

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

LG ELECTRONICS INC.

Petitioner,

v.

PANTECH CORPORATION,

Patent Owner.

Case IPR2023-01273

U.S. Patent No. 9,136,924

**DECLARATION OF DR. BERTRAND HOCHWALD
IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 9, 136,924**

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I. INTRODUCTION

1. I have been retained by LG Electronics Inc. (whom I will refer to as “LGE”) to provide my opinions on certain issues related to U.S. Patent No. 9,136,924 (the “’924 patent,” which I understand has been designated as Exhibit 1001) in connection with the above-captioned *inter partes* review (IPR) proceeding. In particular, I have been asked to provide my insights, analysis, and opinions regarding the validity of claims 17-24, and 26-28 of the ’924 patent (“Challenged Claims”), and whether the Challenged Claims are rendered obvious by the prior art references identified below and as to whether persons interested and ordinarily skilled in the subject matter or art exercising reasonable diligence could have located these references. A listing of the Challenged Claims, including the element numbers assigned to each element in those claims, is attached to this declaration as **Appendix C**.

2. I understand the ’924 patent is titled “Transmitting device and a method of communicating therewith, and receiving device and a method of communicating therewith,” identifies as its named inventors Kyoungmin Park, and is currently owned by Pantech Corporation. I have considered the ’924 patent.

3. I understand that the file history of the '924 patent has been designated as Exhibit 1002. I have considered this file history, and I will refer to it as the "'924 File History" or by its exhibit number.

4. I understand that the '924 patent was filed as International Patent Application No. PCT/KR2011/004835 on July 1, 2011. I also understand that the '924 patent claims priority to Korean patent application no. 10-2010-0064573, filed on July 5, 2010.

5. I have considered the prior art cited in my declaration, including:

1. U.S. Patent App. Pub. 2011/0274188 to Sayana ("**Sayana**")¹, titled "Method and precoder information feedback in multi-antenna wireless communication systems," filed April 15, 2011, claiming priority to May 5, 2010, and published November 10, 2011. I understand that a copy of this patent has been designated as Exhibit 1005.
2. International Patent App. Pub. WO2010/050689 to Lee ("**Lee-689**"), titled "Method of controlling interference in a wireless communication system having multiple antennas," filed October 14, 2009 and published May 6, 2010. I understand that a copy of this patent has been designated as Exhibit 1007.
3. 3GPP TS36.213 v8.8.0, *LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (3GPP TS 36.213 version 8.8.0 Release 8)*, 3GPP Technical Specification (2009-10) ("**TS36.213**").

¹ All emphasis has been added unless otherwise indicated.

I understand that a copy of this reference has been designated as Exhibit 1008.

4. 3GPP TS36.211 v8.8.0, *LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (3GPP TS 36.211 version 8.8.0 Release 8)*, 3GPP Technical Specification (2009-10) (“**TS36.211**”). I understand that a copy of this reference has been designated as Exhibit 1009.
5. U.S. Patent App. Pub. 2013/0064129 to Koivisto (“**Koivisto**”), titled “Apparatus, Method and Computer Program Product for Selecting Beam Group and Subset of Beams in Communication System,” filed Jun. 2, 2010 and published March 14, 2013. I understand that a copy of this patent has been designated as Exhibit 1010.
6. R1-102630, *Refinements of Feedback and Codebook Design*, 3GPP TSG-RAN WG1 Meeting #61 (May 10-14, 2010) (“**Ericsson**”). I understand that a copy of this reference has been designated as Exhibit 1011.

6. I am being compensated by LGE at my standard hourly consulting rate of \$675 for my time on this matter. My compensation is not dependent on the outcome of this proceeding.

7. In forming my opinions, I relied on the documents cited in this declaration and the documents identified in the attached **Appendix B**. These documents comprise patents, file histories, printed publications, and other related documents. As discussed below, each document is a type that experts in my field would have reasonably relied upon when forming their opinions. Further, experts in

my field would have had access to each document either through the applicable patent offices and/or well-known libraries, conferences, or publications in the field. My opinions are also based upon my personal and professional experience.

8. In parallel with this declaration, I have prepared declarations for IPR2023-01272 and IPR2023-01267. I also understand that declarations are being prepared by other experts in IPR2023-01269, IPR2023-01270, IPR2023-01271, and IPR2023-01268. Due to overlap in subject matter and prior art references and similarities in corresponding analyses, I understand that some parts of my declaration may bear superficial similarities to documents filed in these other IPRs, but all analysis and opinions presented herein are my own.

II. QUALIFICATIONS

9. My qualifications for forming the opinions in this report are summarized here and also noted in my Curriculum Vitae (“CV”), which is submitted as **Appendix A**.

10. In 1995, I received a Ph.D. in Electrical Engineering from Yale University. My Ph.D. work involved the analysis and processing of electromagnetic and audio signals for the estimation of the location of electromagnetic and audio sources. In 1993, I received a M.A. in Statistics from Yale University. My primary area of study was Signal Processing and Communications. I received a M.S. in

Electrical Engineering from Duke University in 1986, and a B.S. in Engineering from Swarthmore College in 1984.

11. I have twenty-eight years of combined industry and academic experience in the research and design of hardware, software, and systems for various technologies, including electronic devices, sensors, signal and image processing, networking and wireless communications. I have worked in various industry jobs, including at the Department of Defense, Bell Labs, and a start-up in California before joining the University of Notre Dame in 2011. As I explain below, much of my work has been in the general areas of audio/video signal processing and communications.

12. My most recent appointment, starting in 2011, is with the University of Notre Dame, where I am currently a Freimann Chaired Professor of Electrical Engineering. I have taught both graduate and undergraduate classes in signal processing, information theory, communications, and in systems theory. I have also taught courses in electronics, analog and digital signal sensing, processing, computation, and electronic forms of wireline and wireless networking and communications. My primary areas of research include the design and analysis of wireless systems, sensors, and signal processing. I advise graduate students who are attaining Ph.D. degrees through research and coursework. My research work now

includes processing of high data rate signals (similar to those used to transmit and receive coded signals) in communication systems.

13. An example of my current work at the University includes a project that I lead called RadioHound distributed spectrum sensor system for remote monitoring using radio signals (<https://wireless.nd.edu/research/radiohound-distributed-spectrum-sensing/>), which is a multi-year effort involving several students, faculty, and technicians. The RadioHound system captures data from hundreds of sensors and displays it in a real-time setting for human interpretation and assessment. This project, which is funded by government and industrial sponsors, involves the design of hardware sensors, and software communications transceivers. The project has become an educational and research tool used by laboratories inside and outside the University of Notre Dame.

14. Prior to Notre Dame, I worked from 2005-2010 at Beceem Communications, a 4G WiMax and LTE cellular communication chipset start-up company in Santa Clara, California, where I was Chief Scientist and Vice President of Systems Engineering. I was an integral part of the chipset development team. Beceem was bought by Broadcom Corporation in 2010 and no longer exists as a separate company. Several aspects of channel coding and wireless communications for our products were developed within this team.

15. From 1996-2005, I worked at Lucent Bell Laboratories in New Jersey, where I was a Distinguished Member of the Technical Staff doing research into various communication and networking systems. For example, my work in Bell Labs included wireless communications and multi-antenna signal processing and coding.

16. Before Bell Laboratories, I was a Visiting Assistant Professor at the University of Illinois in Urbana-Champaign during the 1995-1996 school year, where I worked on a broad range of research topics related to signal processing and wireless communications.

17. Prior to completing my Ph.D., during 1986-1989 I worked at the Department of Defense as a system engineer for signal processing and wireless communication systems. In this role I designed wireless communication equipment for audio and video signal monitoring and processing. Much of this work is classified for security reasons.

18. As a result of my research, I have obtained 50 patents, and I have published more than one-hundred articles in scholarly journals, many of them within the journals of the Institute of Electrical and Electronic Engineers (IEEE), one of the premier societies for electrical engineers. I have been an invited and plenary speaker at several international conferences throughout the world and have received awards

and recognition for my research and publications. An example relevant publication includes B. Hochwald and S. ten Brink, “Achieving near-capacity on a multiple-antenna channel,” *IEEE Transactions on Communications*, vol. 53, pp. 389-399, March 2003.

19. Since 2012, I have engaged in consulting work as an expert in various litigation matters including acoustic echo cancelling, multi-antenna technologies, cellular and wireless local-area-net standards and technologies, and touch-screen technologies. I have served as an expert on behalf of both plaintiffs and defendants in patent cases. I have served as a technology expert in various aspects of the litigation process, including trade secret disputes, trial testimony, *Markman* hearings, and IPRs.

20. Some of my patents deal with coding for multi-antenna communications. An example is US Patent No. 6,363,121, which describes multidimensional constellations with a unitary structure for transmission across multiple antennas.

III. LEGAL UNDERSTANDING

A. My Understanding of Claim Construction

21. I have been informed that patent claims are construed from the viewpoint of a person of ordinary skill in the art of the patent at the time of the

invention. I have been informed that patent claims generally should be interpreted consistent with their plain and ordinary meaning as understood by a person of ordinary skill in the art in the relevant time period (*i.e.*, at the time of the purported invention, or the so called “effective filing date” of the patent application), after reviewing the patent claim language, the specification, and the prosecution history (*i.e.*, the intrinsic record).

22. I have further been informed that a person of ordinary skill in the art must read the claim terms in the context of the claim itself, as well as in the context of the entire patent specification. I understand that in the specification and prosecution history, the patentee may specifically define a claim term in a way that differs from the plain and ordinary meaning. I understand that the prosecution history of the patent is a record of the proceedings before the U.S. Patent and Trademark Office, and may contain explicit representations or definitions made during prosecution that affect the scope of the patent claims. I understand that an applicant may, during the course of prosecuting the patent application, limit the scope of the claims to overcome prior art or to overcome an examiner’s rejection, by clearly and unambiguously arguing to overcome or distinguish a prior art reference, or clearly and unambiguously disavowing claim coverage.

23. In interpreting the meaning of the claim language, I understand that a person of ordinary skill in the art may also consider “extrinsic” evidence, including expert testimony, inventor testimony, dictionaries, technical treatises, other patents, and scholarly publications. I understand this evidence is considered to ensure that a claim is construed in a way that is consistent with the understanding of those of ordinary skill in the art at the time of the claimed invention. For example, this can be useful for a technical term whose meaning may differ from its ordinary English meaning. I understand that extrinsic evidence may not be relied on if it contradicts or varies the meaning of claim language provided by the intrinsic evidence, particularly if the applicant has explicitly defined a term in the intrinsic record.

1. Means Plus Function Terms

24. I have been informed and understand that certain claim terms can be means-plus-function terms. I understand that a “means-plus-function” term is one that is expressed as a means or step for performing a specified function without the recital of structure, material, or acts in support of that function in the claim. I understand that a term is presumed not to be a means-plus-function term if it is not drafted using the term means. I also understand that a term that connotes sufficient structure to a person of ordinary skill in the art would not be a means-plus-function term.

25. I understand that for means-plus-function terms, the term is construed to cover the corresponding structure, material, or acts described in the specification and equivalents thereof. My understanding of the doctrine of equivalents and equivalent structure is set forth below in Section III.C.

26. If a term is determined to be a means-plus-function term, I understand that the disclosed structure in the specification is deemed to be corresponding structure if the specification or prosecution history clearly links or associates that structure to the claimed function and the disclosure must be sufficient to achieve the claimed function.

B. My Understanding of Obviousness

27. I understand that a claim may be invalid if the subject matter described by the claim as a whole would have been obvious to a hypothetical person of ordinary skill in the art in view of a prior art reference or in view of a combination of references at the time the claimed invention was made. Therefore, I understand that obviousness is determined from the perspective of a hypothetical person of ordinary skill in the art and that the asserted claims of the patent should be read from the point of view of such a person at the time the claimed invention was made. I further understand that a hypothetical person of ordinary skill in the art is assumed

to know and to have all relevant prior art in the field of endeavor covered by the patent in suit.

28. I have been informed that there are two criteria for determining whether prior art is analogous and thus can be considered prior art: (1) whether the art is from the same field of endeavor, regardless of the problem addressed, and (2) if the reference is not within the field of the patentee's endeavor, whether the reference still is reasonably pertinent to the particular problem with which the patentee is involved. I have also been informed that the field of endeavor of a patent is not limited to the specific point of novelty, the narrowest possible conception of the field, or the particular focus within a given field. I have also been informed that a reference is reasonably pertinent if, even though it may be in a different field from that of the patentee's endeavor, it is one which, because of the matter with which it deals, logically would have commended itself to a patentee's attention in considering their problem.

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

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

- A combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results;
- When a device or technology is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or in a different one, so that if a person of ordinary skill can implement a predictable variation, the variation is likely obvious;
- If a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond their skill;
- An explicit or implicit teaching, suggestion, or motivation to combine two prior art references to form the claimed combination may demonstrate obviousness, but proof of obviousness does not depend on or require showing a teaching, suggestion, or motivation to combine;
- Market demand, rather than scientific literature, can drive design trends and may show obviousness;
- In determining whether the subject matter of a patent claim would have been obvious, neither the particular motivation nor

the avowed purpose of the named inventor controls whether the claim is obvious;

- One of the ways in which a patent's subject can be proved obvious is by noting that there existed at the time of invention a known problem for which there was an obvious solution encompassed by the patent's claims;
- Any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed;
- "Common sense" teaches that familiar items may have obvious uses beyond their primary purposes, and in many cases a person of ordinary skill will be able to fit the teachings of multiple patents together like pieces of a puzzle;
- A person of ordinary skill in the art is also a person of ordinary creativity, and is not an automaton;
- A patent claim can be proved obvious by showing that the claimed combination of elements was "obvious to try," particularly when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions such that a person of ordinary skill in the art would have had good reason to pursue the known options within his or her technical grasp; and
- One should be cautious of using hindsight in evaluating whether a claimed invention would have been obvious.

31. I further understand that, in making a determination as to whether the claimed invention would have been obvious to a person of ordinary skill, the Board may consider certain objective factors if they are present, such as: commercial success of products practicing the claimed invention; long-felt but unsolved need; teaching away; unexpected results; copying; and praise by others in the field. These factors are generally referred to as "secondary considerations" or "objective indicia" of nonobviousness. I understand, however, that for such objective evidence to be

relevant to the obviousness of a claim, there must be a causal relationship (called a “nexus”) between the claim and the evidence and that this nexus must be based on a novel element of the claim rather than something in the prior art. I also understand that even when they are present, secondary considerations may be unable to overcome primary evidence of obviousness (such as motivation to combine with predictable results) that is sufficiently strong.

C. My Understanding of the Doctrine of Equivalents

32. I have been informed that there is a “doctrine of equivalents” in patent law that supports a finding of invalidity if a prior art element is equivalent to a claimed element, even if the prior art element is not identical to the claimed element. Equivalence may be established if the prior art element performs the identical function specified in the claim in substantially the same way and produces substantially the same result.

33. I also understand that insubstantial differences between a prior art element and a claimed element—as understood in light of its specification—will not preclude a finding of invalidity. For example, a difference in a number of parts in a prior art element and the corresponding element disclosed in the patent specification may be an insubstantial difference. Similarly, if a prior art element lacks several components of an overall structure corresponding to a claimed function, that

difference may be insubstantial. And, potential advantages of a structure that do not relate to a claimed function should not be considered in an equivalents determination.

34. I understand that the structures, materials, and acts to be considered equivalent or non-equivalent may be described in a patent's specification. A specification may therefore establish a narrow or broad range of equivalents, although an applicant also need not exhaustively describe the full range of equivalents.

D. My Understanding of Written Description and Enablement

35. I understand that the written description and enablement requirements are set forth in Pre-AIA 35 U.S.C. §112. This section provides:

The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

36. I have been informed that to have an adequate written description, the patent must convey with reasonable clarity to a person skilled in the art that, as of the filing date sought, the named inventor was in possession of the invention.

37. I have also been advised that, to demonstrate possession of the invention, the specification must permit a person with ordinary skill in the art to

visualize or recognize the identity of the subject matter purportedly described. Although the specification need not describe the claimed subject matter verbatim to demonstrate possession of the invention, generalized language will not suffice if it does not convey the detailed identity of an invention.

38. I have also been advised that, to have an adequate written description, each limitation of the claimed invention must be disclosed expressly or inherently in the specification. It is not sufficient that the missing claim limitation may be obvious from the specification.

39. To be an enabling disclosure, the specification must adequately disclose to a person skilled in the art how to make or carry out the claimed invention without undue experimentation.

40. The omission of minor details from a patent specification's written description does not cause the specification to fail to meet the enablement requirement. However, when there is no disclosure of any specific starting material or of any of the conditions under which a process can be carried out, undue experimentation is required and there is a failure to meet the enablement requirement that cannot be rectified by asserting that all the disclosure related to the process is within the skill of the art.

E. My Understanding of the Priority Date of a Patent for Prior Art Purposes

41. I understand that for a prior art patent or patent application to be entitled to the priority date of a provisional application to which that patent or patent application claims priority, the specification of the provisional must contain a written description of the invention and the manner and process of making and using it, in such full, clear, concise, and exact terms, to enable a person of ordinary skill in the art to practice the invention claimed in the non-provisional application. To satisfy this requirement, I understand that the disclosure of the provisional application must provide enabling written description support for both the claims of the patent and the subject matter of the patent relied upon for prior art purposes.

42. My understanding is that, similarly, a patent can claim priority to an earlier filing date of a foreign patent application if the patent expressly claims the benefit of the earlier filing date, and if disclosure of the foreign patent application provides support for the claims of the patent. I also understand, however, that a patent reference cannot claim the benefit of a filing date of a foreign priority document to establish the patent as prior art.

IV. BACKGROUND OF THE TECHNOLOGY

43. The '924 patent is generally directed to using “precoders” to reduce interference in transmissions from a base station (*e.g.*, “BS”) to a user equipment

(e.g., “UE”) in cellphone systems that used multiple antennas at the BS and the UE—also referred to as Multiple-Input Multiple-Output (“MIMO”) systems. “Precoders” are selected from a “codebook,” and are used at the transmitting BS to map data bits to transmissions from the BS, as well as tune signals from the BS, to avoid interfering with signals that are being transmitted from other devices over a shared wireless medium. ’924, Abstract (“An embodiment of the present invention relates to a wireless communication system, and more specifically *relates to a wireless communication system using multi-input and multi-output (MIMO) antennas in all transmission and reception terminals.*”), 1:19-51, 3:13-41, 5:10-7:60 (“In addition, *the use of precoding matrices that are predicted to cause inter-cell interference may be restricted by the codebook restriction and thus, the inter-cell interference may be prevented in advance.* In particular, when a beamforming like precoding that is based on a location of each user equipment is performed, a user equipment located in a cell edge may cause serious inter-cell interference. To prevent the inter-cell interference in advance, a codebook restriction may be performed for each cell and thus, the inter-cell interference may be controlled. ...”), 8:7-18, 18:13-19:52 (“FIGS. 8 through 10 are conceptual diagrams illustrating a process of *controlling inter-cell interference using a codebook restriction scheme*”).

in a wireless communication system according to embodiments of the present invention.”), Figs. 1-4, 8-10.

44. The '924 patent describes a communications system in which the UE measures a channel quality of the communication channel from the BS to the UE (for example by analyzing a known reference signal that is transmitted from the BS to the UE). Based on the measured channel quality, the UE provides two channel status information (“CSI”) feedback (e.g., 1st channel status information and 2nd channel status information) to the BS. '924, 6:45-54 (“Also, a *CSI-RS is used as a reference signal that a base station transmits to obtain channel status information (CSI)* of a center cell or adjacent cells from the user equipment 110 in a case of downlink transmission. *The CSI-RS may be used for reporting a CQI (Channel Quality Indicator)/PMI (Precoder Matrix Indicator)/RI (Rank Indicator)*, and the like.”), 7:11-23, Figs. 2-4. For example, each feedback includes a precoding matrix indicator (“PMI”), for example as part of the CSI, that indicates a precoding matrix for the BS to use to tune a corresponding precoder within the BS. *Id.*, 4:6-9 (“*The base station 20 receives precoding matrix indices from each user equipment 10, and selects a MIMO mode or a user equipment or performs precoding based on the received precoding matrix indices.*”). In such systems, both the BS and the UE share known “codebooks” for precoding matrices. The UE selects an indicator of a

precoding matrix from one of the “codebooks” as feedback to the BS. *Id.*, 3:57-4:9 (“*To embody an effective MIMO system, a MIMO wireless communication system may need to provide, to a transmitting device, information associated with a propagation channel or information associated with a precoder or a precoding matrix (hereinafter referred to as a precoding matrix) appropriate for a propagation channel, to increase transmission capacity.*”). In some use cases, certain precoding matrices are predicted to cause inter-cell interference with other cells. ’924, 5:10-19. In such cases, the BS uses “codebook subset restriction” information to indicate a limited subset of the codebook’s precoding matrices to exclude the precoding matrices that are predicted to cause inter-cell interference. ’924, 5:40-52, Figs. 1-4. Such precoding matrices should not be used because those precoding matrices would decrease overall throughput in a wireless system. *Id.*

45. In restricting the codebook, the BS, which is deciding which precoding matrix works well from its point of view, is telling the UE that certain matrices are restricted (should not be considered) because they would have adverse effects to the performance of the overall communication system. ’924, 3:57-4:33 (“When the codebook restriction scheme is used, the whole wireless communication system has a large size codebook, but a *codebook that is used by each cell or each user equipment is configured of subsets of the codebook, and has a small size, and is*

configured of only precoding matrices appropriate for a given environment and thus, a precoding gain may be increased.”).

46. The United States Patent and Trademark Office (“USPTO”) allowed the Challenged Claims during prosecution after the claims were amended to recite transmitting the first and second feedback information to the BS at different periods. ’924, 14:62-15:3; ’924 File History, 544-559 (4/9/2015 Response to 1/9/2015 Office Action, amending application claims 18 and 25, corresponding to issued claims 17 and 23), 563-570 (5/11/2015 Notice of Allowability).

47. However, it was known in the art to send first and second feedback information at different periods. As an example, **Sayana** discloses a MIMO wireless communication system in which “a first representation of a first matrix” and “a second representation of a second matrix” are selected from the respective “first codebook” and “second codebook” by a UE. The UE feeds back the selected first and second representations of the first and second matrices to the BS “at different time instances and/or periodicities.” Sayana, Abstract (“A method for two component feedback in wireless communication systems is disclosed, with a wireless communication device *sending a first representation of a first matrix chosen from a first codebook*, wherein the first matrix has at least two columns, the wireless communication device *sending a second representation of a second matrix*

chosen from a second codebook, and the base station obtaining a precoder from the first representation and the second representation.”), [0006], [0047], [0058], [0065], [0070]-[0082], [0085]-[0095], [0099] (“*the first matrix may be further feedback at different time instances and/or periodicities compared to the second matrix.*”).

48. Other references that I discuss within my declaration also taught other features of the claims. For example, **Lee-689**, **TS36.213**, and **TS36.211** teach using a “bitmap” as codebook restriction information that indicates from a BS to a UE precoder matrices that are selectable for feedback by the UE. Lee-689, Abstract, 2:3-7, 3:6-14, 6:3-16, 15:4-10, 16:17-18:15 (“A base codebook subset indication can be expressed by *bitmap*.”); TS36.213, p.34 (“A UE is restricted to report PMI and RI within a precoder codebook subset specified by a *bitmap parameter codebookSubsetRestriction*² configured by higher layer signalling.”); TS36.211, pp.53-55. **Koivisto**, which incorporates by reference Ericsson, teaches limitations of dependent claims 20-21 and 26-27.³ Koivisto, [0044]-[0046].

² Italics of *codebookSubsetRestriction* in original.

³ It is my understanding that, because of this incorporation by reference, the disclosures of Ericsson are a part of and fully included in the disclosures of **Koivisto**.

