad \text{EQ. 44}$$

$$\begin{aligned} p_2(k; n_1, n_2) &= d_2(k, 1; n_1, n_2) \\ &= p_{02}(k)p_{12}(k; n_1)p_{22}(k; n_2) \end{aligned} \quad \text{EQ. 45}$$

where symbol index l is referenced to the start of the adaptation frame, and where

$p_{01}(k)$ is a pseudorandom, constant modulus uplink “network” or “subnet” pilot that is known and used at each node in a network or subnet;

$p_{02}(k)$ is a pseudorandom, constant modulus downlink “network” or “subnet” pilot that known and used at each node in the network;

$p_{21}(k;n_2)$ is a pseudorandom, constant modulus uplink “recipient” pilot that is known and used by every node intending to transmit data to node n_2 during uplink transmission intervals;

$p_{12}(k;n_1)$ is a pseudorandom, constant modulus downlink “recipient” pilot that is known and used by every node intending to transmit data to node n_1 during downlink transmission intervals;

$p_{11}(k;n_1)=\exp\{j2\pi\delta_1(n_1) k\}$ is a sinusoidal uplink “originator” pilot that is used by node n_1 during uplink transmission intervals;

$p_{22}(k;n_2)=\exp\{j2\pi\delta_2(n_2) k\}$ is a sinusoidal downlink “originator” pilot that is used by node n_2 during downlink transmission intervals;

The “pseudodelays” $\delta_1(n_1)$ and $\delta_2(n_2)$ can be unique to each transmit node (in small networks), or provisioned at the beginning of communication with any given recipient node (in which case each will be a function of n_1 and n_2). In either case, the minimum spacing between any pseudodelays used to communicate with a given recipient node should be larger than the maximum expected timing offset observed at that recipient node. This spacing should also be an integer multiple of $1/K$, where K is the number of tones used in a single FFT-based LS algorithm. If K is not large enough to provide a sufficiency of pseudodelays, additional OFDM

symbols can be used for transmission of pilot symbols, either lengthening the effective value of K , or reducing the maximum number of originating nodes transmitting pilot symbols over the same OFDM symbol (for example, the recipient node can direct 4 originators to transmit their pilot symbols over the first OFDM symbol in each adaptation frame, and 4 other originators to transmit their pilot symbols over the next OFDM symbol, allowing the recipient node to construct combiner weights for 8 originators). In the preferred embodiment, K should also be large enough to allow effective combiner weights to be constructed from the pilot symbols alone.

305. EX-1004, 64:43-65:48.

306. The specific calculation of the weights using the FFT-LS algorithm is taught by Agee in Figs. 35-38 and at 65:49-67:55.

307. The adapted “combiner weights” are used to: (a) to receive beam-formed transmissions in the “Multilink Diversity combining 138” block; and (b) transmit beam-formed transmissions as “distribution weights” in block 152 of Figure 24 shown above.

308. Moreover, as detailed below Agee’s system uses OFDM with each tone being a part of the weight calculation (as shown in the quotation above). The OFDM tones reflect different transmissions at different frequencies received separately and simultaneously on the different antennas.

309. Thus, Agee uses a Butler matrix to receive different signal informations on different antennas simultaneously. Agee uses those signal informations to determine weights used to construct beam-formed transmission signals and transmits signals based on those weights – as claimed in the ‘235 patent. Effectively, by using the weights for transmit (and receive), Agee is constructing/adapting beams of beams from the existing beams created by the Butler matrix.

310. As I have noted herein, Agee teaches all the Challenged Claims’ elements– using the same technology relied upon by the ‘235 specification and priority documents.

311. Agee’s claims 40 and 180 recite many of the elements used in the substantive invalidity analysis below. For example, claim 40 is listed below (claim 180 is largely the same).

40. A method for optimizing a wireless electromagnetic communications network, comprising:

organizing a wireless electromagnetic communications network, comprising

a set of nodes, said set further comprising,

at least a first subset of MIMO-capable nodes, each MIMO-capable node comprising:

Declaration of Dr. Mark P. Mahon

a spatially diverse antennae array of M antennae, where $M \geq 2$, said antennae array being polarization diverse, and circularly symmetric, and providing 1-to- M RF feeds;

a transceiver for each antenna in said array, said transceiver further comprising

a Butler Mode Forming element, providing spatial signature separation with a FFT-LS algorithm, reciprocally forming a transmission with shared receiver feeds, such that the number of modes out equals the numbers of antennae, establishing such as an ordered set with decreasing energy, further comprising:

a dual-polarization element for splitting the modes into positive and negative polarities with opposite and orthogonal polarizations, that can work with circular polarizations, and

a dual-polarized link CODEC;

a transmission/reception switch comprising,

a vector OFDM receiver element;

a vector OFDM transmitter element;

a LNA bank for a receive signal, said LNA Bank also instantiating low noise characteristics for a transmit signal;

Declaration of Dr. Mark P. Mahon

a PA bank for the transmit signal that receives the low noise characteristics for said transmit signal from said LNA bank;

an AGC for said LNA bank and PA bank;

a controller element for said transmission/reception switch enabling baseband link distribution of the energy over the multiple RF feeds on each channel to steer up to Kfeed beams and nulls independently on each FDMA channel;

a Frequency Translator;

a timing synchronization element controlling said controller element;

further comprising a system clock, a universal Time signal element;

GPS;

a multimode power management element and algorithm;

and,

a LOs element;

said vector OFDM receiver element comprising

Declaration of Dr. Mark P. Mahon

an ADC bank for downconversion of received RF signals into digital signals;

a MT DEMOD element for multitone demodulation, separating the received signal into distinct tones and splitting them into 1 through Kfeed FDMA channels, said separated tones in aggregate forming the entire baseband for the transmission, said MT DEMOD element further comprising

a Comb element with a multiple of 2 filter capable of operating on a 128-bit sample; and,

an FFT element with a 1,024 real-IF function;

a Mapping element for mapping the demodulated multitone signals into a 426 active receive bins, wherein

each bin covers a bandwidth of 5.75 MHz;

each bin has an inner passband of 4.26 MHz for a content envelope;

each bin has an external buffer, up and down, of 745 kHz;

each bin has 13 channels, CH0 through CH12, each channel having 320 kHz and 32 tones, T0 through T31, each tone being 10 kHz, with the inner 30 tones being used information bearing and T0 and T31 being reserved;

Declaration of Dr. Mark P. Mahon

each signal being $100\ \mu\text{s}$, with $12.5\ \mu\text{s}$ at each end thereof at the front and rear end thereof forming respectively a cyclic prefix and cyclic suffix buffer to punctuate successive signals;

a MUX element for timing modification capable of element-wise multiplication across the signal, which halves the number of bins and tones but repeats the signal for high-quality needs;

a link CODEC, which separates each FDMA channel into 1 through M links, further comprising

a SOVA bit recovery element;

an error coding element;

an error detection element;

an ITI remove element;

a tone equalization element;

and,

a package fragment retransmission element;

a multilink diversity combining element, using a multilink Rx weight adaptation algorithm for Rx signal weights $W(k)$ to adapt transmission gains $G(k)$ for each channel k ,

Declaration of Dr. Mark P. Mahon

an equalization algorithm, taking the signal from said multilink diversity combining element and controlling a delay removal element;

said delay removal element separating signal content from imposed pseudodelay and experienced environmental signal delay, and passing the content-bearing signal to a symbol-decoding element;

said symbol-decoding element for interpretation of the symbols embedded in the signal, further comprising:

an element for delay gating;

a QAM element; and

a PSK element;

said vector OFDM transmitter element comprising:

a DAC bank for conversion of digital signals into RF signals for transmission;

a MT MOD element for multitone modulation, combining and joining the signal to be transmitted from 1 through Kfeed FDMA channels, said separated tones in aggregate forming the entire baseband for the transmission, said MT MOD element further comprising

a Comb element with a multiple of 2 filter capable of operating on a 128-bit sample; and,

Declaration of Dr. Mark P. Mahon

an IFFT element with a 1,024 real-IF function;

a Mapping element for mapping the modulated multitone signals from 426 active transmit bins, wherein

each bin covers a bandwidth of 5.75 MHz;

each bin has an inner passband of 4.26 MHz for a content envelope;

each bin has an external buffer, up and down, of 745 kHz;

each bin has 13 channels, CH0 through CH12, each channel having 320 kHz and 32 tones, T0 through T31, each tone being 10 kHz, with the inner 30 tones being used information bearing and T0 and T31 being reserved;

each signal being 100 μ s, with 12.5 μ s at each end thereof at the front and rear end thereof forming respectively a cyclic prefix and cyclic suffix buffer to punctuate successive signals;

a MUX element for timing modification capable of element-wise multiplication across the signal, which halves the number of bins and tones but repeats the signal for high-quality needs;

a symbol-coding element for embedding the symbols to be interpreted by the receiver in the signal, further comprising:

Declaration of Dr. Mark P. Mahon

an element for delay gating;

a QAM element; and

a PSK element;

a link CODEC, which aggregates each FDMA channel from 1 through M links, further comprising

a SOVA bit recovery element;

an error coding element;

an error detection element;

an ITI remove element;

a tone equalization element;

and,

a package fragment retransmission element;

a multilink diversity distribution element, using a multilink Tx weight adaptation algorithm for Tx signal weights to adapt transmission gains $G(k)$ for each channel k , such that $g(q;k) \propto w^*(q;k)$;

a TCM codec;

a pilot symbol CODEC element that integrates with said FFT-LS algorithm a link separation, a pilot and data signal

elements sorting, a link detection, multilink combination,
and equalizer weight calculation operations;

means for diversity transmission and reception,

and,

means for input and output from and to a non-radio
interface;

linking said set of nodes according to design rules that
create and support a condition of network reciprocity by
meeting the first of the following criteria, and at least two
out of five of the remaining following criteria:

subdividing said set of nodes into two or more proper
subsets of nodes, with a first proper subset being a transmit
uplink/receive downlink subset, and a second proper
subset being a transmit downlink/receive uplink subset;

allowing each node in said set of nodes to simultaneously
belong to only as many transmitting uplink or receiving
uplink subsets as it has diversity capability means;

allowing each node in the transmit uplink/receive
downlink subset to simultaneously link to only as many
nodes with which it will hold time and frequency
coincident communications in its field of view, as it has
diversity capability means;

Declaration of Dr. Mark P. Mahon

allowing each node in the transmit downlink/receive uplink subset to simultaneously link to only as many nodes with which it will hold time and frequency coincident communications in its field of view, as it has diversity capability means;

allowing each member of the transmit uplink/receive downlink subset to engage in simultaneous, time and frequency coincident communications with any other member of that transmit uplink/receive downlink subset only if both that other member also belongs to a different proper subset and the communication is between different proper subsets;

and,

allowing each member of the transmit downlink/receive uplink subset to engage in simultaneous, time and frequency coincident communications with any other member of that transmit downlink/receive uplink subset only if both that other member also belongs to a different proper subset and the communication is between different proper subsets;

transmitting, in said wireless electromagnetic communications network, independent information from each node belonging to a first proper subset, to one or more receiving nodes belonging to a second proper subset that are viewable from the transmitting node;

processing independently, in said wireless electromagnetic communications network, at each receiving node belonging to said second proper subset, information transmitted from one or more nodes belonging to said first proper subset;

and,

designing the network such that substantially reciprocal symmetry exists for the uplink and downlink channels by,

if the received interference is spatially white in both link directions, setting $g_2(q) \propto w_2^*(q)$ and $g_1(q) \propto w_1^*(q)$ at both ends of the link, where $\{g_2(q), w_1(q)\}$ are the linear transmit and receive weights used in the downlink;

but if the received interference is not spatially white in both link directions, constraining $\{g_1(q)\}$ and $\{g_2(q)\}$ to satisfy:

$$\sum_{q=1}^{Q_{21}} g_1^T(q) R_{i_1 i_1}(n_1(q)) g_1^*(q) = \sum_{n=1}^{N_1} \text{Tr}\{R_{i_1 i_1}(n)\} = M_1 R_1$$
$$\sum_{q=1}^{Q_{12}} g_2^T(q) R_{i_2 i_2}(n_2(q)) g_2^*(q) = \sum_{n=1}^{N_2} \text{Tr}\{R_{i_2 i_2}(n)\} = M_2 R_2;$$

Declaration of Dr. Mark P. Mahon

using any standard communications protocol, including
TDD, FDD, simplex,

and,

optimizing the network by dynamically adapting the
diversity capability means between nodes of said
transmitting and receiving subsets.

312. EX-1004, Claim 40. I have highlighted in this claim some of the elements discussed below. For example, this claim shows an antenna array with each element having a radio transceiver that is connected to a Butler matrix for beamforming. It shows that the output of the Butler mode provides a “pilot symbol” which, in conjunction with the FFT algorithm calculates weights to be used for transmission and reception. It shows an OFDM receiver and transmitter that include the usage of the elements for calculating the beam weights. Effectively, this claim alone would show to a POSITA each of the claim elements of the Challenged Claims.

313. Thus, given that Agee teaches

- using the known antenna array technology with multiple antenna elements;
- using the known technology for a transceiver on each antenna array;

Declaration of Dr. Mark P. Mahon

- using the known OFDM technology to transmit / receive simultaneously multiple different OFDM tones at different frequencies;
- using the known Butler matrix technology to perform beam-forming and to separate the signals to identify the links from which signals came;
- using known pilot symbols to compare against received pilot symbols to calculate weights using known FFT-LS algorithms
- applying the weights calculated to create beams both for reception and transmission of data signals...

314. Agee teaches everything that is recited in the Challenged Claims as further detailed below.

315. This paragraph left intentionally blank.

B. Butler

316. U.S. Pat. No. 3,255,450 was filed on June 15, 1960 and issued on June 7, 1966 (“Butler”). I have been advised that Butler is prior art under 102(a), (b), and (e) which is consistent with my understanding of how certain references qualify as “prior art” for purposes of invalidity analyses. Butler was not cited nor applied by the Examiner during prosecution of the challenged patent.

317. As I have noted in my discussion of Agee above, the concept of a Butler matrix as used in the '235 patent, the Littlejoe priority documents and the prior art herein was well-known back to the 1960s. A POSITA would have understood the reference to a Butler beamformer in the context of reception and transmissions (such as radio waves) and would have known the operation based upon this knowledge.

318. Butler's patent provides some of the relevant details (although, by 2002, new technology may have improved on the basic operation with this new technology also known to a POSITA at that time).

319. The Butler matrix and its operation is shown by the Figs. 3 and 4 of Butler's patent (EX-1005). "FIGURE 3 shows a specific system for providing eight directional beams from eight antennas, and FIGURE 4 shows the relative orientation of the eight beam patterns for the circuit of FIGURE 3." EX-1005, 2:11-14.

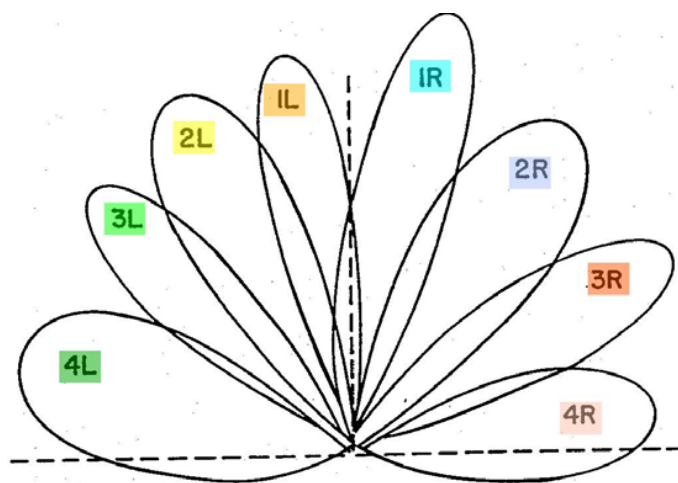


Fig.4

320. EX-1005, Fig. 4.

321. The beam pattern from Figure 4 is created by the specific circuitry chosen to implement the Butler matrix as shown in Figure 3:

The basic building block component in FIGURE 2 of a four port power divider and a fixed phase shifter can be adapted readily to any array of two to the n th power elements where n is an integer, indicating the number of stages to be used. Thus, in FIGURE 3 where eight antennas are to be used and eight directional beams are desired this integer would be three, since $2^3=8$. Here is shown schematically the feed structure for an eight element array with eight independent feed terminals and designed to produce eight patterns which will overlap at the three db points. If halfwave lengths spacing is used between the elements the patterns will cover a 180-degree sector as shown in FIGURE 4. In the first stage the output terminal ports of the power dividers are connected to those antennas $n/2$ apart, where n is the number of antennas to be used.

In FIGURE 3 the antennas a to h are connected to dividers 27 to 30 with each divider connected to corresponding antennas in the left and right sections in the same manner as in FIGURE 2. Following the basic formula of connecting those elements together which are $n/2i$ apart, where n is the number of elements, this

Declaration of Dr. Mark P. Mahon

constitutes the first stage with the input terminals of the dividers connected in the same manner to terminal points of the first stage a1 through h1. A second stage of power dividers 40, 41, 42, and 43 likewise connect to these terminal points since there were four divider elements in the first stage with their input terminals connected at a1 through h1. The power dividers of the second stage, 40 to 43, are connected to these terminals in the same pattern of connecting those elements which are $n/2$ apart. Therefore, divider 40 will be connected to dividers 27 and 29 at points a1, 01, divider 41 will be connected to dividers 28 and 30 through terminals b1, d1, all being connected to the left input ports. Similarly, dividers 42 and 43 will be connected to the right hand input ports of dividers 27 to 30. Divider 42 is thus connected to divider 27 at terminal h1 and to divider 29 at terminal g1. Also, divider 43 is connected to divider 28 at terminal f1 and to divider 30 at terminal h1. Phase shifters 36, 37, 38, and 39 are connected to the outer output ports of dividers 40-43 as shown. Terminals a2 to h2 form the input connections for the power dividers of the second stage.

The third stage power dividers 48, 49, 50, and 51 are connected to these terminals in a similar manner.

However, in connecting the third stage dividers the dividers in the second stage must be considered as separate left and right sections, with dividers 40 and 41 being the

left sections, since they connect to the left ports of the first stage dividers, and dividers 42 and 43 being considered the right section with their ports connected to the right ports of the dividers of the first section. Thus, with 40 and 41 considered as one section and following the formula for connecting those elements $n/2$ apart, divider 48 is connected to both left ports and divider 49 is connected to both right ports of dividers 40 and 41. In the same manner and considering dividers 42 and 43 to comprise one section, divider 50 is connected to the left ports and divider 51 is connected to the right ports of dividers 42 and 43. Connections a3 and h3 form the input connections for energy sources to produce the various beam patterns identified therewith and as shown in FIGURE 3.

322. EX-1005, 3:12-73.

323. As noted in the quote above, various circuitry (dividers, shifters, combiners) connects the two sets of input/outputs. The top ports in Fig. 3 are connected to a set of antennas (“a”-“h”) (“antenna ports”). *E.g.*, EX-1005, 3:28-29 (“In FIGURE 3 the antennas a to h are connected to dividers 27 to 30 with each divider connected to corresponding antennas in the left and right sections in the same manner as in FIGURE 2.”).

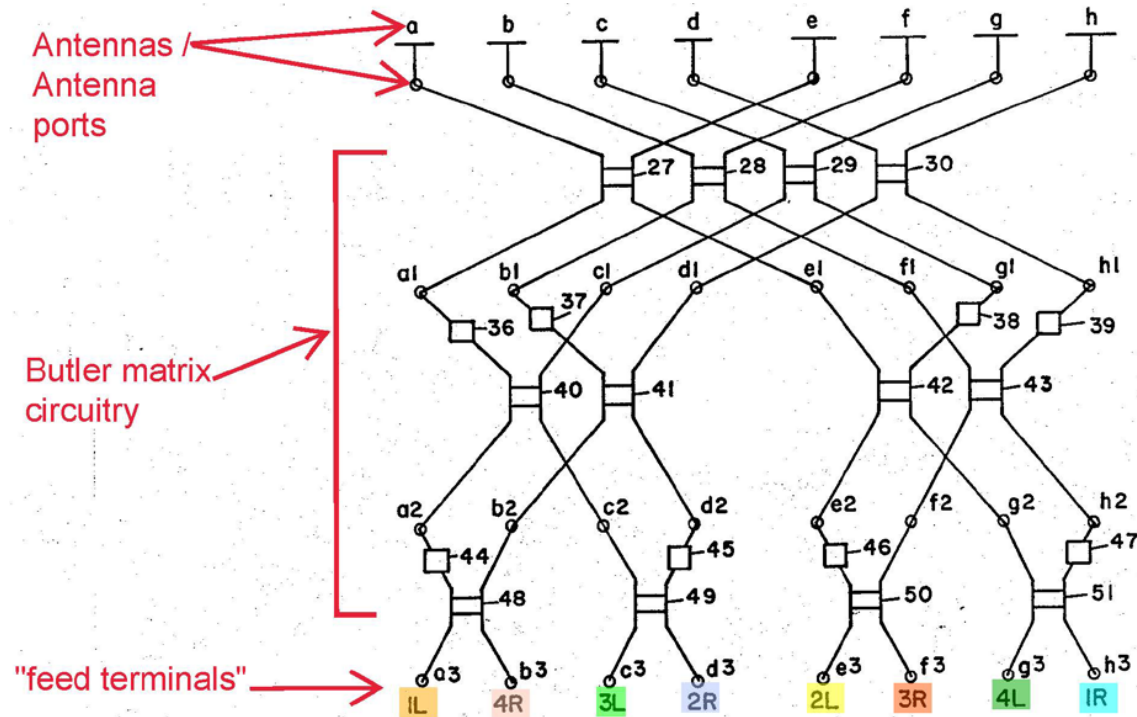


Fig.3

324. At the bottom are “feed terminals” that correspond to the beams (1L, 1R, 2L, 2R, 3L, 3R, 4L, 4R) generated (or received) by the antennas based on the signals of the antennas connected to those “feed terminals” through the circuitry. The feed terminals can be referenced as:

- (a) “combiner” or “receiver” feeds for reception because they output the “combined” signals from the multiple antennas being received and aggregated to form each reception beam; or
- (b) “distributer” or “transmitter” feeds for transmissions because the signals applied to these terminals are distributed to the various antennas to form a transmission beam by the antenna transmissions.

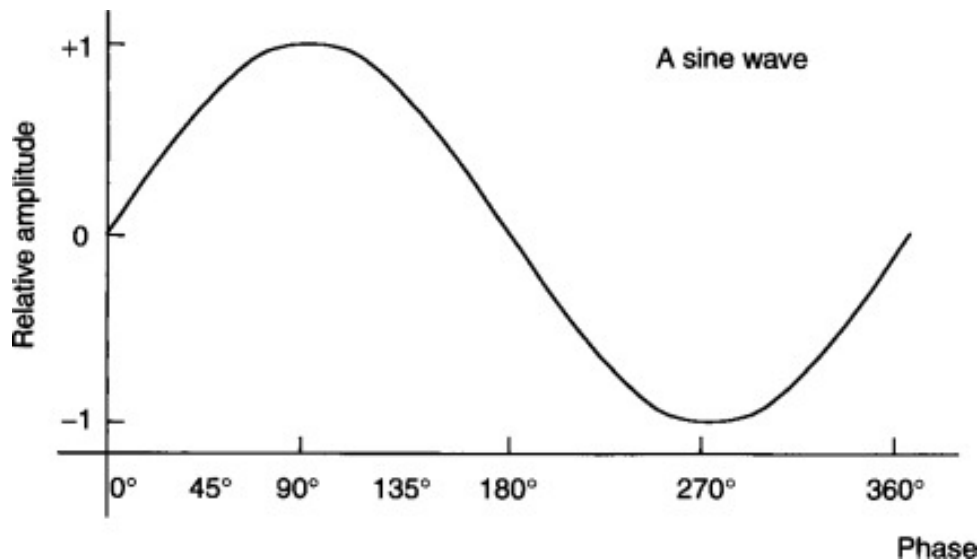
325. *E.g.*, EX-1005, 3:70-73 (“Connections a3 and h3 form the input connections for energy sources to produce the various beam patterns ... in FIGURE 3.”). “Here is shown schematically the feed structure for an eight element array with eight independent feed terminals and designed to produce eight patterns which will overlap at the three db points.” EX-1005, 3:16-22. “It is therefore an object of the present invention to provide for a four port power divider for use with a plurality of antennas for directional beam steering through phasing of feeder signals.” EX-1005, 1:51-54;
326. The circuitry between the antenna ports at the top and the “feeds” at the bottom is configured such that the different collection of signals to / from one or more antennas forms each beam. This circuitry includes dividers (which divide the signals) and phase shifters (which shift the phase of signals). EX-1005, 3:28-73.
327. The beams can be formed for transmission or reception.

The amount of phase shifting of the signals depends upon the desired direction of the beam to be received or transmitted. This system is equally adaptable to reception as well as transmission of signals.

328. EX-1005, 5:16-20.
329. In one Butler embodiment, the same Butler matrix is used both to receive signals using the beams and then re-transmit those same signals back along the original beam. *E.g.* EX-1005, 4:16-37, Fig. 6. This embodiment functions similarly to a transponder

which receives a radio (perhaps radar) signal and transmits back a response along the same direction (beam) from which the original signal was received.

330. The “signal transmissions” are received by the antennas connected to the antenna ports in the form of continuous radio waves, as exemplified in the sine wave below which represents using a single frequency.



331. The relative amplitude of the signal wave is the “signal strength” which, as shown in this diagram, can be represented as going from -1 at the bottom to 1 at the top. Any particular units or scaling can be chosen to represent this range of signal strengths.