V. '924 PATENT AND PROSECUTION HISTORY

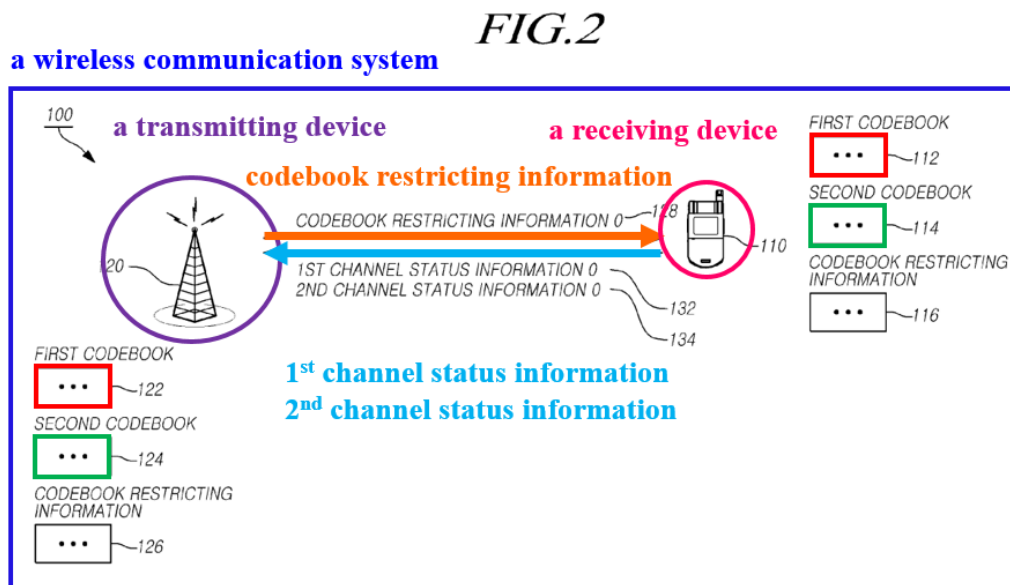
A. '924

49. As discussed in Section IV (Background of the Technology), the Challenged Claims relate to a cellphone system in which a BS tunes its transmissions to a UE using two precoders (with different codebooks) to avoid interfering with other signals in a shared wireless medium. For example, in some cases different precoder matrices cause beamforming that directs the signal towards UEs in a focused spatial manner to avoid interfering with each other.

50. Based on the prosecution history of the '924 patent discussed below in Section V.B (Prosecution History of the '924 Patent), the Challenged Claims were allowed because they recite the sending from the UE to the BS of a first CSI feedback signal and a second CSI feedback signal at different periods. '924, 14:62-15:3.

51. I have colored Fig. 2 below to illustrate an embodiment of the '924 patent. Fig. 2 shows a **BS transmitting device** that sends **codebook restricting information** ("CRI") to a **UE receiving device**. The **CRI** includes information for each of a **first codebook** and a **second codebook** associated with a respective first precoder and second precoder. The codebook restriction reduces inter-cell interference between cells of different base stations by restricting respective base stations from using precoding matrices that overlap and interfere with transmissions

of another base station. '924, 5:10-19. The **CRI** signals to a **UE receiving device** which precoding matrices of the codebooks are available for selection by a **UE receiving device**, and which are not available for selection. The **UE** selects indicators of two precoding matrices (one from the **first codebook** and a **second codebook**), which are not restricted by the **CRI**, and feeds back the selected indicators to the **BS** for use in the two respective precoders located at the **BS**. '924, Abstract, 1:19-22, 1:66-2:30, 3:7-51, 5:40-52, Figs. 1-2.



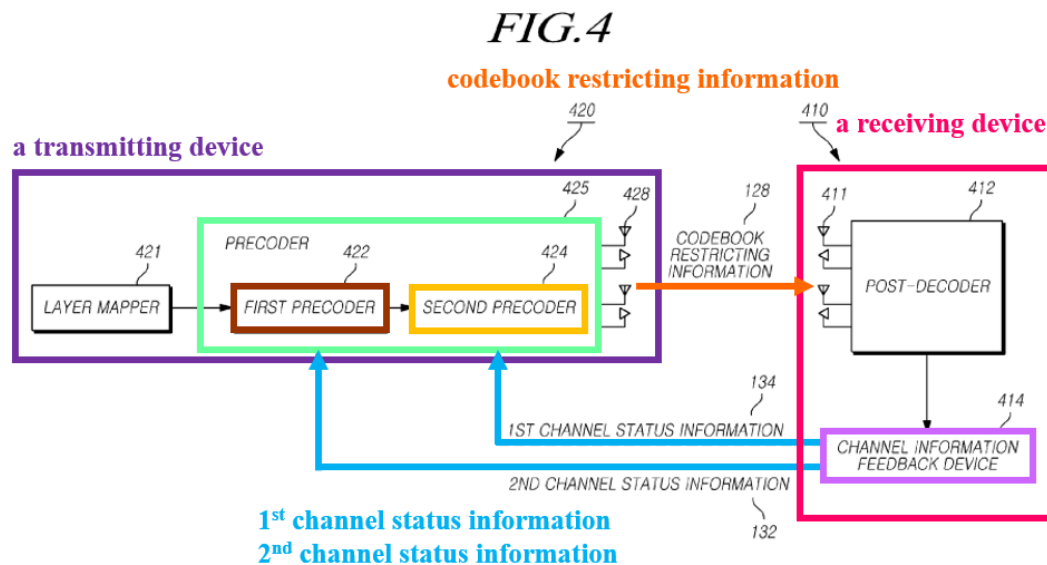
52. In the wireless systems depicted in Fig. 2 and Fig. 4 (which I have also colored below), the **UE** and **BS** each stores a **first codebook** and a **second codebook** that are known to both **UE** and **BS**. The **first codebook** and **second codebook** known to the **UE** and **BS** are identical, and include N precoding matrices and M precoding matrices, respectively. '924, 5:53-60, 6:55-63 ("Referring again to FIG.

2, the user equipment 110 stores a *first codebook 112 that expresses N first precoding matrices used for a first precoder and first indices indexing the first precoding matrices* and a second codebook 114 that expresses *M second precoding matrices used for a second precoder and second indices indexing the second precoding matrices*. The first codebook 112 and the second codebook 114 may be identical to the first codebook 122 and the second codebook 124 stored in the base station 120, respectively.”), Fig. 2.

53. In the wireless systems depicted in Fig. 2 and Fig. 4, the **UE** receives **CRI** from the **BS**, where the **CRI** signals to the **UE** at least one precoding matrix from each of the **first codebook**, and **second codebook**. For example, the **CRI** includes at least one precoding matrix from the **first codebook**, and at least one precoding matrix from the **second codebook** that are restricted from selection by the **UE**. '924, 5:61-6:7, 7:4-10, Figs. 2-3. The **CRI** associated with the **first codebook** is an N bit sequence, and the **CRI** associated with the **second codebook** is an M bit sequence. In each **CRI** bit sequence, each bit corresponds to one precoding matrix of the respective codebook, and indicates whether the corresponding precoding matrix is selectable for feedback by the **UE**. '924, 4:55-64, 7:4-10, 11:11-16 (“as described in the foregoing, *a first index PMI1 for setting a first precoding matrix W_1 and a second index PMI2 for setting a second precoding matrix W_2 may be*

independently selected and thus, a codebook may be restricted independently with respect to each precoding matrix, for each rank and for each of the first precoder and the second precoder. Table 5 expresses precoders that are restricted in a restriction book when codebook restriction is determined with respect to the first index=0 (PMI1=0) and the second index=1 (PMI2=1) in a rank 1.”), 11:17-12:39.

54. Provided below is a colored version of Fig. 4 that illustrates components of the **UE receiving device** and the **BS transmitting device**.



As shown above, the **BS transmitting device** includes a **multistage precoder** that is formed from a **first precoder** and a **second precoder**. '924, 1:41-2:31, 5:20-60 (“The base station 20 may use a multistage precoder including at least two precoders. The codebook restriction that restricts a precoding matrix to be used for each precoder may also be applicable, when the multistage precoder is used.

In this example, a number of precoding matrices is generally increased and a number of bits to be used for codebook restricting information for the codebook restriction may also be increased.”), 6:55-63, 8:19-28, Fig. 4. The **UE receiving device** includes a **channel information feedback device** that sends **1st channel status information** and **2nd channel status information** as feedback information to the **BS transmitting device** at different periods. ’924, 7:50-8:18 (“The channel information feedback device 414 may receive a reference signal and may estimate a channel using the reference signal. The *channel information feedback device 414 may generate channel information including 1st channel status information and 2nd channel status information*. The channel information feedback device 414 may feed back the channel information to the base station 420.”), 14:62-15:3, Fig. 4.

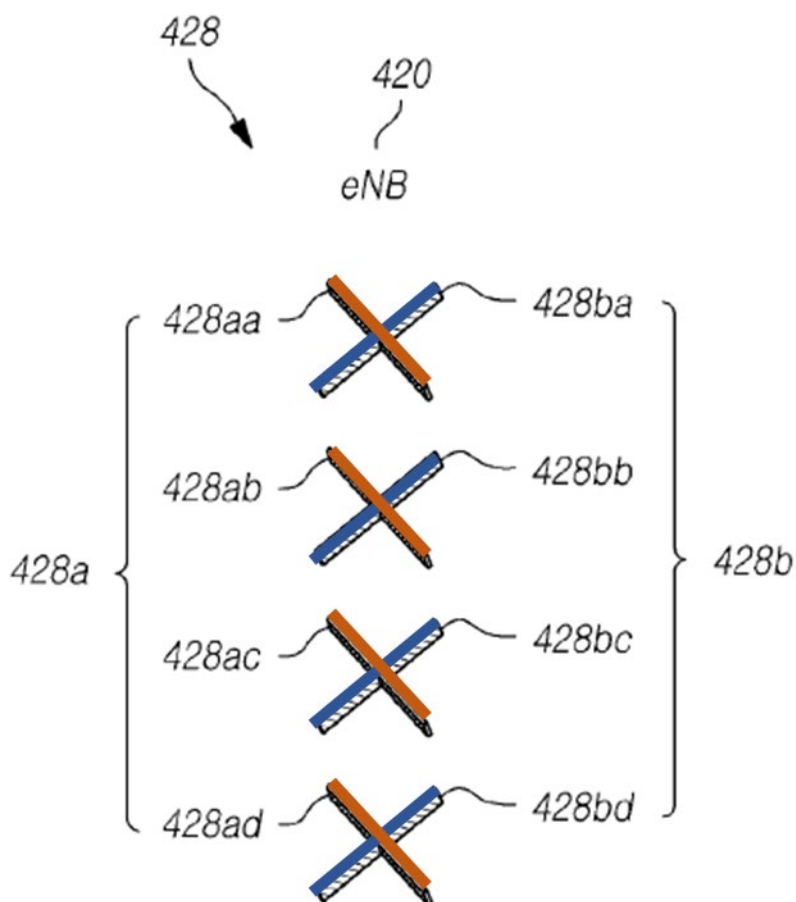
55. The **1st channel status information** indicates a first precoding matrix selected by the **UE receiving device** from the **first codebook** of precoding matrices that is not restricted by the **CRI** and that is signaled for use by the **first precoder**. The **2nd channel status information** indicates a second precoding matrix selected by the **UE receiving device** from the **second codebook** that is not restricted by the **CRI** and that is signaled for use by the **second precoder**. ’924, 1:66-2:30, 4:65-5:9-43, 6:8-11, 7:11-41 (“The *user equipment 110 determines, based on the first information included in the codebook restricting information 128, a first*

precoding matrix excluding precoding matrices that are restricted from being used as a first precoding matrix, and reports/feeds back 1st channel status information 132 associated with the determined precoding matrix to the base station 120. Also, each user equipment 110 determines, based on the second information included in the codebook restricting information 128, a second precoding matrix excluding precoding matrices that are restricted from being used as a second precoding matrix, and reports/feeds back 2nd channel status information 134 associated with the determined second precoding matrix to the base station 120.”), Figs. 2-3.

56. Claims 20-21 and 26-27 of the '924 patent further recite limitations relating to signal cross-polarization: (A) an “antenna pair” having first and second domains polarized in different and intersecting directions, (B) a first “precoding matrix” that “performs precoding” on the first and second domains separately, and (C) a second “precoding matrix” that “performs phase mismatch correction” between the first and second domains.

57. In regards to (A), Fig. 5 from the '924 patent depicted and annotated below, illustrates a “dual polarized antenna array,” which includes an array of antennas arranged perpendicular to each other in a cross configuration pattern at the BS. '924, 7:42-8:48. This array includes a first domain (“428a”) of a first antenna set (“428aa-ad”) polarized in a first direction (**brown** below), and a second domain

(“428b”) of a second antenna set (“428ba-bd”) polarized in a second direction (**blue** below). *Id.*; *See also* Ex. 1026, Figs. 11.2, 11.5, 252-276; Ex. 1027.



58. In regards to (B), the '924 patent's first precoding matrix (W_1), shown below, precodes the antenna array domains as “two independent domains.” This matrix type, having ‘0’ off diagonal elements, is categorized as a “block diagonal” matrix. '924, 9:33-10:24.

$$\frac{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}{w_1}$$

59. In regards to (C), the '924 patent's second precoding matrix (W_2), shown below, performs "phase mismatch correction (co-phasing) between domains." ' Λ ' provides phase correction. '924, 8:48-10:24.

$$\frac{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}{w_2}$$

B. Prosecution History

60. In formulating my opinions, I considered the contents of the '924 File History. The '924 File History shows that the applicant amended the claims to include a limitation ([17.e], [23.e]) relating to transmitting feedback at different periods in order to secure allowance of the '924 over the prior art. That limitation (pasted below) was incorporated into the independent claims from respective dependent claims that had been objected to by the Examiner, but not rejected on the merits based on any prior art reference:

wherein a period of transmitting the information relating to the precoding matrix of the first precoder and a period of transmitting the information

relating to the precoding matrix of the second precoder are different from each other.

Challenged Claims 17 and 23, which are independent claims, were initially filed as application claims 18 and 25, but without the limitation pertaining to different periods. '924 File History at 12/28/2012 filing at pp.50-58 (listing of initially filed claims including application claims 18 and 25). The limitation pertaining to different periods of transmitting the feedbacks for the first precoding matrix of the first precoder and the second precoding matrix of the second precoder were initially recited in application claims 23 and 30, which depended from application claims 18 and 25. In a 6/02/2014 Office Action, the Examiner rejected independent application claims 18 and 25 over U.S. 2011/0249713 ("Hammarwall," Exhibit 1012), but indicated that dependent application claims 23 and 30 were allowable if rewritten in independent form. '924 File History at 6/02/2014 Office Action at pp.419-435. The applicant filed a response on 9/2/2014 that amended independent claims 18 and 25 to require first and second bit sequences to restrict a first and second precoding matrices from respective codebooks, but did not incorporate the different periods subject matter from dependent claims 23 and 30. '924 File History at 9/2/2014 Reply at pp.449-465. In a subsequent 9/17/2014 Office Action, the Examiner rejected application claims 18 and 25 over Hammerwall and U.S. 2011/0034192 ("Lim," Exhibit 1013) and again indicated that dependent application claims 23 and 30

(pertaining to the different periods was allowable if rewritten in independent form). '924 File History at 9/17/2014 Office Action at pp.468-487). The applicant filed a response on 11/14/2014 that amended independent claims 18 and 25 to require multiplying the precoding matrix of the first precoder with the precoding matrix of the second precoder. '924 File History at 11/14/2014 Response at pp.489-507. In a subsequent 1/9/2015 Office Action, the Examiner rejected application claims 18 and 25 over Hamarwall and Lim and again indicated that dependent application claims 23 and 30 (pertaining to the different periods was allowable if rewritten in independent form). '924 File History at 1/9/2015 Office Action at pp.522-542. The applicant filed a response on 4/9/2015 that incorporated the "periods" limitation of dependent application claims 23 and 30 into independent application claims 18 and 25. '924 File History at 4/9/2015 Response at pp.544-559. The Examiner subsequently allowed the claims, which issued on 9/15/2015. '924 File History at 5/11/2015 Notice of Allowance at pp.563-570 and 9/15/2015 Issuance at p.595. The Examiner allowed the claims, with the above amendment, over Hammarwall, Lim and U.S. 2011/0305263 ("Jongren," Exhibit 1014) (a reference relied upon for other features of dependent claims). '924 File History at 4/9/2015 Response at pp.544-559, and 5/11/2015 Notice of Allowance at pp.563-570. Although **Sayana** was cited

in a Notice of References Cited accompanying an Office Action, none of the Office Actions used Sayana in a rejection. '924 File History at 435, 593.

VI. THE '924 PATENT PRIORITY DATE

61. I understand the international patent application leading to the '924 patent was filed on July 1, 2011, and that the '924 patent claims priority to a Korean patent application no. 10-2010-0064573, filed on 7/5/2010. I have not formulated any opinion about the correct priority date for the '924 patent. For purposes of this declaration, I was asked to assume, with respect to each of the prior art Grounds discussed in this declaration, that the '924 patent is entitled to the priority date of July 5, 2010. As further discussed below, regardless of whether the '924 patent is entitled to a 7/5/2010 alleged priority date, each of **Sayana**, **Lee-689**, **TS36.213**, **TS36.211**, and **Koivisto** is prior art to the Challenged Claims in any event. I have been instructed to consider the patent and the prior art from the perspective of a person of ordinary skill in the art as of July 5, 2010. However, a later or earlier priority date would not impact my opinions as long as these references are still prior art.

VII. LEVEL OF ORDINARY SKILL

62. In rendering the opinions set forth in this declaration, I was asked to consider the Challenged Claims of the '924 patent and the prior art cited in this

declaration through the eyes of a person of ordinary skill in the art at the time of the alleged invention. I understand determining the ordinary level of skill in a field of art includes looking at multiple factors including: (1) the level of education and practical experience; (2) the types of problems encountered in the field; (3) the teachings of the prior art; and (4) and the sophistication of the technology at the time of the alleged invention. I understand that a person of ordinary skill in the art is not a real individual, rather a hypothetical individual having a certain set of qualities that embody the aforementioned factors listed. I understand that a person of ordinary skill in the art would also have knowledge from the teachings of the prior art, including the prior art cited in this declaration.

63. In my opinion, on or before the '924's alleged priority date of July 5, 2010, a person of ordinary skill in the art would have had a bachelor's degree in electrical and computer engineering, computer science, or the equivalent thereof, and at least two years of experience with networking and wireless communications systems. Additional graduate education could substitute for practical experience, or significant practice experience in the field could substitute for formal education. '924, 1:16-37.

64. I am qualified to opine concerning what a person of ordinary skill in the art would have known and understood at that time of the alleged invention. Indeed,

by 7/5/2010, my level of skill in the art was at least that of a person of ordinary skill, as I have defined above. My analysis and conclusions herein are from the perspective of a person of ordinary skill in the art as of 7/5/2010.

65. I understand that Pantech's expert, Dr. Todor Cooklev, has taken a similar position that a person of ordinary skill in the art "would have had a bachelor's degree in electrical engineering, or equivalent training, and approximately two years of experience working in the field of networking and wireless devices." Ex. 1017, ¶26. This definition is consistent with the level of ordinary skill in the art I have considered above, and I have applied both definitions (both mine and Dr. Cooklev's) in my analysis in this declaration. Under either definition, the prior art renders the Challenged Claims unpatentable for the reasons explained herein.

VIII. CLAIM CONSTRUCTION

66. In rendering the opinions set forth in this declaration, I was instructed that the Challenged Claims of the '924 patent are to be given their ordinary and customary meaning as understood by a person of ordinary skill in the art at the time of the alleged invention. I understand this meaning may shift in light of the '924 specification and prosecution history pertaining to it and its patent family. I have followed these principles in the analysis I lay out in this declaration.

67. I understand that there is a pending district court litigation between LGE and Pantech involving the '924 patent, and the parties have proposed the constructions reflected in Exhibit 1018. I understand LGE has proposed a construction for “period of transmitting the information relating to the precoding matrix ...” ([17.e], [23.e]) as “time interval between periodically transmitting the information relating to the precoding matrix ...”, whereas Pantech has proposed plain and ordinary meaning. These constructions do not impact the opinions set forth in this declaration because the Challenged Claims are disclosed in the prior art regardless of either parties’ proposed constructions.

A. Preambles

68. I understand the preamble of a claim may or may not be limiting. For the purposes of this declaration, I have not been asked to formulate any opinion as to whether the preamble of any claim is limiting or not, nor have I formed any such opinion. However, as I will discuss further below, regardless of whether the preambles are limiting, the prior art discloses the preambles. *See* Section IX (Grounds of Unpatentability).

IX. GROUNDS OF UNPATENTABILITY

69. In this section, I explain why the teachings from the following references alone or in combination disclose and/or render obvious each of the

Challenged Claims under the following grounds. I have been instructed to assume that each of these references qualifies as prior art. I understand that LGE has retained Dr. Friedhelm Rodermund, an expert on 3GPP proceedings, to provide testimony regarding public accessibility of **TS36.213**, **TS36.211**, and **Ericsson**. The table below incorporates his analysis. See Declaration of Friedhelm Rodermund in Support of Petition for *Inter Partes* Review of U.S. Patent No. 9,136,924 (“Rodermund”). I have reviewed Dr. Rodermund’s declaration and agree with his analysis, which is incorporated into the table below with respect to TS36.213, TS36.211 and Ericsson. Rodermund, ¶¶1-152; Exs. 1051-1113.

Name	Publication/ Title	Exhibit	Filed	Published/ Issued
Sayana	U.S. 2011/0274188	1005	4/15/2011	11/10/2011
Lee-689	WO2010/050689	1007	10/14/2009	5/06/2010
TS36.213	TS 36.213 v8.8.0	1008	N/A	By 5/2010 ⁴

⁴ I understand from Dr. Rodermund’s analysis that in addition to publication of TS36.213 by the 3rd Generation Partnership Project (3GPP), the ETSI organization also published a substantively identical version TS 136.213 (Ex. 1074). My analysis with respect to TS36.213 applies equally to ETSI’s TS 136.213. Ex. 1074; Rodermund, ¶¶85-89.

Name	Publication/ Title	Exhibit	Filed	Published/ Issued
TS36.211	TS 36.211 v8.8.0	1009	N/A	By 6/2010 ⁵
Koivisto	U.S. 2013/0064129	1010	6/2/2010	3/14/2013
Ericsson	R1-102630	1011	N/A	By 5/2010 ⁶

70. As I explain below, the Challenged Claims are invalid based upon the following prior art grounds:

71. **Ground 1:** Challenged Claims 17-19, 22-24, 28 are rendered obvious by **Sayana** in view of **Lee-689**.

⁵ I understand from Dr. Rodermund's analysis that in addition to publication of TS36.211 by the 3rd Generation Partnership Project (3GPP), the ETSI organization also published a substantively identical version TS 136.211 (Ex. 1089). My analysis with respect to TS36.211 applies equally to ETSI's TS 136.211. Ex. 1089; Rodermund, ¶¶107-111.

⁶ I understand from Dr. Rodermund's analysis that R1-103333, a substantively similar version of Ericsson, was presented and discussed at 3GPP Meeting #61 by 5/10/2010. My analysis herein with respect to Ericsson applies equally to its updated version, R1-103333. Exs. 1110-1111; Rodermund, ¶139.

72. **Ground 2:** Challenged Claims 17-19, 22-24, 28 are rendered obvious by **Sayana** in view of **TS36.213**.

73. **Ground 3:** Challenged Claims 17-19, 22-24, 28 are rendered obvious by **Sayana** in view of **TS36.213** and **TS36.211**.

74. **Ground 4:** Challenged Claims 20-21, 26-27 are rendered obvious by **Sayana** in view of **Lee-689** and **Koivisto**.

75. **Ground 5:** Challenged Claims 20-21, 26-27 are rendered obvious by **Sayana** in view of **TS36.213** and **Koivisto**.

76. **Ground 6:** Challenged Claims 20-21, 26-27 are rendered obvious by **Sayana** in view of **TS36.213**, **TS36.211** and **Koivisto**.

77. It is my opinion that Challenged Claims of the '924 patent are unpatentable as explained below. I note that in this discussion, I may focus on the particular language in the specific claims, but it should be understood that my analysis applies to the corresponding elements of all Challenged Claims containing identical or substantially identical language.

A. Ground 1: Sayana in View of Lee-689 (Claims 17-19, 22-24, 28)

1. Overview of Sayana

78. **Sayana** discloses “a wireless communication system” between a user equipment or UE and a base station that minimizes “the mutual interference among

multiple transmissions . . . at each UE” by using a “precoding” scheme. Sayana, Abstract, [0003] (“**Precoding operations** can be in the context of single-user multiple input multiple output (SU-MIMO) or multi-user MIMO (MU-MIMO), where two or more users are served by a single base station. *An eNB needs accurate spatial channel information in order to perform a high rank transmission to a single UE or to perform precoding to two or more UEs simultaneously so that the mutual interference among multiple transmissions can be minimized at each UE.*”), [0015]-[0016], [0049]. “Precoding” allows for “beam-forming transmissions” by the base station to “deliver more power to a targeted user while minimizing interference.” Sayana, [0003] (“*[C]hannel state information* at a transmitter, for example, at a base station, *is important for beam-forming transmissions (also referred to as precoding) that deliver more power to a targeted user while minimizing interference on other users.*”).

79. Similar to the '924 patent's “first precoder” and “second precoder” used by the base station, **Sayana's** base station also uses “two” component precoders that form a combined precoder. These precoders are similar to the '924 patent's “first” and “second” precoders. See '924, 5:20-60, 7:34-41, 17:42-60, Fig. 4; compare '924, 5:20-60 (“The base station 20 may use a *multistage precoder including at least two precoders.*”; “The base station 120 includes a *multistage*

precoder including at least two precoders, that is, first and second precoders.”), 7:34-41, 17:42-60, Fig. 4 *with Sayana*, Abstract (“A method for *two component feedback* in wireless communication systems is disclosed”), [0003], [0006] (“to feedback the correlated and uncorrelated channel characteristics, i.e., *two components*, at different rates and/or with different levels of quantization/overhead in time and frequency to reduce feedback overhead.”), [0015]-[0016], [0048] (“*two component feedback scheme*”), [0049] (“*two component precoders*”), [0091]-[0095]. *Sayana* discloses that precoders “map[] a set of data streams to an antenna set using a matrix.” *Sayana*, [0029]. Accordingly, *Sayana*’s “first” precoder and “second” precoder use precoder matrices selected from a “first codebook” and a “second codebook,” which are “predefined codebook[s] that consist[] of a set of predefined vectors or matrices.” *Sayana*, Abstract, [0029] (“The precoding weights may or may not be constrained to *a predefined codebook that consists of a set of pre-defined vectors or matrices.*”), [0058], [0085]. In particular, the base station implements the first and second precoders based on two respective sets of feedback received from the UE, namely, “a first representation of a first matrix chosen from a first codebook” and “a second representation of a second matrix chosen from a second codebook.” *Sayana*, [0058].

80. **Sayana** also teaches that a base station restricts the use of certain matrices of the first and second codebooks that the UE uses to generate the feedback for the first and second precoding operations of the base station. Sayana, [0085] (“The construction above presents a product design followed by reshaping to provide improved flexibility in the two component feedback. However, further overhead reduction can be configured by eNB, by enabling codebook subset restrictions at wideband and subband level. *A codebook subset restriction is essentially where eNB signals the UE to only use a subset of codebook entries for the feedback. Subset restriction can be applied to either the first codebook, or the second codebook, or both.*”), [0086] (“*Codebook subset restriction can be used for both wideband and subband components* in a pre-configured and compatible manner, which we will further describe with some exemplary methods.”), [0087]-[0094]. A base station communicates this restriction information by transmitting to the UE a “codebook subset restriction . . . signal[ing] the UE to only use a subset of codebook entries for the feedback” for the “first” precoder and “second” precoder. Sayana, [0085]-[0094]. The UE receives the “codebook subset restriction” information from the base station and applies it to both “the first codebook” and “second codebook” when selecting representations of the first and second components for feedback to the base station. Sayana, [0085]-[0094]. The base station selects a precoding matrix

for use in each of the “first” precoder and “second” precoder based on the feedback received from the UE of the first representation of a first matrix corresponding to a first codebook, and the second representation of a second matrix corresponding to a second codebook. Sayana, Abstract (“A method for two component feedback in wireless communication systems is disclosed, with *a wireless communication device sending a first representation of a first matrix chosen from a first codebook*, wherein the first matrix has at least two columns, *the wireless communication device sending a second representation of a second matrix chosen from a second codebook*, and the base station obtaining a precoder from the first representation and the second representation.”), [0029]-[0030], [0058] (“The above discussion on the precoder structure is tied to feedback method in this invention. In the feedback scheme for a wireless communication device to send a precoder matrix information to a base station, *the wireless communication device sends a first representation of a first matrix chosen from a first codebook*, wherein the first matrix has at least two column vectors. *The wireless communication device sends a second representation of a second matrix chosen from a second codebook*, wherein the first representation and the second representation together convey a precoder matrix of one or more vectors associated with one or more spatial layers.”), [0059], [0080]-[0094].

81. **Sayana** further discloses that the first and second components of the two component feedback scheme, in some use cases, corresponds to “wideband” and “subband” communications, respectively. Sayana, [0006] (“The above structure in the antennas has some unique spatial characteristics that can be exploited. For example, the correlation among correlated antennas changes slowly and is confined to a smaller vector space on an average. *This can be used to feedback the correlated and uncorrelated channel characteristics, i.e., two components*, at different rates and/or with different levels of quantization/overhead in time and frequency to reduce feedback overhead. *One of the components representing the correlated channel characteristics can be fed back on a wideband basis* and/or slowly in time, *while the other component is fed back on a subband basis and/or more frequently in time.*”), [0085]-[0086] (“*Codebook subset restriction can be used for both wideband and subband components* in a pre-configured and compatible manner, which we will further describe with some exemplary methods.”), [0087]-[0092]. According to **Sayana**, when respective channel components addressed by the “first” and “second” precoders have different channel characteristics (e.g., changing with “different rates and/or with different levels of quantization/overhead in time and frequency”), it is beneficial to separately select feedback precoding matrices for a “first” precoder and a “second” precoder and feed them back “at different time

instances and/or periodicities” to “reduce feedback overhead.” Sayana, Abstract, [0006] (“For example, the correlation among correlated antennas changes slowly and is confined to a smaller vector space on an average. *This can be used to feedback the correlated and uncorrelated channel characteristics, i.e., two components, at different rates and/or with different levels of quantization/overhead in time and frequency to reduce feedback overhead.* One of the components representing the correlated channel characteristics can be fed back on a wideband basis and/or slowly in time, while the other component is fed back on a subband basis and/or more frequently in time.”), [0058], [0074]-[0082], [0093]-[0094], [0099]-[0100]. For example, **Sayana** discloses that some characteristics are “fed back on a wideband basis and/or slowly in time” and that other characteristics are “fed back on a subband basis and/or more frequently in time.” Sayana, [0006]. As such, when the “wideband” feedback is transmitted less frequently than the “subband” feedback, feedback overhead over a time period is reduced because fewer bits are consumed for “wideband” feedback. Sayana, [0006].

82. **Sayana** describes various examples of precoder feedback and codebook subset restriction. *See, e.g.*, Sayana, [0025]-[0082] (describing examples of precoder feedback); [0083]-[101] (describing examples of codebook subset restriction). The disclosures of **Sayana** relied on herein are all interrelated and

complimentary and describe aspects of two precoder feedback and codebook subset restriction. If instead these disclosures were considered separate and distinct embodiments, a person of ordinary skill in the art would have been motivated to modify, apply, and combine teachings from these examples into one system that implemented two precoder codebooks, with two precoder feedback, and codebook subset restrictions. Two precoder systems and codebook subset restriction were well-known. For example, **Sayana** described examples of “two precoder” that used two codebooks for a first precoder and second precoder, where a first codebook, for example addressed wideband and a second codebook addressed subband. Sayana, Abstract (“two component feedback in wireless communication systems”), [0006] (feedback on wideband and subband), [0048]-[0049] (describing “two component precoders” for “two-component feedback”). **Koivisto** also describes “dual codebook-based channel status information” that supports “MIMO operation.” Koivisto, [0035], [0044]-[0046] (describing multiple codebook structures). **Sayana** also described various examples of codebook subset restriction, for example in context of first and second codebooks directed to wideband and subband, respectively. Sayana, [0083]-[0101]. **Koivisto** likewise describes codebook subset restriction. Koivisto, [0050].

83. As I explain further below, codebook subset restriction improves wireless communications, for example by excluding precoding matrices that cause interference to other transmitting devices across a shared wireless medium. *See* paragraphs 94-101. Codebook subset restriction is also used to limit precoding matrices to those suitable for certain antenna arrangements. *Id.* Furthermore, **Sayana** describes its teachings relating to codebook subset restriction as “exemplary methods” that further improve communications when applied “at wideband and subband level.” Sayana, [0085]-[0086].

84. In light of these discussions in **Sayana** a person of ordinary skill in the art would have understood the various teachings to be design choices that are to be applied to one another to form a system that uses two codebooks, two precoder feedback, and codebook subset restriction applied to respective two codebooks and precoders. In light of the foregoing, a person of ordinary skill in the art would have further expected success in such modifications, applications and/or combinations.

2. Sayana’s Effective Priority Date

85. I understand that **Sayana** claims priority to U.S. Provisional Application No. 61/331,818 (Sayana-Prov, Exhibit 1006), filed on May 5, 2010, which predates the alleged July 5, 2010 priority date of the ’924.

86. In forming my opinions, I was asked to consider whether **Sayana** is entitled to claim priority to the filing date of Sayana-Prov, including by considering whether Sayana-Prov provides written description and enablement support for at least one claim of **Sayana**, as well as written description and enablement support for those portions of **Sayana** that I rely upon for my opinions. *See* Sections III.D (Written Description and Enablement), III.E (Priority Date for Prior Art). It is my opinion that **Sayana** provides such written description support and such is entitled to the priority date of Sayana-Prov.

87. First, it is my opinion that Sayana-Prov provides enabling written description support for at least claim 1 of **Sayana**. In the table below, and having reviewed the intrinsic evidence, I have identified example disclosures from Sayana-Prov that provide such enabling written description support for each element of claim 1 of **Sayana**. Aside from **Sayana** incorporating by reference Sayana-Prov, not only are the claims in **Sayana** identical to the claims in Sayana-Prov, but the **Sayana** specification is identical to Sayana-Prov. Note that in preparing this table, it was unnecessary to construe any of the claim terms of **Sayana**, including by determining whether or not the preamble of claim 1 is limiting, because under any reasonable interpretation of the claim, Sayana-Prov provides sufficient enabling

written description support. I reserve the right to consider the proper construction of the claim below if asked to do so at a later time.

Sayana Claim 1	Sayana-Prov.
[1.pre] A method for a wireless communication device to send a precoder matrix information to a base station , the method comprising:	e.g., Abstract (“A method for two component feedback in wireless communication systems is disclosed, with <i>a wireless communication device sending a first representation of a first matrix chosen from a first codebook</i> , wherein the first matrix has at least two columns, <i>the wireless communication device sending a second representation of a second matrix chosen from a second codebook</i> , and the base station obtaining a precoder from the first representation and the second representation.”)
[1.a] the wireless communication device sending a first representation of a first matrix chosen from a first codebook, wherein the first matrix has at least two column vectors;	¶¶[0016] (“The remote units may be fixed units or wireless communication devices. The remote unit may also be referred to as a receiver, subscriber station (SS), mobile, mobile station (MS), mobile terminal, user, terminals, <i>user equipment (UE)</i> , user terminal (UT) or by other terminology used in the art.”)
[1.b] the wireless communication device sending a second representation of a second matrix chosen from a second codebook;	[0048] (“As can be seen, two structures are shown which allow expressing the <i>overall precoder as a Kronecker product of two precoders.</i> ”)
[1.c] wherein the first representation and the second representation together convey a precoder matrix of one or more vectors associated with one or more spatial layers, the precoder matrix comprises a first sub-precoder matrix including a first set of weights on a first subset of transmit antennas of the base station, and a second sub-precoder matrix including a second set of weights on a second subset of transmit antennas of the base station, wherein the first and second subsets of transmit antennas are non-overlapping,	
[1.d] wherein the first sub-precoder matrix is one or more column vectors of the first matrix corresponding to the	

Sayana Claim 1	Sayana-Prov.
first representation, multiplied by one or more entries of the second matrix corresponding to the second representation, and the second sub-precoder matrix is one or more column vectors of the first matrix corresponding to the first representation, multiplied by one or more entries of the second matrix corresponding to the second representation.	[0057] (“The optimal precoding vector V (optimal in an information theoretic capacity maximizing sense) can be obtained from the Eigen decomposition of the narrowband covariance matrix for band indexed ‘b’ as follows. $R_{NB,b} = V_{NB,b} D_{NB,b} V_{NB,b}^H \quad (0.8)$ For the rank-2 or 2-layer precoder, the ideal precoder is simply the first two columns of $V_{NB,b}$. Let us denote the rank-2 Eigen decomposition based precoder as follows (a partition based representation of $V_{NB,b}$) $\begin{bmatrix} v_{11} & v_{12} \\ v_{21} & v_{22} \end{bmatrix} \quad (0.9)$ where v_{ij} is a 4×1 (assuming 8-Tx eNB) vector. Clearly, each block corresponds to a vector of weights applied on a subset of antennas (e.g., ULA subset) corresponding to one spatial layer of data stream.”), [0060] (“FIG. 5 further describes the above precoding operation from two subsets of antennas. Two non-overlapping subsets of antennas 510, 520 are weighted by a first and a second sub-precoder matrix, respectively. Each sub-precoder matrix corresponds to one or more spatial layers of data transmission, for example in FIG. 5, the first sub-precoder is for spatial layer 1 (530) and layer-2 (540). Similarly for the second-precoder, it corresponds to

Sayana Claim 1	Sayana-Prov.
	two spatial layers. Mathematically, as an example with eight antennas composed of two groups of 4 antennas, where the first subgroup is number 1-4, and second subgroup numbered 5-8, a rank r precoder may be expressed as follows $\begin{bmatrix} v_{11} & v_{12} & \dots & v_{1r} \\ v_{21} & \dots & \dots & \dots \\ v_{31} & \dots & \dots & \dots \\ v_{41} & \dots & \dots & v_{4r} \\ v_{51} & v_{52} & \dots & v_{5r} \\ v_{61} & \dots & \dots & \dots \\ v_{71} & \dots & \dots & \dots \\ v_{81} & \dots & \dots & v_{8r} \end{bmatrix}$ In the above the first sub-precoder is the top 4 rows (1-4) and the second sub-precoder is the bottom 4 rows (5-8”), [0065] (“The above discussion on the precoder structure is tied to feedback method in this invention. In the feedback scheme for a wireless communication device to send a precoder matrix information to a base station, the wireless communication device sends a first representation of a first matrix chosen from a first codebook, wherein the first matrix has at least two column vectors. The wireless communication device sends a second representation of a second matrix chosen from a second codebook, wherein the first

Sayana Claim 1	Sayana-Prov.
	representation and the second representation together convey a precoder matrix of one or more vectors associated with one or more spatial layers. The precoder matrix comprises a first sub-precoder matrix including a first set of weights on a first subsets of transmit antennas of the base station and a second sub-precoder matrix including a second set of weights on a second subset of transmit antennas of the base station. The first sub-precoder matrix is one or more column vectors of the first matrix corresponding to the first representation, multiplied by one or more entries of the second matrix corresponding to the second representation, and the second sub-precoder matrix is one or more column vectors of the first matrix corresponding to the first representation, multiplied by one or more entries of the second matrix corresponding to the second representation.”), claim 1

88. Second, it is my opinion that Sayana-Prov provides enabling written description support for those portions of **Sayana** that I rely upon in formulating my opinion that **Sayana** in view of **Lee-689**, **TS36.213**, **TS36.211** and/or **Koivisto**

renders obvious the Challenged Claims. I have prepared a redline document that compares the passages from **Sayana** with Sayana-Prov. Ex. 1019. Based on my review of this comparison document, **Sayana** is substantively identical to Sayana-Prov, with the exception of paragraph [0001] in **Sayana** that includes a statement that **Sayana-Prov** was incorporated by reference into **Sayana**. Additionally, each of **Sayana's** claims appear identically in Sayana-Prov. In view of the same disclosures between **Sayana** and Sayana-Prov, the passages relied upon from **Sayana** are identical and enabled by corresponding passages from Sayana-Prov. Compare Sayana with Sayana-Prov; Ex. 1019. I have also prepared the table below to illustrate a mapping of paragraphs from Sayana-Prov to paragraphs from **Sayana**. Accordingly, as set forth in this section, Sayana-Prov provides enabling written description support for each claim of **Sayana**, as well those disclosures from **Sayana** that render the Challenged Claims invalid as obvious.

Sayana-Prov	Sayana
[0001]-[0023]	[0002]-[0024]
[0024]-[0025]	[0025]
[0026]-[0027]	[0026]
[0028]-[0029]	[0027]
[0030]-[0033]	[0028]-[0031]
[0034]-[0035]	[0032]
[0036]	[0033]

Sayana-Prov	Sayana
[0037]-[0038]	[0034]
[0039]	[0035]
[0040]-[0041]	[0036]
[0042]-[0046]	[0037]-[0041]
[0047]-[0048]	[0042]
[0049]-[0062]	[0043]-[0056]
[0063]-[0064]	[0057]
[0065]-[0066]	[0058]-[0059]
[0067]-[0068]	[0060]
[0069]-[0073]	[0061]-[0065]
[0074]-[0075]	[0066]
[0076]-[0077]	[0067]
[0078]-[0081]	[0068]-[0071]
[0082]-[0083]	[0072]
[0084]-[0090]	[0073]-[0079]
[0091]-[0092]	[0080]
[0093]-[0094]	[0081]
[0095]-[0096]	[0082]-[0083]
[0097]-[0099]	[0084]
[0100]-[0101]	[0085]-[0086]
[0102]-[0103]	[0087]
[0104]-[0118]	[0088]-[0102]

89. Based on the disclosures in the provisional cited herein and in the table above comparing claim 1 of **Sayana** with Sayana-Prov, a person of ordinary skill in the art at the time (relative to the **Sayana** reference) would have been able to practice

the claim without undue experimentation. By that timeframe, these concepts were well-understood in the field.

3. Overview of Lee-689 and Motivation to Apply Lee-689's Teachings to Sayana

90. **Lee-689** is an international patent publication WO2010/050689, filed October 14, 2009, and published May 6, 2010. **Lee-689** is directed to systems for using codebook subset restriction in order to restrict use of precoding matrices in a first cell of a cellphone system, that would cause interference to a second cell. **Lee-689** teaches that, via a “closed-loop” feedback from a UE to a base station, selection of precoder matrices is limited to a “base codebook subset.” Lee-689, Abstract, 2:3-7, 3:6-14 (*“In a closed-loop multiple antenna system, a receiver selects a precoding matrix from a predetermined codebook and transmits an index of the selected precoding matrix to a transmitter.* Then, the transmitter multiplies data by the selected precoding matrix and transmits the data.”), 6:3-16 (*“a method of controlling interference by a receiver of a wireless communication system with multiple antennas comprises receiving a base codebook subset indication representing at least one precoding matrix included in a base codebook subset from a transmitter, wherein the base codebook subset includes at least one precoding matrix selected from a base codebook, receiving indication information indicating whether the receiver use the base codebook or the base codebook subset to the*

receiver, *selecting a precoding matrix from the base codebook or the base codebook subset according to the indication information; and transmitting identification information of the selected precoding matrix to the transmitter.*”), 15:4-10, 18:5-15 (“*A base codebook subset indication represents which precoding matrixes are included in a base codebook* subset among a rank 1 base codebook or not.”). In particular, **Lee-689** teaches performing this selection by using a “bitmap” to signal the codebook entries that are excluded from the base codebook subset depending on whether a bit is 0 or 1. Lee-689, 16:17-18:15 (“A base codebook subset indication can be expressed by bitmap.”). “For example, if *ith* element of a base codebook subset indication expressed by bitmap is 0, a base codebook subset does not include *ith* element of a base codebook. And, if *ith* element of a base codebook subset indication expressed by bitmap is 1, a base codebook subset includes *ith* element of a base codebook.” *Id.* Lee-689, 18:5-15. As an example, **Lee-689** teaches a “base codebook” W consisting of 8 matrices ($W = [W_0 \ W_1 \ W_2 \ W_3 \ W_4 \ W_5 \ W_6 \ W_7]$). *Id.* The 1’s in the bitmap (bolded in “0**b1001111**0”, $W = [W_0 \ W_3 \ W_4 \ W_5 \ W_6]$) correspond to the permitted first, fourth, fifth, sixth and seventh positions, and thus indicate selecting a “base codebook subset” from this base codebook. The 0’s in the bitmap correspond to the restricted

second, third, and eighth positions. *Id.* The number of elements in the bitmap (*i.e.*, eight) is the same as the number of matrices in the “base codebook.” *Id.*

91. **Sayana** and **Lee-689** are analogous to and in the same field as the '924 patent, which includes multiple input multiple output (MIMO) wireless communications, and reasonably pertinent to the alleged problems identified in the '924—*e.g.*, improving communication efficiency. '924, 1:34-36 (“the system is required to *minimize loss of information and increase transmission efficiency* of the system so as to enhance performance of the system.”), 3:57-65 (“To embody an effective MIMO system, a MIMO wireless communication system may need to provide, to a transmitting device, information associated with a propagation channel or information associated with a precoder or a precoding matrix (hereinafter referred to as a precoding matrix) appropriate for a propagation channel, *to increase transmission capacity*. In this example, the former requires a large amount of feedback overhead, whereas the latter requires a relatively small amount of feedback overhead.”), 4:10-19 (“when a large size codebook is used, a codebook restriction or a codebook subset restriction that restricts at least one precoding matrix in a codebook may need to be used *for more effective precoding*”); Sayana, [0003] (“*Precoding operations* can be in the context of single-user multiple input multiple output (SU-MIMO) or multi-user MIMO (MU-MIMO)”), [0004]-[0005] (“The

antenna configurations which support a large number of antennas in practice must allow large beamforming gains and also larger spatial multiplexing gains achieved from higher rank transmission. Beamforming allows efficient support for low geometry users and also for multi-user transmission ***thereby improving cell-edge and cell-average throughput*** with larger number of users in the system, while spatial multiplexing allows higher peak spectral efficiency.”), [0085] (“The construction above presents a product design followed by reshaping ***to provide improved flexibility in the two component feedback***. However, further overhead reduction can be configured by eNB, by enabling codebook subset restrictions at wideband and subband level. A codebook subset restriction is essentially where eNB signals the UE to only use a subset of codebook entries for the feedback. Subset restriction can be applied to either the first codebook, or the second codebook, or both.”); Lee-689, 1:10-14 (“Multi-Input Multi-Output (MIMO) technology ***improves efficiency of data transmission*** and receipt using a multiple transmission antenna and a multiple receipt antenna”), 14:5-21 (“In a method of controlling interference according to embodiments of the present invention, a receiver requests a transmitter of neighbor cells not to use precoding matrixes which give more interference than others to the receiver if the receiver receives interference from precoding matrixes of neighbor cells. Or, the receiver can request the transmitter to ***use precoding matrixes which***

give less interference than others to the receiver. That is, the receiver transmits first precoding matrixes indexes (PMIs) which the receiver request the transmitter of the neighbor cells not to use or second precoding matrixes indexes (PMIs) which the receiver request the transmitter of the neighbor cells to use. Then, excepting the first precoding matrixes indexes from a base codebook, and leaving the second precoding matrixes indexes in the base codebook, the transmitter generates a new codebook and use the new codebook.”).