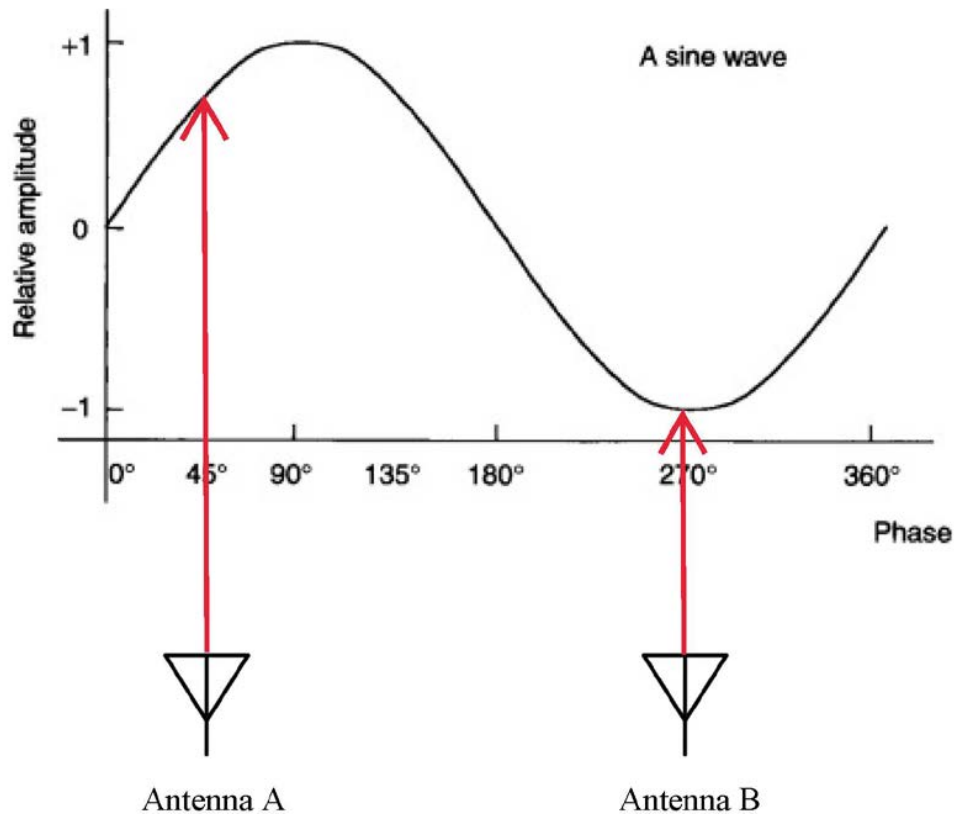
332. The wave’s amplitude (*i.e.*, signal strength) varies depending on the “phase” of the wave; in this example, the amplitude is 0 at a phase angle 0 degrees, and is 1 at phase angle 90 degrees.

333. Similarly, the wavelength determines the amount of distance a single wave will travel (calculated in meters by dividing the propagation speed in meters per second by the frequency in cycles or wavelengths per second resulting in meters per wavelength). Thus, because different wavelengths will result in different phase values at each antenna (assuming the same antennas are sensing the two different signals and excluding spatial aliasing), different frequencies (different wavelengths) will result in different signal strengths at each measuring antenna.
334. While the received signal's amplitude and signal strength vary over time, the signal wave is continuous and is "sampled" by the receiver(s) at particular times known as "sampling instants" or "sampling times"; that is, the continuous waveform is sampled at the antennas at an instant in time whenever the sample is taken rather than the antenna being thought of as limited to sampling the signal at one in time.
335. Furthermore, because the wave is traveling spatially from the transmitter to an antenna, it has a "phase front" (similar to a weather front moving geographically) associated with directionality and which determines the signal's "path." Accordingly, circuitry sampling the signal (wave) at each antenna element of an antenna array at the same time will detect different "amplitudes" (or signal strengths) depending upon the angle of arrival of the signal's phase front with respect to the relative orientation of the antenna elements in the array. In order for the output of an array to have "gain" or "coherent combining" or "stacking" in a particular direction,

Declaration of Dr. Mark P. Mahon

it must account for the phase difference of the wave that is traveling across it at a given instant in time. That is, the array has to adjust each antenna feed based upon the phase difference between it and a particular reference antenna in the array. This causes the phase-adjusted signal to be temporally aligned as if the same phase of the signal was being received at each antenna at the same instant, and in an ideal case, resulting in the output signal being amplified by an amount equal to the number of antenna elements in the array and thus resulting in a stronger signal (i.e. gain in a given beam direction).

336. To illustrate this point, two antenna elements are depicted below and the wave is sampled simultaneously at the two antennas. Because of the physical separation of the antennas, each sample reflects a different “phase” (*i.e.*, at a different location which translates directly into a different phase value for the propagating wave), and the circuitry, which samples the wave received at each antenna, detects and measures a different signal strength (amplitude) for the same received signal.



337. In other words, at a given sampling instance, the wave is in the process of propagating across the antenna array and antenna A detects the signal when it is at phase 45 degrees and detects a signal strength of around 0.7 ($\sin(45^\circ)$). Antenna B is physically located such that (sampling at the same time as Antenna A) it detects the same signal at phase 270 degrees and will measure a received signal strength of -1.0 ($\sin(270^\circ)$). If the array summed those two values, the output of the array would in this case be $\sin(45^\circ) + \sin(270^\circ) = 0.7 + -1.0 = -0.3$ which is much less than the value at antenna A (0.7) without summation. However, if the sample value at antenna B is adjusted by the “phase shift” or “phase difference” between A and B (i.e., 235°),

Declaration of Dr. Mark P. Mahon

the sum would be $\sin(45^\circ) + \sin(270^\circ - 235^\circ) = 0.7 + 0.7 = 1.4$, which is twice as large as the value at antenna A (0.7) without the coherent summation.

338. The Butler matrix purposefully uses these different phases detected simultaneously by the antennas. The Butler matrix has “phase shifters” that account for the physical separation of the antennas (based on a fixed mathematical relationship between phase, frequency and distance for a propagating). These phase shifters (and later combiners) generate the beams:

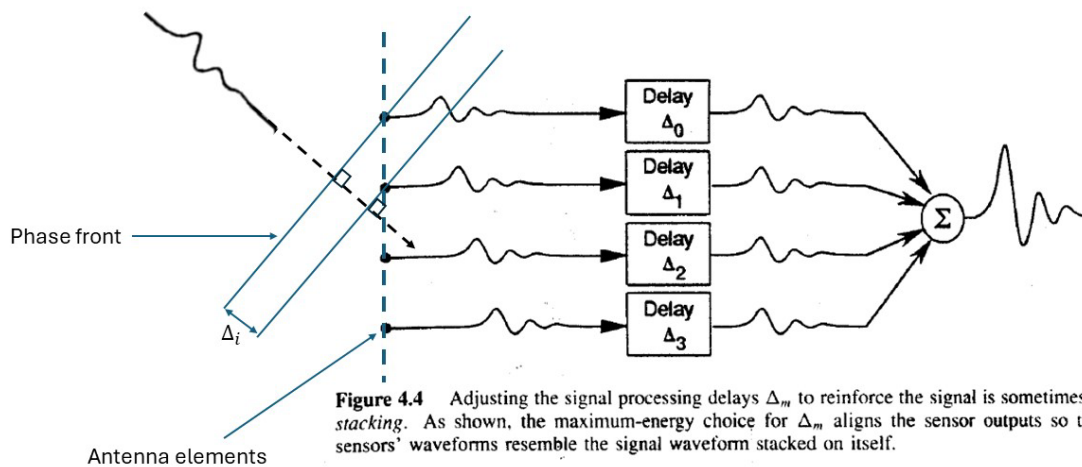
Through suitable wavelength spacing of the antennas from each other and phasing of the signal paths, the directional patterns can be varied as desired. The phase shifters 25 may preferably be an extra length of transmission line to cause signals therethrough to lag those signals going through the parallel paths.

339. EX-1005, 35-37.

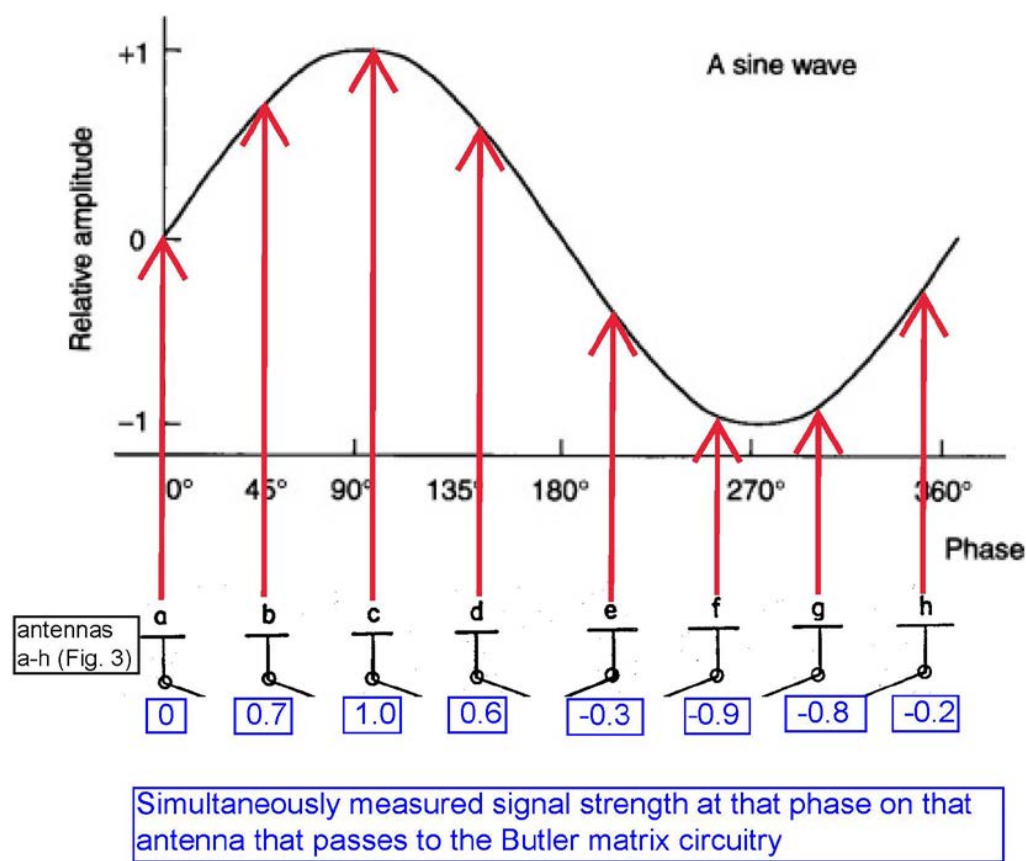
The amount of phase shifting of the signals depends upon the desired direction of the beam to be received or transmitted. This system is equally adaptable to reception as well as transmission of signals.

340. EX-1005, 17-20. This simultaneous sampling and the use of the phase shifters facilitate the purpose of a Butler matrix, which is to measure signals simultaneously on antennas that are physically spaced apart and then “shift” and “combine” (or

divide) the different signals to form the “beams.” This is called “coherent combining”, “coherent gain”, or “stacking”. In doing so, the Butler matrix takes advantage of the signal wave being at different phases when measured simultaneously at the differently located antennas. This concept is depicted in the following annotated diagram, from the book “Array Signal Processing: Concepts and Techniques,” Johnson and Dudgeon, Prentice Hall (1993).



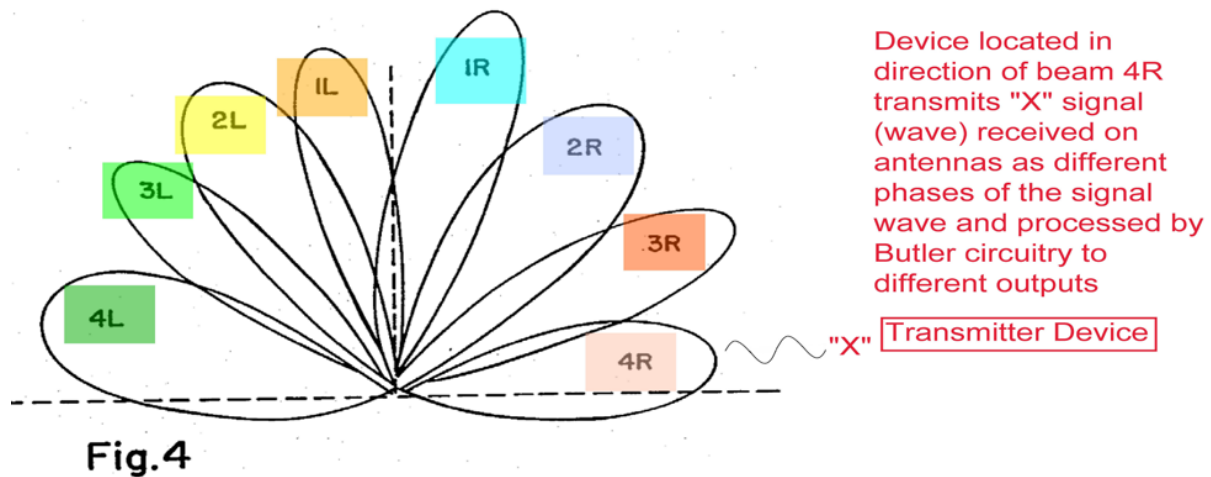
341. The Butler matrix can use this same approach and provide more specific results when more antenna elements receive the signal wave to be sampled. As shown below the signal wave is simultaneously detected on each of the Butler matrix antennas “a” through “h” as shown in Figure 3:



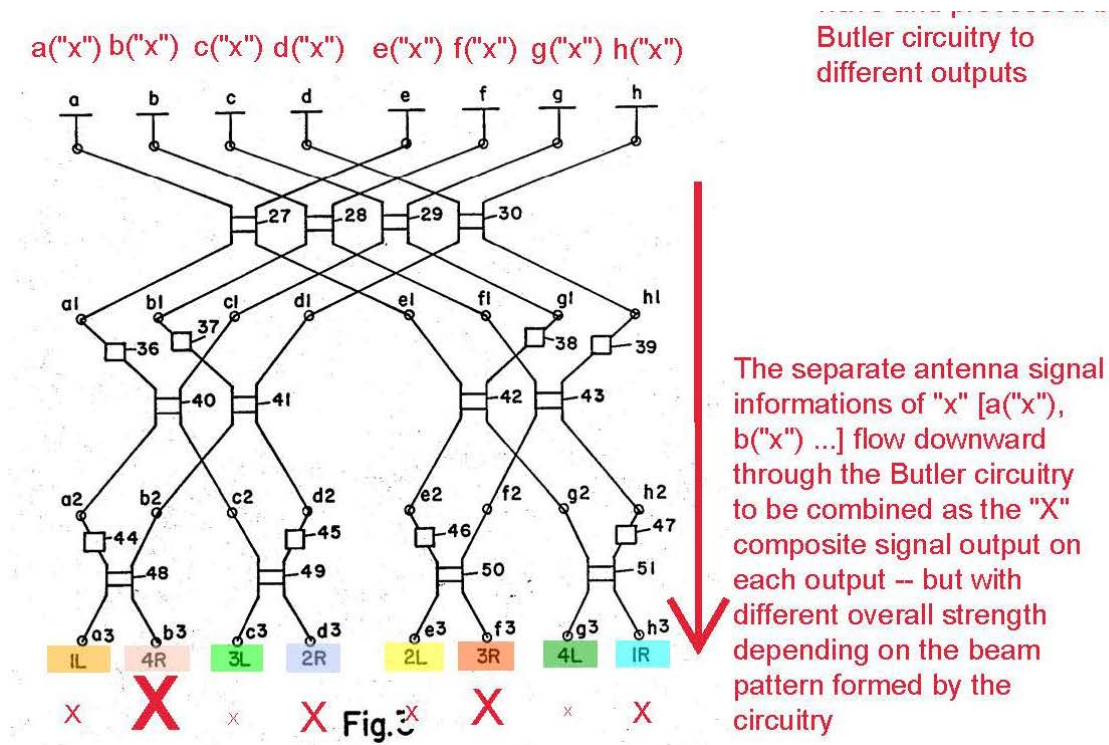
342. Each antenna receives simultaneously its own signal strength (amplitude) which in the example above, is different (from other antennas). These measurements are passed into the circuitry of shifters and dividers / combiners. The phase shifters time align the signals (via a phase shift) from each antenna for a given direction of signal arrival/departure resulting in coherent combining of the received/transmitted signals for that direction and conversely results in non-coherent combining for signals received/transmitted for other directions.
343. The following annotated figures from EX-1005 show how the Butler matrix can be used for beamforming based on its processing of simultaneously received signals.

Declaration of Dr. Mark P. Mahon

In this example, there is a “transmitter device” in the direction of beam 4R that transmits a signal transmission on wave “X.”



344. Each antenna receives that transmission at different phases, which are detected through sampling, each representing different informations associated with signal strengths, which are processed by the Butler matrix circuitry as shown below



345. Because the “transmitter device” is located such that it is in the direction of beam “4R”, the Butler circuitry processing will result in a very strong coherently combined signal being output at the feed terminal associated with “4R” at the bottom. The other feed terminals will output progressively weaker signals as the antennas/antenna ports move away from the transmitter’s location. Thus, beam “4L” will have the smallest reported combined signal strength (possibly 0) because the circuitry has “pointed” that beam away from the transmitter device.

346. Note that, the signal measurements for each antenna [a(x), b(x) ... h(x)] are different (*i.e.*, different portions of the continuous wave) with different signal

Declaration of Dr. Mark P. Mahon

informations (phase and amplitudes) because the propagating wave is being measured at different points.

347. In addition to the phase difference, the signal strengths differ due to different distances from the antenna. Signal strength varies inversely with the square of the distance for free-space path loss. For antennas that are very closely spaced, this signal strength differential would be smaller than if the antennas were spaced further away.

348. The different signals (measured at different phases and amplitudes) are what allows the Butler matrix to “form” the beam or conversely it can be understood that the Butler matrix is accounting for the phase differences from antenna to antenna to “form” a coherent signal at the output associated with the beam direction. The Butler matrix circuitry is taking the signal measurements of multiple antennas and combining those measurements in a manner such that the aggregated measurements are either increased or decreased based on the “direction” of the beam (formed by the circuitry) in comparison to the direction of the transmitter – as reflected in the different phase / amplitude measurements.

349. The point of the Butler matrix is to capture, and use, the different signals being received on different antennas to form an aggregated signal that reflects peaks (and nulls) to form a “beam.” If the signals on each antenna were not adjusted by the Butler matrix, it would be effectively the same as using only a single antenna – which

Declaration of Dr. Mark P. Mahon

would not allow for beamforming through leveraging the information implicitly contained in the different phases and amplitude.

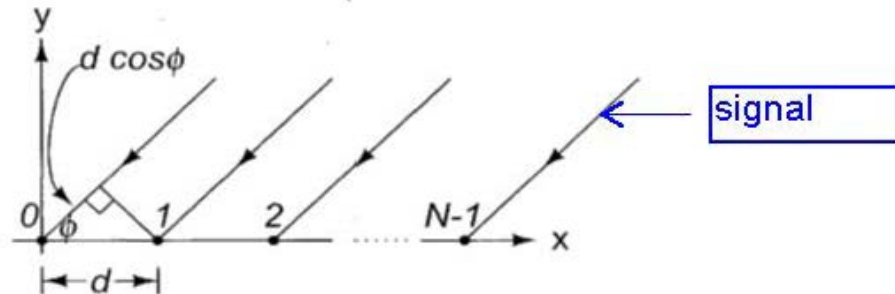
350. The beamforming criteria determined by the Butler matrix circuitry in response to the simultaneous receipt of signal informations then is used to determine the orientation of beams for transmission. As a signal to be transmitted is applied on the feed(s) corresponding to the desired beam(s) (*see* bottom of Butler Fig. 3), the circuitry then divides, shifts and distributes the signal and weights to the antennas used to form desired beam(s).

351. The Littlejoe priority document explains the use of the Butler matrix consistent with the above, but using a different diagram to represent the wave. In Littlejoe's discussion, the transmitter is in the upper right and the signal wave is arriving from the upper right.

Appendix A - Butler Matrix Beamforming

transmitter

Consider a uniformly-spaced linear antenna array with N elements spaced a distance d along the x -axis.



A unit-amplitude signal at a distance ($\gg d$) arriving at an angle ϕ relative to the x axis undergoes a phase shift per element of $\frac{2\pi}{\lambda} d \cos \phi$. The signal at the n 'th element is:

$$v(n) = e^{j(\frac{2\pi}{\lambda} d n \cos \phi)} \quad (1)$$

352. EX-1009, 0134. Littlejoe discloses each antenna element (on the X axis) will detect different phases because the “signal ... undergoes a phase shift” that depends on the distance between the antennas. The circuitry sampling each antenna measures a different phase of the received signals and determines a different signal information (as shown above). Then, the Butler matrix circuitry combines the different antennas’ receptions to form the beams.

353. This paragraph left intentionally blank.

IX. CLAIM CONSTRUCTION

354. 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. THE CHALLENGED CLAIMS OF THE '235 PATENT ARE OBVIOUS OVER AGEE ALONE OR IN COMBINATION WITH BUTLER.

A. The Motivation to Combine Agee With Butler With A Reasonable Expectation of Success.

355. The '235 Patent, Agee and Butler are all directed to wireless communication including wireless base stations that use beamforming techniques to communicate with other wireless stations.

356. I have described the Butler patent above. In my opinion, a POSITA as of the priority date would have known about the Butler matrix technology described in the Butler patent. A POSITA would have known the basic functionality and operation of a Butler matrix without needing to refer to a source reference such as the Butler patent.

357. However, to the extent that Butler is needed as a secondary reference for obviousness for its teachings, a POSITA would have been motivated to combine Butler with Agee. The reasons for such motivation include first that Agee expressly references that Butler matrix technology that Butler disclosed (and invented). Agee references its Butler technology in the context of beamforming using an antenna array – the arrangement that would have been known and familiar to a POSITA as of the priority date of the '235 patent.

Declaration of Dr. Mark P. Mahon

358. Agee discusses, and relies upon the Butler technology for “reciprocal” beamforming for both receive and transmit operations. The Butler patent itself discusses this reciprocal nature of its technology for transmit and receive beamforming.

359. Agee discusses and claims the Butler technology using functionality for which the Butler matrix was known to implement including link identification, spatial separation, and to arrange the different beams in order of energy.

360. Moreover, the Butler matrix had been pervasively well-known to POSITA’s for many years prior to Agee’s 2000 priority dates. This long knowledge, combined with Agee’s express reference, would have motivated a POSITA to combine the long-known functionality in Butler’s patent with Agee’s disclosure.

361. Obviously, there were substantial improvements in electronic circuitry between 1960 (when Butler filed his patent) and 2000 (when Agee filed its priority documents). Thus, the combination uses the functionality of the Butler disclosure and would not necessarily use the exact electrical components identified in Butler’s patents. A POSITA would have known in 2000 how to adapt Butler’s basic functionality to the existing available circuit components at that time to implement that functionality.

362. Finally, a POSITA would have a reasonable expectation of success because Agee is using the Butler technique for its well-known and intended purpose. Agee relies upon the known functionality of reciprocal beamforming.

363.

364. Agee and Butler are directed to the same problems of increasing system performance (including overcoming interferences) at wireless base stations communicating to other wireless devices.

365. Both Agee and Butler offer improvements through the uses of beam transmissions (and receptions). Both Agee and Butler cite the use of techniques such as beamforming to overcome the prior art problems.

366. A POSITA would have known that Butler's techniques correspond to the techniques referenced in Agee – particular techniques related to beamformed transmissions and receptions.

367. This paragraph left intentionally blank.

B. Challenged Claims.

1. Detailed Application of Agee alone or in combination with Butler

a. Claim 1

[1.0] A receiver for use in a wireless communications system, the receiver comprising: an antenna, wherein the antenna comprises a first antenna element and a second antenna element;

Declaration of Dr. Mark P. Mahon

368. Agee, alone or in combination with Butler, discloses¹⁵ these elements as part of Agee's BS's. Agee's BS's all include a MIMO transceiver that include an antenna array comprised of multiple elements that each provide an "RF feed." A "transceiver" includes a "receiver."

369. Agee teaches its transceiver in the context of a wireless network (the claimed wireless communication system) that has different "nodes." The nodes correspond to various wireless devices including "Base Station(s) (BS)" that communicate with other BS's and "Subscriber Units (SU)."

370. The BS and SU are each called "nodes." "FIG. 3 illustrates a more complex PMP network with multiple BS and SU nodes..." EX-1004, 34:15-16. See also EX-1004, 4:3 ("BS or SU nodes..."); 70:34-58 ("BS nodes are equipped with larger antennas... or BS to BS transmissions"); 71:68 ("more at BS than SU nodes...").

The preferred embodiment of the present form of the invention includes a number of interacting and synergistic elements, both in hardware and in operational software. The preferred embodiment, as a network, will incorporate particular functional elements at individual nodes, as well as overall systemic features which may not be shared by or incorporated in the hardware of each particular node

¹⁵ As used throughout this declaration, "discloses" encompasses what a reference would teach, suggest, or render obvious to a POSITA.

(i.e. there may exist specialization amongst the nodes). As stated in the summary, each node preferentially has an antennae array; multiple, multitone, transceivers (one per antenna); and constrains itself to reciprocal uplinks and downlinks (FIGS. 13 A and 13B). The antennae array is spatially and/or polarization diverse and transmits and receives signal energy during alternating time slots (or sequences of time slots in TDD-TDMA systems). Each transceiver is a vector OFDM transceiver, with digital signal processing elements, that downconverts, A/D converts, and frequency channelizes data induced on each antenna (or other diversity channel) during receive time slots, and inverse channelizes, D/A converts, and upconverts data intended for each antenna (or diversity channel) during transmit time slots; linearly combines data received over each diversity channel, on each frequency channel and receive time slot; redundantly distributes data intended for each diversity channel, on each frequency channel and transmit time slots; and computes combiner and distributor weights that exploit the, narrowband, MIMO channels response on each frequency channel and time slot (FIG. 15). Although the preferred embodiment of the invention allows individual nodes to vary greatly in their capacities, a set of nodes preferentially will incorporate the hardware capabilities detailed in the following paragraphs.

The first preference is that the transmission element be a multi-tone front end, using OFDM with cyclic prefixes at fixed terminals (generally, BS) (FIG. 22, Items 314, 318, 322,) and generalized multitone with guard-time gaps (FIG. 22, Item 310) at mobile terminals (generally, SU). To minimize aperture blur, the system uses tone grouping into narrowband frequency channels (FIG. 22, Item 348). The OFDM can be readily implemented in hardware using Fixed-Fourier Transform enabling chips; it also simplified the equalization procedure, eliminated decision feedback, and provides a synergistic blend with adaptive arrays. An alternative uses frequency-channelized PSK/QAM with modulation-on-symbol CDMA (that is, synchronous CDMA).

Each node of the network incorporates a MIMO transceiver. FIG. 24 displays a functional representation of such, and the hardware and processing is detailed over the next several paragraphs.

Each MIMO transceiver possesses an antennae array where the antennae are spatially separated and the antennae array itself is preferentially circularly symmetric (FIG. 15, Item 110). This provides 1-to-M modes (RF feeds) for the signals to be transmitted or received over, maximizes the separability of transmission links, enables a scalable DSP backend, and renders the MIMO transceiver fault-tolerant to LNA failures.....

371. EX-1004, 44:64-45:54.

372. As noted above, each antenna in the antenna array has its own radio transceiver which is capable of sending/receiving multiple OFDM tones simultaneously (as discussed below) “on each frequency channel and receive time slot.”

373. Agee’s Figures (including Fig. 15 cited above) show the antenna arrays (elements 110, 125) with individual antenna elements that are discussed in the passages above. For example, Figure 15 (referenced in the quote above) shows the following diagram in which multiple transmissions (on each “frq chn” or frequency channel (corresponding to the individual OFDM tones)) are sent/received simultaneously between nodes during each TDD “time slot.”

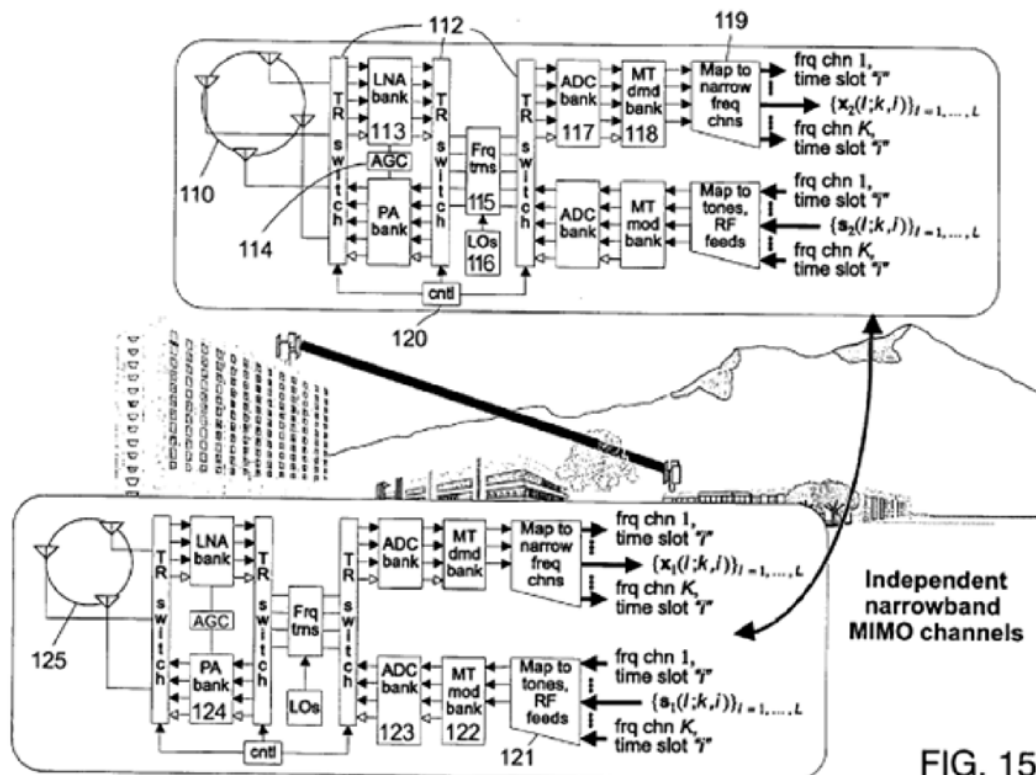


FIG. 15

374. EX-1004, Fig. 15. As discussed in Agee's specification:

FIG. 15 illustrates more details of the MIMO-capable node, including on the receiving side: **receiving spatially and/or polarization diverse antennae in a multiple antennae array (Item 110), a vector OFDM transceiver switch (Item 112)**, a LNA bank (Item 113), an AGC (Item 114), a Frequency translator (Item 115), a LOs ((Item 116), an ADC bank (Item 117), a MultiTone Demodulator Bank (Item 118), means for mapping received data over each diversity channel, **on each frequency channel and receive time slot** (Item 119), and a transceiver controller (Item 120); and including on the transmitting side means for mapping transmitted data for each frequency channel and transmit time slot (Item 121), a MultiTone Modulator bank (Item 122), a DAC bank (Item 123), the transceiver switch, a PA bank (Item 124), and transmitting spatially and/or polarization diverse antennae in a multiple antennae array (Item 125) which may be distinct from those used in receiving (Item 110).

375. EX-1004, 35:10-26. See also 45:45-47:9 (describing Figure 15).

376. Fig. 24 shows a BS block diagram from a functional level with the various functional blocks and their connections. Many of these blocks (such as blocks 136, 138, and 152) are discussed below in the context of calculating weights and then using those weights for transmission and reception:

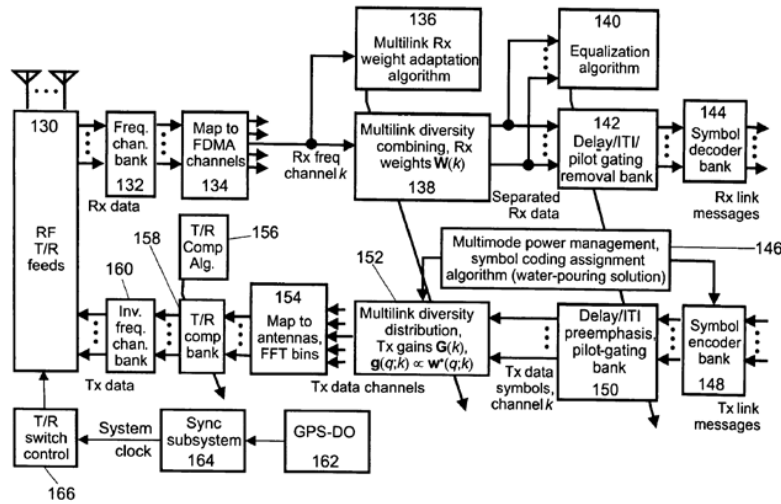


FIG. 24

377. EX-1004, Fig. 24.

FIG. 24 illustrates one embodiment of the MIMO transceiver, with the RF feeds (Item 130), the Frequency channel bank (Item 132), the mapping element (Item 134), the Multilink Rx weight adaptation algorithm (Item 136), the Multilink diversity Rx weights combining element (Item 138), the equalization algorithm (Item 140) and Delay/ITI/pilot gating removal bank (Item 142), symbol decoder bank (Item 144), multimode power management, symbol coding assignment algorithm element (Item 146), the synchronization elements (Items 162, 164), and T/R comp. Algorithm (Item 156) and element (Item 158), and multilink diversity distribution of Tx Gains element (Item 152).

378. EX-1004, 36:6-17.

379. Agee's other Figures show similar arrangements of antennas. *See* EX-1004, Figs. 16-18, 20, 25, 31.

380. For example, regarding the antenna elements, Agee teaches that the "1-to-M modes (RF feeds) for the signals to be transmitted or received" (EX-1004, 45:50-52) are received (as shown above) from the Butler matrix to a "Multilink Weight Adaptation Algorithm" that calculates receive / transmit weights. EX-1004, 45:47-47:9. This is discussed in further detail below. For elements 1.4 through 1.7.

381. I also note Agee's claims recite multiple antennas in each antenna array with a transceiver for each antenna. For example, Agee's BS has "a spatially diverse antennae array of M antennae, where $M \geq \text{one [two]}$ " and "a transceiver for each antenna." EX-1004, claims 1, 2, 40, 98, 105, 110, 180.

382. Thus, Agee discloses this element.

[1.1] a transceiver operatively coupled to the antenna and configured to transmit and receive electromagnetic signals using the antenna;

383. Agee discloses this "transceiver" in two fashions. First, Agee's "MIMO transceiver" includes each functional block in Fig. 24 that "illustrates one embodiment of the MIMO transceiver...." EX-1004, 36:6-8.

Each node of the network incorporates a MIMO transceiver. FIG. 24 displays a functional representation of such, and the hardware and processing is detailed over the next several paragraphs.

384. EX-1004, 45:43-46 (see also 45:47-47:9 comprising the “next several paragraphs” discussing Fig. 24 and its functional blocks).

385. Agee’s “A MIMO transceiver contains and uses simultaneously a multiple of single RF feeds. A signal passes between the Butler Mode Forming element and a Band Pass Filter, or preselection, element, and then between the Band Pass Filter element and the Transceiver switch.....” EX-1004, 59:23-29 (describing Fig. 25).

386. Second, as part of its overall “MIMO transceiver,” each of the antenna elements has its own vector OFDM transceiver. E.g., EX-1004, claims 40, 180. Agee teaches:

As stated in the summary, **each node preferentially has an antennae array; multiple, multitone, transceivers (one per antenna)**; and constrains itself to reciprocal uplinks and downlinks (FIGS. 13 A and 13B). The antennae array is spatially and/or polarization diverse and transmits and receives signal energy during alternating time slots (or sequences of time slots in TDD-TDMA systems). **Each transceiver is a vector OFDM transceiver**, with digital signal processing elements, that downconverts, A/D converts, and **frequency channelizes data induced on each antenna (or other diversity channel) during receive time slots, and inverse channelizes**, D/A converts, and upconverts data intended for each antenna (or diversity channel) during transmit time slots; linearly combines data received over each diversity channel, on each frequency channel and receive

time slot; redundantly distributes data intended for each diversity channel, on each frequency channel and transmit time slots; and computes combiner and distributor weights that exploit the, narrowband, MIMO channels response on each frequency channel and time slot (FIG. 15). Although the preferred embodiment of the invention allows individual nodes to vary greatly in their capacities, a set of nodes preferentially will incorporate the hardware capabilities detailed in the following paragraphs.

387. EX-1004, 44:64-45:28.

388. Thus, the “MIMO transceiver” and the individual radio transceivers (acting collectively) meet the requirements for this element.

389. As noted in element 1.0, Agee’s independent claims recite antenna arrays with multiple antennas with a radio transceiver for each antenna. *E.g.*, EX-1004, claims 40, 180.

390. I discuss in the elements below that Agee teaches using beams for receiving and transmitting signals between the nodes (e.g., BS to BS). Fig. 38A shows a graphic example of the beamformed signals being transmitted / received among nodes (BS).

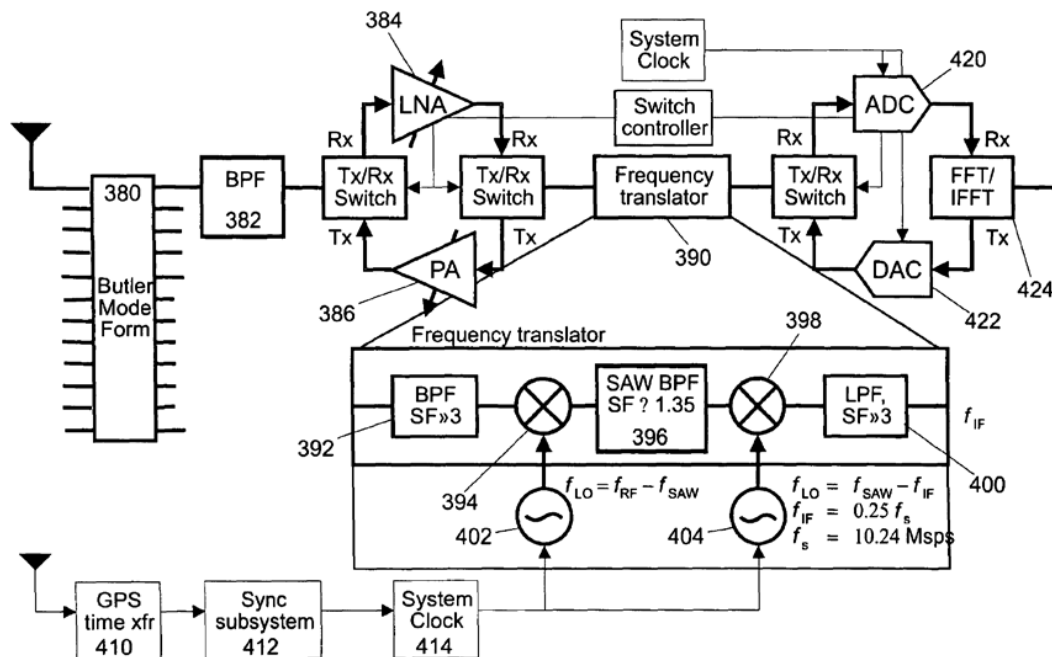


FIG. 25

395. EX-1004, Fig. 25. “FIG.25 illustrates in more detail the frequency translator, detailing the Band Pass Filters, element wise multiplier, sinusoids, SAW BPF, and LPF elements.” EX-1004, 36:18-20. This components form, in part, the transceiver.
396. A POSITA would understand the circuitry to the right of element 380 (starting with element 382, which is an optional component (45:57-58)) would be replicated for each Butler matrix 380 output. The lines leading to the right depict that the components that perform some of the frequency processing for the tones. EX-1004, 59:34-60:39.
397. See also EX-1004 Figs. 16-18, 24, 31 (all of which show the operatio of various aspects of the transceiver).

398. Thus, Agee discloses the claimed “transceiver” in both the individual antenna’s transceivers (alone or collectively) and the overall “MIMO transceiver” that encompasses each of those individual radio transceivers.

[1.2] a processor operatively coupled to the transceiver, the processor configured to:

399. Agee discloses the element.

400. The “processor” in this element performs the functions in elements 1.3 to 1.7 below of receiving signals, calculating weights and using the weights for a transmission and reception of information.

401. As an initial matter, I note what the ‘235 describes that appears to correspond to this “processor” element. The only embodiment in the ‘235 patent that discusses the calculation of weights used for beamforming appears at 24:25-27:67 of the ‘235 patent, including Figs. 12-15 referenced therein. The weight calculations are described in the following paragraphs:

These signals, both desired and undesired, are received via antenna array 302 and are provided to the signal control and coordination logic 304 (shown in FIG. 3) from the receiver/transmitters (Rx/Tx) 824(0), 824(1), . . . , 824(N) (also shown in FIG. 8B). In this example, the signal control and coordination logic 304 includes the scanning receiver 822 that is configured to update routing information 1206 with regard to the received signals. For

example, scanning receiver 822 may identify information about different classes of interferers (e.g., known and unknown types) within the routing information 1206. In this example, routing information 1206 includes connection indexed routing table(s) based on identification information, such as address information, CID, and the like. The routing table includes identifiers of the desired sources and other identifiers for the interferers (“Int”). Further, the routing table includes stored **weighting** values (w) each associated with a particular signal source 1202 (e.g., sources A and B). Other information such as “keep out” identifiers may also be included in this exemplary routing table.

A description of the received signal(s) can be stored in the routing table in the form of the pattern or **weighting of the signal(s)**. In this example, a polynomial expansion in z, $w(z)=w_0+w_1z+w_2z^2+w_3z^3+w_4z^4+\dots+w_iz^i$ can be utilized to establish the values of the weights (w_i) to be **applied to a weight vector**. The routing table(s) may store such weighing patterns as a function of θ , or the zeroes of the polynomial, for example. One advantage of zero storage is that the zeros represent directions for communication that should be nulled out to prevent self-interference or interfering with other nodes or possibly other known wireless communication systems, such as WLAN 1204 that is not part of the wireless routing

network, but is operating within at least a portion of a potential coverage area 1208 and frequency bands.

The polynomial expansion in z , $w(z)$, and the zeroes may be calculated from each other and each may be stored. Updates can be generated frequently (e.g., in certain implementations, about every millisecond), and a zero storage system may be more advantageous in most wireless network environments because only a few values will change at a given time. Storing the weighting values will in general require changes to all of the weighting values $w(i)$ when any change in the pattern occurs. Note that $w(i)$ and $A(\theta)$ may be expressed as Fourier transform pairs (discrete due to the finite antenna element space). The $w(i)$ is equivalent to a time domain impulse response (e.g., a time domain unit sample response) and the $A(\theta)$ is equivalent to the frequency response (e.g., an evaluation of $w(z)$ sampled along a unit circle).

The stored weighting values associated with each connection, data signal, and/or source are utilized in a weighting matrix 1210 which operates to apply the latest weighting values to the received signals and also to transmitted signals. In this illustrative example, subsequently received signals will be processed using the most recent weighting values in the weighting matrix 1210. Thus, as described herein, the multi-beam directed signal system 206 is configured to control the transmission

amplitude frequency band and directionality of data packets to other nodes and assist in reducing the effects associated with received noise and interference (e.g., self interference and/or external interference). This is accomplished with the signal control and coordination logic 304 within the multi-beam directed signal system 206.

402. EX-1001, 24:34-25:30. Notably, this passage above describing the “weight” determination is described functionally without any express statement that this functionality (weight determination) is performed by a “processor.” The closest is that the passage states that “subsequently received signals will be processed using the most recent weighting values in the weighting matrix” but this is a usage of the weights, not a determination.

403. The ‘235 Patent does continue onward to describe its embodiment with a Butler matrix and various processors, but never expressly associates the functionality with any particular processor.

FIG. 13 illustrates an exemplary multi-beam directed signal system 206 that includes an antenna array 302 and a Butler matrix 1300 implemented as a beam-forming network (e.g., transmit beam-forming network 808 and/or receive beam-forming network 810 shown in FIGS. 8A and 8B). The multi-beam directed signal system 206 also includes multiple signal processors (SPs) 1302 and one or

more baseband processors (e.g., baseband units 902 described with reference to FIGS. 9 and 10). Baseband processors 902 accept communication signals from and provide communication signals to the multiple receiver/transmitters 824 (FIG. 8B). A separate baseband processor 902 may be assigned to each signal processor 1302, or a single baseband processor 902 may be assigned to any number of the multiple signal processors 1302.

Exemplary Butler matrix 1300 is a passive device that forms, in conjunction with antenna array 302, communication beams 214 using signal combiners, signal splitters, and/or signal phase shifters. Butler matrix 1300 includes a first side with multiple antenna ports (designated by “A”) and a second side with multiple transmit and/or receive signal processor ports (designated by “Tx/Rx”). The number of antenna ports and transmit/receive ports indicate the order of the Butler matrix 1300, which in this example, includes sixteen antenna ports and sixteen transmit/receive ports. Thus, Butler matrix 1300 has an order of sixteen.

Although Butler matrix 1300 is so illustrated, the antenna ports and transmit/receive ports need not be distributed on separate, much less opposite, sides of a Butler matrix. Also, although not necessary, Butler matrices typically have an equal number of antenna ports and transmit and/or receive signal processor ports. Furthermore, although

Declaration of Dr. Mark P. Mahon

Butler matrices are typically of an order that is a power of two (e.g., 2, 4, 8, 16, 32, 64, . . . , $2n$), they may alternatively be implemented with any number of ports.

404. EX-1001, 25:31-65.

405. Agee describes its same operations in comparable functional terms used by the '235 patent. Notably, in the '235 patent, none of the weight calculations above are expressly identified with any particular processor (or even a processor at all).

406. Agee BS uses a “processor” for the functions recited in the claim elements. As detailed below, elements 1.3 to 1.7 are (in part) performed by Agee’s “Multilink weight adaptation algorithm” which is also referenced by Agee as the “Multilink RX weight adaptation algorithm,” the “Multilink Receive weight adaption algorithm” or the “Multilink Adaptation Algorithm.” As I have noted below, the other algorithms (the “Multilink diversity combining” and “Multilink diversity distributing” as shown in Figure 25) perform the functions related to using the weights for receiving and transmitting beamformed signals.

407. Agee teaches that the incoming, and outgoing, transmissions are processed by algorithms running on a “processor” that also generally controls the BS operations and the signal processing algorithms (including the Multilink Weight Adaptation Algorithm, the “Multilink diversity combining” and “Multilink diversity distributing” algorithms).

408. Agee describes a processor: (1) receiving a “pilot signal;” (2) using the Multilink weight adaptation algorithm to calculate weights based on that pilot signal; and (3) using those weights in the “Multilink diversity combining” algorithm to receive data (using receive beamforming):

When a communication is transmitted, it will be received; and the MIMO reception is, like the transmission, adaptive. See FIG. 30, detailing the logical processing involved. Received data passes through both a Multilink weight adaptation algorithm and (to which that part is combined) a Multilink diversity combining of the Reception weights. **The functional and firmware processing (fixed logic hardware, limited purpose firmware, or combined software, processors and circuitry).**

409. EX-1004, 58:43-61.

410. Agee continues forward to describe (at a high-level) the “Multilink weight adaptation algorithm” (detailed in element 1.6).

The **received symbol $[x](i,1)$** , comprising a matrix combination of L Link and M multitone elements, is first modified by the pilot tone generator that sends the recipient node, network, and group modifications for an element-wise reverse multiplication, to strip off that component of the signal and identify if the received

symbol is from any originating source trying to send to this particular recipient. If the recipient pilot signal matches, then the signal passed on to a circuit that separates the pilot signal elements from the data signal elements. The pilot signal elements are passed through a link detection circuit that preferentially uses a FFT-LS algorithm to produce link quality statistics for that particular received transmission, identifies the **weighting elements that were contained in the pilot signal** and passes those over to the multilink combination circuit

411. EX-1004, 58:60-59:15. Thus, this paragraph links a processor to the algorithms that receive data, calculate weights and use those weights as claimed in the ‘235 patent.

412. A POSITA would understand Agee’s disclosure to include (and at a minimum, render obvious) that the described algorithms would be implemented on a processor. This is, in many ways, similar to the concept that the ‘235 patent’s disclosure would render obvious that its described functions were implemented using a processor.

413. Furthermore, Agee describes its processing performed by a “DSP” (“digital signal processor” or “digital signal processing”) which discloses the claimed processor. EX-1004, 35:1-5 (“nodes with multiple antennae, multitone transceivers with DSP capability); 45:53-54; 48:19-45; 19:66-20:15. The DSP receives and processes the Butler matrix outputs from the antennas. EX-1004, 45:55-46:6; 48:4-12.

414. Agee's DSP calculation is analogous to the "signal processor" that is referenced throughout the specification of the '235 patent. E.g., EX-1001, 26:1-6 ("The sixteen antenna ports of Butler matrix 1300 are identified or otherwise numbered from A(0, 1, . . . , 15). Similarly, the sixteen transmit/receive ports are numbered from Tx/Rx(0, 1, . . . , 15). Antenna ports A(0-15) are coupled to and populated with sixteen antenna elements 400(0), 400(1), . . . , 400(15), respectively. Likewise, transmit/receive ports Tx/Rx(0-15) are coupled to and populated with sixteen signal processors 1302(0), 1302(1), . . . , 1302(15), respectively.").

415. Agee's claims reflect this the algorithms discussed above (and for the elements below) are performed by a DSP at each node. E.g., EX-1004, claim 40 at 87:38-40, 86:58, 86:33-34, 86:19-20. *See also* EX-1004, claim 180, 106:29-110:34. Agee's other claims recite elements such as the "diversity capability means" (associated with a "processor" as noted above) and "dynamically adapting the diversity capability means." E.g., EX-1004, claims 1-7, 12, 20-21, 25-32.

416. Moreover, Agee's "algorithms" are implemented in "software." EX-1004, 44:64-66; 29:14-15; 33:33-35; 40:52-54; 74:11-17; 4:63-64.

417. At a minimum, it would have been obvious to a POSITA to implement the recited functions (including the Multilink Weight Adaptation Algorithm, the "Multilink diversity combining" and "Multilink diversity distributing" algorithms) in a "processor." It is merely an obvious design choice to implement those algorithms in

Declaration of Dr. Mark P. Mahon

either special-purpose hardware or in a “processor” executing software. A POSITA would understand that there may be benefits and detriments to using a processor vs. a special purpose logic. A POSITA would also understand how to implement the algorithms using either software on a processor or special purpose hardware. Such conversions (and tradeoffs between implementations) are the type of decisions that POSITA’s make in developing functioning systems.

418. A POSITA would have recognized that processor implementations provided benefits. It is quicker and easier to adjust the algorithm if implemented in software operating on a processor. For example, a designer would be able to adapt the algorithm or make a change / correction more easily in software than could be done if hardware circuitry were used to implement the algorithm.

419. The algorithm and system can be more adaptable to new technology such as new coding techniques or standards. For example, if the system was designed to be able to process different channel coding standards, swapping such implementations is more readily accomplished in software. Agee specifically identifies this type of tradeoff:

The preferred embodiment incorporates into each node a multitone QAM decoder, with a soft-optimized, Viterbi algorithm (SOVA) embodied in the decoder, such that the network can effect changes in the decoder at its nodes by a software or information transmission that re-sets the

hardware (EEPROM, FPGA, PAL, or other semiconductor chip) and software at that node for the new decoding scheme. An alternative embodiment with lesser cost and complexity at each node, but lesser flexibility, is to use hard-optimized, Viterbi or Reed-Solomon, decoders at each node in the network. A third alternative is to combine both SOVA and HOVA decoders in the network and establish hierarchies wherein the more flexible stations moderate as needed to communicate with their less flexible but simple contacts.

420. EX-1004, 74:11-24.

421. “Processors” are available off-the-shelf. A wide variety of known (and already developed and tested) processors are available to purchase and use in a system. The designer would not need to fabricate new hardware circuitry. Thus, the implementation and testing of such a system would not require as lengthy of a time as special-purpose hardware would require.

422. Thus, Agee discloses (including rendering obvious) that the claimed actions occur on a processor – particularly in light of the lack of any express disclosure in the ‘235 patent associating the calculation of a weight specifically with a processor (unless in Agee).

[1.3] receive a first signal transmission from a remote station via the first antenna element and a second signal transmission from the remote station via the second antenna element simultaneously;

423. Agee discloses the element.¹⁶

424. Claim 1 recites a “first signal transmission” and “a second signal transmission.”

I noted initially that claim 1 recites that the “receive... simultaneously” is an action performed by the “processor” (not necessarily the antennas). Claim 1 recites:

1. A receiver for use in a wireless communications system, the receiver comprising:

an antenna, wherein the antenna comprises a first antenna element and a second antenna element;

a transceiver operatively coupled to the antenna and configured to transmit and receive electromagnetic signals using the antenna; and

a processor operatively coupled to the transceiver, the processor configured to:

receive a first signal transmission from a remote station via the first antenna element and a second signal transmission from the remote station via the second antenna element simultaneously;

determine first signal information for the first signal transmission;

¹⁶

Declaration of Dr. Mark P. Mahon

determine second signal information for the second signal transmission, wherein the second signal information is different than the first signal information;

determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals;

cause the transceiver to transmit a third signal to the remote station via the antenna, the third signal comprising content based on the set of weighting values.