92. Similar to the '924 patent, **Lee-689**'s bitmap solution enables reduction of inter-cell interference in a system where a first base station transmits a set of precoding matrices to a neighboring second base station to be used or restricted by the second base station to reduce interference to the first base station. '924, 5:10-19 (“the use of *precoding matrices that are predicted to cause inter-cell interference may be restricted by the codebook restriction* and thus, the inter-cell interference may be prevented in advance. In particular, when a beam forming like precoding that is based on a location of each user equipment is performed, a user equipment located in a cell edge may cause serious inter-cell interference. To prevent the inter-cell interference in advance, a codebook restriction may be performed for each cell and thus, the inter-cell interference may be controlled.”), 17:52-19:52 (“FIGS. 8 through 10 are conceptual diagrams illustrating *a process of controlling inter-cell*

interference using a codebook restriction scheme in a wireless communication system according to embodiments of the present invention. ... When the second base station 820 b *restricts a codebook so that the first precoder matrix corresponding to the $PM_{11}=13$ is not to be used*, the user equipment 810 b receives a signal from only the first base station 820 a and *thus, inter-cell interference due to multiple-interference may be prevented in advance*. ... When the first base station 820 a *restricts a codebook so that the first precoder matrix corresponding to the $PM_{11}=8$ is not to be used*, user equipments 810 c and 810 d receive a signal from only the second base station 820 b and *thus, inter-cell interference due to multiple-interference may be prevented in advance.*”), Figs. 8-10; Lee-689, 12:21-14:21 (“[I]n embodiments of the present invention, a method of controlling interference will be proposed, wherein the method restricts use of precoding matrixes of neighbor cells. A method of controlling interference according to embodiments of the present invention will hereinafter be described with reference to FIGS. 3 to 4. In a method of controlling interference according to embodiments of the present invention, *a receiver requests a transmitter of neighbor cells not to use precoding matrixes which give more interference than others to the receiver* if the receiver receives interference from precoding matrixes of neighbor cells. Or, the receiver can request the transmitter to use precoding matrixes which give less interference than others to

the receiver. That is, the receiver transmits first precoding matrixes indexes (PMIs) which the receiver request the transmitter of the neighbor cells not to use or second precoding matrixes indexes (PMIs) which the receiver request the transmitter of the neighbor cells to use. Then, excepting the first precoding matrixes indexes from a base codebook, and leaving the second precoding matrixes indexes in the base codebook, the transmitter generates a new codebook and use the new codebook.”), 15:11-16:16 (“In case that the transmitter receives the information of first precoding matrixes indexes or the information of second precoding matrixes indexes from the transmitter of neighbor cells, *the receiver of neighbor cell, which receives interference, transmits the information of first precoding matrixes indexes or the information of second precoding matrixes indexes to the transmitter of neighbor cell* and the transmitter transmits the information of first precoding matrixes indexes or the information of second precoding matrixes indexes through backbone network to the transmitter.”).

93. **Sayana** does not specify how to implement the communication of its codebook subset restriction. In particular, while **Sayana** discloses that the codebook subset restriction includes a set of multiple values each of which maps to a codebook subset, it does not specify the form of the codebook subset restriction information that is signaled from a base station to a UE. *E.g.*, Sayana, [0085]-[0090], [0091] (“In

other words, an UE *may receive an UE-specific or cell-specific higher layer subset-restriction parameter* which can take a set of multiple values each of which maps to a ‘codebook subset’ pair for W1 and W2.”), [0092]. **Lee-689** provides detailed teachings about how to implement the form of such a codebook subset restriction. **Lee-689** teaches, “A base codebook subset indication can be expressed by bitmap. For example, if an *i*th element of a base codebook subset indication expressed by bitmap is 0, a base codebook subset does not include the *i*th element of a base codebook. And, if an *i*th element of a base codebook subset indication expressed by bitmap is 1, a base codebook subset includes the *i*th element of a base codebook. Lee-689, 18:5-15. **Lee-689** also teaches that, for example, to facilitate selection of entries from a base codebook including 8 entries (e.g., $W = [W_0 \ W_1 \ W_2 \ W_3 \ W_4 \ W_5 \ W_6 \ W_7]$), the corresponding bit sequence of the base codebook indication also comprises 8 bit values (e.g., “0b10011110,” where the bits “10011110” indicates selection of subset). Lee-689, 17:2-20, 18:5-15. Within this bitmap, the 1s in the bitmap correspond to the first, fourth, fifth, sixth and seventh positions that are permitted, and the 0s correspond to the second, third, and eighth positions that are restricted. *Id.* Accordingly, applying the bits “10011110” to select a subset of the base codebook $W = [W_0 \ W_1 \ W_2 \ W_3 \ W_4 \ W_5 \ W_6 \ W_7]$ generates the subset $W = [W_0 \ W_3 \ W_4 \ W_5 \ W_6]$. *Id.*

94. A person of ordinary skill in the art would have been motivated to modify **Sayana** to implement its “codebook subset restriction” using **Lee-689**’s teachings of bitmaps to improve the signaling of restricted precoding matrices to UEs for several reasons that I list below.

95. **First**, both **Sayana** and **Lee-689** recognize that precoding and restrictions on precoding matrices improve wireless transmission power to the intended UE while reducing interference to unintended UEs. Sayana [0003] (“In wireless communication systems, channel state information at a transmitter, for example, at a base station, *is important for beam-forming transmissions (also referred to as precoding) that deliver more power to a targeted user while minimizing interference on other users.* Precoding operations can be in the context of single-user multiple input multiple output (SU-MIMO) or multi-user MIMO (MU-MIMO), where two or more users are served by a single base station. *An eNB needs accurate spatial channel information in order to perform a high rank transmission to a single UE or to perform precoding to two or more UEs simultaneously so that the mutual interference among multiple transmissions can be minimized at each UE.*”); Lee-689, 6:19-7:3 (“First of all, since a base codebook subset generated effectively is used, performance of a wireless communication system is improved. Second, *since precoding matrixes which neighbor cells*

*request not to use are not used, interference to neighbor cells is reduced.”); 20:14-21:3 (“As described above, **a receiver selects a precoding matrix from a codebook determined by a base codebook subset indication**, a codebook coordination enable, a single user base codebook type, and a multi user base codebook type, and **transmits identification information of the selected precoding matrix to a transmitter**. Then, a transmitter receives the identification information of the selected precoding matrix S340. **The identification information of the selected precoding matrix can be an index of the selected precoding matrix. [¶]. A transmitter generates a precoding matrix from the received identification information, and precodes data with the generated precoding matrix, and transmits the precoded data to a receiver S350.”).***

Both **Sayana** and **Lee-689** recognize that using codebook restriction helps fulfill cell-specific and UE-specific requirements for the multiple-antenna transmission, including interference control—**Lee-689** also uses codebook restriction to control interference arising from precoded transmissions. Sayana [0003] (“**[C]hannel state information at a transmitter**, for example, at a base station, **is important for** beam-forming transmissions (also referred to as **precoding**) that deliver more power to a targeted user **while minimizing interference on other users**. ... An eNB needs **accurate spatial channel information in order to perform a high rank transmission to a single UE or to perform precoding to two or more UEs simultaneously so that**

the mutual interference among multiple transmissions can be minimized at each UE.”), [0004] (“it is desirable that the *UE feedback be designed efficiently with good performance overhead trade-off*, so that feedback does not scale linearly with the increasing number of antennas.”), [0091]-[0092] (“In general, *the subset restriction may be useful under certain persistent long-term conditions* like whether link is line of sight (LOS) or non line of sight (NLOS), the eNB antenna configuration if a general codebook is used for all configurations (say ULA/XPOL), UE geometry which could limit the uplink feedback link capacity and iv) additional feedback required for other transmission modes like multiuser MIMO which may provision fewer bits to higher-ranked SU transmission.”); Lee-689 13:23-14:4 (“Therefore, in embodiments of the present invention, *a method of controlling interference will be proposed, wherein the method restricts use of precoding matrixes of neighbor cells. A method of controlling interference* according to embodiments of the present invention will hereinafter be described with reference to FIGS. 3 to 4.”).

96. **Second, Sayana** does not specify how “codebook subset restriction” is generated by the base station and communicated to the UE. Sayana, [0085]-[0092]. In addition, although **Sayana** discloses using different numbers of bits in other contexts, for example, as “feedback bits to capture the wideband information” and

“subband information” in representing codebooks, **Sayana** does not teach how to restrict the codebooks. Sayana, [0060], [0070] (“*[U]se more feedback bits to capture the wideband information and used fewer bits to capture subband information*.”). An exemplary embodiment is to use a *2 bit codebook for subband vectors and a 4 or 6 bit codebook to represent the wideband entries*. In general, the selection of (B1, B2) may depend on the feedback mode. More specifically, it could depend on the number of sub-bands the feedback is requested on.”). For example, while **Sayana** discloses “2 bit codebook for subband vectors and a 4 or 6 bit codebook to represent the wideband,” with each codebook being “a set of predetermined precoding matrices,” these “2 bit” and “4 or 6 bit” codebooks refer to the number of “feedback bits” used to generate an index into a codebook, rather than a number of bits used for subset restriction information. Sayana, [0039] (“To support precoding operation from the base station, *a user terminal will be reporting back to the base station a preferred Precoding Matrix Index (PMI) which is an index to a set of predetermined precoding matrices*.”), [0070].⁷ On the other hand,

⁷ **Sayana** describes a 2-bit codebook is associated with (2^2) 4 precoding matrices in a codebook. **Sayana** also describes a 4-bit codebook is associated with (2^4) 16 precoding matrices in a codebook. **Sayana** further describes a 6-bit codebook is

Lee-689 teaches a “base codebook subset” indication using bitmaps. Lee-689, 17:2-20, 18:5-15 (“A base codebook subset indication can be expressed by bitmap.”). A person of ordinary skill in the art would have been motivated to modify **Sayana’s** teachings of codebook subset restriction to use **Lee-689’s** method because doing so would combine prior art elements and teachings according to known methods to yield predictable results. Using bitmaps to restrict codebook entries selectable by a UE was well-known in the art. Lee-689, 18:5-15; International Pat. Pub. No. WO2009/025619 (“Göransson”, Ex. 1020), [0030] (“According to exemplary

associated with a maximum of (2^6) 64 precoding matrices in a codebook. Sayana describes that a “representation” of a chosen matrix is “the index of the chosen matrix within a codebook.” Sayana, [0060] (“A user feeds back a representation of a first chosen matrix that has a set of vectors v_{11} , v_{12} , v_{21} , v_{22} , wherein *the representation can be just the index of the chosen matrix within a codebook*. Then, the user feeds back *a representation of a second matrix* of the form of [] *also as index within a codebook format*.”). As such, **Sayana’s** reference to “bits” refers to an index into a codebook, rather than a bitmap of restriction information taught by **Lee-639** and **TS36.213**, where the length of the bitmap is also the size of the codebook. Lee-639, 17:7-18:15; TS36.213, p.34.

embodiments, codebook subset restrictions (CBSSRs) *can be signaled to a UE 14 using a bitmap mask which differentiates between allowed entries and disallowed entries within a codebook ...*”); see also TS36.213, p.34 (“A UE is restricted to report PMI ... within a precoder codebook subset specified by a bitmap parameter *codebookSubsetRestriction*⁸”). In particular, a person of ordinary skill in the art would have been motivated to combine **Sayana’s** teachings of codebook restriction with **Lee-689’s** teachings of generating the codebook restriction to a base codebook subset via a bitmap to yield the predictable result of obtaining a codebook restriction that the base station can communicate to the UE. Sayana, [0085]-[0092]; Lee-689, 18:5-15.

97. **Third**, a person of ordinary skill in the art would have been motivated to apply **Lee-689’s** bitmap teachings in implementing **Sayana’s** codebook subset restriction to reduce inter-cell interference. Lee-689, 12:21-14:21, 15:11-16:16. In particular, **Lee-689** teaches that a first base station transmits information about a subset of precoding matrices to a neighboring second base station. *Id.*, 15:11-16:16 (“The transmitter *receives the information of first precoding matrixes indexes or the information of second precoding matrixes indexes from a receiver or a*

⁸ Emphasis in original.

transmitter of neighbor cells. . . . In case that the transmitter receives the information of first precoding matrixes indexes or the information of second precoding matrixes indexes from the transmitter of neighbor cells, *the receiver of neighbor cell, which receives interference, transmits the information of first precoding matrixes indexes or the information of second precoding matrixes indexes to the transmitter of neighbor cell* and the transmitter transmits the information of first precoding matrixes indexes or the information of second precoding matrixes indexes through backbone network to the transmitter.”). Here, the subset indicated by the neighboring base station excludes precoding matrices that cause interference when the first and second base stations simultaneously transmit to respective UEs connected to the first and second base stations, and therefore reduces interference that the respective UEs experience from the transmission of the first and second base stations. *Id.*, 14:5-21 (“In a method of *controlling interference* according to embodiments of the present invention, a *receiver requests a transmitter of neighbor cells not to use precoding matrixes which give more interference than others to the receiver if the receiver receives interference from precoding matrixes of neighbor cells*. Or, the *receiver can request the transmitter to use precoding matrixes which give less interference than others to the receiver*.”): As a result, the second base station generates its “base codebook subset” based on the bitmap received from the first base station so that

communications in its cell will not use precoding matrices that cause interference to the neighboring cell. *Id.*

98. **Fourth**, a person of ordinary skill in the art would have been motivated to apply **Lee-689**'s teachings of a bitmap in implementing **Sayana**'s codebook subset restriction to provide flexibility in the specification of codebook subset restriction within a particular codebook. It was known in the art that a "bitmap can specify all possible precoder codebook subsets" "[f]or a specific precoder codebook." *See e.g.*, TS36.213, p.34. Accordingly, implementing **Sayana**'s codebook subset restriction using **Lee-689**'s bitmap advantageously would provide precise control to selectively disable certain precoding matrices of a respective codebook, that result in sub-optimal communications, for example, by causing interference to neighboring cells, and to select separately from the respective codebooks to address different properties of precoding matrices (*e.g.*, wideband and subband) of the codebooks. Sayana, [0085]-[0087] ("***Codebook subset restriction can be used for both wideband and subband components***" in a pre-configured and compatible manner, which we will further describe with some exemplary methods."); Lee-689, 14:5-21, 15:4-17:1, 18:5-15. For example, it was well-known in the art to use a subset of precoding matrices to avoid precoding matrices that would cause interference to other cells; and to avoid precoding matrices that would

result in sub-optimal communications given antenna configurations within a cell. As discussed above, **Lee-689** describes using codebook restriction to avoid matrices that cause interference to UEs of other cells. Lee-689, 12:21-14:21, 15:11-16:16. **Lee-689** describes a first base station determining a set of precoding matrices that cause interference to UEs within its cell, and sends that subset of precoding matrices to a second base station to be restricted from use within the cell of the second base station, and thereby reduce interference to UEs within the first cell. *Id.* Göransson describes using codebook subset restriction where a subset of precoding matrices are “suitable for a particular antenna arrangement” within the cell. Göransson, ¶[0023] (“Codebook subset restrictions (CBSSRs) can be used by the system to restrict the user equipment (UE) from using the complete set of available precoders. ***One reason for using CBSSRs is that only parts of the entries in a codebook may be suitable for a particular antenna arrangement.*** For example, ***if a correlated array (also known as a traditional beamformer) is used at the cell site, only elements in the codebook corresponding to beamforming vectors are of value for selection and use.*** To ensure that a UE selects an appropriate beamforming vector, ***the system can restrict the UE to search for the ‘best’ precoder among the subset of precoders which containing suitable beamforming vectors,*** and prevent the UE from using and/or evaluating other codebook elements, i.e., those which do not provide such

beamforming vectors.”). In addition, a person of ordinary skill in the art would have understood that using a separate bitmap for codebook subset restriction of each codebook, rather than a combined bitmap codebook subset restriction of pairs across both codebooks, requires fewer bits, and reduces the overhead in communicating codebook subset restriction information. As an example, if a first codebook has 16 precoding matrices and a second codebook has 4 precoding matrices, there are 64 (16 x 4) possible pairs of precoding matrices. One way to represent the codebook subset restriction information is using a 64 bit bitmap to select among the 64 pairs. On the other hand, sending a 16 bit bitmap to separately select among the precoding matrices of the first codebook and a 4 bit bitmap to separately select among the precoding matrices of the second codebook would require 20 bits for codebook subset restriction information, which is fewer bits than required to select among all pairs. A person of ordinary skill in the art would have been motivated to reduce the number of transmitted bits in the bitmaps of codebook subset restriction information and would have had a reasonable expectation of success in doing so. For example, U.S. Patent App. Pub. 2011/0249713 (“Hammarwall”, Exhibit 1012) teaches that “[c]odebooks with large numbers of precoders require long bitmaps, and the signaling overhead associated with transmitting long bitmaps becomes prohibitive,” and that “maintaining low signaling overhead remains an important design target in

wireless systems.” Hammarwall, ¶¶[0010], [0018]. Because there are two options: a combined bitmap of more bits, and a separate bitmap of fewer bits, both options are predictable and obvious.

99. **Fifth**, a person of ordinary skill in the art would have been motivated to apply **Lee-689’s** bitmap teachings to implement a separate bitmap for each of **Sayana’s** codebook subset restriction for Sayana’s two codebooks, because doing so would be a design choice or predictable variation. There are two ways that **Lee-689’s** bitmap is applied to **Sayana’s** codebook restriction information for two codebooks, as I discussed above. First, **Lee-689’s** bitmap is implemented as a combined bitmap across the two codebooks. This provides more granularity for selectively enabling and disabling each possible pair of precoding matrices from the first codebook and second codebook. Second, **Lee-689’s** bitmap is implemented as two separate bitmaps across the two codebooks. This uses fewer bits for transmission as discussed above. In view of these limited design choices, and the varying benefits of each approach, a person of ordinary skill in the art would have been motivated to and found it obvious to use two bitmaps, one for each codebook, and would have had a reasonable expectation of success in doing so.

100. In light of my discussion above, a person of ordinary skill in the art also would have had a reasonable expectation of success in modifying **Sayana** to

implement its codebook subset restriction using **Lee-689's** teachings of a bitmap having the same number of bits as the number of precoder matrices. Both **Sayana** and **Lee-689** are directed to restriction of subsets of precoder matrices that are selectable by a UE for generating feedback for a base station. Lee-689, 17:7-18:15; Sayana, [0085]-[0092]. Further, using bitmaps having a number of bits that are the same as the number of precoders to provide codebook subset restriction was well understood. *See e.g.*, Lee-689, 17:7-18:15 (teaching using a bit map comprising 8 bits (“10011110”) to restrict a set of 8 precoders (“ $\mathbf{W} = [\mathbf{W}_0 \ \mathbf{W}_1 \ \mathbf{W}_2 \ \mathbf{W}_3 \ \mathbf{W}_4 \ \mathbf{W}_5 \ \mathbf{W}_6 \ \mathbf{W}_7]$ ”)); TS36.213 p.34 (teaching associating a bit map comprising 6 bits ($a_0, a_1, a_2, a_3, a_4, a_5$) with the same number of precoders), Göransson-619, [0023], [0030] (teaching using a bit map comprising 16 bits (“[0 1 1 0 0 1 1 0 0 0 0 0 0 0 0 0]”) to restrict the same number of precoders). As such, modifying **Sayana** to implement its codebook subset restriction by using **Lee-689's** teachings of a bitmap would have been a straightforward application of **Lee-689's** teachings in a manner that is consistent with the techniques that were well known at the time to advantageously provide the ability to restrict precoder matrices that are used in the feedback from the UE.

101. Based on my discussion above, a person of ordinary skill in the art would have been motivated to apply **Lee-689's** teachings of using a bitmap that has

the same number of bits as the number of precoding matrices in implementing **Sayana’s** “codebook subset restriction” information for **Sayana’s** “first component” precoder. In such an implementation, any of the precoding matrices in **Sayana’s** “first codebook” can advantageously be selected or restricted. Sayana, [0039], [0070], [0085]-[0092]; Lee-689, 15:4-17:1, 18:5-15. Furthermore, for the same reasons discussed above, a person of ordinary skill in the art also would have been motivated to apply these same teachings to **Sayana’s** “codebook subset restriction” information for **Sayana’s** “second” component precoder. *Id.* For example, it was well-known to use a bitmap as codebook subset restriction information, and the same benefits of interference reduction and flexibility to specify any precoder subsets would be realized when applying **Lee-689’s** teachings of a bitmap to **Sayana’s** “second” component precoder.

4. **Sayana and Lee-689 Analysis**

102. In addition to Sections IX.A.1 (Overview of Sayana)-IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana), my discussion below explains that each claim element challenged in this ground is disclosed and/or rendered obvious.

(a) Element [17.pre]

103. **Element [17.pre]** recites “**A communication method of a receiving device in a wireless communication system, the method comprising.**” This element is met by **Sayana** alone.

104. **Sayana** discloses a communication method (*e.g.*, “feedback scheme...to send a precoder matrix information to a base station” [0058]) **of a receiving device** (*e.g.*, “a wireless communication device” [0016] such as a “UE” [0016] that “receives transmissions from a plurality of antennas” [0018]) **in a wireless communication system** (*e.g.*, “a wireless communication system[.]” [0002]-[0003], [0015], [0019]).

105. **Sayana** discloses “a feedback framework in wireless communication systems.” **Sayana**, [0002]. **Sayana** discloses a “feedback scheme for a wireless communication device to send a precoder matrix information to a base station” where the precoder matrix information includes “a first representation of a first matrix chosen from a first codebook” and “a second representation of a second matrix chosen from a second codebook, wherein the first representation and the second representation together convey a precoder matrix of one or more vectors associated with one or more spatial layers.” *Id.*, [0058]. In particular, **Sayana** discloses a “‘precoding’ operation” where “the base station transmits a signal” to the

UE “via weighting each antenna signal with a complex value.” *Id.*, [0016], [0025], [0058], Figures 1-2. In response to receiving the downlink signal from the base station, the UE “send[s] a precoder matrix information to a base station.” *Id.*, [0058].