425. The adverb “simultaneously” modifies the verb “receive” performed by the processor.

426. I also note that Claim 8 does not recite the “receiving” to be done at a “processor” but also does not expressly recite that the signals be “receiv[ed]” by the antennas simultaneously.

427. Regardless of the “simultaneously” meaning, Agee shows that the signals are received both simultaneously by multiple antenna elements and simultaneously by other components (such as the processor) used in processing the signals as discussed below.

428. As detailed below, the signals are “received” simultaneously on the antennas because, for example, the antennas on the Butler matrix sample the signals at the

same time – including, for example, each of the OFDM tones (frequencies) used in the OFDM transmission discussed below. The signals are “received” simultaneously by the processor because the data from the antennas (out of the Butler matrix) is being input into the Multilink Weight Adaptation Algorithm as digitized data a single data set (which it needs to be able to calculate the weights properly).

429. I also note that claim does not expressly recite that the two “signal transmissions” must be “different.”

430. As detailed below, Agee (and Butler as necessary) discloses the “signal transmissions” whether they are required to be different or not.

(a) **Agee’s Butler Matrix Teaches Simultaneously Receiving Signal Transmissions In The Same Way As PO Argued That The ‘235 Patent And Priority Document Teach It.**

431. As I have noted elsewhere herein, PO repeatedly asserted that the use of a Butler matrix satisfies this “simultaneously” claim element. But to repeat for context:

... an ordinary artisan would recognize that each WLAN radio on each **Butler matrix port** will “listen simultaneously,” It would be clear to an ordinary artisan from Document C [Littlejoe] alone that Little Joe’s sixteen antenna elements with sixteen receivers results in simultaneous reception.

432. EX-1011 at 000007-000008.

433. Agee discloses an analogous arrangement of a Butler matrix with multiple antenna elements with “receivers in simultaneous reception” of multiple signals that have arrived on each antenna. Figure 25 of Agee discloses the Butler Mode Form as element 380 which is connected to the antennas in the antenna arrays:

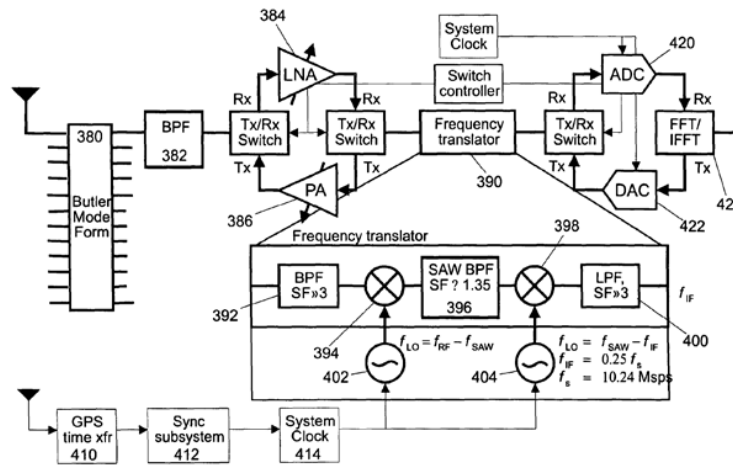


FIG. 25

434. EX-1004, Fig. 25.

435. Agee explains Figure 25 as:

Each node of the network incorporates a MIMO transceiver. FIG. 24 displays a functional representation of such, and the hardware and processing is detailed over the next several paragraphs.

Each MIMO transceiver possesses an antennae array where the antennae are spatially separated and the antennae array itself is preferentially circularly symmetric (FIG. 15, Item 110). This provides 1-to-M modes (RF

feeds) for the signals to be transmitted or received over, maximizes the separability of transmission links, enables a scalable DSP backend, and renders the MIMO transceiver fault-tolerant to LNA failures.

In an alternative embodiment the transceiver sends the transmission signal through Butler Mode Forming circuitry (FIG. 25, Item 380), which includes in a further embodiment a Band Pass Filter (FIG. 25, Item 382) where the transmission is reciprocally formed with the shared Receiver feeds, and the number of modes out equals the numbers of antennae, established as an ordered set with decreasing energy. The Butler Mode Forming circuitry also provides the spatial signal separation adaptation, preferentially with a FFT-LS algorithm that integrates the link separation operation with the pilot/data sorting, link detection, multilink combination, and equalizer weight calculation operations. This Butler Mode Forming approach means that the transmission forming is readily reciprocal with the receiver feeds (also shared), makes the transmission fault tolerant for PA (Phase-Amplitude) failures, and enables a readily scalable DSP front end; it also enables the transceiver to ratchet the number of antennae used for a particular transmission or reception up or down.

Having passed through the Butler Mode Forming circuitry, the transmission is then sent through the

Declaration of Dr. Mark P. Mahon

transmission switch (FIG. 15, Item 112), with the uplink frequencies being processed by the LNA bank (FIG. 15, Item 113), moderated by an AGC (FIG. 15, Item 114), and the downlink frequencies being processed by a PA bank (FIG. 15, Item 124). The LNA bank also instantiates the low noise characteristics for the outgoing signal and communicates the characteristics to the PA bank to properly manage the power amplification of the incoming signals to moderate the transmission overlap.

436. EX-1004, 45:43-46:16.

437. As I have noted above, the “spatial signal adaptation” performed by the Butler matrix is the formation of beams. The Butler matrix spatially separates the signals to reflect “beams.” This allows for “link separation” and “link detection” (identifying the node that transmitted a particular stream of data)

438. The “transmission forming is readily reciprocal with the receiver feeds (also shared)” discussion confirms that the same beams are used for transmission and reception.

439. Agee’s Butler matrix provides the antenna signals (combined) such as the antenna strengths as measured at each antenna for a particular frequency which is the input data for the “FFT-LS” algorithm – the basis of the Multilink Weight Adaptation Algorithm.

440. The Multilink Weight Adaptation Algorithm calculates (determines) the weights for each tone (frequency) for each link (to a particular other node such as a BS or SU).

441. The calculations for the weight determination are extensively described in Agee.

442. Agee notes that the beamforming is used to separate the signals (link separation):

The preferred embodiment uses a substantively null-steering network wherein each node transmits baseband data (complex symbols provided by a multirate codec) through the multiplicity of reciprocal linear matrix operations prior to transmission into the antenna array during transmit operations, and after reception by the antenna array during receive operations, in a manner that physically separates messages intended for separate recipients. This is accomplished by

(1) forming uplink and downlink transmit signals using the matrix formula

$$s_1(k,l;n_1)=G_1(k,l;n_1)d_1(k,l;n_1) \quad \text{EQ. 40}$$

$$s_2(k,l;n_1)=G_2(k,l;n_2)d_2(k,l;n_2)$$

where

$$d_1(k,l;n_1)=[d_1(k,l;n_2(1),n_1) \ . \ . \ . \ d_1(k,l;n_2(N_2),n_1)]^T$$

d_1 represents the vector of complex data symbols transmitted

from node n_1 and intended for each of nodes $\{n_2(q)\}$, respectively, within uplink channel (k,l) ;

$d_2(k,l;n_2)=[d_2(k,l;n_1(1),n_2) \ . \ . \ . \ d_2(k,l;n_1(N_1),n_2)]^T$
represents the vector of complex data symbols transmitted from node n_2 and intended for each of nodes $\{n_1(q)\}$, respectively, within downlink channel (k,l) ;

$G_1(k,l;n_1)=[g_1(k,l;n_2(1),n_1) \ . \ . \ . \ g_1(k,l;n_2(N_2),n_1)]$
represents the complex distribution weights used to redundantly distribute symbol vector $d_1(k,l;n_1)$ onto each diversity channel employed at node n_1 within uplink channel (k,l) ; and

$G_2(k,l;n_2)=[g_2(k,l;n_1(1), n_2) \ . \ . \ . \ g_2(k,l;n_1(N_1),n_2)]$
represents the complex distribution weights used to redundantly distribute symbol vector $d_2(k,l;n_2)$ onto each diversity channel employed at node n_2 within downlink channel (k,l) ;

(2) reconstructing the data intended for each receive node using the matrix formula

$$\begin{aligned} y_1(k,l;n_1) &= W_1^H(k,l;n_1)x_1(k,l;n_1) \\ y_2(k,l;n_2) &= W_2^H(k,l;n_2)x_2(k,l;n_2) \end{aligned} \quad \text{EQ. 41}$$

where $(\)^H$ denotes the conjugate-transpose (Hermitian transpose) operation, and where

Declaration of Dr. Mark P. Mahon

$$y1(k,l;n1)=[y1(k,l;n2(1),n1) \ . \ . \ . \ y1(k,l;n2(N2),n1)]^T$$

represents the vector of complex data symbols intended for node $n1$ and transmitted from each of nodes $\{n2(q)\}$, respectively, within downlink channel (k,l) ;

$$y2(k,l;n2)=[y2(k,l;n1(1),n2) \ . \ . \ . \ y2(k,l;n1(N1),n2)]^T$$

represents the vector of complex data symbols intended for node $n2$ and transmitted from each of nodes $\{n1(p)\}$, respectively, within uplink channel (k,l) ;

$$W1(k,l;n1)=[w1(k,l;n2(1),n1) \ . \ . \ . \ w1(k,l;n2(N2),n1)]$$

represents the complex combiner weights used at node $n1$ to recover symbol symbols $\{d1(k,l;n2(q), n1)\}$ intended for node $n1$ and transmitted from nodes $\{n2 (q)\}$ within uplink channel (k,l) ; and

$$W2(k,l;n2)=[w2(k,l;n1(1),n2) \ . \ . \ . \ w2(k,l;n1(N),n2)]$$

represents the complex combiner weights used at node $n2$ to recover symbol symbols $\{d2(k,l;n1(p),n2)\}$ intended for node $n2$ and transmitted from nodes $\{n1(p)\}$ within uplink channel (k,l) .

(3) developing combiner weights that $\{w1(k,l;n2,n1)\}$ and $\{w2(k,l;n1,n2)\}$ that substantively null data intended for recipients during the symbol recovery operation, such that for $n1 \neq n2$:

$$|w^H_1(k,l;n_2,n_1)a_1(f_{12}(k),t_{12}(l);n_2,n_1)| \ll$$

$$|w^H_1(k,l;n_1,n_1)a_1(f_{12}(k),t_{12}(l);n_1,n_1)| \quad \text{EQ. 42}$$

and

$$|w^H_2(k,l;n_1,n_2)a_2(f_{21}(k),t_{21}(l);n_1,n_2)| \ll$$

$$|w^H_2(k,l;n_2,n_2)a_2(f_{21}(k),t_{21}(l);n_2,n_2)| \quad \text{EQ. 43}$$

(4) developing distribution weights $\{g_1(k,l;n_2,n_1)\}$ and $\{g_2(k,l;n_1, n_2)\}$ that perform equivalent substantive nulling operations during transmit signal formation operations;

(5) scaling distribution weights to optimize network capacity and/or power criteria, as appropriate for the specific node topology and application addressed by the network;

(6) removing residual timing and carrier offset remaining after recovery of the intended network data symbols; and

(7) encoding data onto symbol vectors based on the end-to-end SINR obtainable between each transmit and intended recipient node, and decoding that data after symbol recovery operations, using channel coding and decoding methods develop in prior art.

443. EX-1004, 63:4-64:27. The “combiner weights ... that substantively null data...” form receive beams. The distribution weight for transmit beams.

444. Agee teaches that each OFDM tone is used to build the weights and the weights are applied on each OFDM tone:

In the preferred embodiment, OFDM modulation formats is used to instantiate the invention, and substantively similar distribution and combining weights are computed and applied over as broad a range of tones (frequency channels k) and OFDM symbols (time slots l) as is practical. The range of practical use is determined by the frequency selectivity (delay spread) and time selectivity (Doppler spread) of the communications channel, which determines the degree of invariance of the channel response vectors a_1 and a_2 on (k,l) ; the dynamics of interference i_1 and i_2 ; latency requirements of the communications network; and dimensionality of linear combiners used at each node in the network, which determine the number of frequency-time channels needed to determine reliable substantively null-steering distribution and combining weights.

445. EX-1004, 64:28-42.

446. The FFT algorithm, using the pilot signals, is used to calculate the weights to form the beams. 64:43-67:55, Figs. 35-38.

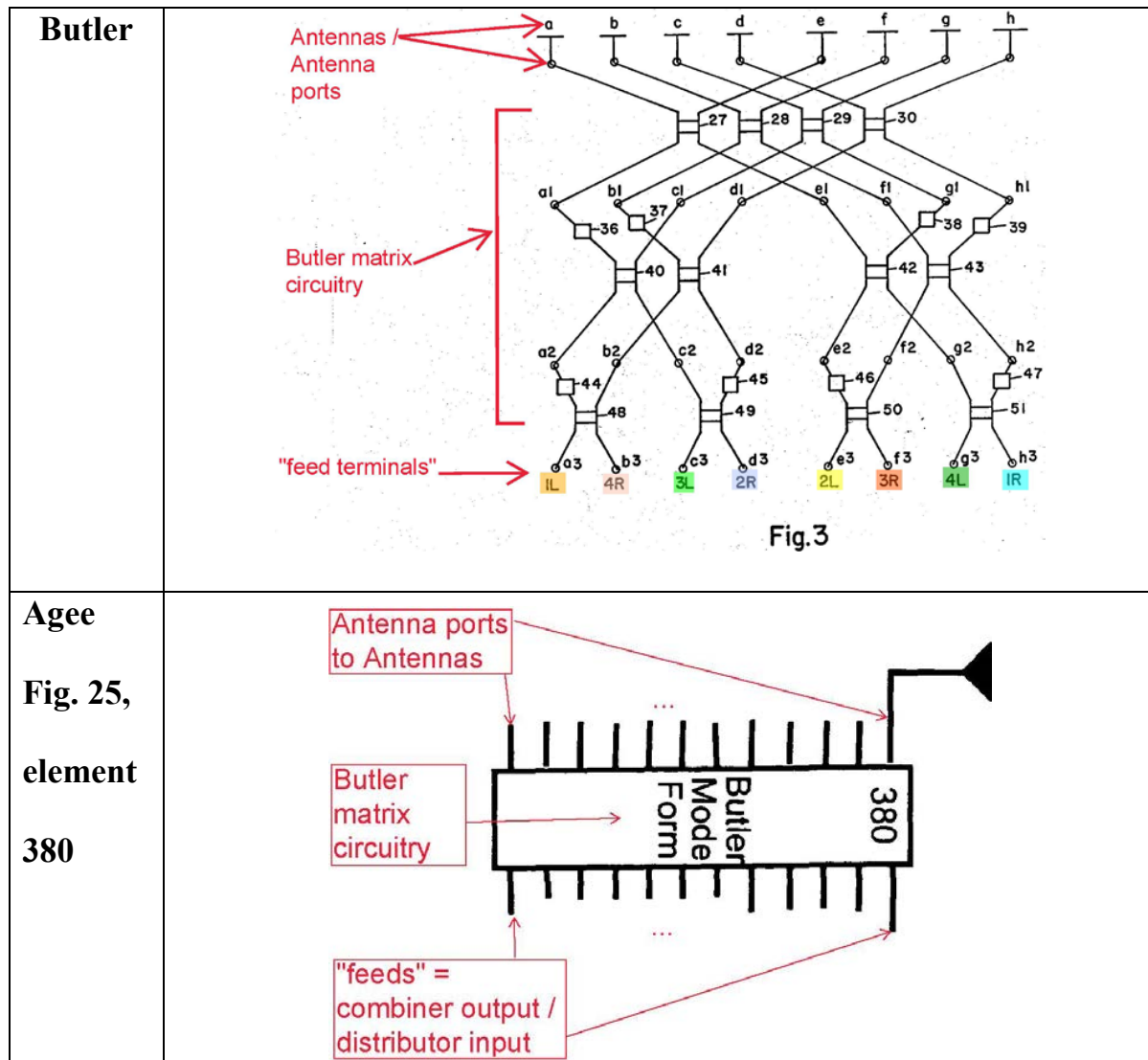
Declaration of Dr. Mark P. Mahon

447. Agee's Butler matrix is used for both receiving and transmitting using beams.

EX-1004, 64:55-64, 86:8-89:60, 106:29-110:33 (claims 40 and 180).

448. Agee uses the term "combiner output" to reference the Butler matrix output which consists of "combined" different signals received on multiple antennas and output on the RF feeds and which is used to calculate the weights.

449. Agee's Butler matrix is arranged like the Butler matrix from the Butler's patent as shown in the following diagrams in which Agee's Butler matrix is turned on its side to highlight the similarity in the diagrams:



450. As detailed herein, the different signals from different antennas are output on the Butler matrix outputs that are received to the BS processing circuitry including the Multilink Adaptation Algorithm discussed below that calculates the weights used to form the receive and transmit beams.

451. As noted in Section V.F.1, PO argued successfully to the Examiner that this “receive...” element was disclosed by the single sentence in Littlejoe that stated “C-

3: “The signal received by the array elements will be the **vector sum of signals arriving by many paths**.”¹⁷ This statement is true about **any** antenna and does not say anything about “simultaneously” receiving multiple signal transmissions from the same remote station. Agee’s received signals on its array elements for its Butler matrix are similarly “the vector sum of signals arriving by many paths.”

452. If PO argues that this claim element somehow requires “multipath” transmissions, Agee discloses such multipath transmissions. EX-1004, Figs. 11, 12, 4, 28:38-41, 60:13-22, 62:63-64:27. Agee has the same disclosure as Littlejoe because the transmissions would travel to Agee’s antennas along different paths (even originating from the same remote station). As those transmissions were received by each antenna, the signal information (e.g., signal strength and phase) would be different. Agee has the same (or more) disclosure than Littlejoe and/or the ‘235 patent.

453. Thus, Agee discloses this “receive” element (including using OFDM as discussed below).

(b) Agee’s Other Teachings Of The Simultaneous

¹⁷ PO cited also to Littlejoe’s reference to “arrival of signals from the desired and undesired users.” Section V.F.1, *supra*. However, Crilly contained substantively same language. EX-1008, ¶¶0090-0092 (discussing “desired and undesired” signals). Thus, this “desired and undesired” language does not disclose the “simultaneously” aspect because the Examiner repeatedly determined that Crilly did not disclose the “simultaneously” aspect. *See* Section V.F.1.

Receiving Element.

454. Agee includes other teachings that confirm that it is receiving multiple signal transmissions simultaneously on different antennas. Thus, even if Agee's Butler matrix operation were not considered, Agee's transceiver (and the antennas associated with it) rely upon simultaneous reception of signals from the same remote station.

455. First, Agee expressly notes this simultaneous action:

[Agee's] MIMO transceiver contains and **uses simultaneously a multiple of single RF feeds**. A signal passes between the Butler Mode Forming element and a Band Pass Filter, ...

456. EX-1004, 59:23-27 (describing Fig. 25 shown below). By itself, this one sentence in Agee contains greater express disclosure of using signal transmissions on different antennas ("multiple RF feeds") "simultaneously" than the entirety of the '235 patent and its priority document Littlejoe.

457. The "uses simultaneously" language reflects that the "MIMO transceiver" (which, as noted herein and as shown in claim 40) includes the components such as the Butler matrix, the OFDM receiver and transmitter, and the components that perform all of the recited elements. EX-1004, 45:43-48:46, 36:6-17, 35:10-26, Figs. 15, 24, 25, 26. This language reflects all of the teachings discussed herein including the TDD, pseudodelay usage, operation of the Butler matrix (including the sampling of the

antennas), operation of the weight calculation algorithms on the output of the Butler matrix.

458. Second, Agee uses a “TDD” system in which each node “receives” at very specific times.

The network of nodes uses MIMO-capable nodes, that is, nodes with multiple antennae, multitone transceivers and preferentially reciprocal uplinks and downlinks (FIG. 13A and FIG. 13B). In the preferred embodiment **each node transmits and receives signal energy during alternating time slots** (or sequences of time slots in TDD-TDMA systems) (FIG. 14); has a spatially and/or polarization diverse multiple-antenna array, a **vector OFDM transceiver that downconverts, A/D converts, and frequency channelizes data induced on each antenna (or other diversity channel) during receive time slots**, and inverse channelizes, D/A converts, and upconverts data intended for each antenna (or diversity channel) during transmit time slots; **linearly combines data received over each diversity channel, on each frequency channel and receive time slot**; redundantly distributes data intended for each diversity channel, on each frequency channel and transmit time slots; and computes combiner and distributor weights that exploit the, narrowband, MIMO channels response **on each frequency channel and time slot** (FIG. 15).

459. EX-1004, 30:3-22.

460. This is an explicit teaching of using the different data (for each different OFDM transmission of different frequency/time in each slot) that is “induced on each antenna” at a specific time slot. The “induced on each antenna” language teaches to a POSITA that the signal transmissions are being “received” on each antenna and sampled simultaneously to correspond to the time slot.

461. Fig. 15 shows the reception “time slots ‘i’” with each different OFDM frequency (tone) receiving its tone separately and simultaneously on each antenna:

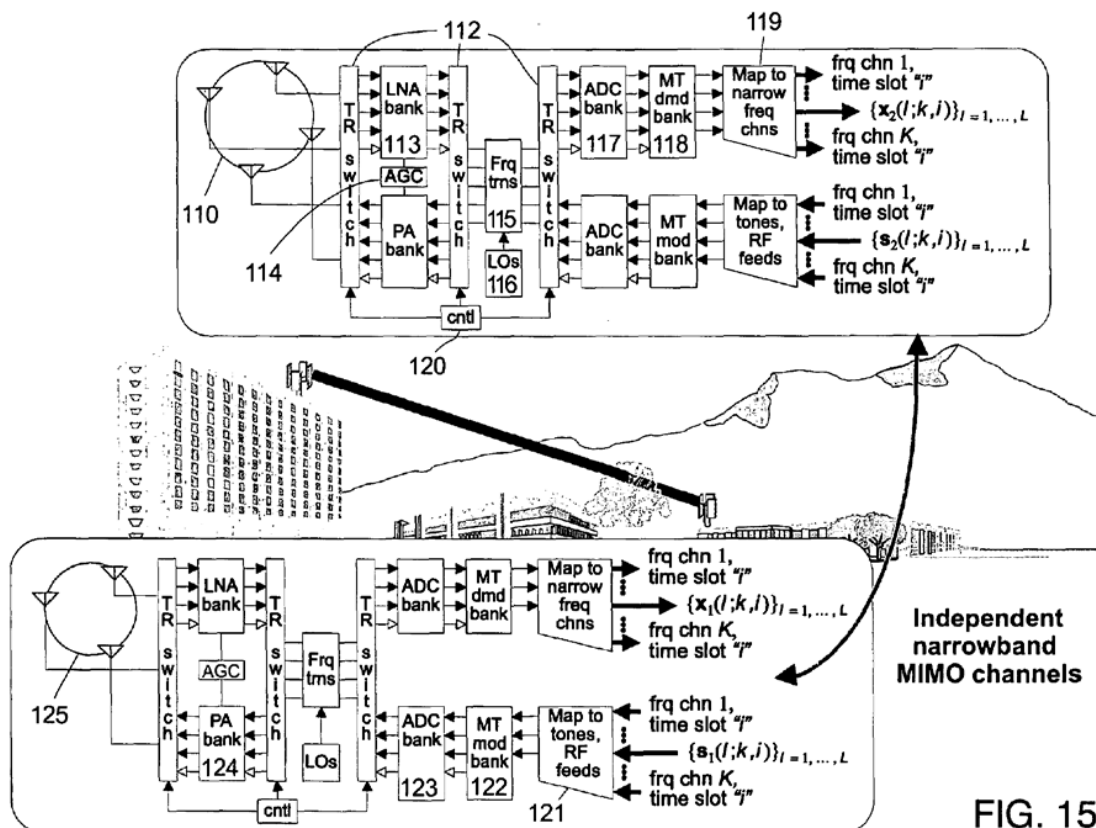


FIG. 15

462. EX-1004, Fig. 15.

463. Agee shows an example of the time slots in Fig. 17:

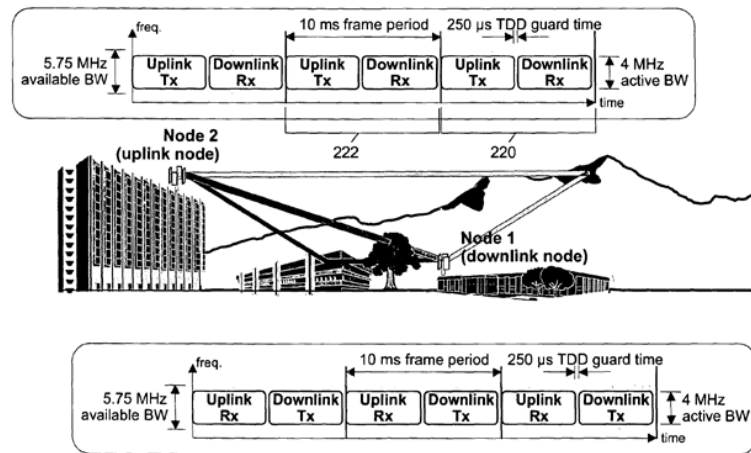


FIG. 17

464. EX-1004, Fig. 17.

465. Figure 17 is showing the alternating time slots for each of the different TDD slots.

“FIG. 17 illustrates a PTP MIMO node layout employing TDD, but one using a guard-time prefix (Item 220) and a 10 ms content frame period (Item 222), where the uplink Tx for Node 2 is at the time for the Uplink Rx for Node 1.” EX-1004, 35:37-40.

466. Agee repeatedly teaches that the weights are calculated based upon the different information that is received by the antennas simultaneously during the receive time slots:

The antennae array ... transmits and receives signal energy during alternating time slots (or sequences of time slots in TDD-TDMA systems). Each transceiver is a

vector OFDM transceiver, with digital signal processing elements, that downconverts, A/D converts, and frequency channelizes data induced on each antenna (or other diversity channel) during receive time slots, ... and computes combiner and distributor weights that exploit the, narrowband, MIMO channels response on each frequency channel and time slot (FIG. 15).

467. EX-1004, 45:8-22.

468. Agee thus expressly relies upon the simultaneous reception of signals “on each frequency channel” during “receive time slots.” I have discussed above that the “induced” language is the simultaneous receiving of the signal transmissions on “each antenna.”

469. The antennas necessarily sample their received signals at the same time (starting at the time slot beginning) and passing that simultaneously received data to the remaining transceiver portions simultaneously for processing. *See also* EX-1004, 30:7-27, 60:40-45, Figs. 39-41 (all discussing receiving data during the time slot).

470. Relatedly, Agee relies upon specific timing for the receiver to detect the particular “pilot signals” from each individual transmitter.

471. I have copied portions of the passages describing the pilot signals herein in other sections. The use of the pilot signals is explained, in part, at EX-1004, 64:44-67:27; Figs. 35-38. The “pilot signals” are received on the Butler matrix antennas simultaneously as explained in the discussion of the Butler matrix above.

472. Agee's pilot signals (as measured) are effectively compared against "known" versions of the pilot signals to calculate the weights specific to each link to a different node and to identify each other node. This was referenced as "spatial separation" and "link detection" in my discussion above.

473. For example, the "pilot signal" is transmitted "at the start of an adaptation frame" which is "tied to the TDD frame."

In the preferred embodiment, substantively nulling combiner weights are formed using an FFT-based least-squares algorithms that adapt $\{w_1(k,l;n_2,n_1)\}$ and $\{w_2(k,l;n_1,n_2)\}$ to values that minimize the mean-square error (MSE) between the combiner output data and a known segment of transmitted pilot data. Operations used to implement this technique during receive and transmit operations are shown in FIGS. 35 and 36, respectively. The preferred pilot data is applied to an entire OFDM symbol at the start of an adaptation frame comprising a single OFDM symbol containing pilot data followed by a stream of OFDM symbols containing information data. The pilot data transmitted over the pilot symbol is preferably given by

474. EX-1004, 64:50-51,

The "pseudodelays" $\delta_1(n_1)$ and $\delta_2(n_2)$ can be unique to each transmit node (in small networks), or provisioned at

the beginning of communication with any given recipient node (in which case each will be a function of n_1 and n_2). In either case, the minimum spacing between any pseudodelays used to communicate with a given recipient node should be larger than the maximum expected timing offset observed at that recipient node. This spacing should also be an integer multiple of $1/K$, where K is the number of tones used in a single FFT-based LS algorithm. If K is not large enough to provide a sufficiency of pseudodelays, additional OFDM symbols can be used for transmission of pilot symbols, either lengthening the effective value of K , or reducing the maximum number of originating nodes transmitting pilot symbols over the same OFDM symbol (for example, the recipient node can direct 4 originators to transmit their pilot symbols over the first OFDM symbol in each adaptation frame, and 4 other originators to transmit their pilot symbols over the next OFDM symbol, allowing the recipient node to construct combiner weights for 8 originators). In the preferred embodiment, K should also be large enough to allow effective combiner weights to be constructed from the pilot symbols alone.

The remaining information-bearing symbols in the adaptation frame are then given by

$$d_1(k,l;n_2,n_1)=p_1(k;n_2,n_1)d_{01}(k,l;n_2,n_1) \quad \text{Eq. 46}$$

$$d_2(k,l;n_1,n_2)=p_2(k;n_{[1]},n_{[2]})d_{02}(k,l;n_1,n_2) \quad \text{Eq. 47}$$

where $d_{01}(k,l;n_2,n_1)$ and $d_{02}(k,l;n_1,n_2)$ are the uplink and downlink data symbols provided by prior encoding, encryption, symbol randomization, and channel preemphasis stages.

Preferably, the adaptation frame is tied to the TDD frame, such that the TDD frame comprises an integer number of adaptation frames transmitted in one link direction, followed by an integer number of adaptation frames transmitted in the reverse link direction.....

475. EX-1004, 65:24-62, claim 53. Thus, the receiver must necessarily simultaneously sample the received signals on all antennas all at the “start of an adaptation frame” or potentially miss the pilot on one or more antennas.

476. The passages above highlight how Agee uses “pseudodelays” that are “unique to each transmit node” and include specific time offsets for each different transmitting node. EX-1004, 65:24-46.

477. The “pseudodelays” provide specific timing for the receiver to detect the pilot signals from each transmitting node. Basically, by detecting the timing position of the pilot signal in the received symbol, Agee detects which specific link (other node) is associated with that pilot symbol. Such a system would not work if the antennas

Declaration of Dr. Mark P. Mahon

were not sampling at the same time (and processing the sampled signals at the same time).

478. Agee's BS compares that observed pilot signal to a "known" pilot signal (which reflects the "target pseudodelay"). EX-1004, 66:13-67:4. This matching to the target pilot signal uses the "actual observed timing offset for that [received] link (observed pseudodelay)." The timing offset allows the link detection and spatial separation. EX-1004, 66:14-16.

479. If the signals are not received and processed simultaneously across all antennas, then the "observed timing offset" could not be used because it would reflect a different "observed timing offset" for different antennas and negatively impact (or defeat) Agee's ability to detect and use the pilot signals. (And such a non-simultaneous reception is not how a butler matrix works and is inconsistent with Agee's discussion of the "data induced on each antenna" being sampled during the receive time slots.

480. The timing of the pseudodelays (target and "observed") is shown in Figs. 38A/B.

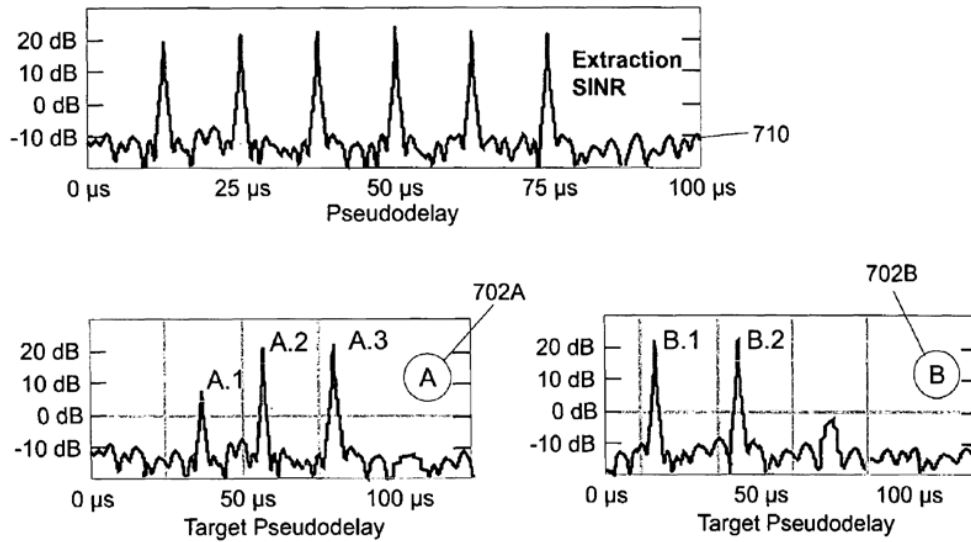


FIG. 38B

481. EX-1004, Fig 38B. The “peaks” in Fig. 38B and Fig. 38A (lower left) correspond to links A.1, A.2, and A.3 in Fig. 38A:

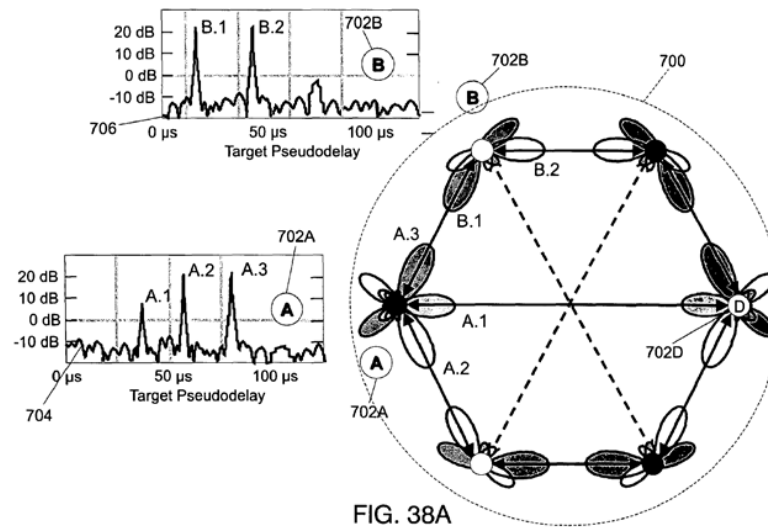


FIG. 38A

482. EX-1004, 67:3-27.

483. The “observed pseudodelay” timing necessarily has to be based upon using the antennas to simultaneously received (and pass to the processor) the signals from the known “target” node (performing the transmission).

484. Thus, beyond the known operation of the Butler matrix, and beyond the OFDM tones (both discussed herein as separately showing receiving simultaneous different signals), Agee contains many additional statements teaching (including rendering obvious) receiving signal transmissions simultaneously (both at the the processor in the form of digitized data and at the antennas in the form of energy “induced on each antenna”).

(c) Agee’s BS Antennas Receive Multiple OFDM Tones Simultaneously

485. Agee uses OFDM – which Agee also references as “multitone” or “frequency diversity.” OFDM technology uses different frequency “bins” to separately transmit (and receive) OFDM “tones” simultaneously on each antenna. Each OFDM tone is a different claimed “signal transmission” on its own distinct frequency carrying different information and is received on each antenna.

486. First, Agee states that it uses a “vector OFDM transceiver” that receives and processes data “over each diversity channel, on each frequency channel and receive time slot...” A POSITA would understand this “vector” OFDM transceiver to be a transmitter and receiver that simultaneously receives and processes the different

OFDM frequencies that correspond to each of the OFDM tones in the “multitone” OFDM transmission.

FIG. 15 illustrates more details of the MIMO-capable node, including on the receiving side: receiving spatially and/or polarization diverse antennae in a multiple antennae array (Item 110), a vector OFDM transceiver switch (Item 112), a LNA bank (Item 113), an AGC (Item 114), a Frequency translator (Item 115), a LOs ((Item 116), an ADC bank (Item 117), a MultiTone Demodulator Bank (Item 118), means for mapping received data over each diversity channel, on each frequency channel and receive time slot (Item 119), and a transceiver controller (Item 120); and including on the transmitting side means for mapping transmitted data for each frequency channel and transmit time slot (Item 121), a MultiTone Modulator bank (Item 122), a DAC bank (Item 123), the transceiver switch, a PA bank (Item 124), and transmitting spatially and/or polarization diverse antennae in a multiple antennae array (Item 125) which may be distinct from those used in receiving (Item 110).

487. EX-1004, Fig. 15, 35:10-26.

As stated in the summary, each node preferentially has an antennae array; multiple, multitone, transceivers (one per antenna); and constrains itself to reciprocal uplinks and

downlinks (FIGS. 13 A and 13B). The antennae array is spatially and/or polarization diverse and transmits and receives signal energy during alternating time slots (or sequences of time slots in TDD-TDMA systems). **Each transceiver is a vector OFDM transceiver, with digital signal processing elements, that downconverts, A/D converts, and frequency channelizes data induced on each antenna (or other diversity channel) during receive time slots,** and inverse channelizes, D/A converts, and upconverts data intended for each antenna (or diversity channel) during transmit time slots; linearly combines data received over each diversity channel, on each frequency channel and receive time slot; redundantly distributes data intended for each diversity channel, on each frequency channel and transmit time slots; and computes combiner and distributor weights that exploit the, narrowband, MIMO channels response on each frequency channel and time slot (FIG. 15).

488. EX-1004, 45:4-26. This passage confirms that Agee's receiver (attached to each antenna) is simultaneously receiving (and sampling and processing) separately each OFDM tone on each antenna each time slot.

489. The "data induced on each antenna" reflects the different signal transmissions (for each different OFDM tone at each different associated frequency) received on each antenna. *See also* EX-1004, 23:62-64.

490. Agee also uses “frequency diversity” to reference OFDM tone transmissions.

Various methods for obtaining signal diversity are known. Frequency diversity is one of many diversity methods. The same modulation is carried by several carrier channels separated by nominally the coherence bandwidth of each respective channel. In time diversity, the same information is transmitted over different time slots.

491. EX-1004, 22:53-56.

492. Agee uses a time-division duplex (“TDD”) system using “time slots” to transmit and receive data from each node EX-1004, Fig. 17. Agee’s Fig. 15 shows the different OFDM tones being transmitted (and received) on each slot.

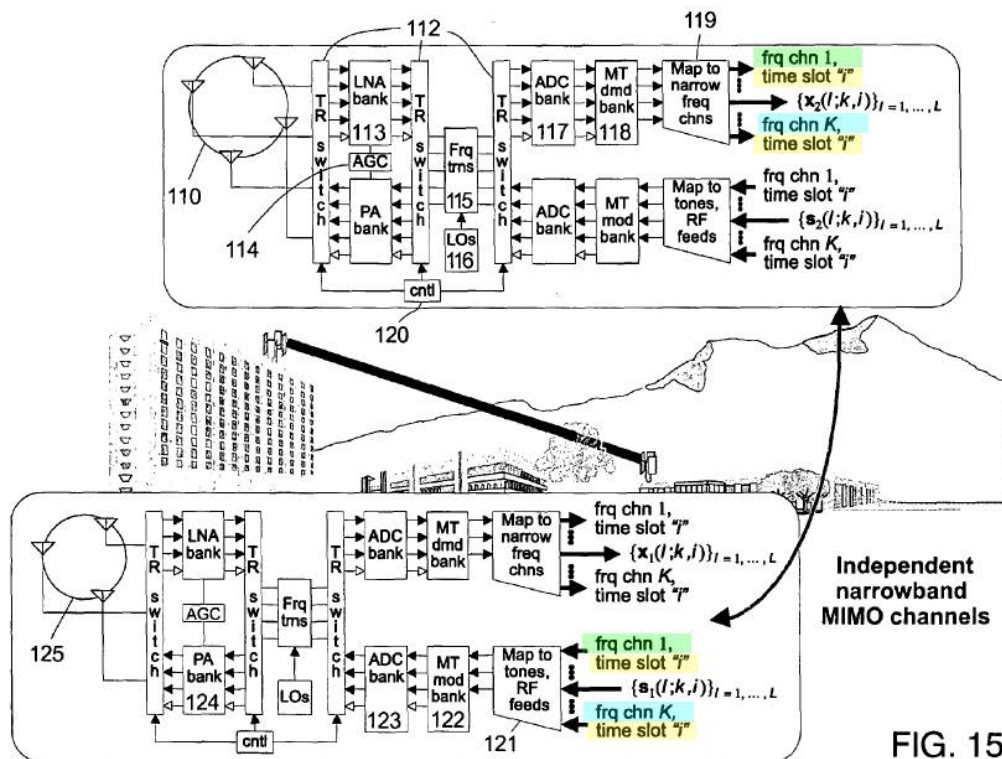


FIG. 15

Declaration of Dr. Mark P. Mahon

493. EX-1004, Fig. 15, 45:10-46:63, . In each time slot “i”, there are “1” to “k” different simultaneous transmissions on different frequencies. EX-1004, 45:7-26, 35:10-26, 29:66-30:22. Each frequency carries an OFDM tone.
494. Fig. 15 demonstrates what Agee references in the quotes above about the “vector OFDM transceiver” with the “vector” being the multiple different tones transmitted at different frequencies.
495. Each OFDM tone carries separate “information.” That is the nature of OFDM and also how Agee describes it. EX-1004, 47:28-37 (“information bearing tones”); 73:4-17 (“information-bearing tone”); 65:24-48 (“information bearing symbols” comprised of tones); claims 40, 179, 180 (“information bearing tones”). The point of OFDM is to carry separate information on each tone.
496. Agee’s Fig. 22 shows that in each “time slot”, Agee’s system simultaneously uses 13 different frequency “channels” (“Ch 0” to “Ch 12”) – each of which are 320 kHz per channel.

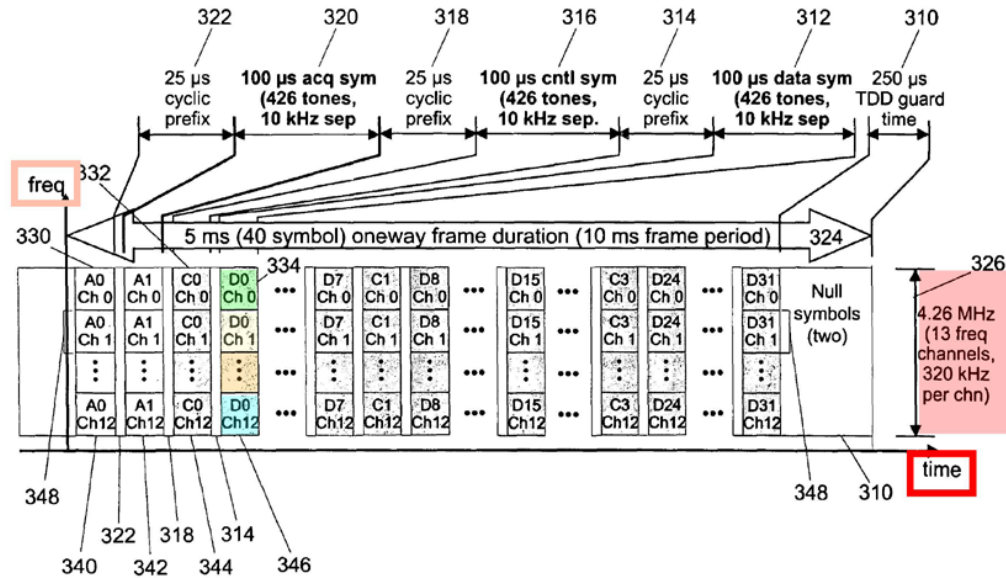
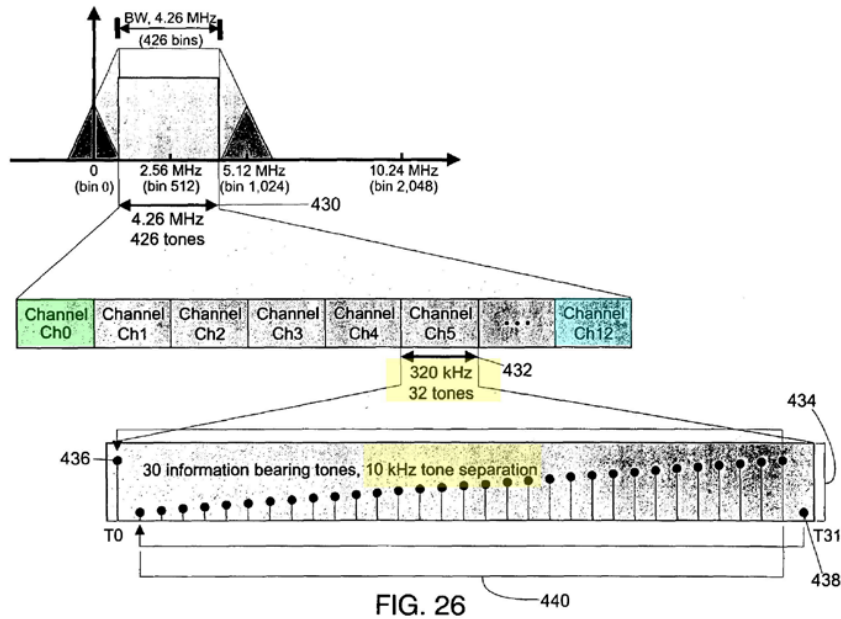


FIG. 22

497. EX-1004, Fig. 22. This is described at 45:29-42, 47:6-42. These channels are all different frequencies (and separated even further below) that have different transmissions simultaneously.
498. Fig. 26 shows that for each of these 320 kHz “channel”, there are 32 10 kHz sub-channels that transmit / receive “tones” simultaneously.



499. EX-1004, Fig. 26, 47:28-39, claims 40, 180. Each OFDM tone transmits information (using a unique 10 kHz frequency). (Agee does describe an alternative tone arrangement that transmits fewer tones using larger frequency ranges for each tone, but the basic concept is the same).

500. Thus, in each time slot, Agee's BS receives simultaneously 32 different OFDM tones transmitted on different frequencies ("frequency bins") on each antenna. EX-1004, 47:6-39.

In the preferred embodiment ..., the tone layout divides the 4.26 MHz into 426 'bins', each of 10 kHz separation; these are then shared such that thirteen channels, each with 32 tones covering 320 kHz, from Channel 0 to Channel 12 are formed, with each channel further carrying of the 32 tones a network-information-bearing tone ...

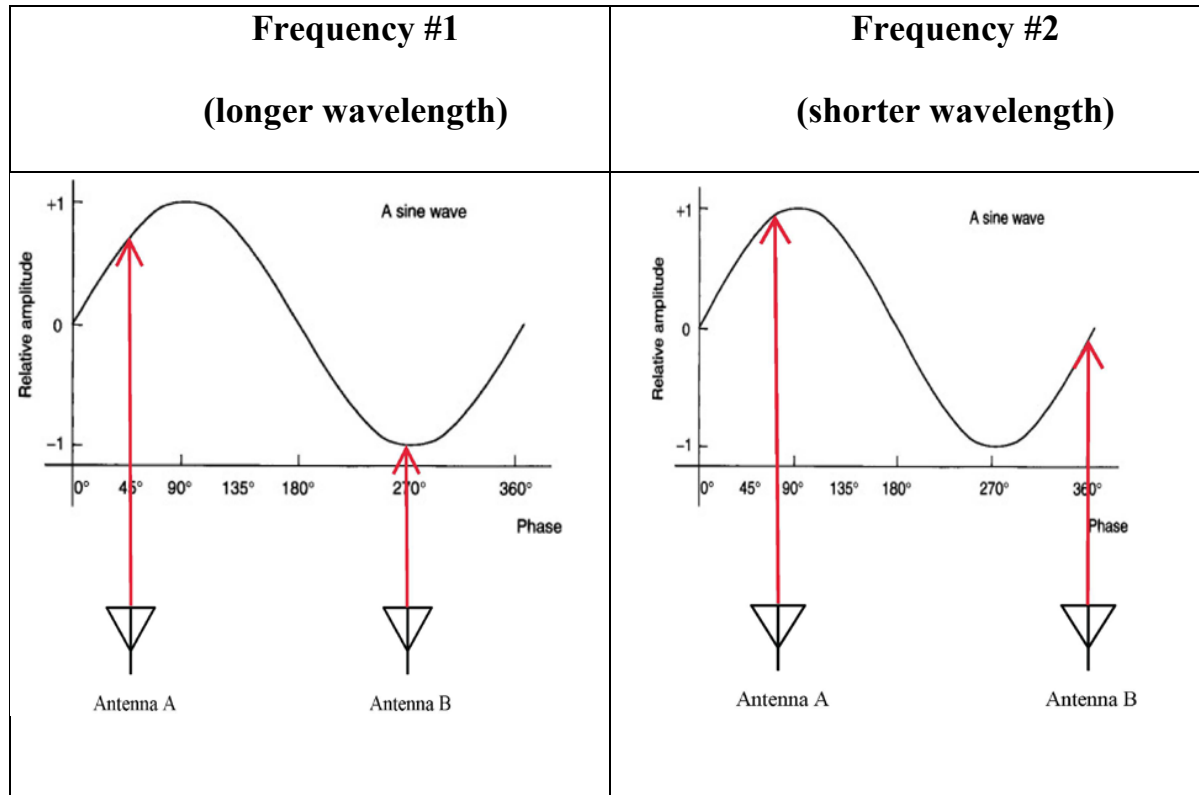
501. EX-1004, 72:66-73:24. The 32 OFDM tones transmitted simultaneously in a time slot is an “OFDM symbol.” The tones are the “data induced on each antenna” during a “receive time slot” as discussed above.

502. Agee’s Butler matrix processes each of these 32 different OFDM transmissions (tones) separately for each separate antenna. This is conceptually a separate (replicated) Butler matrix for each different tone (frequency). Agee’s system includes a separate radio for each antenna that can send / receive all of the different “tones” at the different frequencies. EX-1004, 45:6 (Agee’s BS includes “multitone [] transceivers (one per antenna)”). See also 30:4-22 (“multitone receivers ... [that] downconverts, A/D converts and frequency channelizes data induced on each antenna ... during receive time slots...”). Thus, each antenna can transmit/receive all of the OFDM tones during each time slot (simultaneously). These “multitone” receivers allow for simultaneously processing the different transmissions on the different frequencies. That is the nature of OFDM.

503. As detailed in the description of the Butler matrix above, the Butler matrix measures different signal strengths on different antennas at different phases of a wave. Because different frequencies have different wavelengths, the measurements at each antenna for each tone (frequency bin) will be different. This is depicted below in which frequencies #1 and #2 have different wavelengths resulting in different

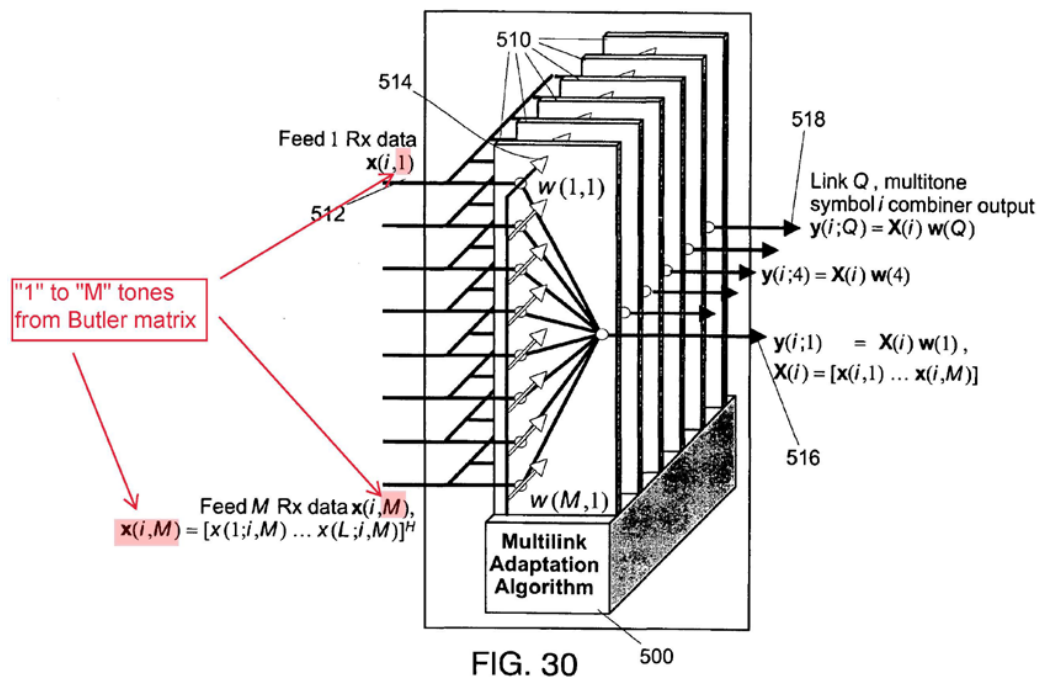
Declaration of Dr. Mark P. Mahon

relative signals strengths on each of Antenna “A” and “B” for the different frequencies.