106. *E.g.*, Sayana:

- **Sayana Figure 1**

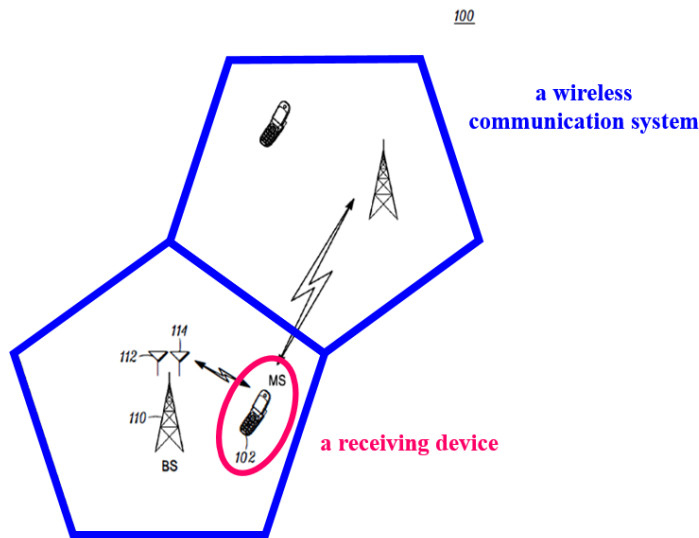


FIG. 1

- **Sayana Figure 2**

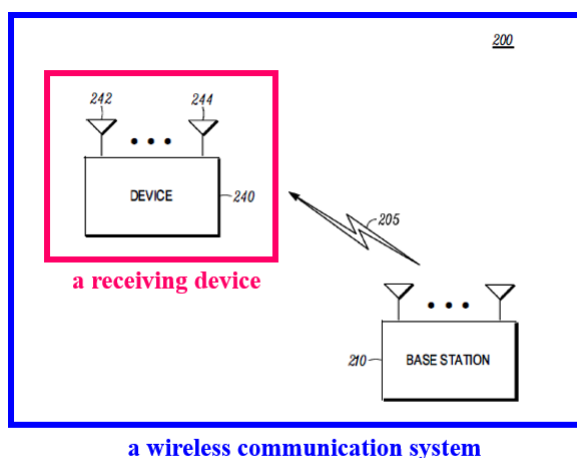


FIG. 2

- **Sayana [0002]** (“The present disclosure relates generally to *wireless communications* and, more particularly, to *a feedback framework in wireless communication systems*.”)
- **Sayana [0003]** (“*In wireless communication systems, channel state information at a transmitter, for example, at a base station, is important for beam-forming transmissions (also referred to as precoding)* that deliver more power to a targeted user while minimizing interference on other users. Precoding operations can be in the context of single-user multiple input multiple output (SU-MIMO) or multi-user MIMO (MU-MIMO), where two or more users are served by a single base station. An eNB needs accurate spatial channel information in order to perform a high rank transmission to a single UE or to perform precoding to two or more UEs simultaneously so that the mutual interference among multiple transmissions can be minimized at each UE.”)
- **Sayana [0015]** (“In FIG. 1, *a wireless communication system 100* comprises one or more fixed *base infrastructure units 110 and 120 forming a network* distributed over a geographical region for serving *remote units* in the time and/or frequency domain. *The base infrastructure unit may also be referred to as the transmitter, access point (AP), access terminal (AT), base, base station (BS), base unit (BU), Node-B (NB), enhanced Node-B (eNB), Home Node-B (HNB), Home eNB (HeNB) or by other terminology used in the art.* The base units are generally part of a radio access network that includes one or more controllers communicably coupled to one or more corresponding base units.”)
- **Sayana [0016]** (“*The one or more base units serve a number of remote units*, for example, remote unit 102 and 104 in FIG. 1, within a corresponding serving area, for example, a cell or a cell sector of the base unit, via

a wireless communication link. *The remote units may be fixed units or wireless communication devices. The remote unit may also be referred to as a receiver, subscriber station (SS), mobile, mobile station (MS), mobile terminal, user, terminals, user equipment (UE), user terminal (UT) or by other terminology used in the art.* The remote units also comprise one or more transmitters and one or more receivers. In FIG. 1, *the base unit 110 transmits downlink communication signals to serve remote unit 102* in the time and/or frequency domain. The remote unit 102 communicates directly with base unit 110 via uplink communication signals.”)

- **Sayana [0018]** (“In the diagram 200 of FIG. 2, at 210, a base unit transmits from a plurality of antennas. Also in FIG. 2, *a remote unit receives transmissions from a plurality of antennas*, which may or may not be co-located. In a typical embodiment, a base unit may be associated with a cell-ID, by which it identifies itself to a remote unit. As a conventional mode of operation, also sometimes referred to as a single-point transmission scheme, a remote unit 240 receives transmissions from a plurality of antennas of a single base unit 210. Such a base unit is also referred to as a serving cell (or serving base unit) to the user device/remote unit.”)

- **Sayana [0019]** (“*[T]he wireless communication system is compliant with the Third Generation Partnership Project (3GPP) Universal Mobile Telecommunications System (UMTS) Long Term Evolution protocol, also referred to as Evolved Universal Terrestrial Radio Access (EUTRA), or some future generation thereof*, wherein the base unit transmits using an orthogonal frequency division multiplexing (OFDM) modulation scheme on the downlink and the user terminals transmit on the uplink using a single carrier frequency division multiple access (SC-FDMA) scheme. In another implementation, the wireless communication system is compliant with the IEEE 802.16 protocol or a future generation thereof. More generally, however, the *wireless communication system may implement some other open or proprietary communication protocol where channel feedback is useful or desired.*”)

- **Sayana [0058]** (“*In the feedback scheme for a wireless communication device to send a precoder matrix information to a base station*, the wireless communication device sends a first representation of a first matrix chosen from a first codebook, wherein the first matrix has at least two column vectors. The wireless communication device sends a second representation of a second matrix chosen from a second codebook, wherein the first representation and the second representation together convey a precoder matrix of one or more

vectors associated with one or more spatial layers.”)

- *See also Sayana [0025].*

(b) Element [17.a]

107. Element [17.a] recites “receiving codebook restricting information including at least one of⁹ a first bit sequence to restrict at least one precoding matrix from a first precoding matrix group and a second bit sequence to restrict at least one precoding matrix from a second precoding matrix group.” This element is met by Sayana in view of Lee-689.

108. Sayana discloses receiving codebook restricting information (*e.g.*, receiving “codebook subset restriction” [0085]) to restrict at least one precoding matrix from a first precoding matrix group (*e.g.*, “codebook subset restriction ...signals the UE to only use a subset of codebook entries” [0085] from a “first codebook” [0085], “wideband codebook” [0087], “W₁” [0082], [0094] where “a predefined codebook [] consists of a set of pre-defined vectors or matrices” [0029]) and to restrict at least one precoding matrix from a second precoding

⁹ While [17.a] requires that “codebook restricting information” include only “at least one of” a “first bit sequence” and a “second bit sequence,” Ground 1 nevertheless shows both sequences.

matrix group (e.g., “codebook subset restriction ...signals the UE to only use a subset of codebook entries” [0085] from a “second codebook” [0085], “subband codebook” [0084]-[0085], [0087], “W₂” [0082], [0094]).

109. **Lee-689 teaches codebook restricting information including at least one bit sequence to restrict at least one precoding matrix** (e.g., a “bitmap” of “codebook subset indication” 18:5-15).

110. See my discussion for element [17.pre]. **Sayana** further discloses, as part of the downlink communication, the UE receives “[a] codebook subset restriction . . . where eNB signals the UE to only use a subset of codebook entries for the feedback,” eNB referring to eNodeB or the base station. Sayana, [0085] (“A *codebook subset restriction* is essentially where *eNB signals the UE to only use a subset of codebook entries for the feedback*. Subset restriction can be applied to either the first codebook, or the second codebook, or both.”). Here, the subset of codebook entries consists of “a set of pre-defined vectors or matrices” within “a predefined codebook.” Sayana, [0029] (“The precoding weights may or may not be constrained to a *predefined codebook that consists of a set of pre-defined vectors or matrices*.”), [0039], [0058]. **Sayana** teaches that “[s]ubset restriction can be applied to either the first codebook, or the second codebook, or both.” *Id.*, [0079], [0082], [0085]. Based on these subset restrictions, the UE selects and feeds back a

“preferred Precoding Matrix Index (PMI)” from each codebook. *Id.*, [0039] (“To support precoding operation from the base station, a user terminal ***will be reporting back to the base station a preferred Precoding Matrix Index (PMI) which is an index to a set of predetermined precoding matrices.***”), [0087], [0094], Figs. 1-2.

111. For example, **Sayana** discloses that the first and second codebooks and their respective subset restrictions are used for “long-term” (e.g., “wide frequency band”) feedback and “short-term” (e.g., “subband/narrowband” frequency), respectively. Sayana, [0006], [0050] (“For the purpose of discussion, we will assume the ***long-term/correlated component corresponds to a wide frequency band*** such as the whole system bandwidth and the ***short-term component corresponds to a subband/narrowband*** that is composed of a set of contiguous subcarriers and is a part of the wideband.”).

112. As discussed above, **Sayana** does not specify the form of the codebook subset restriction information that is signaled from a base station/eNB to a UE.

113. Like **Sayana**, **Lee-689** teaches using “a base codebook subset indication” as codebook subset restriction to “represent[] which precoding matrixes are included in a base codebook subset among a rank 1 base codebook or not.” Lee-689, 18:5-15. **Lee-689** further teaches that a “base codebook subset indication can be expressed by bitmap” and that “[f]or example, if *i*th element of a base codebook

subset indication expressed by bitmap is 0, a base codebook subset does not include *ith* element of a base codebook” whereas “if *ith* element of a base codebook subset indication expressed by bitmap is 1, a base codebook subset includes *ith* element of a base codebook” and furthermore that “a base codebook subset indication for a base codebook subset of equation 7 is ‘0b10011110’.” *Id.*

114. As I discuss in more detail in Section IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana), a person of ordinary skill in the art would have been motivated to modify **Sayana** to implement its “codebook subset restriction” information using **Lee-689’s** bitmaps , resulting in a system in which a separate bitmap is used for each of **Sayana’s** codebooks (e.g., , wideband and subband) to identify precoding matrices to restrict from each respective codebook (Sayana, [0085]; Lee-689, 18:5-15), to advantageously provide flexibility in the signaling of precoding matrices to UEs by specifying precoder subsets for each specific precoder codebook. *See* Section IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana). In particular, by applying **Lee-689’s** restriction information to **Sayana**, the restriction information separately provides a first bitmap (a first bit sequence) as first codebook restriction information and a second bitmap (a second bit sequence) as second codebook restriction information. For example, when the first and second codebooks apply to the

wideband and subband feedback, respectively, as **Sayana** teaches, the separate restriction information for each codebook advantageously allows providing distinct restriction information for the wideband and subband communications, to address different restriction requirements among the two types of communications. Sayana, [0006] (“This can be used to *feedback the correlated and uncorrelated channel characteristics, i.e., two components, at different rates and/or* with different levels of quantization/overhead in time and frequency to reduce feedback overhead. *One of the components* representing the correlated channel characteristics can be *fed back on a wideband basis and/or slowly in time*, while the *other component is fed back on a subband basis and/or more frequently in time*”), [0085] (“A codebook subset restriction is essentially where eNB signals the UE to only use a subset of codebook entries for the feedback. *Subset restriction can be applied to either the first codebook, or the second codebook, or both.*”); Lee-689, 18:5-15. Also, as I described above in Section IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana), application of **Lee-689’s** teachings to **Sayana’s** teachings would improve transmission power to intended UEs and reduce interference to unintended UEs. Lee-689, 17:2-18:15.

115. *E.g., Sayana:*

- **Sayana [0006]** (“*One of the components* representing the correlated channel characteristics *can be fed back on a wideband basis and/or slowly in*

time, while the other component is fed back on a subband basis and/or more frequently in time.”)

- **Sayana [0029]** (“The precoding weights may or may not be constrained to *a predefined codebook that consists of a set of pre-defined vectors or matrices*. In an embodiment with constrained precoding, *the precoding matrix may be signaled by the base unit efficiently with a precoding matrix index (PMI) or with an index to a precoding matrix within a predefined codebook*. The term ‘matrix’ in this context may include the degenerated special case of vector, which applies to single stream transmission. In the most generic sense, the term ‘precoding’ refers to any possible transmission scheme that may be deemed as mapping a set of data streams to an antenna set using a matrix V.”)

- **Sayana [0039]** (“To support precoding operation from the base station, a user terminal will be reporting back to the base station *a preferred Precoding Matrix Index (PMI) which is an index to a set of predetermined precoding matrices*. The recommended precoding matrix is obtained at the user terminal based on a certain metric such as maximizing the post-precoding link quality or throughput and is selected from one of the quantized codebook entries, wherein the codebook is known to the transmitter and the receiver.”)

- **Sayana [0050]** (“For the purpose of discussion, we will assume the *long-term/correlated component corresponds to a wide frequency band* such as the whole system bandwidth and the *short-term component corresponds to a subband/narrowband* that is composed of a set of contiguous subcarriers and is a part of the wideband.”)

- **Sayana [0058]** (“In the feedback scheme for *a wireless communication device to send a precoder matrix information to a [BS], the wireless communication device sends a first representation of a first matrix chosen from a first codebook*, wherein the first matrix has at least two column vectors. *The wireless communication device sends a second representation of a second matrix chosen from a second codebook, wherein the first representation and the second representation together convey a precoder matrix* of one or more vectors associated with one or more spatial layers.”)

- **Sayana [0079]** (“In a preferred embodiment, a product matrix based method of precoder matrix representation can be used to describe the *two-component feedback*.”)

- **Sayana [0082]** (“The final precoder is obtained as
$$W = \text{reshape}(W_1 W_2)$$

where a ‘reshaping’ operation is to re-arrange the columns of the product matrix to

form the precoder matrix. ...

$$\text{reshape}(X = [X_1 X_2 X_3 X_4]) = \begin{bmatrix} X_1 & X_3 \\ X_2 & X_4 \end{bmatrix},,$$

• **Sayana [0084]** (“In another embodiment, the subband codebook may be expanded allowing the incorporation of a rotation codebook, in which case *the wideband and subband codebook could be represented mathematically* as

$$W_1 = \left[\text{diag} \left(\begin{bmatrix} 1 & e^{\frac{2\pi j n_1}{N_1}} & \dots & e^{\frac{2\pi j L n_1}{N_1}} \end{bmatrix} \right), \text{diag} \left(\begin{bmatrix} 1 & e^{\frac{2\pi j n_2}{N_1}} & \dots & e^{\frac{2\pi j L n_2}{N_1}} \end{bmatrix} \right) \right]$$

$$= \begin{bmatrix} 1 & 0 & \dots & 0 & 1 & 0 & \dots & 0 \\ 0 & e^{\frac{2\pi j n_1}{N_1}} & \dots & 0 & 0 & e^{\frac{2\pi j n_2}{N_1}} & \dots & 0 \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 \\ 0 & 0 & \dots & e^{\frac{2\pi j L n_1}{N_1}} & 0 & 0 & \dots & e^{\frac{2\pi j L n_2}{N_1}} \end{bmatrix}$$

$$n_1, n_2 \in \{0, 1, \dots, N_1 = 2^{B_1} - 1\}$$

$$W_2 = \left\{ \begin{bmatrix} u_1 & 1 e^{\frac{2\pi j k_1}{4}} & u_1 & -1 e^{\frac{2\pi j k_2}{4}} \\ 0 & 0 & 0 & 0 \end{bmatrix}, \right.$$

$$\text{or } \begin{bmatrix} \rho u_1 & \sqrt{1-\rho^2} e^{\frac{2\pi j k_1}{4}} u_1 & 0 & 0 \\ 0 & 0 & \sqrt{1-\rho^2} u_2 & \rho e^{\frac{2\pi j k_2}{4}} u_2 \end{bmatrix},$$

$$\text{or } \left. \begin{bmatrix} \rho u_1 & 0 & 0 & \rho e^{\frac{2\pi j k_2}{4}} u_1 \\ 0 & \sqrt{1-\rho^2} e^{\frac{2\pi j k_1}{4}} u_2 & \sqrt{1-\rho^2} u_2 & 0 \end{bmatrix} \right\},$$

where

$$\rho^2 \in \{0.5, 0.75, 0.9, 1\}, k_1, k_2 \in \{0, 1, 2, 3\};$$

$$u_1, u_2 \in CB_{ij} = \left\{ \begin{bmatrix} 1 & e^{\frac{2\pi j n}{N_1 K}} & e^{\frac{2\pi j 2n}{N_1 K}} & \dots & e^{\frac{2\pi j L n}{N_1 K}} \end{bmatrix}^T, \right.$$

$$\left. n = -2^{B_2-1} = -N_2/2, -(N_2/2-1), \dots, 0, \dots, N_2/2-1 \right\}$$

where 0, 1 represent Lx 1 vectors of zeros and ones respectively.”)

• **Sayana [0085]** (“The construction above presents a product design followed by reshaping to provide improved flexibility in the two component feedback. However, further overhead reduction can be configured by *eNB* by

enabling codebook subset restrictions at wideband and subband level. A

codebook subset restriction is essentially where eNB signals the UE to only use a subset of codebook entries for the feedback. Subset restriction can be applied to either the first codebook, or the second codebook, or both.”)

- **Sayana [0086]** (“***Codebook subset restriction can be used for both wideband and subband components***”)
- **Sayana [0087]** (“In one embodiment, ***a subset restriction can be imposed at wideband level*** to only transmit information regarding v1, ***by defining [a] wideband codebook*** as follows

$$W_1 = \left[\text{diag} \left(\begin{bmatrix} 1 & e^{\frac{2\pi j n_1}{N_1}} & \dots & e^{\frac{2\pi j L n_1}{N_1}} \end{bmatrix} \right) \text{diag}([1 \ 1 \ \dots \ 1]) \right]$$

With this restriction, only B1 bits of information need to be sent, and may be beneficial when ULA is highly rank 1 as in certain LOS cases, and only structure one may be used for all sub-bands included in the feedback. This would also implicitly result in ***following restriction for the subband codebook***

$$W_2 = \left\{ \begin{bmatrix} u_1 & e^{\frac{2\pi j k_1}{4}} & u_1 & -e^{\frac{2\pi j k_2}{4}} \\ 0 & 0 & 0 & 0 \end{bmatrix}, k_1, k_2 \in \{0, 1, 2, 3\}; \right.$$

$$u_1, u_2 \in CB_{ij} = \left\{ \begin{bmatrix} 1 & e^{\frac{2\pi j n}{N_1 K}} & e^{\frac{2\pi j 2n}{N_1 K}} & \dots & e^{\frac{2\pi j L n}{N_1 K}} \end{bmatrix}^T, \right.$$

$$n = -2^{B_2-1} = -N_2/2, -(N_2/2-1), \dots, 0, \dots, N_2/2-1 \Big\}, \Big)$$

- **Sayana [0094]** (“One embodiment is illustrated in FIG. 6. ***The first component could correspond to a wideband matrix W_1^{WB}*** corresponding to the whole bandwidth **610**, which is composed of one or more sub-bands **620**. Each subband **620** is composed of a set of contiguous subcarriers **630** or in LTE, a set of RBs, which is the minimum scheduling/feedback granularity. ***A second matrix W_2^b*** corresponds to a to a band ‘b’. The precoder for a band ‘b’, represented as W^b is obtained as a function of W_1^{WB} and W_2^b . A preferred example of the function as described above is reshape ($W_1 \times W_2$). ***A UE is required to feedback the wideband precoder/matrix*** for the whole band and the ***subband precoder/matrix*** for each subband.”)

- **See also Sayana Abstract, Sayana [0004], Sayana [0015]-[0016], Sayana [0018]-[0019], Sayana [0025]-[0028], Sayana [0037], Sayana [0043], Sayana [0050], Sayana [0064]-[0072], Sayana [0080]-[0081], Sayana [0088]-[0092].**

116. *E.g.*, Lee-689:

- **Lee-689 18:5:15** (“A base codebook subset indication represents which precoding matrixes are included in a base codebook subset among a rank 1 base codebook or not. *A base codebook subset indication can be expressed by bitmap.* For example, if *i*th element of a base codebook subset indication expressed by bitmap is 0, a base codebook subset does not include *i*th element of a base codebook. And, if *i*th element of a base codebook subset indication expressed by bitmap is 1, a base codebook subset includes *i*th element of a base codebook. That is, a base codebook subset indication for a base codebook subset of equation 7 is ‘0b10011110’.”)

- *See also* Lee-689 12:5-16; Lee-689 17:7-20:23.

(c) Element [17.b]

117. Element [17.b] recites “each bit of the first bit sequence corresponding to one precoding matrix of the first precoding matrix group, respectively, the at least one precoding matrix of the first precoding matrix group being restricted from being used as a precoding matrix of a first precoder, each bit of the second bit sequence corresponding to one precoding matrix of the second precoding matrix group, respectively, and the at least one precoding matrix of the second precoding matrix group being restricted from being used as a precoding matrix of a second precoder.” This element is met by Sayana in view of Lee-689.

118. Sayana discloses the at least one precoding matrix of the first precoding matrix group (*see* [17.a]; *e.g.*, restricted precoding matrix from a “first

codebook” [0085], “wideband codebook” [0087], “ W_1 ” [0094] where “a predefined codebook [] consists of a set of pre-defined vectors or matrices” [0029]) **being restricted from being used as a precoding matrix of a first precoder** (*see* [17.a]; *e.g.*, “codebook subset restrictions at wideband ... level” [0085], “first” precoder [0094], “ W_1 ” [0094]), **and the at least one precoding matrix of the second precoding matrix group** (*see* [17.a], *e.g.*, restricted precoding matrix from a “second codebook” [0085], “subband codebook” [0084]-[0085], [0087], “ W_2 ” [0094]) **being restricted from being used as a precoding matrix of a second precoder** (*see* [17.a]; *e.g.*, “codebook subset restrictions at ... subband level” [0085], “second” precoder [0094], “ W_2 ” [0094]).

119. **Lee-689** discloses each bit of the bit sequence corresponding to one **precoding matrix of the precoding matrix group, respectively** (*see* [17.a], *e.g.*, “if *i*th element of a base codebook subset indication expressed by bitmap is 0, a base codebook subset does not include *i*th element of a base codebook”, 18:5-15).

120. See my discussion for the elements [17.pre]-[17.a]. **Sayana** discloses “two” component precoders including a “first” precoder and a “second” precoder “to achieve two-component feedback.” Sayana, [0048]-[0049]. As I discuss in Section IX.A.1 (Overview of Sayana), like the ’924 patent’s multistage precoder including first and second precoders, **Sayana’s** first and second precoders together

form one composite precoder at the base station. *See* Section IX.A.1 (Overview of Sayana); '924, 5:20-60, 7:34-41, 8:19-28, 17:42-60, Fig. 4; Sayana, Abstract, [0003], [0006], [0015]-[0016], [0048]-[0050], [0058]-[0059], [0091], [0095]. In particular, Sayana's "two" component precoders include a "wideband" precoder "W1" or " W_1^{WB} " and a "subband" precoder "W2" or " W_2^B ". *See* Section IX.A.1 (Overview of Sayana); Sayana, Abstract, [0048]-[0050], [0082], [0093]-[0094]. As such, the composite (or "final") precoder is "simply based on $W = \text{reshape}(W_1 W_2)$," "where a 'reshaping' operation is to re-arrange the columns of the product matrix to form the precoder matrix." Sayana [0082], [0094].

121. As I discuss for element [17.a], **Sayana** also discloses using a "codebook subset restriction" applied to the entries of the "first codebook" and "second codebook," where the entries consist of "precoding matrices" *See* [17.a]; Sayana, [0049], [0085]-[0086]. Accordingly, the codebook subset restriction information indicates to the UE to "use a subset of codebook entries" of a codebook for a "first" precoder and a codebook for a "second" precoder of "two" component precoders. *Id.* Thus, the codebook subset restriction information restricts the use of certain precoding matrices in the respective precoding matrix groups for the first and second precoders. *Id.*

122. As discussed above, **Sayana** does not specify the form of “codebook subset restriction” that is signaled from a base station/eNB to a UE for first and second components (e.g., wideband and subband components). *See* Sections IX.A.1 (Overview of Sayana)-IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana).