504. Agee’s Butler matrix measures (and combines) a different signal strength at each antenna for each of the 32 OFDM tones because they are transmitted using different frequencies – hence the “multitone receiver” in Agee discussed above that “frequency channelizes data induced on each antenna.” As shown above (and in Agee), the distance between the antennas remains the same (particularly because the OFDM tones are being transmitted/received simultaneously so there is no ability to change the distance between antennas even if that were possible or desirable).

505. Agee's Fig. 30 shows this arrangement. Each input line from the left (coming from the antenna) is for a specific "tone" (from 1 to "M") tones. "The received symbol $[x](i,1)$, comprising a matrix combination of L Link and M multitone elements..." EX-1004, 58-62.



506. EX-1004, Fig. 30. Agee describes this Figure as:

When a communication is transmitted, it will be received; and the MIMO reception is, like the transmission, adaptive. See FIG. 30, detailing the logical processing involved. Received data passes through both a Multilink weight adaptation algorithm and (to which that part is combined) a Multilink diversity combining of the Reception weights. This reweighted transmission now

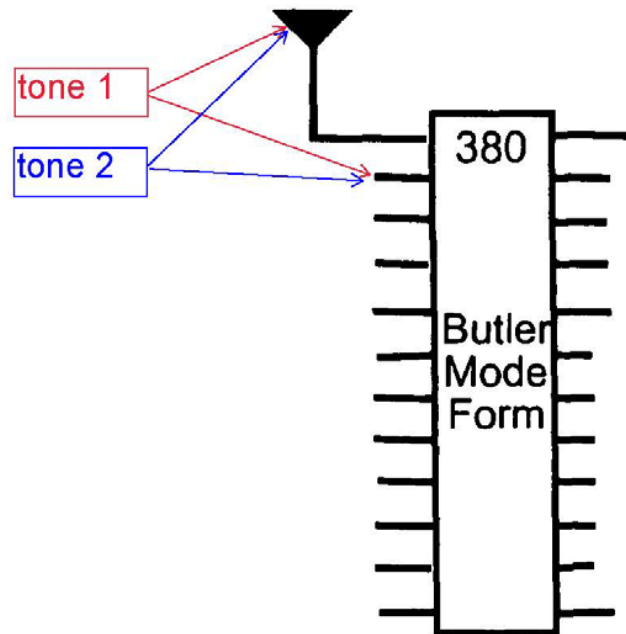
passes through the equalization algorithm and (to which that is combined) a Delay/ITI/pilot-gating removal bank stage. These sort out the properly weighted tones, perform the recombinations, and undo the pilot-gating distortion to effectively reassemble at the reception end the symbol pattern of the original signal. That now passes through a symbol decoder bank to recover the message from the symbolic representation and the whole now is joined with the other received and linked messages for final reassembly. The functional and firmware processing (fixed logic hardware, limited purpose firmware, or combined software, processors and circuitry). **The received symbol $[x](i,1)$, comprising a matrix combination of L Link and M multitone elements,** is first modified by the pilot tone generator that sends the recipient node, network, and group modifications for an element-wise reverse multiplication, to strip off that component of the signal and identify if the received symbol is from any originating source trying to send to this particular recipient. If the recipient pilot signal matches, then the signal passed on to a circuit that separates the pilot signal elements from the data signal elements. The pilot signal elements are passed through a link detection circuit that preferentially uses a FFT-LS algorithm to produce link quality statistics for that particular received transmission, identifies the weighting elements that were contained in the pilot signal and passes those over to the

Declaration of Dr. Mark P. Mahon

multilink combination circuit, and sends the pilot weights over to the circuit for equalizing weight calculations. The data signal, combined with the pilot weighting elements, now is combined with the equalizer calculated factors to strip off all pilot information from the traffic data. Next, the re-refined traffic data passes through a link demodulator to produce the original channel-by-channel link streams of data. In an alternative embodiment, the first channel, which has been reserved for decryption, decoding, and error detection signal ling, not passes through the ITI correction circuitry and thence to the instantiated decryption, decoding, or retransmission circuitry as indicated by the data elements of the first channel signal; meanwhile, the remaining data channel elements are available, having been refined from the combined received elements.

507. EX-1004, 58:43-59:34.

508. The receiving of each tone (frequency range) on each antenna is depicted as per below:



509. Each OFDM tone (frequency bin) is a different claimed signal transmission.

Each OFDM tone is a different piece of information being transmitted / received on a different frequency with all tones transmitted / received simultaneously.

510. Thus, even if the Challenged Claims require “different” signal transmissions (as I have mentioned above), Agee’s use of OFDM tones shows different signal transmissions. For example, as shown above Agee uses OFDM **tone 1** is received on antenna #1 and OFDM **tone 2** is received on antenna #2. These are different signal transmissions received simultaneously on different antennas on **different frequencies** conveying **different information** (the different “information-bearing-tone”) from the same remote station that made the OFDM transmission.

511. Each antenna receives all 32 different transmissions (the different tones).

However, the claims do not exclude each antenna from receiving each transmission.

Rather, the claims merely require two antennas receiving two signal transmissions.

512. As I have detailed below (and quoted passages above) Agee states that it calculates weights **for each tone** – thus confirming that the Butler matrix is outputting the (combined) signal strengths for each tone because the Butler matrix (and the associated receivers on each antenna) are providing the frequency channelized data for each tone to allow for such weight calculations on a per tone bases (as showing in Figure 30 and its description above). See EX-1004, 64:28-32 (“distribution and combining weights are computed and applied over as broad a range of tones (frequency channels k)”); 65:31-33.

513. Thus, for each of the various separate reasons that I have discussed in the sections above, Agee discloses different signal transmissions (including the different tones) received simultaneously on the Butler matrix antenna elements.

514. Thus, Agee discloses this element in far greater detail than anything than a POSITA would understand to be disclosed in the ‘235 patent.

[1.4] determine first signal information for the first signal transmission;

[1.5] determine second signal information for the second signal transmission, wherein the second signal information is different than the first signal information;

515. Agee discloses these elements in several ways including by using the “signal strength” measured on each antenna that was cited as meeting this element for Littlejoe and the ‘235 specification.

516. PO argued that these elements were disclosed by Littlejoe’s statement that “[t]he beamforming application uses the **signal strength information** derived from packet receptions by the ‘searcher’ receivers” in the Butler matrix. EX-1002, 000131. Agee does the same “determine” steps as cited by the PO when Agee’s Multilink Weight Adaptation Algorithm uses the signal strength information derived from the receptions by the antennas in the Butler matrix discussed in 1.3 and 1.7. The outputs from the receivers associated with the antennas and the Butler matrix technology is shown as the input into the Multilink Weight Adaptation Algorithm as I have discussed in detail herein including in Figures 25 and 30.

517. PO argued that Littlejoe disclosed determining the different “signal information” by measuring different “signal strengths.” The ‘235 specification references “signal information” only one time:

[R]outing and **signal information** which can **include** transmit power level information, transmit data rate information, antenna pointing direction information, weighting information, constraints information, null/zero location information, peak location information, quality of service (QoS) information, priority information, lifetime

Declaration of Dr. Mark P. Mahon

information, frequency information, timing information, user and node authentication information, ... that is associated with each sending and receiving communication channel

518. EX-1001, 15:44-56.

519. A POSITA would recognize the “transmit power level” as measured at the receiver as the “signal strength.”

520. Agee teaches many forms of the claimed signal information.

521. First, as detailed in the section above describing the basic Butler matrix technology and element 1.3, Agee’s Butler matrix measures different signal informations (signal strengths) received on each antenna even for the same signal wave due to the phase difference resulting from the antennas’ spatial separation.

522. Moreover, as I have detailed above, Agee measures those signal strengths for each of the OFDM tones (using each different frequency associated with each different tone) on each antenna simultaneously.

523. These measurements of the different transmission signals correspond to the “transmit power level information” in the ‘235 patent – particularly because this is what PO relied upon during prosecution and in prior IPRs for this element as detailed herein.

524. Moreover, such measurements are detecting and processing the signal strength in the passages regarding the OFDM vector receiver receiving and detecting data induced on each antenna:

As stated in the summary, each node preferentially has an antennae array; multiple, multitone, transceivers (one per antenna); and constrains itself to reciprocal uplinks and downlinks (FIGS. 13 A and 13B). The antennae array is spatially and/or polarization diverse and transmits and receives signal energy during alternating time slots (or sequences of time slots in TDD-TDMA systems). Each transceiver is a vector OFDM transceiver, with digital signal processing elements, that downconverts, A/D converts, and frequency channelizes data induced on each antenna (or other diversity channel) during receive time slots, and inverse channelizes, D/A converts, and upconverts data intended for each antenna (or diversity channel) during transmit time slots; linearly combines data received over each diversity channel, on each frequency channel and receive time slot; redundantly distributes data intended for each diversity channel, on each frequency channel and transmit time slots; and computes combiner and distributor weights that exploit the, narrowband, MIMO channels response on each frequency channel and time slot (FIG. 15). Although the preferred embodiment of the invention allows individual nodes to vary greatly in their capacities, a set of nodes preferentially will incorporate the hardware capabilities detailed in the following paragraphs.

Declaration of Dr. Mark P. Mahon

525. EX-1004, 45:4-28. These steps all correspond to the claimed “determine” and are all performed on each of the OFDM tones / frequencies.

526. As noted above, Agee’s Butler matrix measures a different signal strength for each of the 32 OFDM tones on each antenna. As detailed below, these measurements are used to calculate the weights.

527. Beyond the “signal strengths,” Agee’s disclosure corresponds to other forms of “signal information” identified by the ‘235 patent at EX-1001, 15:44-56. These include that the “data induced on each antenna” in Agee provides “antenna pointing direction information,” “null/zero location information,” “peak location information,” “frequency information,” and “timing information” – which are each forms of “signal information.”

528. Agee’s 32 different OFDM tones are all separate transmissions at different frequencies and thus provide “frequency information.” For example, the information about the transmission at each “frequency” is allowing Agee to calculate weights specific to each tone for receive and transmit beams as I have discussed herein.

529. As detailed above, Agee’s measured signals provide the pilot signal’s “observed timing offset” – which is used to provide “timing information” for Agee’s system to properly detect and use the pilot signal to calculate weights to receive (and transmit) data using the beamforming provided by those weights.

530. Agee uses the received information to authenticate the nodes to ensure that they are part of Agee's network. For example, Agee's "pseudodelays" are "node authentication information" and thus are "signal informations." EX-1004, 65:24-66:19. "Unauthorized pilot symbols" reflect nodes that are not allowed on the network.

531. Similarly, as noted above in the discussion of pseudodelays and their usage in link separate, link identification and weight calculation, different antenna informations are used to detect "peaks" in "observed pseudodelays" – which corresponds to "peak location information." These "peaks" are used to calculate "null/zero location information" (another form of "signal information") to form beams. EX-1004, 67:3-55.

532. Agee's different signals on the antennas provide the "observed (possibly time-varying) azimuth and elevation" of a transmitting node. EX-1004, claim 45. The "azimuth" is a "peak location information" and "antenna pointing direction information." The "link quality statistics" formed from the antenna data is also a form of antenna pointing direction information and QoS information. EX-1004, 59:2-9.

533. In Agee's Butler matrix, signal informations (signal strengths) from multiple antennas are combined on each Butler combiner output. Thus, each individual Butler combiner output by itself is a determination of a first signal information (from a first

antenna's signal) and second signal information (from a second antenna's signal) as claimed.

534. Agee's teaching includes another related disclosure of these claim elements. The Butler outputs collectively ("combiner output data") constitute a determination of different signal informations. For example, the first and second signal informations are Butler output #1 and Butler output #2 in Fig. 25, respectively. Each output is a determination of different signal informations resulting from multiple signals on multiple antennas connected to that output.

535. Furthermore, as I have detailed at length above, Agee teaches that it receives and processes "data induced on each antenna" during each "receive slot" – which is a form of the claimed receiving and determining both by the processor and antenna. This processing is all a form of the claimed "determining."

536. Thus, Agee discloses this element.

[1.6] determine a set of weighting values based on the first signal information and the second signal information;

537. Agee discloses the element.

538. Agee uses a pilot data signal (the "combiner output data") that it receives from the Butler matrix:

In the preferred embodiment, substantively nulling combiner weights are formed using an FFT-based least-squares algorithms that adapt $\{w_1(k,l;n_2,n_1)\}$ and $\{w_2(k,l;n_1,n_2)\}$ to values that minimize the mean-square error (MSE) between the combiner output data and a known segment of transmitted pilot data. Operations used to implement this technique during receive and transmit operations are shown in FIGS. 35 and 36, respectively. The preferred pilot data is applied to an entire OFDM symbol at the start of an adaptation frame comprising a single OFDM symbol containing pilot data followed by a stream of OFDM symbols containing information data. The pilot data transmitted over the pilot symbol is preferably given by

$$\begin{aligned} p_1(k; n_2, n_1) &= d_1(k, 1; n_2, n_1) \\ &= p_{01}(k)p_{21}(k; n_2)p_{11}(k; n_1) \end{aligned} \quad \text{EQ. 44}$$

$$\begin{aligned} p_2(k; n_1, n_2) &= d_2(k, 1; n_1, n_2) \\ &= p_{02}(k)p_{12}(k; n_1)p_{22}(k; n_2) \end{aligned} \quad \text{EQ. 45}$$

where symbol index l is referenced to the start of the adaptation frame, and where

$p_{01}(k)$ is a pseudorandom, constant modulus uplink “network” or “subnet” pilot that is known and used at each node in a network or subnet;

Declaration of Dr. Mark P. Mahon

$p_{02}(k)$ is a pseudorandom, constant modulus downlink “network” or “subnet” pilot that known and used at each node in the network;

$p_{21}(k;n_2)$ is a pseudorandom, constant modulus uplink “recipient” pilot that is known and used by every node intending to transmit data to node n_2 during uplink transmission intervals;

$p_{12}(k;n_1)$ is a pseudorandom, constant modulus downlink “recipient” pilot that is known and used by every node intending to transmit data to node n_1 during downlink transmission intervals;

$p_{11}(k;n_1)=\exp\{j2\pi\delta_1(n_1) k\}$ is a sinusoidal uplink “originator” pilot that is used by node n_1 during uplink transmission intervals;

$p_{22}(k;n_2)=\exp\{j2\pi\delta_2(n_2) k\}$ is a sinusoidal downlink “originator” pilot that is used by node n_2 during downlink transmission intervals;

The “pseudodelays” $\delta_1(n_1)$ and $\delta_2(n_2)$ can be unique to each transmit node (in small networks), or provisioned at the beginning of communication with any given recipient node (in which case each will be a function of n_1 and n_2). In either case, the minimum spacing between any pseudodelays used to communicate with a given recipient node should be larger than the maximum expected timing offset observed at that recipient node. This spacing should also be an integer multiple of $1/K$, where K is the number of tones used in a single FFT-based LS algorithm. If K is not large enough to provide a sufficiency of pseudodelays, additional OFDM

symbols can be used for transmission of pilot symbols, either lengthening the effective value of K , or reducing the maximum number of originating nodes transmitting pilot symbols over the same OFDM symbol (for example, the recipient node can direct 4 originators to transmit their pilot symbols over the first OFDM symbol in each adaptation frame, and 4 other originators to transmit their pilot symbols over the next OFDM symbol, allowing the recipient node to construct combiner weights for 8 originators). In the preferred embodiment, K should also be large enough to allow effective combiner weights to be constructed from the pilot symbols alone.

539. EX-1004, 64:43-65:48.

540. As noted above (and below), the pilot data evaluation, using the FFT-LS algorithm, allows for weights to be calculated to reflect the beams used for receiving and transmitting.

541. This overall process is described by Agee in Figures 35-37.

FIGS. 35 and 36 illustrate the FFT-based LS algorithm used in the preferred embodiment that adapt $\{w_1(kl;n, n)\}$ and $\{w_2(kl;n, n)\}$ to values that minimize the mean square error (MSE) between the combiner output data and a known segment of transmitted pilot data.

FIG. 37 illustrate the FFT-based LS algorithm used in the preferred embodiment for the normalized MMSE or, in an alternative embodiment, the Gauss-Newton algorithm.

542. EX-1004, 36:51-58. The “w1” and “w2” values are the receive weights “used at node n1 to recover” transmissions.

$W_1(k,l;n_1)=[w_1(k,l;n_2(1),n_1) \dots w_1(k,l;n_2(N_2),n_1)]$ represents the complex combiner weights used at node n_1 to recover symbol symbols $\{d_1(k,l;n_2(q), n_1)\}$ intended for node n_1 and transmitted from nodes $\{n_2(q)\}$ within uplink channel (k,l) ; and

$W_2(k,l;n_2)=[w_2(k,l;n_1(1),n_2) \dots w_2(k,l;n_1(N),n_2)]$ represents the complex combiner weights used at node n_2 to recover symbol symbols $\{d_2(k,l;n_1(p),n_2)\}$ intended for node n_2 and transmitted from nodes $\{n_1(p)\}$ within uplink channel (k,l) .

543. EX-1004, 63:58-67.

544. Agee details the calculations and math theory behind the calculations in columns 64-68. Claim 53 specifically claims the usage (and calculations) of the pilot symbols received from the butler matrix (claim 40) for calculating the weights for the received pilot symbol (which consists of the individual OFDM tones at the different frequencies).

545. Figure 35 shows that if the received data is a “pilot symbol” (a determination done at block 593), then block 594 computes “combiner weights W.”

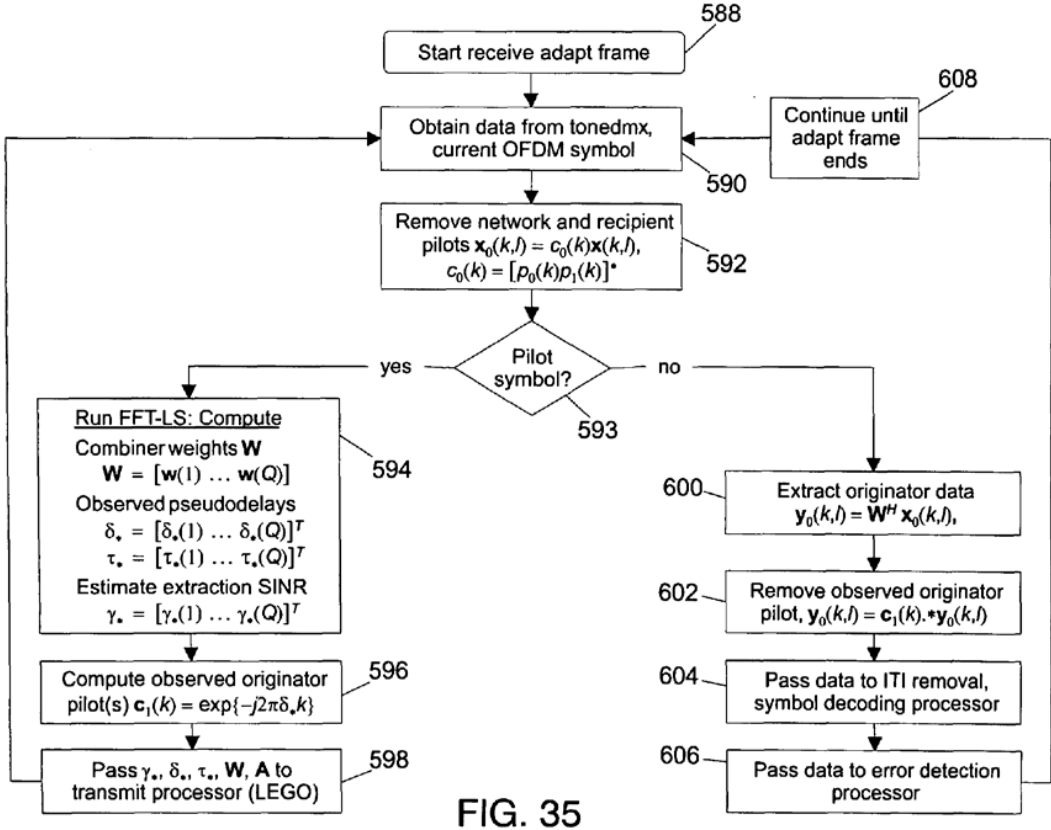


FIG. 35

546. EX-1004, Fig. 35.

547. Fig. 37 shows the calculation in box 594 for the “combiner weights W ” (shown in various blocks) using the “FFT-LS” algorithm (using the Butler matrix outputs). These butler matrix outputs are denoted as processing the pilot signal which is shown as the “ x_0 ” term in Fig. 37 and are used at the start of the algorithm.

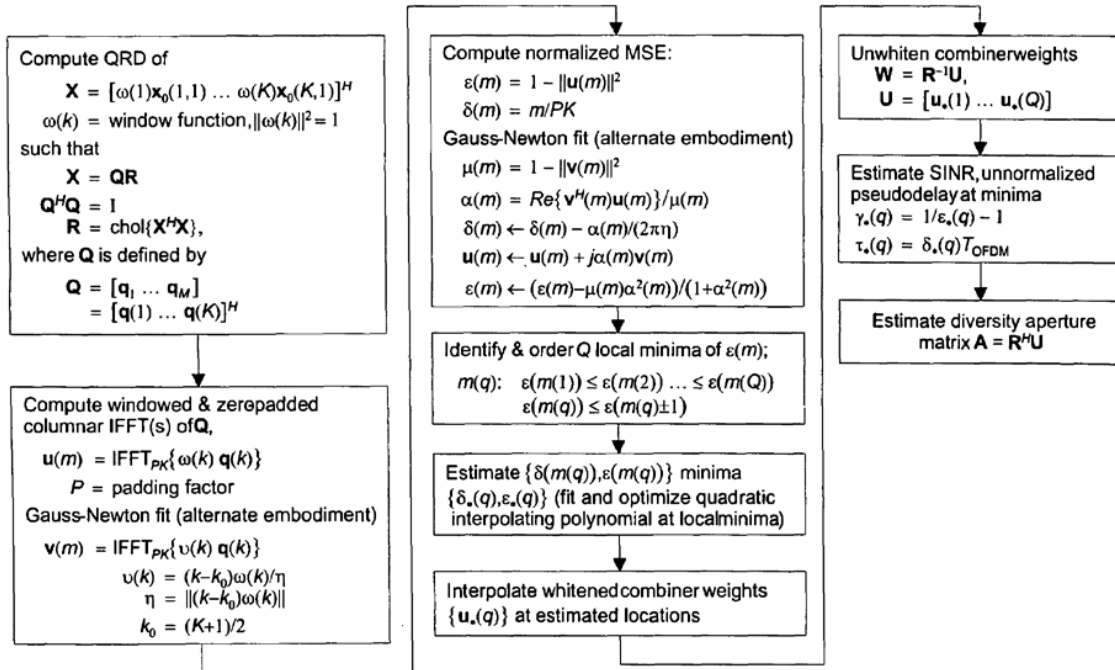


FIG. 37

548. EX-1004, Fig. 37.

549. Agee describes the math in Figure 37 as follows and specifically notes that the “pilot symbol” is the “x0(k,l)” value that starts the determination of the weights:

The FFT-based LS algorithm is shown in FIG. 37. **The pilot symbol, notionally denoted x0(k,l)** in this Figure (i.e., with reference to uplink/downlink set and node index suppressed), is multiplied by a unit-norm FFT window function, and passed to a QR decomposition algorithm, preferably a block modified-Gram-Schmidt Orthogonalization (MGSO), and used to compute orthogonalized data {q(k)} and upper-triangular Cholesky statistics matrix R. Each vector element of {q(k)} is then

multiplied by the same window function, and passed through a zero-padded inverse Fast Fourier Transform (IFFT) with output length PK , with padding factor P , preferably $P=4$, to form uninterpolated, spatially whitened processor weights $\{u(m)\}$, where lag index m is proportional to target pseudodelay $\delta(m)=m/PK$. The whitened processor weights are then used to estimate the mean-square-error (MSE) obtaining for a signal received at each target pseudodelay, $\varepsilon(m)=1-\|u(m)\|^2$, yielding a detection statistic (pseudodelay indicator function) with a minimum (valley) at IFFT lags commensurate with the observed pseudodelay (alternately, combiner output SINR $\gamma(m)=\varepsilon^{-1}(m)-1$ can be measured at each target pseudodelay, yielding a detection statistic (peak) at FFT lags commensurate with that pseudodelay. The pilot symbol, notionally denoted $x_0(k,l)$ in this Figure (i.e., with reference to uplink/downlink set and node index suppressed), is multiplied by a unit-norm FFT window function, and passed to a QR decomposition algorithm, preferably a block modified-Gram-Schmidt Orthogonalization (MGSO), and used to compute orthogonalized data $\{q(k)\}$ and upper-triangular Cholesky statistics matrix R . Each vector element of $\{q(k)\}$ is then multiplied by the same window function, and passed through a zero-padded inverse Fast Fourier Transform (IFFT) with output length PK , with padding factor P , preferably $P=4$, to form uninterpolated, spatially

whitened processor weights $\{u(m)\}$, where lag index m is proportional to target pseudodelay $\delta(m)=m/PK$. The whitened processor weights are then used to estimate the mean-square-error (MSE) obtaining for a signal received at each target pseudodelay, $\varepsilon(m)=1-\|u(m)\|^2$, yielding a detection statistic (pseudodelay indicator function) with a minimum (valley) at IFFT lags commensurate with the observed pseudodelay (alternately, combiner output SINR $\gamma(m)=\varepsilon^{-1}(m)-1$ can be measured at each target pseudodelay. The IFFT windowing function is dependent on the minimum spacing between pseudodelays, and is designed to minimize interlag interference (“picket fence” effect) between pilot signal features in the pseudodelay indicator function. In the preferred embodiment, and for a node capable of forming four links, a Kaiser-Bessel window with parameter 3 is preferred.