123. As I discuss for element [17.a], **Lee-689** teaches using “a base codebook subset indication” “expressed by a bitmap” for codebook subset restriction. *See* [17.a]; Lee-689, 18:5-15. **Lee-689** teaches that the bitmap used as the codebook restriction comprises a sequence of bits, where each bit of the bit sequence corresponds to an “element” (e.g., a precoding matrix) of the respective “base codebook” (e.g., precoding matrix group). *Id.* “For example, if [an] *i*th element of a base codebook subset indication expressed by bitmap is 0, a base codebook subset does not include [the] *i*th element of a base codebook” and “if [an] *i*th element of a base codebook subset indication expressed by bitmap is 1, a base codebook subset includes [the] *i*th element of a base codebook” such that “a base codebook subset indication for a base codebook subset of equation 7 is ‘0b10011110’.” *Id.*

124. As I discussed in more detail in Section IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana), a person of ordinary skill

in the art would have been motivated to modify **Sayana** to implement its “codebook subset restriction” information using **Lee-689**’s teachings of bitmaps, resulting in a system in which a separate bitmap is used for each codebook (*e.g.*, wideband and subband) to identify a respective codebook subset restriction, rendering obvious this element, to advantageously provide flexibility in the signaling of precoding matrices to UEs by enabling specification of various precoder subsets of a specific precoder codebook. *See* Section IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana); [17.a].

125. *E.g., Sayana:*

- **Sayana [0048]** (“*As can be seen, two structures are shown which allow expressing the overall precoder as a Kronecker product of two precoders.*”)
- **Sayana [0049]** (“*Though the Kronecker representation leads to an elegant separation to two component precoders* and is one way to achieve two-component feedback , it also imposes some limitations, where either the ULA or the cross-pol component is assumed to be rank **1** for deriving an overall rank-**2** precoder. In general, however a more general two-component precoder structure is useful for higher ranks, which will be further discussed below.”)
- **Sayana [0050]** (“For the purpose of discussion, we will assume the *long-term/correlated component corresponds to a wide frequency band* such as the whole system bandwidth and the *short-term component corresponds to a subband/narrowband* that is composed of a set of contiguous subcarriers and is a part of the wideband.”)
- **Sayana [0082]** (“The final precoder is obtained as

$$W = \text{reshape}(W_1 W_2)$$

where a ‘reshaping’ operation is to re-arrange the columns of the product matrix to form the precoder matrix. For example, for 8 Tx with a 4-by-2 W_1 and a 2-by-4

W_2 and 4-by-4 product matrix can be column-wise reshaped to 8×2 precoder W as follows.

$$\text{reshape}(X = [X_1 X_2 X_3 X_4]) = \begin{bmatrix} X_1 & X_3 \\ X_2 & X_4 \end{bmatrix}$$

")

- **Sayana [0085]** (“The construction above presents a product design followed by reshaping to provide improved flexibility in the two component feedback. However, further overhead reduction can be configured by *eNB* by ***enabling codebook subset restrictions at wideband and subband level. A codebook subset restriction is essentially where eNB signals the UE to only use a subset of codebook entries for the feedback. Subset restriction can be applied to either the first codebook, or the second codebook, or both.***”)

- **Sayana [0086]** (“***Codebook subset restriction can be used for both wideband and subband components*** in a pre-configured and compatible manner, which we will further describe with some exemplary methods.”)

- **Sayana [0093]** (“***The two component feedback scheme described above is applicable to multiple feedback modes as further described below.***”)

- **Sayana [0094]** (“One embodiment is illustrated in FIG. 6. The ***first component could correspond to a wideband matrix W_1^{WB}*** corresponding to the whole bandwidth 610, which is composed of one or more sub-bands 620. Each subband 620 is composed of a set of contiguous subcarriers 630 or in LTE, a set of RBs, which is the minimum scheduling/feedback granularity. ***A second matrix W_2^b corresponds to a band ‘b’.*** The precoder for a band ‘b’, represented as ***W^b*** is obtained as a function of ***W_1^{WB}*** and ***W_2^b*** . A preferred example of the function as described above is reshape ($W_1 \times W_2$). A UE is required to feedback the wideband precoder/matrix for the whole band and the subband precoder/matrix for each subband.”)

- **See also Sayana [0003], Sayana [0006], Sayana [0015]-[0016], Sayana [0029], Sayana [0039], Sayana [0054], Sayana [0092], Sayana [0095].**

126. E.g., Lee-689:

- **Lee-89 18:5-15.**

(d) Element [17.c]

127. Element [17.c] recites **“transmitting, to a transmitting device, 1st channel status information indicating the precoding matrix of the first precoder and 2nd channel status information indicating the precoding matrix of the second precoder.”** This element is met by **Sayana** alone.

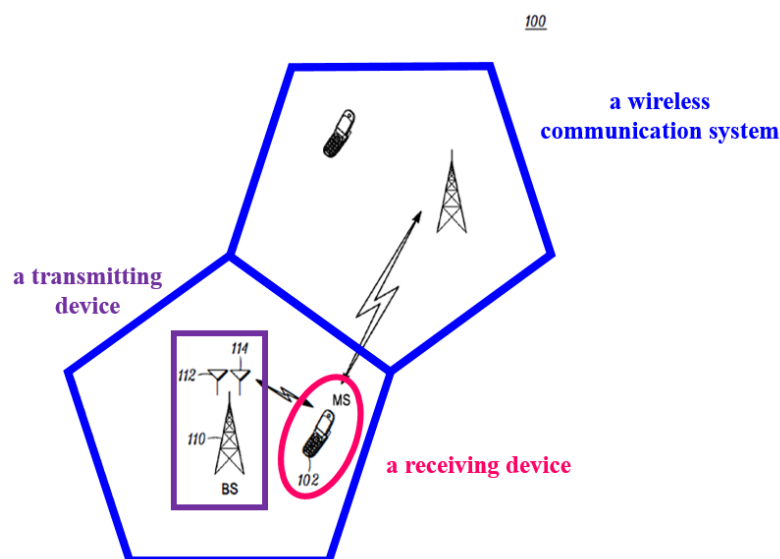
128. **Sayana discloses transmitting, to a transmitting device** (*see* [17.pre]; *e.g.*, transmitting to the [BS]/“eNB” [0015] “via uplink communication signals” [0016]), **1st channel status information indicating the precoding matrix of the first precoder** (*e.g.*, “a first representation of a first matrix chosen from a first codebook” [0058] “along with an associated CQI feedback” [0095]; *see* [17.pre]-[17.b]) **and 2nd channel status information indicating the precoding matrix of the second precoder** (*e.g.*, “a second representation of a second matrix chosen from a second codebook” [0058] “along with an associated CQI feedback” [0095]; *see* [17.pre]-[17.b])).

129. See my discussion for elements [17.pre]-[17.c]. **Sayana** also discloses, “[i]n the feedback scheme for a wireless communication device to send a precoder matrix information to a base station, the wireless communication device sends a first representation of a first matrix chosen from a first codebook,” and a “second representation of a second matrix chosen from a second codebook” “via uplink

communication signals.” Sayana, Figures 1-2, [0015]-[0016], [0018], [0058]. Such “two-component feedback conveys the information of a precoder matrix recommended by the user to the base station.” Sayana, [0059]. As such, the first representation corresponds to the “index of the chosen matrix within” the first “codebook” of the first precoder and the second representation corresponds to the “index of the chosen matrix within” the second “codebook” of the second precoder. See [17.pre]-[17.b]; Sayana, Abstract, [0058], [0060]. **Sayana** further discloses that “the feedback [of the UE] could be defined along with an associated CQI feedback.” Sayana, [0095].

130. *E.g.*, **Sayana**:

- **Sayana Figure 1**



- **Sayana Figure 2**

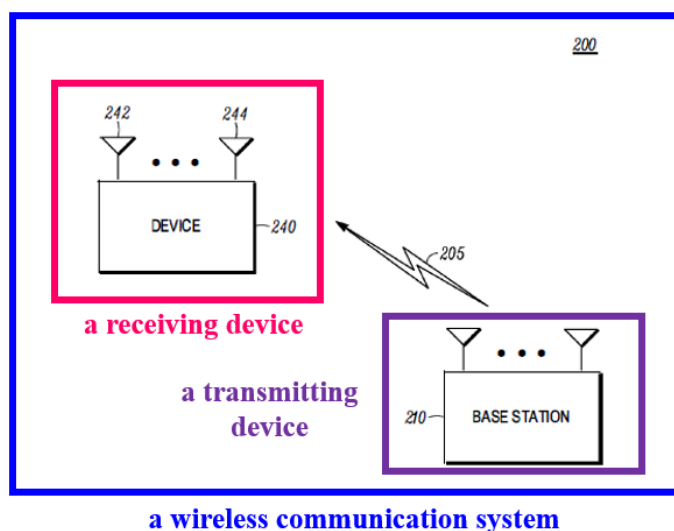


FIG. 2

- **Sayana Abstract** (“A method for two component feedback in wireless communication systems is disclosed, with *a wireless communication device sending a first representation of a first matrix chosen from a first codebook, wherein the first matrix has at least two columns, the wireless communication device sending a second representation of a second matrix chosen from a second codebook*, and the base station obtaining a precoder from the first representation and the second representation.”)

- **Sayana [0015]** (“In FIG. 1, *a wireless communication system 100* comprises one or more fixed *base infrastructure units 110 and 120* forming a network ... remote units The *base infrastructure unit may also be referred to as the transmitter, access point (AP), access terminal (AT), base, [BS], base unit (BU), Node-B (NB), enhanced Node-B (eNB), Home Node-B (HNB), Home eNB (HeNB) or by other terminology used in the art.*”)

- **Sayana [0016]** (“*The one or more base units serve a number of remote units*, for example, remote unit 102 and 104 in FIG. 1 *The remote units may be fixed units or wireless communication devices. The remote unit may also be referred to as a receiver, subscriber station (SS), mobile, mobile station (MS), mobile terminal, user, terminals, user equipment (UE), user terminal (UT) or by other terminology used in the art. ... In FIG. 1, the base unit 110 transmits downlink communication signals to serve remote unit 102 The remote unit 102 communicates directly with base unit 110 via uplink communication signals.*”)

- Sayana [0018] (“In the diagram 200 of FIG. 2, at 210, a base unit transmits from a plurality of antennas. *Also in FIG. 2, a remote unit receives transmissions from a plurality of antennas*, which may or may not be co-located. In a typical embodiment, a base unit may be associated with a cell-ID, by which it identifies itself to a remote unit. As a conventional mode of operation, also sometimes referred to as a single-point transmission scheme, a remote unit 240 receives transmissions from a plurality of antennas of a single base unit 210. Such a base unit is also referred to as a serving cell (or serving base unit) to the user device/remote unit.”)
- Sayana [0058] (“*In the feedback scheme for a wireless communication device to send a precoder matrix information to a base station, the wireless communication device sends a first representation of a first matrix chosen from a first codebook*, wherein the first matrix has at least two column vectors. *The wireless communication device sends a second representation of a second matrix chosen from a second codebook, wherein the first representation and the second representation together convey a precoder matrix* of one or more vectors associated with one or more spatial layers.”)
- Sayana [0059] (“*The two-component feedback conveys the information of a precoder matrix recommended by the user to the base station.*”)
- Sayana [0060] (“*A user feeds back a representation of a first chosen matrix ... wherein the representation can be just the index of the chosen matrix within a codebook. Then, the user feeds back a representation of a second matrix ... also as index within a codebook format.* The precoder information conveyed by these two representations corresponds to a final precoder matrix”)
- Sayana [0095] (“In one embodiment, the *feedback could be defined along with an associated CQI feedback*. The CQI feedback could correspond to a modulation and coding scheme (MCS) recommendation and/or a rank indication. The CQI could further consist of multiple CQI, one per each subband. In this case, the UE must select the *components W_1^{WB} and W_2^b* such that the subband precoders can support the CQI reported corresponding to the subband on the hypothesis UE is allocated that subband, while satisfying an error rate target.”)
- See also Sayana Abstract, Sayana [0003], Sayana [0017], Sayana [0085]-[0086].

(e) Element [17.d]

131. Element [17.d] recites **“the precoding matrix of the first precoder and the precoding matrix of the second precoder being selected, based on the codebook restricting information, from among precoding matrices that are not restricted.”** This element is met by **Sayana** alone.

132. **Sayana discloses the precoding matrix of the first precoder and the precoding matrix of the second precoder** (*see* [17.b]; *e.g.*, “a first representation of a first matrix chosen from a first codebook”; “a second representation of a second matrix chosen from a second codebook” [0058], “first” precoder , “W1”, “second” precoder, “W2” [0094]) **being selected** (*e.g.*, “first representation of a first matrix chosen from a first codebook”; “second representation of a second matrix chosen from a second codebook” [0058]), **based on the codebook restricting information, from among precoding matrices that are not restricted** (*see* [17.a]; *e.g.*, “subset restriction ... signals the UE to only use a subset of codebook entries” and “can be applied to either the first codebook, or the second codebook, or both” [0085]).

133. See my discussions for elements [17.pre]-[17.c]. As I discuss for elements [17.a]-[17.b], **Sayana** discloses “two” component precoders including a “first” precoder associated with “wideband” information and a “second” precoder associated with “subband” information “to achieve two-component feedback.” *See*

[17.a]-[17.b]. **Sayana** also discloses that a base station “signals the UE to only use a subset of codebook entries for the feedback” from among precoding matrices of “the first codebook” and “the second codebook” that are not restricted. Sayana, [0085], [0094]. For example, to select wideband and subband components of a precoder matrix, a respective “index to a set of predetermined precoding matrices” is used, which serves as “information of a precoder matrix recommended by the user to the base station.” Sayana, [0039] (“*To support precoding operation from the base station, a user terminal will be reporting back to the base station a preferred Precoding Matrix Index (PMI) which is an index to a set of predetermined precoding matrices.* The recommended precoding matrix is obtained at the user terminal based on a certain metric such as maximizing the post-precoding link quality or throughput and is selected from one of the quantized codebook entries, wherein the codebook is known to the transmitter and the receiver.”), [0059] (“*The two-component feedback conveys the information of a precoder matrix recommended by the user to the base station.* The actual precoder used by the base station may be different from the suggested precoder, but the actual precoder is derived from the recommended feedback.”).

134. *E.g., Sayana:*

- **Sayana [0039]** (“To support precoding operation from the [BS], *a user terminal will be reporting back to the [BS] a preferred Precoding Matrix*

Index (PMI) which is an index to a set of predetermined precoding matrices. The recommended precoding matrix is obtained at the user terminal based on a certain metric such as maximizing the post-precoding link quality or throughput and is selected from one of the quantized codebook entries, wherein the codebook is known to the transmitter and the receiver.”)

- Sayana [0048] (“*As can be seen, two structures are shown which allow expressing the overall precoder as a Kronecker product of two precoders.*”)

- Sayana [0049] (“*Though the Kronecker representation leads to an elegant separation to two component precoders and is one way to achieve two-component feedback*”)

- Sayana [0050] (“*For the purpose of discussion, we will assume the long-term/correlated component corresponds to a wide frequency band such as the whole system bandwidth and the short-term component corresponds to a subband/narrowband that is composed of a set of contiguous subcarriers and is a part of the wideband.*”)

- Sayana [0058] (“*In the feedback scheme for a wireless communication device to send a precoder matrix information to a base station, the wireless communication device sends a first representation of a first matrix chosen from a first codebook, wherein the first matrix has at least two column vectors. The wireless communication device sends a second representation of a second matrix chosen from a second codebook, wherein the first representation and the second representation together convey a precoder matrix of one or more vectors associated with one or more spatial layers.* ”)

- Sayana [0059] (“*The two-component feedback conveys the information of a precoder matrix recommended by the user to the [BS].*”)

- Sayana [0085] (“*The construction above presents a product design followed by reshaping to provide improved flexibility in the two component feedback. However, further overhead reduction can be configured by eNB by enabling codebook subset restrictions at wideband and subband level. A codebook subset restriction is essentially where eNB signals the UE to only use a subset of codebook entries for the feedback. Subset restriction can be applied to either the first codebook, or the second codebook, or both.*”)

- Sayana [0086] (“*Codebook subset restriction can be used for both wideband and subband components in a pre-configured and compatible manner, which we will further describe with some exemplary methods.*”)

- Sayana [0087] (“*In one embodiment, a subset restriction can be imposed at wideband level to only transmit information regarding v1, by defining*

[a] wideband codebook This would also implicitly result in *following restriction for the subband codebook.*)

- **Sayana [0094]** (“One embodiment is illustrated in FIG. 6. *The first component could correspond to a wideband matrix W_1^{WB}* corresponding to the whole bandwidth **610**, which is composed of one or more sub-bands **620**. Each subband **620** is composed of a set of contiguous subcarriers **630** or in LTE, a set of RBs, which is the minimum scheduling/feedback granularity. *A second matrix W_2^b* corresponds to a band ‘b’. The precoder for a band ‘b’, represented as W^b is obtained as a function of W_1^{WB} and W_2^b . A preferred example of the function as described above is reshape ($W_1 \times W_2$). A UE is required to feedback the wideband precoder/matrix for the whole band and the subband precoder/matrix for each subband.”)

- **See also Sayana [0030], Sayana [0087], Sayana [0091], Sayana [0095].**

(f) Element [17.e]

135. Element [17.e] recites “wherein a period of transmitting the information relating to the precoding matrix of the first precoder and a period of transmitting the information relating to the precoding matrix of the second precoder are different from each other.” This element is met by Sayana alone.

136. Sayana discloses a period of transmitting the information relating to the precoding matrix of the first precoder (*see*, [17.a]-[17.d]) and a period of transmitting the information relating to the precoding matrix of the second precoder (*see, e.g.*, [17.a]-[17.d]) are different from each other (*e.g.*, “the first matrix may be further feedback [sic] at different time instances and/or periodicities compared to the second matrix” [0099]).

137. See my discussions for elements [17.pre]-[17.d]. As I discuss for element [17.c], **Sayana** teaches transmitting from the UE to the base station the indicators of the first and second precoding matrices of the first and second precoders, respectively. See [17.c]. **Sayana** further discloses that the information of the first and second precoding matrices are fed back from a UE to a base station “at different time instances and/or periodicities.” **Sayana**, [0058], [0099]. According to **Sayana**, “[t]his can, for example, be useful to alleviate the feedback load on the uplink in a single reporting instance like a subframe.” **Sayana**, [0099]. **Sayana**, thus discloses that an indication of a first precoding matrix is fed back at a different “time instance” than an indication of a second precoding matrix. *Id.* **Sayana**, also discloses that an indication of a first precoding matrix is fed back at a different periodicity, than an indication of a second precoding matrix. *Id.*

138. *E.g.*, **Sayana**:

- **Sayana [0006]** (“The above structure in the antennas has some unique spatial characteristics that can be exploited. For example, the correlation among correlated antennas changes slowly and is confined to a smaller vector space on an average. ***This can be used to feedback the correlated and uncorrelated channel characteristics, i.e., two components***, at different rates and/or with different levels of quantization/overhead in time and frequency to reduce feedback overhead. ***One of the components representing the correlated channel characteristics can be fed back on a wideband basis and/or slowly in time, while the other component is fed back on a subband basis and/or more frequently in time.***”)

- **Sayana [0050]** (“For the purpose of discussion, we will assume the ***long-term/correlated component corresponds to a wide frequency band*** such as the whole system bandwidth and the ***short-term component corresponds to a***

subband/narrowband that is composed of a set of contiguous subcarriers and is a part of the wideband.”)

- **Sayana [0058]** (“In the feedback scheme for a wireless communication device to *send a precoder matrix information to a [BS], the wireless communication device sends a first representation of a first matrix chosen from a first codebook The wireless communication device sends a second representation of a second matrix chosen from a second codebook,* wherein the first representation and the second representation together convey a precoder matrix”)

- **Sayana [0099]** (“*[T]he first matrix may be further feedback [sic] at different time instances and/or periodicities compared to the second matrix.* This can, for example, be useful to *alleviate the feedback load on the uplink in a single reporting instance like a subframe.*”)

- **See also Sayana [0065], Sayana [0085], Sayana [0086].**

(g) Claim 18

139. Claim 18 recites “The method of claim 17, wherein the first matrix group includes N precoding matrices, and the first bit sequence is an N-bit sequence, where N is an integer.” This additional limitation of this claim is met by Sayana in view of Lee-689.

140. Sayana discloses that the first matrix group includes precoding matrices. See my discussion of the elements [17.pre]-[17.a].

141. Lee-689 teaches a matrix group includes N precoding matrices, and the first bit sequence (e.g., “bitmap”) is an N-bit sequence, where N is an integer (e.g., “0b10011110” has 8 bits).

142. As I discuss for element [17.a], **Lee-689** teaches a base codebook subset indication expressed by bitmap, where the bits represent which precoding matrices are included in a base codebook subset. *See* [17.a]. **Lee-689** also teaches the base codebook includes an integer number of precoding matrices in a “base codebook.” **Lee-689**, 17:7-20, 18:5-15. This not only renders obvious but also affirmatively discloses to a person of ordinary skill in the art to use an N-bit sequence (where N is 8 in the example I provide) that corresponds to a codebook with N precoding matrices. For example, to facilitate selection of combinations of entries from a base codebook including 8 entries (*e.g.*, $W = [W_0 \ W_1 \ W_2 \ W_3 \ W_4 \ W_5 \ W_6 \ W_7]$), the corresponding bit sequence of the base codebook indication also comprises 8 bit values (*e.g.*, “0b10011110,” where the bits “10011110” indicates selection of a subset). *Id.* In particular, “if *i*th element of a base codebook subset indication expressed by bitmap is 0, a base codebook subset does not include *i*th element of a base codebook” and “if *i*th element of a base codebook subset indication expressed by bitmap is 1, a base codebook subset includes *i*th element of a base codebook.” *Id.* Accordingly, applying the bits “10011110” to select a subset of the base codebook $W = [W_0 \ W_1 \ W_2 \ W_3 \ W_4 \ W_5 \ W_6 \ W_7]$ generates the subset $W = [W_0 \ W_3 \ W_4 \ W_5 \ W_6]$. *Id.* Thus, a person of ordinary skill in the art would have been motivated to modify **Sayana’s** “codebook subset restriction” information for a

first precoder to with **Lee-689's** teachings of a bitmap having have a same number of bits as precoding matrices (*e.g.*, an N-bit sequence that corresponds to a codebook with N precoding matrices from which to choose). At minimum, a person of ordinary skill in the art would have found it obvious to do so it in order to advantageously select any combination of the matrices from the codebook as a base codebook subset.

143. As I discuss in Section IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689's Teachings to Sayana), a person of ordinary skill in the art would have been motivated to modify **Sayana** to implement its "codebook subset restriction" information for a "first" precoder using **Lee-689's** teachings of bitmaps, where the bitmap has a same number of bits as precoding matrices. Using a bitmap to indicate codebook subset restriction from a base station to a UE provides flexibility to select any subset of precoding matrices from a particular codebook (via selection of any combination of bits in the bitmap) to send as restriction information from the base station to the UE. *See* Section IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689's Teachings to Sayana); [17.a].

144. *E.g.*, **Lee-689**:

- **Lee-689 17:7-20** ("base codebook is as equation 6"
" $W = [W_0 \ W_1 \ W_2 \ W_3 \ W_4 \ W_5 \ W_6 \ W_7]$ " and a "codebook subset as equation 7"
" $W = [W_0 \ W_3 \ W_4 \ W_5 \ W_6]$ ")

- **Lee-689 18:5-15** (“A base codebook subset indication represents which precoding matrixes are included in a base codebook subset among a rank 1 base codebook or not. *A base codebook subset indication can be expressed by bitmap.* For example, if ith element of a base codebook subset indication expressed by bitmap is 0, a base codebook subset does not include ith element of a base codebook. And, if ith element of a base codebook subset indication expressed by bitmap is 1, a base codebook subset includes ith element of a base codebook. *That is, a base codebook subset indication for a base codebook subset of equation 7 is ‘0b10011110’*”).

(h) Claim 19

145. **Claim 19** recites “The method of claim 17, wherein the use of precoding matrices for the second precoder that make pairs with restricted precoding matrices of the first matrix group is restricted based on the first bit sequence, and the use of precoding matrices for the first precoder that make pairs with restricted precoding matrices of the second matrix group is restricted based on the second bit sequence.¹⁰” The additional limitation of this claim is met by **Sayana** in view of **Lee-689**.

146. **Sayana** discloses that the use of precoding matrices for the second precoder (see [17.a]-[17.b]; e.g., precoding matrices of a “second codebook”

¹⁰ While limitation [17.a] and claim 19 require only “at least one of” a “first bit sequence” and a “second bit sequence,” it is my opinion that Ground 1 renders obvious both sequences for the reasons discussed herein.

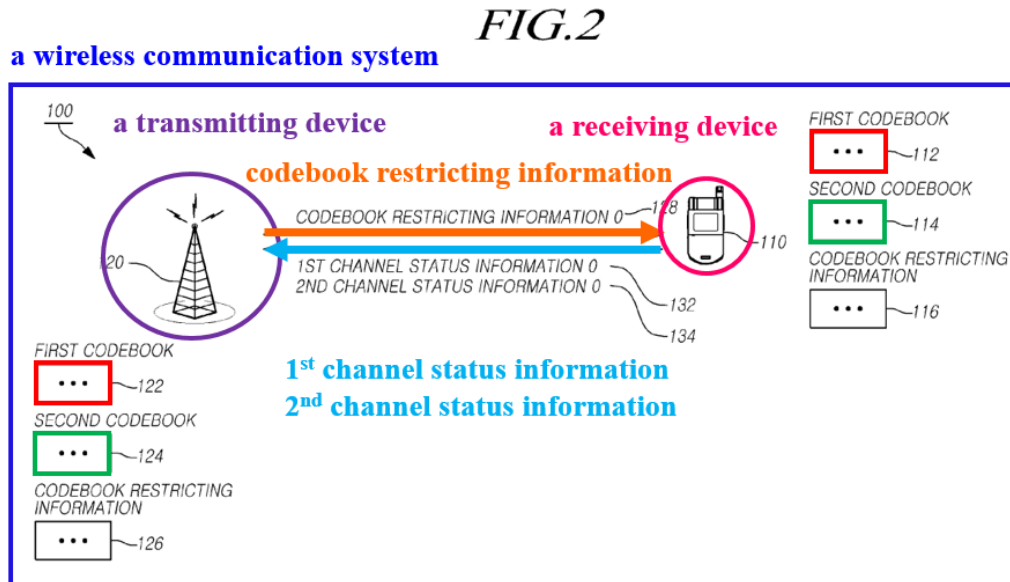
[0085], “ W_2^B ” [0094]) **that make pairs with restricted precoding matrices of the first matrix group** (see [17.a]-[17.b]; e.g., “codebook subset restriction information” [0085] applied to a “first codebook” [0085], “ W_1^{WB} ” [0094]) **is restricted, and the use of precoding matrices for the first precoder** (see [17.a]-[17.b]; e.g., precoding matrices of a “first codebook” [0085], “ W_1^{WB} ” [0094]) **that make pairs with restricted precoding matrices of the second matrix group** (see [17.a]-[17.b]; e.g., “codebook subset restriction information” [0085] applied to a “second codebook” [0085], “ W_2^B ” [0094]) **is restricted** (e.g., “[t]he precoder” is a “function” of two components,” “ W_1 ” and “ W_2 ” [0094]).

147. **Lee-689 teaches the matrix group is restricted based on the bit sequence** (see [17.a]; e.g., “bitmap” as “codebook subset indication”).

148. Provided below is a discussion of how the '924 patent describes the restriction required by claim 19 with reference to colored versions of Figs. 2 and 4 of the '924 patent. As further discussed below, **Sayana** in view of **Lee-689** works the same way.

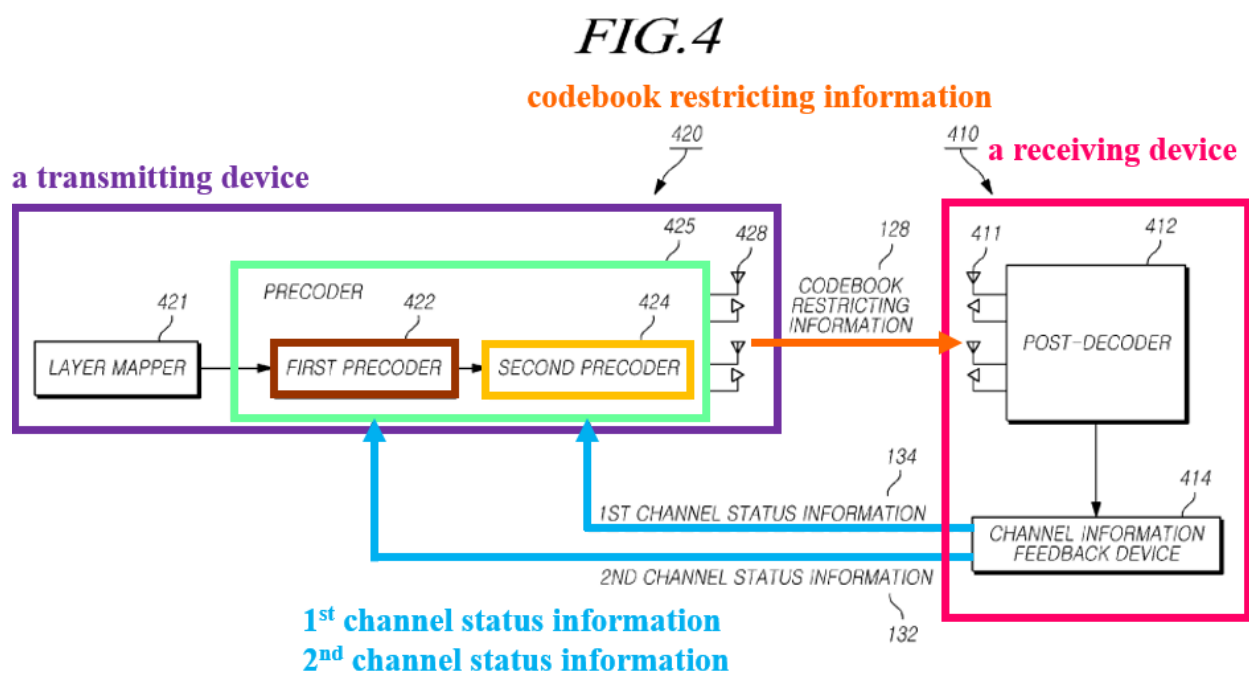
149. As illustrated below in Fig. 2, a **BS transmitting device** sends **codebook restricting information (“CRI”)** for each of two codebooks (e.g., **first codebook** and **second codebook**) associated with the two precoders to signal to a **UE receiving device** which precoding matrices are not available for selection from

the respective codebooks. The **UE** selects and feeds back indicators of two precoding matrices, which are not restricted by the **CRI**, to the **BS** for use in the two respective precoders of the **BS**. '924, Abstract, 1:19-22, 1:66-2:14, 2:14-30, 3:7-51, 5:40-52, Figs. 1-2. As an example, the '924 Patent describes such an indicator as an index to a precoding matrix within a respective codebook for each precoder. '924, 3:66-4:9, 5:40-52.



150. As shown in annotated Fig. 4 below, a **first precoder 422** and a **second precoder 424** collectively form a **multistage precoder 425**. '924, 1:41-2:31, 5:53-60, 6:55-63, 8:19-28, Fig. 4. Each precoding matrix associated with the **multistage precoder 425** is formed from a first precoding matrix from a **first codebook** used in the **first precoder 422** and a second precoding matrix from a **second codebook** used in a **second precoder 424**. Because, as noted above, each precoding matrix used by

the first and second precoders is itself indicated by an index to a respective **first codebook** and **second codebook** of precoding matrices, each precoding matrix used by the **multistage precoder 425** is indicated by a pair of a first index to a precoding matrix from the **first codebook** associated with **first precoder 422**, and a second index to a second precoding matrix from the **second codebook** associated with **second precoder 424**.



151. The '924 Patent describes two forms of the **CRI** sent to the **UE**. In one case, the **CRI** focuses on the total set of selectable precoding matrices for the **multistage precoder 425**. That total set is the total number of pairs of a first index from the **first codebook** and second index from the **second codebook** are restricted. '924, 10:59-11:17. For example, if a **first codebook** includes 16

precoding matrices and that a **second codebook** includes 4 precoding matrices, then there are 64 (16 x 4) pairs of precoding matrices that form 64 possible precoding matrices that are selectable by the **multistage precoder 425**. *Id.* In this case, the **CRI** is a 64 bit length bitmap, where a 1 indicates that a precoding matrix (and associated pair of precoding matrix indices) is selectable, and 0 indicates that a precoding matrix (and associated pair of precoding matrix indices) is restricted and not selectable.

152. In another case, the **CRI** focuses on the precoding matrices that are selectable for the **first precoder 422** and **second precoder 424**, from their associated **first codebook** and **second codebook**. '924, 11:41-12:50. In this case, the **CRI** is composed of two CRI: a first CRI associated with the **first codebook** of the **first precoder 422** and a second CRI associated with the **second codebook** of the **second precoder 424**. The first and second CRI are bit strings that indicate whether matrices of the respective **first codebook** and **second codebook** are selectable. For example, the first CRI is a 16 bit bitstring that indicates whether each of the 16 precoding matrices of the **first codebook** is selectable by the UE for feedback for use by the **first precoder 422**, and the second CRI is a 4 bit bitstring that indicates whether each of the 4 precoding matrices of the **second codebook** is selectable by the UE for feedback for use by the **second precoder 424**. One benefit

of using this second approach is that the collective CRI takes fewer bits (e.g., sum of the number of precoding matrices in the **first codebook** and **second codebook** ($16 + 4 = 20$), rather than the product of the two ($16 \times 4 = 64$) as in the first approach). However, a consequence of this second approach is that restriction of a first precoding matrix from being used also restricts the use of pairs of second precoding matrices with the restricted first precoding matrix, and vice versa that restriction of a second precoding matrix from being used restricts the use of pairs of first precoding matrices with the restricted second precoding matrix. '924, 11:56-12:50.

153. I provide illustrations of this second approach below. In both examples shown below, the indices of the first codebook are shown across the horizontal axis, and the indices of the second codebook are shown across the vertical axis.

154. In the first example, the 0th index of the **first codebook** is restricted as indicated by the blacking out of the cells in the grid. In this case, when the 0th precoding matrix from the **first codebook** is restricted from being used as a first precoding matrix based on the first CRI, the use of second precoding matrices (e.g., PMI2 = 0, 1, 2, and 3) that make pairs with that 0th precoding matrix of the **first codebook** is also restricted. The first clause of the Challenged Claim 19 requires that “*use of precoding matrices for the second precoder*” (e.g., from the second codebook) “*that make pairs with restricted precoding matrices of the first matrix*

group” (e.g., from the first codebook) *“is restricted based on the first bit sequence.”*

In the context of independent Challenged Claim 17 from which Challenged Claim 19 depends, *“the first bit sequence”* is the CRI for the first codebook that indicates which precoding matrices from the first codebook are restricted from selection.

		PMI1								
		first codebook								
PMI2	second codebook		0	1	2	3	4	5	6	7
	0									
	1									
	2									
	3									

155. Likewise, in the second example shown below, the 1th index of the **second codebook** is restricted as indicated by the blacking out of the cells in the grid. In this case, when the 1th precoding matrix from the **second codebook** is restricted from being used as a second precoding matrix based on the second CRI, the use of first precoding matrices (e.g., PMI1 = 0, 1, 2, 3, 4, 5, 6, 7, and 8) that make pairs with that 1th precoding matrix of the **second codebook** is also restricted. The second clause of Challenged Claim 19 requires the opposite from the first clause, that *“use of precoding matrices for the first precoder”* (e.g., from the first codebook)

“that make pairs with restricted precoding matrices of the second matrix group” (e.g., from the second codebook) *“is restricted based on the second bit sequence.”*

In the context of independent Challenged Claim 17 from which Challenged Claim 19 depends, *“the second bit sequence”* is the CRI for the second codebook that indicates which precoding matrices from the second codebook are restricted from selection.

		PMI1								
		first codebook								
PMI2	second codebook		0	1	2	3	4	5	6	7
	0									
	1									
	2									
	3									

156. See my discussion for elements [17.pre]-[17.e]. As I discuss for elements [17.a]-[17.b] and in Section IX.A.1 (Overview of Sayana), **Sayana** discloses that a combined precoder is formed of a “first” precoder and a “second” precoder, where a “final precoder” is the product of a “first” component precoder (e.g., “W1,” “wideband matrix W_1^{WB} ”) and a “second” component precoder (e.g., “W2,” “second [subband] matrix W_2^b ”). See [17.a]-[17.b]; Section IX.A.1

(Overview of Sayana); Sayana, Abstract, [0006], [0079], [0082], [0094]. Specifically, the final precoder is obtained via matrix multiplication of the first and second component precoders (e.g., “ $W = \text{reshape}(W_1 W_2)$ ”), “where a ‘reshaping’ operation is to re-arrange the columns of the product matrix to form the precoder matrix.” See [17.a]-[17.b]; Sayana [0082].

157. **Sayana** also discloses using “codebook subset restriction” information to restrict the use of certain precoding matrix entries of the “first codebook” and “second codebook” in selecting “a subset of codebook entries for the feedback.” Sayana, [0085]-[0086]. For example, when W_1 is selected from a “4” “bit” “first codebook” for wideband, that “first codebook” contains 16 (2^4) wideband precoding matrices, or less if some of the precoding matrices are restricted based on the codebook subset restriction information of the first codebook. Sayana, [0070]. Similarly, when W_2 is selected from a “2 bit” “second codebook” for subband, the second codebook contains 4 (2^2) subband precoding matrices, or less if some of the precoding matrices are restricted based on the codebook subset restriction information of the second codebook. Sayana, [0070], [0085]-[0086]. As such, during the restriction process of the W_1 , a wideband precoding matrix of W_1 makes pair with a subband precoding matrix of W_2 that is selected based on the codebook subset restriction information of second codebook. Sayana, [0079], [0082], [0094].

Similarly, a subband precoding matrix of W2 makes a pair with a wideband precoding matrix of W1 that is selected based on the codebook subset restriction information of a first codebook. Thus, like the '924 patent disclosing that a restriction of a first precoding matrix of a first codebook restricts pairs of a second precoding matrix of a second codebook from being used with that first precoding matrix, **Sayana** also discloses that restriction of a first precoding matrix precludes “second precoding matrices” from being used with the “first precoding matrix,” and vice-versa, restriction of a second precoding matrix of a second codebook precludes “first precoding matrices” from being used with the “second precoding matrix.”

158. See my discussion for element [17.a]. As I discuss for [17.a], when **Lee-689's** teachings are applied to **Sayana**, a first bitmap (a first bit sequence), serving as codebook restriction information to restrict some entries of **Sayana's** “wideband” “first codebook,” and a second bitmap (a second bit sequence), serving as codebook restriction information for **Sayana's** “subband” “second codebook,” will be provided from the base station to the UE. See [17.a]. As discussed above, due to the use of first and second component precoders to obtain a final precoder, as **Sayana** teaches, the restriction of wideband precoding matrices of the “first codebook” as indicated by the first bit sequence also restricts the subband precoding matrices of the subband “second codebook” that makes pairs with the wideband

precoding matrices, and vice-versa, the restriction of subband precoding matrices of the “second codebook” as indicated by the second bit sequence also restricts the wideband precoding matrices of the wideband “first codebook” that makes pairs with the subband precoding matrices as discussed above. *See* Section IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana).

159. *E.g., Sayana:*

- **Sayana [0006]** (“The above structure in the antennas has some unique spatial characteristics that can be exploited. For example, the correlation among correlated antennas changes slowly and is confined to a smaller vector space on an average. This can be used to feedback the correlated and uncorrelated channel characteristics, i.e., two components, at different rates and/or with different levels of quantization/overhead in time and frequency to reduce feedback overhead. One of the components representing the correlated channel characteristics can be fed back on a wideband basis and/or slowly in time, while the other component is fed back on a subband basis and/or more frequently in time.”)

- **Sayana [0070]** (“The main objective of the above representation is to use more feedback bits to capture the wideband information and used fewer bits to capture subband information. An exemplary embodiment is to use a 2 bit codebook for subband vectors and a 4 or 6 bit codebook to represent the wideband entries. In general, the selection of (B_1, B_2) may depend on the feedback mode. More specifically, it could depend on the number of sub-bands the feedback is requested on.”)

- **Sayana [0079]** (“In a preferred embodiment, *a product matrix based method of precoder matrix representation can be used to describe the two-component feedback.*”)

- **Sayana [0082]** (“The final precoder is obtained as

$$W = \text{reshape}(W_1 W_2)$$

where *a ‘reshaping’ operation is to re-arrange the columns of the product matrix to form the precoder matrix.*”)

- **Sayana [0085]** (“The construction above presents a product design followed by reshaping to provide improved flexibility in the two component

feedback. However, further overhead reduction can be configured by eNB, by *enabling codebook subset restrictions at wideband and subband level. A codebook subset restriction is essentially where eNB signals the UE to only use a subset of codebook entries for the feedback. Subset restriction can be applied to either the first codebook, or the second codebook, or both.*")

- Sayana [0086] ("*Codebook subset restriction can be used for both wideband and subband components in a pre-configured and compatible manner, which we will further describe with some exemplary methods.*")

- Sayana [0094] ("*The first component could correspond to a wideband matrix W_1^{WB} A second matrix W_2^b corresponds to a band 'b'. The precoder for a band 'b', represented as W^b is obtained as a function of W_1^{WB} and W_2^b . A preferred example of the function as described above is reshape ($W_1 \times W_2$). A UE is required to feedback the wideband precoder/matrix for the whole band and the subband precoder/matrix for each subband.*")

- See also Sayana [0007], Sayana [0029], Sayana [0039], Sayana [0080]-[0081], Sayana [0091].

160. E.g., Lee-689:

- Lee-689 17:7-20 ("base codebook is as equation 6"
" $W = [W_0 \ W_1 \ W_2 \ W_3 \ W_4 \ W_5 \ W_6 \ W_7]$ " and a "codebook subset as equation 7"
" $W = [W_0 \ W_3 \ W_4 \ W_5 \ W_6]$ ")

- Lee-689 18:5-15 ("A base codebook subset indication represents which precoding matrixes are included in a base codebook subset among a rank 1 base codebook or not. *A base codebook subset indication can be expressed by bitmap.* For example, if ith element of a base codebook subset indication expressed by bitmap is 0, a base codebook subset does not include ith element of a base codebook. And, if ith element of a base codebook subset indication expressed by bitmap is 1, a base codebook subset includes ith element of a base codebook. That is, a base codebook subset indication for a base codebook subset of equation 7 is '0b10011110'.")

- See also Lee-689 12:5-16; Lee-689 17:7-20:23.

(i) **Claim 22**

161. **Claim 22 recites “The method of claim 17, wherein the period of transmitting the information relating to the precoding matrix of the first precoder is longer than the period of transmitting the information relating to the precoding matrix of the second precoder.”** The additional limitation of this claim is met by **Sayana** alone.

162. **Sayana discloses that the period of transmitting the information relating to the precoding matrix of the first precoder (e.g., “fed back on a wideband basis and/or slowly in time” [0006]) is longer than the period of transmitting the information relating to the precoding matrix of the second precoder (e.g., “fed back on a subband basis and/or more frequently in time” [0006]).**

163. See my discussion for elements [17.pre], [17.c]-[17.e]. As I discuss for element [17.e], **Sayana** discloses that the information of the first and second precoding matrices are fed back from a UE to a base station “at different time instances and/or periodicities.” See [17.e]. **Sayana** also discloses a “first representation of a first matrix chosen from a first codebook” that is “fed back on a wideband basis and/or slowly in time,” while the second representation of a second matrix chosen from a second codebook” is “fed back on a subband basis and/or more

frequently in time.” Sayana, Abstract, [0006], [0058], [0085]-[0086], [0094]. **Sayana** therefore discloses that a “first representation” (e.g., wideband) is fed back on a slower “time instance”, and that a “second representation” (e.g., subband) is fed back on a faster “time instance.” **Sayana** also discloses that the period of the “slow[er]” transmission of the wideband feedback is different than the period of the “more frequent” transmission of the subband feedback. *Id.*

164. *E.g., Sayana:*

- **Sayana Abstract** (“A method for two component feedback in wireless communication systems is disclosed, with *a wireless communication device sending a first representation of a first matrix chosen from a first codebook, wherein the first matrix has at least two columns, the wireless communication device sending a second representation of a second matrix chosen from a second codebook*, and the base station obtaining a precoder from the first representation and the second representation.”)
- **Sayana [0006]** (“*One of the components representing the correlated channel characteristics can be fed back on a wideband basis and/or slowly in time, while the other component is fed back on a subband basis and/or more frequently in time.*”)
- **Sayana [0058]** (“The above discussion on the precoder structure is tied to feedback method in this invention. In the feedback scheme for a wireless communication device to send a precoder matrix information to a base station, the *wireless communication device sends a first representation of a first matrix chosen from a first codebook*, wherein the first matrix has at least two column vectors. *The wireless communication device sends a second representation of a second matrix chosen from a second codebook, wherein the first representation and the second representation together convey a precoder matrix* of one or more vectors associated with one or more spatial layers.”)
- **Sayana [0085]** (“The construction above presents a product design followed by reshaping to provide improved flexibility in the two component feedback. However, further overhead reduction can be configured by eNB, by *enabling codebook subset restrictions at wideband and subband level.* *A*

codebook subset restriction is essentially where eNB signals the UE to only use a subset of codebook entries for the feedback. Subset restriction can be applied to either the first codebook, or the second codebook, or both.”)

- Sayana [0086] (“*Codebook subset restriction can be used for both wideband and subband components ...*”)
- Sayana [0094] (“One embodiment is illustrated in FIG. 6. *The first component could correspond to a wideband matrix W_1^{WB} corresponding to the whole bandwidth 610, which is composed of one or more sub-bands 620. Each subband 620 is composed of a set of contiguous subcarriers 630 or in LTE, a set of RBs, which is the minimum scheduling/feedback granularity. A second matrix W_2^b corresponds to a band ‘b’. The precoder for a band ‘b’, represented as W^b is obtained as a function of W_1^{WB} and W_2^b .*”)
- Sayana [0099] (*[T]he first matrix may be further feedback [sic] at different time instances and/or periodicities compared to the second matrix. This can ... be useful to alleviate the feedback load on the uplink in a single reporting instance like a subframe.)*
- *See also Sayana Abstract, Sayana [0015]-[0018], Sayana [0065], Sayana [0100].*

(j) Element [23.pre]

165. Element [23.pre] recites “A receiving device in a wireless communication system, the receiving device comprising.” This element is met by Sayana alone.

166. Sayana discloses a receiving device in a wireless communication system. See my discussion for element [17.pre].

(k) Element [23.a]

167. **Element [23.a] recites “an antenna array to receive, as codebook restricting information, at least one¹¹ of a first bit sequence to restrict at least one precoding matrix from a first precoding matrix group and a second bit sequence to restrict at least one precoding matrix from a second precoding matrix group.”** This element is met by **Sayana** in view of **Lee-689**.

168. **Sayana in view of Lee-689 discloses the receiving device** (*see* 23.pre) **comprises an antenna array** (“remote unit” having an array of “antennas” [0018]) **to receive, as codebook restricting information, at least one of a first bit sequence to restrict at least one precoding matrix from a first precoding matrix group and a second bit sequence to restrict at least one precoding matrix from a second precoding matrix group** (*see* [17.a]).

169. See my discussion for elements [17.a], and [17.pre], [23.pre]. As I discuss for element [23.pre] with reference to [17.pre], **Sayana** discloses a receiving device (*e.g.*, a UE or “user equipment”) in a wireless communication system. *See*

¹¹ While [23.a] requires that “codebook restricting information” include only “at least one of” a “first bit sequence” and a “second bit sequence,” it is my opinion that Ground 1 discloses both sequences.