A valley (or peak) finding algorithm is then used to detect each of these valleys (or peaks), estimate the location of the observed pseudodelays to sub-lag accuracy, and determine additional ancillary statistics such as combiner output SINR, input SINR, etc., that are useful to subsequent processing steps (e.g., LEGO). Depending on the system application, either the Q lowest valleys (highest peaks), or all valleys below a designated MSE threshold (peaks above a designated SINR threshold) are selected, and spatially whitened weights U are interpolated from

weights near the valleys (peaks). The whitened combiner weights U are then used to calculate both unwhitened combiner weights $W=R^{-1}U$, used in subsequent data recovery operations, and to estimate the received channel aperture matrix $A=RHU$, to facilitate ancillary signal quality measurements and fast network entry in future adaptation frames. Lastly, the estimated and optimized pseudodelay vector δ^* . is used to generate $c1(k)=\exp\{-j2\pi\delta^*k\}$ (conjugate of $\{p11(k;n1)\}$ during uplink receive operations, and $\{p22(k;n2)\}$ during downlink receive operations), which is then used to remove the residual observed pseudodelay from the information bearing symbols. (See FIG. 38A, Items 702A, 704, 702B, 706, and FIG. 38B, Item 710, for illustration of the overall [signal] and the signal modified by the correct origination, target, and pilot mask.)

In an alternate embodiment, the pseudodelay estimation is refined using a Gauss-Newton recursion using the approximation

$$\exp\{-j2\pi\Delta(k-k_0)/PK\} \approx 1 - j2\pi\Delta(k-k_0)/PK$$

This algorithm first estimates Δ , providing an initial sublag estimate of pseudodelay, before estimating the lag position to further accuracy. The resultant algorithm can reduce the padding factor P , and reduces interpolation errors in the receive [combination] weights. However, it

requires estimation of an additional IFFT using a modified FFT window, and is therefore not preferred in applications where DSP complexity is of overriding importance.

The optimized combiner weights are substantively null-steering, in that the combiner weights associated with each originating signal will (notionally, in absence of multipath) form a composite antenna pattern that steers nulls in the direction of all other time-and-frequency coincident signals (signals transmitting on the same time slot and frequency channel) impinging on the array. However, the weights will also (notionally, in absence of multipath) form a beam in the direction of the originating signal, further improving performance of the overall network. In the presence of multipath, a clear gain pattern of this sort may not necessarily form; however, the effect of this processing will be the same, and is typically be improved due the He added diversity provided by multipath.

550. See EX-1004, 66:21-67:55.

551. Fig. 30 also depicts the pilot symbol (“x” data arriving from RF feeds) based on the individual OFDM tones received by the antennas attached to the Butler matrix..

552. The “pilot signal” is spread across all OFDM “tones” (all 32 different frequencies) that corresponds to an OFDM symbol. “The preferred pilot data is applied to an

entire OFDM symbol at the start of an adaptation frame...” EX-1004, 64:50-65:45 (detailing formulas for tones for the pilot signals).

553. Thus, the pilot signal information is spread out among multiple different transmissions on different frequencies (tones) that are all transmitted / received simultaneously (because they are on different frequencies). Agee’s system receives the different tones with different informations and uses those various different informations to calculate the weights for beamforming.

554. Agee teaches that it calculates weights using multiple different OFDM tones for each time slot.

“In the preferred embodiment, OFDM modulation formats is used to instantiate the invention, and substantively similar distribution and combining weights are computed and applied over as broad a range of tones (frequency channels k) and OFDM symbols (time slots l).”

555. EX-1004, 64:27-32.

556. This teaching is repeated throughout Agee:

Then from the ADC bank the transmission flows through a Multitone Demodulator Bank (FIG. 15, Item 118), which splits it into 1 through K FDMA channels, where K is the number of feeds. **The now separated tones (1 through M for each channel) in aggregate forms the entire baseband for the transmission, which combines spatial,**

polarization, either, or both, feeds across the FDMA channels or even combines up to K FDMA channels as transmission data density requires. This combination enables steering a greater number of beams and nulls than the RF feeds, up to the number of feeds times the number of FDMA channels. It also separates up to $[K]$ feed links per FDMA channel, improves overall transmission link error and/or retransmission rates, improves overall network capacity and coverage, and reduces the link fade margins, reduces the PA cost, and reduces battery consumption at the other ends of the link.

From the Multitone Demodulator Bank the Rx data is passed to circuitry for mapping the received broadband multitone signal into separated, narrowband frequency channels and time slots (FIG. 15, Item 119).

557. EX-1004, 46:35-54. *See also* Abstract (using “pilot tone data” to calculate weights).

558. Agee teaches how the pilot data is encoded on the OFDM tones in its discussion of the “pilot tone generation” in Figure 21 and its associated description:

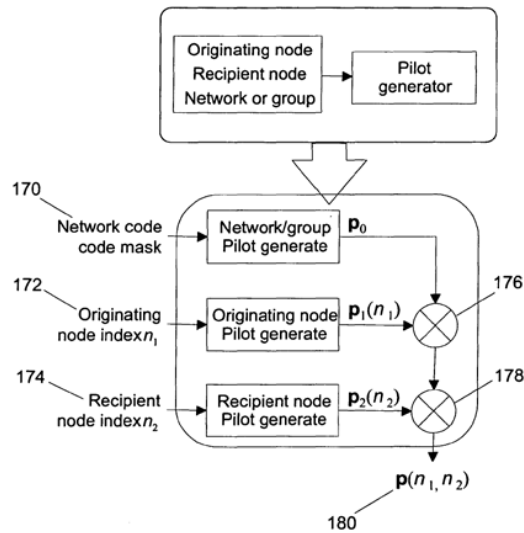


FIG. 21

559. EX-1004, Fig. 21.

Pilot tone generation, summarily disclosed on FIG. 21, is further detailed in FIG. 28. Information concerning one or more of the originating node, recipient node, and network or group channel organization flow into a pilot signal generator, and the resulting pilot signal is further modified by a network code mask. This multilayer mask then is used to form a signal with a pseudorandom sequence that is shared by all nodes in the same network or group, though the sequence may vary over channels and MT symbols to allow further coordination amongst them at the receiving end. Passing on the signal is modified in an element-wise multiplication (typically a matrix operation, embedded in hardware) by a signal that indexes on the originating node,

which in an optional variation includes a nodal pseudodelay, unique to that node in the network or group, which overlay again may vary over channels and frames to improve security. The originating node index overlay is a complex, exponential phase ramping. The combined signal now mixes with a recipient node index, another pseudorandom sequence that is unique to the recipient node, modifying the whole in a second element-wise multiplication. Thus the final pilot tone reflects the content signal, modified to uniquely identify both the originating node and its context, and the receiving node and its context, effecting a signal composition that allows the network to pilot the communication through the network from origin to destination regardless of the intervening channels it takes.

560. EX-1004, 58:16-42.

561. As shown above, Fig. 37 uses $x_0(1,1)$ to $x_0(K,1)$ where $1-K$ is the number of tones.

EX-1004, 65:24-46 (“K is the number of tones used in a single FFT-base LS algorithm” used to calculate “combiner weights.”).

562. Thus, Agee is teaching that each separate tone sent at a separate frequency with the tones received simultaneously consists of different information which is used to determine the weights for beamforming.

563. Based on the pilot tones received (on each frequency used for the OFDM tones) on each antenna simultaneously, Agee calculates the “combiner weights W ... used in subsequent data recovery operations.” EX-1004, 67:3-28.
564. Figure 35 (which is shown above) shows receiving data (including the pilot symbol tones) at the top in blocks 588 and 590, the weights’ calculation (block 594 which corresponds to the detailed calculations shown in Fig. 37) and subsequent using the calculated weights to receive data (element 600). Agee describes this at 66:21-67:27.
565. Figure 36 shows the same process for transmitting data using the calculated weights (block 630). The “combiner weights W ” are used to form beams and nulls for receiving and transmitting data. EX-1004, 67:43-55 (quoted in 1.7, *infra*).
566. Agee’s Fig. 30 demonstrates that the “combiner weights W ” are applied to the received RF data to recover the received information using a “Multilink Adaptation Algorithm.” EX-1004, Fig. 30, 36:30-34. The description of Figure 30 teaches (consistent with Figs. 35-37 above) that the received pilot data tones (“ x ”) is received by the FFT-LS algorithm to calculate the weights based on each OFDM tone (1 to M).

When a communication is transmitted, it will be received;
and the MIMO reception is, like the transmission,
adaptive. See FIG. 30, detailing the logical processing
involved. Received data passes through both a

Multilink weight adaptation algorithm and (to which that part is combined) a Multilink diversity combining of the Reception weights. ... These sort out the properly weighted tones, ... The received symbol $[x](i,1)$, comprising a matrix combination of L Link and M **multitone** elements, ... The pilot signal elements are passed through a link detection circuit that preferentially uses a FFT-LS algorithm to ... **identif[y] the weighting elements that were contained in the pilot signal** and passes those over to the multilink combination circuit, ...

567. EX-1004, 58:43-59:21.

568. Agee expressly confirms that the Butler matrix output is the input to the algorithms described in Fig. 30.

From the Butler Mode Forming element received signals are first passed through the frequency channel bank, then mapped to the FDMA channels. The received data on channel k will be passed through both the Multilink Receive weight adaptation algorithm and the Multilink diversity combining, Receive weights $W(k)$ element, which in turn both feed into the Multilink LEGO gain adaptation algorithm and thus feed-back into the multilink diversity distribution element for outgoing transmissions. The Multilink Receive weight adaptation algorithm passes the adapted data from channel k over to the Multilink Diversity combining, Receive Weights $W(k)$ element

Declaration of Dr. Mark P. Mahon

passes on the signal to ... be turned into the information which had been sent out from the originating transceiver, the inverse process, generally, from the symbol encoding at the transmission end.

569. EX-1004, 57:25-43.

570. This is also described by Agee for the transmission path:

The Transceiver DSP backend for the preferred embodiment is detailed in FIG. 15. The Butler Mode Forming element with its RF transmission and reception leads, is controlled by the T/R switch control, which in turn is subject to the system clock and synchronization subsystem. An transmission signal (which can be continuous, periodic, triggered, human-determined, reactive, context-sensitive, data quality or quantity sensitive) that forms a Tx link message passes through a symbol encoder bank and into the circuitry where Delay/ITI/pilot gating are imposed, said circuitry being linked to its reciprocal for received signals. The transmission data symbols, over k channels, now pass through the multilink diversity distribution circuitry, where for each channel k transmission gains $G(k)$ are adapted to the proper weighting, as determined by the multilink, LEGO gain adaptation element (with both algorithms and circuitry). From the multilink diversity distribution the transmission next is mapped over diversity

modes and FFT bins, then handed to the transmission/reception compensation bank. Here, according to the perceived environment of transmissions and reception and the particular Transmission/Reception compensation algorithm used, the transmission is passed to the inverse frequency channel bank and, finally, into the Butler Mode Forming element. This Transceiver DSP backend also passes the information about the transmission signal from the compensation bank element to the synchronization subsystem.

571. EX-1004, Fig. 15, 48:19-46.

572. Agee uses the different signal informations (the signal strengths received on the different antennas in the Butler matrix including for the different OFDM tones transmitted / received simultaneously using different frequencies) to calculate weights used for receive and transmit beamforming.

[1.7] wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals;

573. As shown in element 1.6, Agee calculates “combiner weights” (“receiver weights”) used to create beams to receive and transmit information. These “combiner weights” are used as “distribution weights” (“transmit weights”) for transmissions or as the basis for calculating distribution / transmit weights. This is shown in the discussion above regarding Figured 36 and 37.

574. Based on its reliance on the reciprocal nature of the channels, Agee uses the weights calculated for the receive beam as the weights also used for transmissions.

For example, Agee claims this usage of the weights:

17. A method as in claim 1, wherein dynamically adapting the diversity capability means and said proper subsets to optimize said network further comprises

using at each node the receive combiner weights as transmit distribution weights during subsequent transmission operations, so that the network is preferentially designed and constrained such that each link is substantially reciprocal,...

575. EX-1004, claim 17;

576. Such an arrangement is also recited in claims 43 and 56 in which the receive weights are “optimized” to be the transmit weights. EX-1004, claims 43, 56. *See also* EX-1004,

577. Unsurprisingly, Agee’s specification also teaches this reciprocity of using the calculate receive weights as part of the transmission processing. 32:64-67 (“each node use[s] the receive combiner weights as transmit distribution weights during subsequent transmission operations...”), 57:30-33, 68:20-31, 60:27-29, 78:66-79:11, 56:41-55, 33:13-19, 72:20-59.

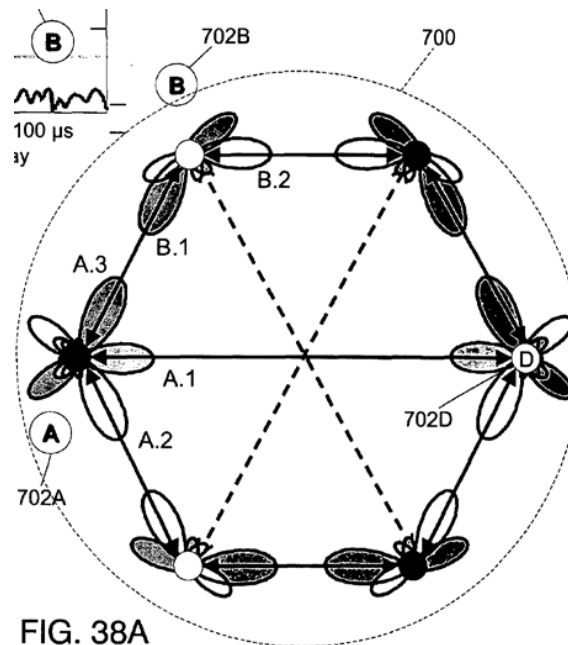
578. Agee expressly teaches that the weights are used to form beams. For example, Agee teaches that the “combiner weights W” (and the distribution / transmit weights) form beams and nulls for reception and transmission:

The optimized combiner weights are substantively null-steering, in that the **combiner weights** associated with each originating signal will (notionally, in absence of multipath) **form a composite antenna pattern that steers nulls in the direction** of all other time-and-frequency coincident signals (**signals transmitting on the same time slot and frequency channel**) impinging on the array. However, the **weights will also** (notionally, in absence of multipath) **form a beam** in the direction of the originating signal, further improving performance of the overall network.

579. EX-1004, 67:43-55. Agee’s language regarding “steer[ing]”, “peaks” and “nulls” matches the same language that the later ‘235 patent used. EX-1001, 6:61-7:4 (“steering”), 6:1-9 (“peaks”), 6:10-26 (“nulls”), 5:55-67, 26:32-44.

580. Notably, the language of Agee that the weights “form a composite antenna pattern that steers nulls in the direction of all other time-and-frequency coincident signals (signals transmitting on the same time slot and frequency channel)” confirms that the beam weights are calculated for each OFDM tone (“time slot and frequency channel”).

581. Fig. 38A depicts the beams and nulls graphically:



582. EX-1004, Fig. 38A. The description of this Figure includes that it shows null steering. EX-1004, 36:59-64.

583. Agee repeatedly teaches that the weights are used to form beams. EX-1004, 51:56-52:8 (“The reciprocity equation insures that the optimal transmit weights puts substantive nulls in the direction of these same co-channel interferers...”).

A POSITA would understand Agee’s language to be referencing the creation and usage of beams for receive and transmit operations in light of Agee’s disclosure. Digital beamforming is used to process the signals received by the adaptive antennae array and to separate interference and noise from genuine signals received from any given direction. For a receiving station, received RF signals at

each antenna element in the array are sampled and digitized. The digital baseband signals then represent the amplitudes and phases of the RF signals received at each antenna element in the array. Digital signal processing (DSP) techniques are then applied to the digital stream from each antenna element in the array. The process of beamforming involves the application of weight values to the digital signals from each antenna element ('transmit weights'), thereby adjusting the numerical representation of their amplitudes and phases such that, when added together, they form the desired beam—i.e. the desired directional receive sensitivity. The beam thus formed is a digital representation within the computer of the physical RF signals received by the antennae array from any given direction. The process of null steering at the transmitter is used to position the spatial direction of null regions in the pattern of the transmitted RF energy. The process of null steering at the receiver is a DSP technique to control the effective direction of nulls in the receiver's gain or sensitivity. Both processes are intended to minimize inter-beam spatial interference.

584. EX-1004, 20:59-21:15.

585. *See also* EX-1004, claims 4, 5, 40, 58, 72-78, 105.

586. Agee's disclosure repeatedly teaches that the weights are used for receive and transmit beamforming.

587. For example,

Further transmission switch processing then hands off the transmission to the frequency translator (FIG. 15, Item 115), which is itself governed in part by the Los circuit (FIG. 15, Item 116). The transmission switch throughout is controlled by a controller (FIG. 15, Item 120) such that baseband link distribution of the outgoing signals takes place such that energy is distributed over the multiple RF feeds on each channel, **steering up to Kfeed beams and nulls independently on each FDMA channel in order to enhance node and network capacity and coverage**. This control further greatly reduces the link fade margin and that node's PA requirements.

From the transmission switch the transmission goes to an ADC bank (FIG. 15, Item 117), while a received signal will come from a DAC bank (FIG. 15, Item 123), the complexity of the analog/digital/analog conversion determining the circuit mix within the banks.

Then from the ADC bank the transmission flows through a Multitone Demodulator Bank (FIG. 15, Item 118), which splits it into 1 through K FDMA channels, where K is the number of feeds. The now separated tones (1 through M for each channel) in aggregate forms the entire baseband for the transmission, which combines spatial, polarization, either, or both, feeds across the FDMA channels or even

combines up to K FDMA channels as transmission data density requires. This combination **enables steering a greater number of beams and nulls than the RF feeds,** up to the number of feeds times the number of FDMA channels. It also separates up to [K]feed links per FDMA channel, improves overall transmission link error and/or retransmission rates, improves overall network capacity and coverage, and reduces the link fade margins, reduces the PA cost, and reduces battery consumption at the other ends of the link.

...

The transmission switch throughout is controlled such that baseband link distribution of the outgoing signals takes place such that energy is distributed over the multiple RF feeds on each channel, steering up to Kfeed beams and nulls independently on each FDMA channel in order to enhance node and network capacity and coverage. This control further greatly reduces the link fade margin and that node's PA requirements.

588. EX-1004, 46:18-47:5; 49:1-2; 50:53-54; 51:36-55; 52:55-58; 78:21-24.

589. The weights form an aperture matrix that forms beams. EX-1004, 67:13-17, 69:10-23.

590. Thus, Agee discloses this element.

[1.8] cause the transceiver to transmit a third signal to the remote station via the antenna, the third signal comprising content based on the set of weighting values.

591. Agee discloses the element.

592. In light of the intrinsic record of the '235 patent, I understand that the phrase “comprising content based on the set of weighting values” to either include, or be rendered obvious by, applying the weighting values to the content to be transmitted. Agee discloses this through its use of the “distributor” weights (also referenced as the transmit weights) that are applied by box 152 (the “Multilink diversity distribution”) as shown in Figure 24 and as described extensively above for many of the elements 1.4-1.7.

593. The intrinsic record supports my conclusion. As I have discussed above, during prosecution, the applicant argued that the scope of this element was that output signal was formed by applying the determined weights to the output signal. For example, when the the applicant was citing to passages within LittleJoe that disclosed this element, the the applicant cited the following:

Document A, at page A-71, lists several “References” used in compiling Document A. Included in the References list is “[2] Ed Casas, ‘Beamforming for LittleJoe’, ViVATO Technical Report, Feb 1, 2002”, which is Document C of the Provisional. At least Document C describes aspects of Applicant’s invention that had been invented at least as early as February, 2002, which is well before Crilly was published (October 31, 2002). As such, at least the disclosure in Document C was invented before Crilly was published, and Crilly is not prior art to such disclosure.

As demonstrated by Document C, at least the limitations that the Office Action contends are taught by Crilly were invented by Applicant prior to Crilly’s publication.

For example, with respect to independent Claim 1 (and OA at pp.6-7) Doc C describes:

....

- cause the transceiver to generate a third signal comprising content based on the set of weighting values
 - C-1: “This signal level information is used to compute the complex weights for a second RF beamformer. This so-called ‘card 13’ beamformer allows independent complex weights on each array element. This beamformer is connected to an additional WLAN card which is the one actually used for communication (it can transmit and receive).”
 - C-4: “The beamforming algorithm computes the beamforming weights for a particular client (identified by its wireless MAC address) and stores it in a table which is made available to the application running the modified (polling) MAC protocol on ‘card 13’”.

594. EX-1002, 000131. As is apparent from the applicant’s statements above, during prosecution, it was asserted that this “content based on the set of weighting values” was merely the application of the computed beamforming weights.

595. As a further check for my understanding, I understand that, in other District Court litigation, PO argued that any other construction “excluded the preferred embodiment.”

During patent prosecution, the patentee stated that “transmitting to the remote station a third signal comprising content based on the set of weighting values” covers the embodiment in Document C describing “compute the complex weights for a second RF beamformer.” Dkt. 42- 22, Office Action Response (July 25, 2018).

596. EX-1016, 000012 (citing to prosecution history excerpt quoted above).

597. However, based upon what the applicant successfully argued, this claim element apparently does not require that the “content” of the signal be the actual computed weights. Rather, the “content” is “based” on the weights by calculating and applying the weights to the content.

598. My analysis is further informed by the content of the ‘235 specification. I have not identified (nor have I seen any identification of) any passage in the ‘235 patent in which the actual weights are transmitted between devices. Instead, the weights are calculated and used by the same device that calculated the weights as adjustment to the transmitted data to form beams. Thus, the ‘235 patent does not include any disclosure of transmitting the weights.

599. Agee discloses this for the same reason as cited for Littlejoe above and for the same reason that this element is disclosed in the ‘235 patent (to the extent it is).

600. As I repeatedly discussed above for the other elements, the computed “combiner” (or “receive”) weights are used as distributor / transmit weights. They are applied in, for example, element 152 of Figure 24 as detailed above. See also EX-1004, 48:19-45, 57:25-47, claims 40, 180.

601. Agee’s output data is modified by the weights (as shown in elements 1.6-1.7 above) before it is transmitted (elements 1.4-1.7 above) and therefore meets this element.

b. Claim 2

- [2] The receiver as recited in claim 1, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.

602. Agee, alone or in combination with Butler, discloses this limitation for the reasons set forth for limitations 1.5 - 1.7.

603. I have detailed above that Agee's received signal transmissions using the Butler matrix comprise transmission peaks and nulls in the beams formed by the antennas and the Butler matrix circuitry.

604. As I have noted repeatedly above, Agee teaches that each node uses beam-forming on both the transmit and receive paths as detailed above – as shown in Fig. 38A.

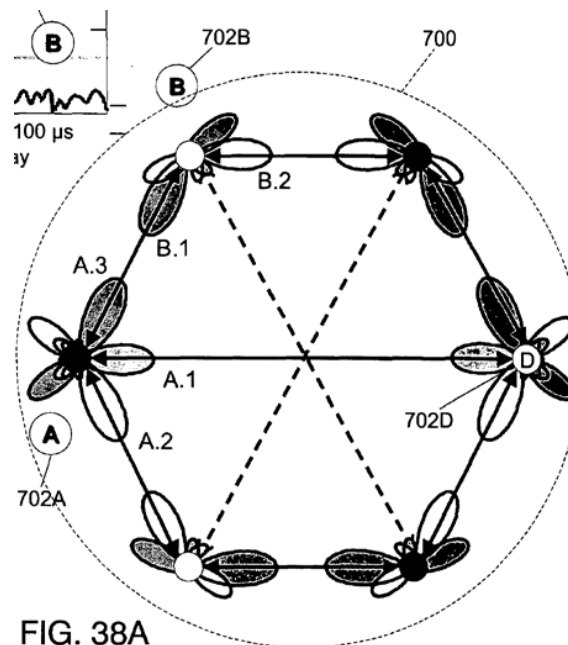


FIG. 38A

605. EX-1004, Fig. 38A. Thus, the signals being received are “transmission peaks and nulls” being formed by the other nodes when those nodes transmit the data being received. EX-1004, 67:43-55.

606. Thus, in Agee, both ends of the transmission are using beamforming which creates peaks and nulls in the transmissions / receptions between the different nodes. This includes for the individual OFDM tones as I have detailed above.

607. In this regard, Agee teaches far more regarding this particular element than is taught in the ‘235 patent.

608. The ‘235 patent does not describe any “remote station” that simultaneously transmits two “signal transmissions” that comprise peaks and nulls. I have not located any disclosure in the ‘235 patent indicating that beamforming is done by the remote station.

609. As I have noted above, at most, the ‘235 patent discloses the use of a Butler matrix to form receive beams (peaks and nulls) on the “receiving” side and then use those weights to form transmit beams back to one or more of the remote stations.

610. Agee discloses that same Butler matrix to determine the receive beams *and* a Butler matrix on the transmitting node (e.g., the remote station in the claims) (which is not disclosed in the ‘235 patent) and thus discloses this element in far greater detail and with far greater disclosure than the ‘235 patent does.

611. Moreover, Agee (unlike the ‘235 patent) teaches the OFDM transmissions using the tones at different frequencies simultaneously transmitted and received.

c. Claim 3

[3] The receiver as recited in claim 2, wherein the first signal transmission and the second signal transmission are directional transmissions.

612. As discussed for elements 1.3-1.6 and claim 2, Agee discloses each node forms beams (receive and transmit). These beams carry the first / second signal transmissions and thus disclose (including rendering obvious) “directional transmissions” at least as how that term is used in the ‘235 patent.

613. For example, the ‘235 patent states:

The wireless communications may be transceived directionally with respect to one or more particular communication beams 214. The multi-beam directed signal system 206 can be implemented for multi-channel directed wireless communication. For example, client device 202 can communicate via directed communication beam 214(1) with a first channel of the multi-beam directed signal system 206, and client device 204 can communicate via directed communication beam, 214(N) with a second channel of the multi-beam directed signal system 206.

614. EX-1001, 5:12-20. This links the “directional” transmissions to directed beams.

Similarly, the ‘235 patent states:

The directed communication beams 214 of antenna array 302 can be directionally controllable, such as steerable in an analog implementation or stepable in a digital implementation. For example, a directed communication beam 214 can be directionally stepable by the width (e.g., degrees) of the communication beam to “steer” or “aim” addressable data packets when communicating with a client device. Further, a communication beam 214 can be directionally controllable such that only an intended client device will receive a directed wireless communication via the communication beam 214, and such that an unintended recipient will not be able to receive the directed wireless communication.

615.

616. EX-1001, 6:61-7:21. This passage explains how the beams are “directionally controllable” such as through using the ability to “steer” the beams (which matches the Agee disclosure that I have discussed above).

Forming directional transmit communication beams has the side effect of hiding the transmitted energy from some client devices in a CSMA network (i.e., negatively impacting the carrier sense mechanism in the network). A

client device measures the energy transmitted from access points and from other client devices. If the client device cannot detect the presence of other transmissions, it attempts to access the medium. Therefore, when directional communication beams are used, many client devices detect the medium as idle when in fact it is busy. This has an effect on the performance of the network and is referred to as the “hidden beam” problem

617. EX-1001, 26:45-56. This passage is from the one embodiment in the ‘235 patent that describes the use of weights for beamforming. It expressly links “directional” with the communication beams.

618. As noted for claim 2, the ‘235 patent does not disclose any instance of a remote station transmitting simultaneously two different signals that are “directional signals.” As with claim 2, the ‘235 discloses (at most) using a Butler matrix to form beams (directional signals) on the receive side. Agee has this same content, as well as directional beams on the transmit side as I have discussed for claim 2, and therefore teaches this element and furthermore has the directional transmissions occurring in the other nodes (the remote stations) as well.

619. Furthermore, I have quoted and detailed above Agee’s ability to “steer” the beams (nulls and peaks). EX-1004, 20:25-22:14, 32:17-44, 33:38-55, 36:59-63, 46:18-47:5, 63:4-12, 64:28-42, 67:43-55, claims 40, 180. These are all examples of the claimed directional transmissions.

d. Claim 4

[4] The receiver as recited in claim 1, wherein the content comprises data configured to be used by the remote station to modify the placement of one or more transmission peaks and one or more transmission nulls in a subsequent signal transmission.

620. Agee, alone or in combination with Butler, discloses this limitation.

621. One example of the claimed “data configured to be used by the remote station...” is the pilot signals that each Agee BS transmits to the other BSs. This pilot signal data is referenced also using related terms such as “pilot tone data,” “pilot data,” “piloting signals,” “pilot tone transmissions,” or “pilot symbols.” EX-1004, Abstract, Figs 21, 35-38, 30:56-64, 65:4-67:4.

622. As I have discussed above, the “pilot signals” are specifically used to construct the receive weights by performing the algorithms identified in, for example, Figures 35-37 and disclosed at 63:4-67:35. This is detailed above in elements 1.4-1.7. Each of the nodes has their own unique pilot symbol which is sent with its own unique pseudodelay to help identify and sort the different links and nodes and to perform spatial separation.

623. I further note that the ‘235 patent does not include any disclosure of the content of any communication being the weights themselves.

624. As detailed in elements 1.4-1.7, Agee’s BS’s use the pilot signals received from other (transmitting) BS’s to calculate receive weights. As detailed in elements 1.7-1.8 and claim 2, those receive weights are used for transmit weights that form beam-

formed transmissions that modify the placement of peaks and nulls in subsequent transmissions.

e. Claim 5

[5] The receiver as recited in claim 4, wherein the set of weighting values is further based on one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data.

625. Agee, alone or in combination with Butler, discloses this limitation for the reasons for limitations 1.3 – 1.6. As noted therein, Agee discloses at least the transmit power level (in the same way as the ‘235 patent using the Butler matrix), the antenna direction (reflecting the receive beams’ direction), frequency data (OFDM tones at different frequencies), and timing data (in the ability to located the “observed timing offset” for the pseudodelay to detect the specific node from which data is being received, and quality of service data (the “link quality statistics”).

f. Claim 8

[8] 8. A method in a wireless communications system, the method comprising.

626. See claim 1. The wireless communication system is Agee’s disclosed network.

[8.1] receiving a first signal transmission from a remote station via a first antenna element of an antenna and a second signal transmission from the remote station via a second antenna element of the antenna simultaneously, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls;

627. I have discussed above for elements 1.4-1.7 the reasons that Agee discloses the claimed signal transmissions (including simultaneously as required) and how those transmissions comprise peaks and nulls.

628. The peaks and nulls result both from Agee's BS using receive and transmit weights to form such peaks and nulls and also from Agee's other nodes using transmit and receive weights to form such peaks and nulls.

[8.2] determining first signal information for the first signal transmission;

[8.3] determining second signal information for the second signal transmission, wherein the second signal information is different than the first signal information;

629. I have discussed these limitations in elements 1.4 – 1.5 above.

[8.4] determining a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the remote station to construct one or more beam-formed transmission signals; and;

630. Agee, alone or in combination with Butler discloses this element. I have discussed above for elements 1.6 – 1.7 that Agee determines a set of weighting values based on the first and second signal informations discussed above in elements 1.4-1.5.

631. Regarding the clause “configured to be used by the remote station,” based on the intrinsic record, Agee discloses (including renders obvious) this element.

632. I note that the applicant stated that this element was met by the calculation of beam-forming weights. When citing to LittleJoe during the prosecution of the Challenged Claims, the applicant stated the following to the Examiner

Document A, at page A-71, lists several "References" used in compiling Document A. Included in the References list is "[2] Ed Casas, 'Beamforming for LittleJoe', ViVATO Technical Report, Feb 1, 2002", which is Document C of the Provisional. At least Document C describes aspects of Applicant's invention that had been invented at least as early as February, 2002, which is well before Crilly was published (October 31, 2002). As such, at least the disclosure in Document C was invented before Crilly was published, and Crilly is not prior art to such disclosure.

As demonstrated by Document C, at least the limitations that the Office Action contends are taught by Crilly were invented by Applicant prior to Crilly's publication.

For example, with respect to independent Claim 1 (and OA at pp.6-7) Doc C describes:

...

- determining a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the remote station to construct one or more beam-formed transmission signals
 - C-4: "The beamforming algorithm computes the beamforming weights for a particular client (identified by its wireless MAC address) and stores it in a table which is made available to the application running the modified (polling) MAC protocol on 'card 13'".

633. EX-1002, 000130-000131.

634. Thus, the applicant had stated, and the Examiner apparently agreed, that the calculation of weights by the station receiving the first and second signal information (e.g., Agee's BS) was sufficient to disclose this element. As detailed above, Agee includes such disclosure.

635. I also am aware of the arguments that PO made during litigations before the District Court directed at previous defendants. Before the District Court, PO argued that this element merely required the preparation of weights.

[C]laim 8 does not require the successful combination with the remote station, much less that the remote station actually use the weighting values... a POSITA understands that this only requires that the device that is performing the method of claim 8 *prepare* or *arrange* the set of weighting values ...

636. EX-1015, 000028. According to PO this limitation merely “requires that the set of weighting values be determined for *that* remote station based on *that* station’s received signals.” EX-1015, 000028-000029. PO further argued:

[C]laim 8 ... only requires that weighting values be prepared or arranged for use by another station, regardless of whether that station will succeed in using them. Moreover, preparing a set of weighting values for use by another station is performed entirely within “access station 102” without any combination with a remote station. **For example, “access station 102” prepares the set of weighting values for use by a remote access station (e.g., “nodes within the wireless routing network”) by computing the weighting values that are associated with received signals from that remote access station.**

Declaration of Dr. Mark P. Mahon

637. EX-1016, 000013-000014. Notably, the ‘235 patent does not include any embodiment in which the weights are transmitted between network entities.
638. The District Court adopted PO’s construction and appeared to (at least implicitly) reject the Defendants’ position in those cases. EX-1017.
639. During IPR2022-00367, PO cited the District Court’s construction that were based on PO’s arguments above. EX-1012, 000012-000013.
640. Agee discloses this element for the same reasons cited in prosecution (and to the District Court). Agee discloses (including renders obvious) this element “by computing the weighting values that are associated with received signals from that remote access station” – exactly as PO argued to the District Court that this element was met. I have described Agee’s process above for calculating weights based on the signals in elements 1.4 – 1.7.
641. At the bare minimum, because Agee operates in exactly the same way that PO argued meets the claims, Agee renders this element obvious.
642. Furthermore, even if the claims required that the data being transmitted between the nodes to be the weights themselves, Agee’s teachings render this obvious. Agee teaches reciprocity in which the expectation is generally that the channels between the two nodes have the same general conditions. Thus, a POSITA would recognize that if Agee transmitted its weights, then other BS (e.g., the claimed remote station) could use those weights for its own beamforming because of the reciprocal channel

conditions. The benefits would include that the other station (whether a BS or SU) would not need to have the independent capacity to calculate the weights. For example, if the other station was a SU, it might have a smaller processor and/or run on batteries. Thus, transmitting the weights would achieve efficiencies and save on battery power as opposed to calculating the weights.

643. Moreover, Agee teaches that, because of reciprocity, the transmit weights used by Agee's BS would be the same as the receive weights used by the remote station (*e.g.*, another Agee BS as shown in Fig. 38A). 32:44-33:38, 62:56-64:27; Figs. 13A, 13B. Each of Agee's BS's have the capacity to employ the weight calculation. EX-1004, 72:20-28. Moreover, in Agee, each side of the transmission (transmitting and receiving) seeks to place the same "nulls" and "peaks" (form the same beams). EX-1004, Fig. 38A, 76:46-51, 32:17-27, 67:42-55. Such reciprocity either discloses this element or, at a minimum, renders this element obvious because the weights that are calculated are configured to be used by the remote station (because of reciprocity) even if those weights are not transmitted to, or used by, the remote station.

[8.5] transmitting to the remote station a third signal comprising content based on the set of weighting values.

644. I have discussed this in element 1.8 above.

g. Claim 9

**[9] The method as recited in claim 8, further comprising:
transmitting the third signal to the remote station via the antenna.**

645. Agee, alone or in combination with Butler discloses this claim for the reason discussed for limitations 1.8. Agee transmits data transmissions using the same antennas and through the same Butler matrix as used for receiving as discussed in limitations 1.3-1.7.

646. For example, Agee's separate OFDM tones are separate transmissions as I have noted above. So, each tone would correspond to another signal.

647. Similarly, future transmissions (for future TDD transmit slots, for example) would meet this claim element as well. Agee does not require the weights to be re-calculated for every receive/transmit TDD slots. Thus, the same weights might be used for successive slots which would also correspond to this claim.

h. Claim 10. The method as recited in claim 8 wherein the first signal transmission and the second signal transmission are directional transmissions.

648. This claim is discussed above for claim 3.

i. Claim 11. The method as recited in claim 8, wherein the set of weighting values is further based on one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data.

649. This claim is discussed above for claim 5.

j. Claim 12

[12] The method as recited in claim 11, wherein the content comprises data configured to be used by the remote station to modify the

placement of one or more transmission peaks and one or more transmission nulls in a subsequent signal transmission.

650. This claim is discussed above for claim 4.

k. Claim 15

[15] 15. An apparatus for use in a wireless communications system, the apparatus comprising: an antenna

651. See claim 1 and elements 1.0, 1.1.

[15.1] a transceiver operatively coupled to the antenna;

652. I discussed the transceiver for element 1.1 above.

[15.2] a processor operatively coupled to the transceiver, the processor configured to:

653. This element is discussed above for element 1.2 (and its functionality in 1.3 – 1.8).

[15.3] receive a first signal transmission from a remote station via the antenna;

[15.4] the first signal transmission comprising first signal information, wherein the first signal information comprises one or more of: a transmit power level, a data transmit rate, an antenna direction, quality of service data, or timing data;

[15.5] receive a second signal transmission from the remote station via the antenna, the second signal transmission comprising second signal information;

654. These limitations are discussed in elements 1.3 - 1.6, and claim 5. Elements 1.4 – 1.5 and claim 5 detail that the “first signal information comprises” multiple different recited options as discussed in this claim.

[15.6] determine a set of weighting values based on the first signal information and the second signal information, wherein the set of weighting values is configured to be used by the transceiver to construct one or more beam-formed transmission signals;

655. Limitation 1.6 above explains how the signal informations are used to determine the weighting values. Limitation 1.7 explains how the weighting values are used to construct beam-formed transmission signals used for both receiving and transmitting data.

[15.7] cause the transceiver to generate a third signal comprising content based on the set of weighting values.

656. This element is discussed above for element 1.8.

l. Claim 16

[16] The apparatus as recited in claim 15, wherein the first signal transmission and the second signal transmission comprise electromagnetic signals comprising one or more transmission peaks and one or more transmission nulls.

657. This claim is discussed above for claim 2.

m. Claim 17

[17] The apparatus as recited in claim 16, wherein the processor is configured to receive a fourth signal transmission from an interferer source, the fourth signal transmission being undesired, and the processor is configured to store identifying information concerning the undesired interferer source and the remote station.

658. Agee, alone or in combination with Butler, discloses this limitation.

659. In Agee, each “node” has “links” to multiple other nodes. EX-1004, 38:13-25.

For example, Fig. 38 shows that node 702A has “links” to three other “nodes as highlighted below with the links being identified as A.1, A.2, A.3.

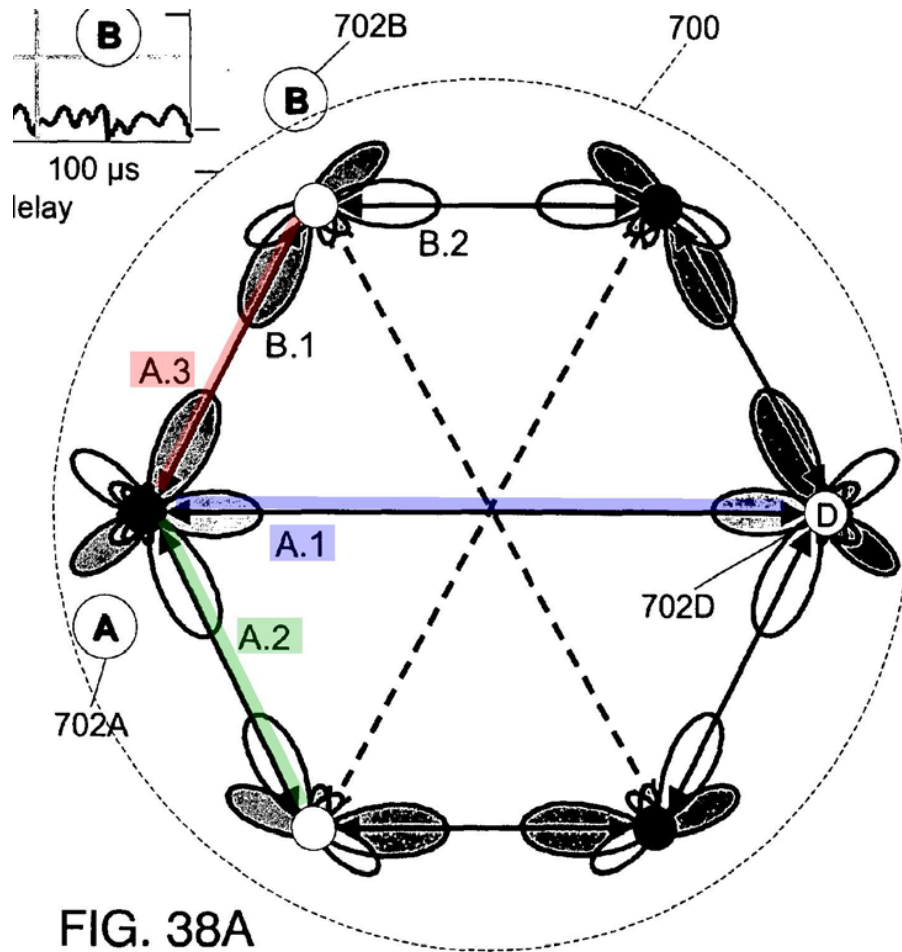


FIG. 38A

660. EX-1004, Fig. 38A. *See also* EX-1004, Figs. 13, 16, 18-19, 39-40.

661. Agee stores “identifying information” about each node that includes, for example, the “known” pilot data for each node as well as the “pseudodelay” discussed in element 1.4-1.6 above. EX-1004, 64:43-67:28, 58:16-67, claim 53. Agee describing using “pseudodelays” that “can be unique to each transmit node” and include specific

time offsets for each of the different nodes. EX-1004, 65:24-46; 58:29-42, 66:21-67:15 (“target pseudodelay”).

662. Furthermore, Agee’s BS stores the identifying node information for every node (not just directly connected nodes) because data might be passed through “intervening” nodes to its destination. EX-1004, 58:16-42

663. Moreover, even if Agee did not teach storing the identifying pseudodelay and known pilot data for each node in the network, storing “identifying information” for each node in a network would be, at most, an obvious modification to Agee. Agee already has the capability to store and provision such information for a (not limited) subset of nodes. A POSITA would have recognized that adding the additional information for all nodes would require little incremental storage (as opposed to the overall existing storage) and would allow for nodes to be rapidly added to the network without addition provisioning and for links to be added between existing BS even when such direct links did not previously exist.

664. When Agee is calculating the “weights” for a particular link (to a particular node), the transmissions from the other nodes are considered as interference – thus making those other nodes an interfering source. So, for example, when detecting link A.1 above and calculating the weights specific to A.1 (for node D), the transmissions on links A.2 and A.3 constitute interference to the weight calculation for A.1. This is shown in, for example, Figure 34 which shows “Interfering BSs” and “Interfering

SUs.” It is also shown in Figure 19 with interfering non-network nodes (item 275). EX-1004, 35:46-52. Agee attempts to mitigate “interferers” including “co-channel interferers” including by “put[ting] substantive nulls in the direction of these same co-channel interferers.” EX-1004, 51:62-52:8. See also EX-1004, 75:43-67, 50:49-59, 63:4-64:42

665. For that reason, the calculation of those weights (for each node / link) results in “nulls” being directed toward those other interfering sources (the other nodes with links). EX-1004, 51:57-67 (“...The reciprocity equation insures that the optimal transmit weights puts substantive nulls in the direction of these same co-channel interferers.”); 67:42-55 (“combiner weights are substantively null-steering....”); 69:10-22; claims 40, 98, 110; EX-1004, 32:17-27; 46:43-45; “[N]ull steering at the receiver is a DSP technique to control the effective direction of nulls ... intended to minimize inter-beam spatial interference)” EX-1004, 21:12-15. *See also* EX-1004, 4:2-5, 19:63-67; EX-1004, 76:47-51 (“the nodes in the preferred embodiment direct nulls (hard or soft) at all observed [t]ransmission nodes in other networks, to minimize the interference from and with the other network’s signals...”).

666. The analogous calculation occurs when calculating weights for link A.3 (A.1 and A.2 are interference) and A.2 (A.1 and A.3 are interference).

667. Thus, when Agee’s BS calculates weights for link A.1, the BS “store[s] identifying information concerning the undesired interferer source (each other node

in Fig. 38A) and the remote station (node D)” as claimed. This identifying information includes the pilot delay and pseudo delays for the other nodes (both the nodes with direct links and nodes without).

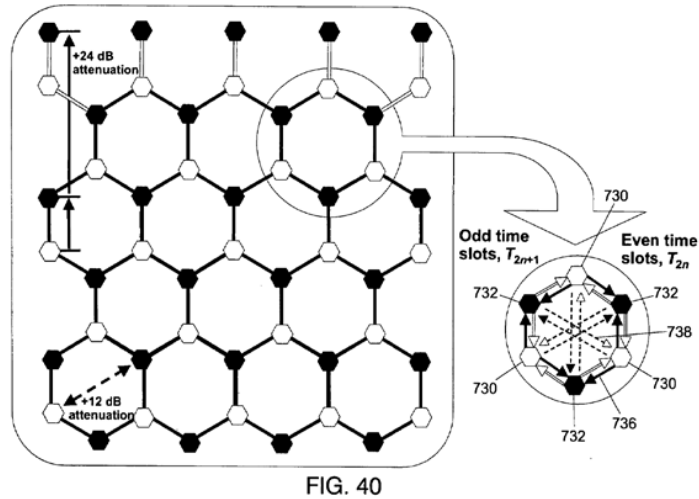
n. Claim 18

[18] The apparatus as recited in claim 17, wherein the processor is configured to identify a further interferer signal transmission from the interferer source, and to identify a further desired signal transmission from the remote station, wherein the processor is further configured to prevent the transceiver from transmitting a fifth signal transmission via the antenna during reception of the further desired signal transmission but to allow the transceiver to transmit a sixth signal transmission via the antenna during reception of the further interferer signal transmission.

668. Agee, alone or in combination with Butler, discloses this limitation.

669. As an initial matter, Agee includes “desired signals” in the form of the transmissions received by the antennas through the Butler matrix and which includes each OFDM tone which is a separate signal at a separate frequency conveying separate information used as described above for claim 1.

670. Agee discloses this claim in its usage of the TDD system in which different nodes transmit and receive in alternating time slots. Fig. 40 shows different time slot allocations for BS’s.



671. EX-1004, Fig. 40. As shown above, the white circles and black circles represent nodes (BSs) that transmit and receive on different slots.
672. An example of one of these hexagonal arrangements of BS's is shown in Fig. 38A in which there are different slots identified for the different nodes (based on being a white circle or a black circle).

in the form of the radio waves regardless of whether the BS A is sampling and using that energy induced on the antenna during its transmit time slot as a result of the transmissions from the other black circle nodes.

o. Claim 19

[19] The apparatus as recited in claim 15, wherein the set of weighting values are applied to the third signal, and wherein the transceiver is configured to receive a fourth signal transmitted from the remote station, and the processor is configured to apply the set of weighting values to the fourth signal.

676. Agee, alone or in combination with Butler, discloses this limitation for the reasons discussed for limitation 1.3 – 1.7. As noted above, the weights that are calculated in Agee are used for receiving and for transmitting.

677. For example, that “combining weights” are used by Agee’s BS to process the pilot signal and then any subsequent data transmissions from a particular remote station until another pilot symbol is received (which results in the weights being updated / adapted). EX-1004, Fig. 24, 48:19-46, 57:25-43, 58:43-59:22, 67:3-27 Figs. 35-37, claim 40. Agee does not require each TDD slot to start with a new pilot and thus the previously calculated weights would continue to be used until a new pilot signal appears during the TDD slot.

XI. SECONDARY CONSIDERATIONS DO NOT REBUT THE PRIMA FACIE CASE OF OBVIOUSNESS

678. In my opinion, secondary considerations do not rebut the prima facie case of obviousness for at least two reasons. *First*, I have not seen any evidence of any secondary consideration to date.

679. Indeed, Patent Owner never proffered such evidence during prosecution of the ‘235 patent, or any of the IPRs.

680. For example, in IPR2022-00367, which proceeded to trial, PO’s Response Brief made many arguments against obviousness. However, PO’s Response brief did not include any citation to secondary considerations.

681. To the extent Patent Owner seeks to proffer secondary considerations evidence in this proceeding, I reserve the right to comment on such evidence.

682. *Second*, I do not believe that Patent Owner will be able to establish a nexus between any secondary consideration and the challenged claims. I have been advised that a nexus does not exist where the alleged secondary consideration results from something other than what is both claimed and novel in the claims.

683. As I explained above, there is nothing novel in the claims. Indeed, all claim elements are disclosed in the prior art. Thus, I do not see a basis for Patent Owner to assert that there is a nexus between any secondary consideration and the claims.

684. Moreover, as I have discussed before, the prosecution of the ‘235 patent would indicate that the purported basis for non-obvious and/or novelty was the

“simultaneously” receiving aspect provided by the Butler matrix in the ‘235 specification and in the Littlejoe priority document. However, as detailed above Ground 1 as well as the State of the Art, such usages of Butler matrix technology had existed since the 1960’s to perform the actions cited by the Applicant to the Examiner in support of patentability as discussed in the Prosecution History section above. Thus, there would not be any nexus between any alleged secondary considerations and any patentable aspect of the claims.

XII. CONCLUSION AND DECLARATION

685. 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.

686. 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

Declaration of Dr. Mark P. Mahon

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.

687. 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.

[SIGNATURE ON COVER PAGE]

APPENDIX A – MATERIALS RELIED UPON

Exhibit #	Description
1001	U.S. Patent No. 10,715,235 (the “‘235 Patent”)
1002	Select portions of prosecution history of the ‘235 Patent (“File History”)
1003	Declaration of Petitioners’ Expert Dr. Mark Mahon [This declaration herein]
1004	U.S. Pat. No. 7,248,841 (“Agee”)
1005	U.S. Pat. No. 3,255,450 (“Butler”)
1006	[This exhibit number intentionally omitted]
1007	[This exhibit number intentionally omitted]
1008	U.S. Pat. App. 2002/0158801 (“Crilly”)
1009	U.S. Provisional Application No. 60/423,660 (includes “Beamforming for Littlejoe” priority document at page 134)
1010	Preliminary Patent Owners Response, IPR2022-00367, Paper 7, 04/19, 2022
1011	Patent Owner’s Sur-Reply To Petitioner’s Reply, IPR2022-00367, Paper 9, 6/16/2022
1012	Patent Owner’s Response, IPR2022-00367, Paper 14, October 20, 2022.
1013	[This exhibit number intentionally omitted]
1014	Comparison of Crilly language vs ‘235 language
1015	XR Claim Construction Brief, <i>XR Comm'ns LLC v. Cisco Sys.</i> , No. 6:21-cv-00623-ADA, Dkt. No. 44 (W.D. Tex. May 6, 2022)
1016	XR Sur-Reply Claim Construction Brief, <i>XR Comm'ns LLC v. Cisco Sys.</i> , No. 6:21-cv-00623-ADA, Dkt. No. 47 (W.D. Tex. June 3, 2022)

Declaration of Dr. Mark P. Mahon

1017	Claim Construction Order, <i>XR Comm'ns LLC v. Cisco Sys.</i> , No. 6:21-cv-00623-ADA, Dkt. No. 56 (W.D. Tex. September 30, 2022)
-------------	---

Declaration of Dr. Mark P. Mahon

APPENDIX B – RÉSUMÉ