[17.pre], [23.pre]; Sayana, [0016] (“The remote unit may also be referred to as a receiver, subscriber station (SS), mobile, mobile station (MS), mobile terminal, user, terminals, *user equipment*, user terminal (UT)”). As I discuss for element [17.a], **Sayana** in view of **Lee-689** renders obvious that the receiving device receives, as codebook restricting information, at least one of a first bit sequence to restrict at least one precoding matrix from a first precoding matrix group and a second bit sequence to restrict at least one precoding matrix from a second precoding matrix group. *See* [17.a]. **Sayana** further discloses that a “remote unit,” such as a UE or receiving device, has an array of “antennas” to function as “one or more transmitters and one or more receivers,” as depicted in Figure 2. Sayana, [0016] (“The remote units also comprise one or more transmitters and one or more receivers.”), [0018] (“Also in FIG. 2, a remote unit receives transmissions from a plurality of antennas, which may or may not be co-located.”). Thus, a person of ordinary skill in the art would have understood that the codebook restriction information is received by the antenna array of the receiving device.

170. **Sayana** also discloses, in Fig. 2 annotated above, a “remote unit” such as a UE that has an array of “antennas” for “one or more transmitters and one or more receivers.” Sayana, [0016], [0018].

171. *E.g.*, **Sayana**:

- Sayana [0016] (“*The remote units also comprise one or more transmitters and one or more receivers.*”)
- Sayana Fig. 2

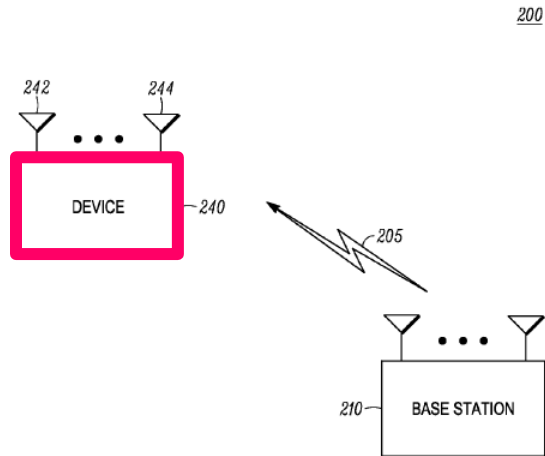


FIG. 2

- Sayana [0018] (“In the diagram 200 of FIG. 2, at 210, a base unit transmits from a plurality of antennas. Also in **FIG. 2**, a remote unit receives transmissions from a plurality of antennas, which may or may not be co-located. In a typical embodiment, a base unit may be associated with a cell-ID, by which it identifies itself to a remote unit. *As a conventional mode of operation, also sometimes referred to as a single-point transmission scheme, a remote unit 240 receives transmissions from a plurality of antennas of a single base unit 210.* Such a base unit is also referred to as a serving cell (or serving base unit) to the user device/remote unit.”)

- Sayana [0028] (“ $y_1 \dots y_{N_R}$ may be the received data at the UE receive antenna #1 to # N_R , respectively. In the example with a rank-1 transmission, or a transmission with one data stream denoted as ‘s’, the Matrix V may be a precoding vector with weights $v_{1,1} \dots v_{N_T,1}$ for base station transmit antenna #1 to # N_T respectively.”)

- See also Sayana [0003], Sayana [0004], Sayana [0031]-[0032], [0085].

(l) Element [23.b]

172. Element [23.b] recites the same limitations as element [17.b]. See my discussion for element [17.b].

(m) Element [23.c]

173. **Element [23.c] recites “a channel Information feedback device to transmit, to a transmitting device, information relating to the precoding matrix of the first precoder and information relating to the precoding matrix of the second precoder.”** This limitation is met by **Sayana** alone.

174. **Sayana discloses the receiving device (see [23.pre]) comprises a channel Information feedback device (e.g., UE processor running software providing a CSI and a channel quality indicator (“CQI”) as “feedback” to a BS) to transmit, to a transmitting device (e.g., “BS”), information relating to the precoding matrix of the first precoder and information relating to the precoding matrix of the second precoder (e.g., UE “reporting back to the [BS] a preferred Precoding Matrix Index (PMI)” [0039] “along with an associated CQI feedback” [0095]).**

175. See my discussion for elements [23.pre], [17.pre] and [17.c]. As I discuss for element [23.pre] with reference to [17.pre], **Sayana** discloses a receiving device in a wireless communication system. See [23.pre], [17.pre]. As I discuss for

element [17.c], **Sayana** in view of **Lee-689** discloses that the receiving device transmits, to a transmitting device, 1st channel status information indicating the precoding matrix of the first precoder and 2nd channel status information indicating the precoding matrix of the second precoder. *See* [17.c]. **Sayana** also discloses that a receiver receives reference signals (*e.g.*, CRS, CSI-RS), and based on such reference signals, “estimates CSI [channel state information]” “between each receiver antenna and each transmitter antenna.” *Sayana*, [0032]. Furthermore, *Sayana* discloses that a “UE” provides a “precoding matrix indicator” “PMI”, and a channel quality indicator (“CQI”) as “feedback” to a base station. *Sayana*, [0032], [0039], [0095]. A person of ordinary skill in the art would have understood that the UE includes a processor running software, or at least that it would have been obvious for a UE to include a processor running software, and thereby operate as a channel information feedback device, to perform the processes of estimating and transmitting CSI information and providing PMI and CQI as a feedback to the base station. For example, U.S. 9,078,236 to Chun which I understand has an effective filing date of at least Jan 5, 2010 (“Chun”, Ex. 1021) teaches that a UE includes a processor. *See e.g.*, Chun, 16:43-55 (“In a mobile communication system, the UE may include a signal input module, a display module, an antenna, a signal processor, and the like.”), Fig. 11. As another example, U.S. 9,247,420 to Jung which I understand has a filing

date of at least December 11, 2008 (“Jung”, Ex. 1022) teaches that a UE “include[s] one or more processors” and that a “processor” executes software code. *See e.g.*, Jung, 15:51-60 (indicating that a UE “include[s] one or more processors”), 16:1-8 (indicating that a “processor” executes software code). At minimum, in view of such well-known teachings as exemplified by Chun and Jung, a person of ordinary skill in the art would have found it obvious to include a processor in the UE to perform these processes, as processors were standard, well-known components that were used to in wireless communication devices to provide feedback to base stations.

176. I have been asked to consider whether this claim would be met if the term “channel information feedback device” were considered to be a means-plus-function limitation. In the first instance, a person of ordinary skill in the art would have understood that the term “channel information feedback device” connotes structure. The operation of “channel information feedback” is well-known and a person of ordinary skill in the art would have understood how to implement channel feedback operations on a processor, such as those included in UEs. For example, U.S. 9,083,411 to Li which I understand has an effective filing date of at least Jan. 13, 2010 (“Li,” Ex. 1023), describes a “channel information feedback method” that includes “calculating a channel State information feedback between a mobile terminal and a serving cell of the mobile terminal ... calculating a channel quality

information feedback for the serving cell of the mobile terminal; and transmitting the channel state information feedbacks and the channel quality information feedback to the serving cell.” Li, 3:4-12. As another example, U.S. 7,369,511 to Utsunomiya which I understand to have a filing date of at least September 24, 2004 (“Utsunomiya,” Ex. 1024) describes a “channel information feedback” process that is carried out by a receiver that estimates a channel and feeds back the “[c]hannel estimation result information” to a transmitter. Utsunomiya, Abstract, 7:4-63. As a further example, U.S. 8,649,456 to Xia which I understand to have a filing date of at least March 11, 2010 (“Xia,” Ex. 1025), describes a “channel information feedback” process between a base station and mobile station; Xia, Abstract, Figs. 1, 3a-3d, 3:56-58, 4:55-5:63, 8:62-10:19.

177. If the claim term including the “channel information feedback device” were considered to be a means-plus-function limitation, despite the foregoing reasons I described which would suggest to the contrary, the prior art references and grounds herein disclose or render obvious the Challenged Claim 23 under any reasonable interpretation. Under a means-plus-function interpretation of Claim 23, the function would be “transmitting, to a transmitting device, information relating to the precoding matrix of the first precoder and information relating to the precoding matrix of the second precoder, the precoding matrix of the first precoder and the

precoding matrix of the second precoder being selected, based on the codebook restricting information, from among precoding matrices that are not restricted,” and the corresponding structure includes, e.g., a processor that performs algorithms disclosed in the ’924 patent for performing this function by “receiv[ing] a reference signal,” “estimat[ing] a channel using the reference signal” (’924, 8:12-18, Fig. 4), feeding back, a first precoding matrix determined by “excluding precoding matrices that are restricted from being used as a first precoding matrix based on first information included in codebook restricting information” and based on the channel estimate and second precoding matrix determined by “excluding matrices that are restricted from being used as a second precoding matrix based on second information included in codebook restricting information” and based on the channel estimate, to a base station (’924, 14:1-7, 17-23).

178. Even under such a means-plus-function construction, this limitation would have been met by **Sayana**. A person of ordinary skill in the art would have understood **Sayana** to disclose a processor that meets this claim element, or its equivalents. For example, **Sayana** discloses a UE, which a person of ordinary skill in the art would have understood or at least found obvious to include a processor, for the reasons discussed above in reference to Chun and Jung, where said processor performs the claimed function (transmitting, to a transmitting device, information

relating to the precoding matrix of the first precoder and information relating to the precoding matrix of the second precoder). Sayana, [0016] (“user equipment (UE)”). **Sayana** discloses a UE that contains a processor that performs the algorithms for performing the claimed **transmitting, to a transmitting device, information relating to the precoding matrix of the first precoder and information relating to the precoding matrix of the second precoder**, by receiving reference signals such as “CRS or CSI-RS”, “estimat[ing] the CSI” based on the reference signals [0032], determining “CQI [channel quality information] feedback” and selecting a first representation of a first precoder (*e.g.*, “ W_1^{WB} ”) and a second representation of a second precoder (*e.g.*, “ W_2^b ”) as components of a precoder for feedback to the base station. Sayana, [0032], [0039], [0058], [0095].

179. Alternatively, **Sayana** discloses a UE, which a person of ordinary skill in the art would have understood or at least found obvious to include a processor, for the reasons discussed above in reference to Chun and Jung that performs the claimed function noted above in substantially the same way as ’924 (measuring reference signals and determining first and second precoding matrices that are not restricted and feedback information associated with the matrices) to achieve the same result (sending indicators of the first and second precoding matrix indicators to the transmitting device), because both **Sayana** and the ’924 determine a first

indicator of a first precoding matrix from a first codebook and a second indicator of a second precoding matrix from a second codebook, and feed back the first and second indicators to a base station for use with the base station's precoders. Sayana, [0032] ("From either CRS or CSI-RS, the remote unit receiver can estimate the CSI."), [0039] ("To support precoding operation from the base station, a user terminal will be reporting back to the base station a preferred Precoding Matrix Index (PMI) which is an index to a set of predetermined precoding matrices. The recommended precoding matrix is obtained at the user terminal based on a certain metric such as maximizing the post-precoding link quality or throughput and is selected from one of the quantized codebook entries, wherein the codebook is known to the transmitter and the receiver."), [0058] ("In the feedback scheme for a wireless communication device to send a precoder matrix information to a base station, the wireless communication device sends a first representation of a first matrix chosen from a first codebook, wherein the first matrix has at least two column vectors. The wireless communication device sends a second representation of a second matrix chosen from a second codebook, wherein the first representation and the second representation together convey a precoder matrix of one or more vectors associated with one or more spatial layers."), [0095] ("In one embodiment, the feedback could be defined along with an associated CQI feedback. The CQI feedback could

correspond to a modulation and coding scheme (MCS) recommendation and/or a rank indication. The CQI could further consist of multiple CQI, one per each subband. In this case, the UE must select the *components* W_1^{WB} and W_2^b such that the subband precoders can support the CQI reported corresponding to the subband on the hypothesis UE is allocated that subband, while satisfying an error rate target.”); ’924, 8:12-18, 14:1-7, 17-23.

180. *E.g., Sayana:*

- **Sayana [0015]** (“In FIG. 1, *a wireless communication system 100* comprises one or more fixed *base infrastructure units 110 and 120 forming a network ... remote units* The *base infrastructure unit* may also be referred to as the *transmitter, access point (AP), access terminal (AT), base, base station, base unit (BU), Node-B (NB), enhanced Node-B (eNB), Home Node-B (HNB), Home eNB (HeNB) or by other terminology used in the art.*”)

- **Sayana [0016]** (“*The one or more base units serve a number of remote units*, for example, remote unit 102 and 104 in FIG. 1.... *The remote units may be fixed units or wireless communication devices. The remote unit may also be referred to as a receiver, subscriber station (SS), mobile, mobile station (MS), mobile terminal, user, terminals, user equipment (UE), user terminal (UT) or by other terminology used in the art.* In FIG. 1, *the base unit 110 transmits downlink communication signals to serve remote unit 102* The remote unit 102 communicates directly with base unit 110 via uplink communication signals.”)

- **Sayana [0020]** (“In a general embodiment, pilots or reference symbols are sent from each antenna in a transmitter. These pilots occupy the operational bandwidth to allow users *to estimate the channel state information (CSI)* of the entire bandwidth.”)

- **Sayana [0032]** (“*From either CRS or CSI-RS, the remote unit receiver can estimate the CSI.*”)

- **Sayana [0039]** (“*To support precoding operation from the base station, a user equipment will be reporting back to the [BS] a preferred Precoding Matrix Index (PMI) which is an index to a set of predetermined precoding matrices.* The recommended precoding matrix is obtained at the user

terminal based on a certain metric such as maximizing the post-precoding link quality or throughput and is selected from one of the quantized codebook entries, wherein the codebook is known to the transmitter and the receiver. Specifically, ***the standard requires the UE to feedback the PMI that supports a MCS (modulation and coding scheme) with the highest rate***, while satisfying a probability if block error target.”)

- **Sayana [0095]** (“***[T]he feedback could be defined along with an associated CQI feedback. The CQI feedback could correspond to a modulation and coding scheme (MCS) recommendation The CQI could ...consist of multiple CQI.... In this case, the UE must select the components W_1^{WB} and W_2^b such that the subband precoders can support the CQI reported*** corresponding to the subband on the hypothesis UE is allocated that subband, while satisfying an error rate target. ... ***[A] single CQI may be reported for the whole band***, in which case the reported CQI must meet the error rate target....”)

- **See also Sayana [0094].**

(n) Element [23.d]

181. Element [23.d] recites the same limitations as element [17.d]. See my discussion for element [17.d].

(o) Element [23.e]

182. Element [23.e] recites the same limitations as element [17.e]. See my discussion for element [17.e].

(p) Claim 24

183. Claim 24 recites the same limitations as claim 18, except that it depends on claim 23 instead of claim 17. See my discussion for claims 18 and 23.

(q) Claim 28

184. Claim 28 recites the same limitations as claim 22, except that it depends on claim 23 instead of claim 17. See my discussion for claims 22 and 23.

B. Ground 2: Sayana in View of TS36.213 (Claims 17-19, 22-24, 28)

1. Overview of TS36.213 and Motivation to Apply TS36.213's Teachings to Sayana

185. As an alternative to **Lee-689**, **TS36.213** teaches that “[a] UE is restricted to report PMI [i.e. precoding matrix indices] ... within a precoder codebook subset specified by a bitmap parameter *codebookSubsetRestriction*.” **TS36.213**, p.34. In particular, “[f]or a specific precoder codebook and associated transmission mode, the bitmap can specify all possible precoder codebook subsets.” *Id.*

186. **TS36.213** is v8.8.0 of a Technical Specification document that is titled “LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures.”

187. Like **Sayana** and for the same reasons I discussed above in Sections IX.A.1 (Overview of Sayana)-IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689's Teachings to Sayana), **TS36.213** is in the same field as the '924 patent, which includes multiple input multiple output (MIMO) wireless communications, and reasonably pertinent to the alleged problems identified in

the '924 patent—*e.g.*, improving communication efficiency. *See* Section IX.A.1 (Overview of Sayana)-IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689's Teachings to Sayana). For example, **TS36.213** describes multi-antenna and MIMO operations, like **Sayana**. TS36.213, p.6 ("The present document specifies and establishes the characteristics of the physicals layer procedures in the FDD and TDD modes of E-UTRA."), 15, 35 (Table 7.2-1c "2 antenna port codebook"), 22 (Section "7.1.5," titled "Multi-user *MIMO* scheme"); 48 ("Transmission mode" 5 uses "Multi-user *MIMO*"). In the context of facilitating MIMO operations, **TS36.213** further teaches that its bitmap solution "specif[ies] all possible precoder codebook subsets" "[f]or a specific precoder codebook," which advantageously provides flexibility and precision in selecting precoding matrices for restriction of the respective codebooks because each combination of matrices is selectable for a respective codebook. TS36.213, p.34.

188. **Sayana** does not specify in what form the "codebook subset restriction" is implemented. *E.g.*, Sayana, [0085]-[0092]. **TS36.213** teaches how to implement the codebook subset restriction. In particular, **TS36.213** teaches, in implementing the codebook subset," using a "bitmap parameter *codebookSubsetRestriction*" that "forms [a] bit sequence," "where a bit value of zero indicates that the PMI ... is not allowed to correspond to precoder(s) associated with the bit." TS36.213, p.34.

Furthermore, **TS36.213** teaches an integer number of precoding matrices corresponding to the number of the bits within the bit sequence. TS36.213, Table 7.2-1b. For example, **TS36.213's** Table 7.2-1c, which I have reproduced below, teaches an “[a]ssociation of bits in *codebookSubSetRestriction* bitmap to precoders in the 2 antenna port codebook,” where the number of bits of the bitmap is 6 (e.g., $a_0, a_1, a_2, a_3, a_4, a_5$), is the same as the number of precoding matrices or “precoders,” denoted by the 6 entries highlighted in yellow in Table 7.2-1c. TS36.213, Table 7.2-1c.

Table 7.2-1c: Association of bits in *codebookSubSetRestriction* bitmap to precoders in the 2 antenna port codebook of Table 6.3.4.2.3-1 in [3].

Codebook index i_c	Number of layers ν	
	1	2
0	a_0	-
1	a_1	a_4
2	a_2	a_5
3	a_3	-

TS36.213's Table 7.2-1b also provides further examples of bitmaps showing that a number of bits in the bitmap (“ A_c ”), associated a same number of precoders configured for a particular “[t]ransmission [m]ode” and number of “antenna ports.” TS36.213, Table 7.2-1b.

Table 7.2-1b: Number of bits in codebook subset restriction bitmap for applicable transmission modes.

		Number of bits A_c	
		2 antenna ports	4 antenna ports
	Transmission mode 3	2	4
	Transmission mode 4	6	64
	Transmission mode 5	4	16
	Transmission mode 6	4	16

189. A person of ordinary skill in the art would have been motivated to modify **Sayana** to implement its “codebook subset restriction” using **TS36.213’s** teachings of bitmaps to advantageously improve the signaling of restricted precoding matrices to UEs, for the same reasons discussed above in Section IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana), which include: (1) **Sayana** and **TS36.213** both regard the importance of precoding for improving wireless transmission power to a subset of UEs while reducing the interference to UEs that are not intended recipients of communications, (2) **Sayana’s** lack of details regarding communicating “codebook subset restriction” information and **TS36.213’s** detailed teachings regarding communication “codebook subset restriction” information; (3) **TS36.213’s** teachings of a bitmap facilitates the

reduction of inter-cell interference; (4) **TS36.213's** teachings of a bitmap provides flexibility in the specification of codebook subset restriction within a particular codebook.

190. In light of the my discussions above and for the same reasons that I discuss in Section IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689's Teachings to Sayana), a person of ordinary skill in the art also would have had a reasonable expectation of success in modifying **Sayana** to implement its codebook subset restriction using **TS36.213's** bitmap, which includes the same number of bits as the number of precoder matrices.

191. Based on my discussion above, a person of ordinary skill in the art would have been motivated to apply **TS36.213's** teaching of using a bitmap that includes the same number of bits as the number of precoding matrices in implementing **Sayana's** "codebook subset restriction" information for **Sayana's** "first" component precoder such that any of the precoding matrices in **Sayana's** "first codebook" are advantageously selected or restricted for feedback to a base station. Sayana, [0039], [0070], [0085]-[0092]; TS36.213, p.34. Furthermore, for the same reasons discussed above, a person of ordinary skill in the art also would have been motivated to apply these same teachings to **Sayana's** "codebook subset

restriction” information for **Sayana’s** “second” component precoder. Sayana, [0039], [0070], [0085]-[0092]; TS36.213, p.34.

2. TS36.213 Analysis

192. **TS36.213’s** teachings of bitmap codebook restricting information provide an alternative to **Lee-689’s** teachings of a bitmap. In addition to Section IX.B.1 (Overview of TS36.213 and Motivation to Apply TS36.213’s Teachings to Sayana), my discussion below following bulleted excerpts explains how each limitation challenged in this ground is disclosed and/or, when combined with **Sayana’s** teachings, rendered obvious in view of **TS36.213**. My analysis below applies to all Challenged Claims where references to **TS36.213** are an alternative to **Lee-689**.

(a) Element [17.a]

193. **Element [17.a]** recites “receiving codebook restricting information including at least one of¹² a first bit sequence to restrict at least one precoding matrix from a first precoding matrix group and a second bit sequence to restrict

¹² While [17.a] requires that “codebook restricting information” include only “at least one of” a “first bit sequence” and a “second bit sequence,” it is my opinion that Ground 2 nevertheless discloses both sequences.

at least one precoding matrix from a second precoding matrix group.” This limitation is met by **Sayana** in view of **TS 36.213**.

194. **TS36.213 teaches codebook restricting information including at least one bit sequence to restrict at least one precoding matrix** (*e.g.*, a “bitmap parameter *codebookSubsetRestriction*” or “bit sequence” of which a “bit value of zero indicates that the PMI ... is not allowed to correspond to precoder(s) associated with the bit”).

195. **TS36.213** teaches that a “UE is restricted to report PMI ... within a precoder codebook subset specified by a bitmap parameter *codebookSubsetRestriction*.” TS36.213, p.34. In particular, the “bitmap parameter *codebookSubsetRestriction*” “forms the bit sequence” “where a bit value of zero indicates that the PMI ... is not allowed to correspond to precoder(s) associated with the bit.” TS36.213, p.34. As I further discuss in Section IX.B.1 (Overview of TS36.213 and Motivation to Apply TS36.213’s Teachings to Sayana), a person of ordinary skill in the art would have been motivated to modify **Sayana** to implement its “codebook subset restriction” information using **TS36.213’s** bitmaps to advantageously provide flexibility in the signaling of precoding matrices to UEs within a particular codebook as **TS36.213’s** bitmaps “specif[ies] all possible precoder codebook subsets” “[f]or a specific precoder codebook.” TS36.213, p.34;

see Section IX.B.1 (Overview of TS36.213 and Motivation to Apply TS36.213's Teachings to Sayana). In particular, by applying **TS36.213's** restriction information to **Sayana**, the restriction information separately provides a first bitmap (a first bit sequence) as first codebook restriction information and a second bitmap (a second bit sequence) as second codebook restriction information. For example, when the first and second codebooks apply to the wideband and subband feedback, respectively, as **Sayana** teaches, the separate restriction information for each codebook advantageously allows providing distinct restriction information for the wideband and subband communications, and have different restriction requirements. Sayana, [0006]; TS36.213, p.34.

196. *E.g.*, **TS36.213**:

- **TS36.213 pp.33-34** (“§7.2 ...*The time and frequency resources that can be used by the UE to report ... PMI ...*”)
- **TS36.213 p.34** (“*A UE is restricted to report PMI ... within a precoder codebook subset specified by a bitmap parameter codebookSubsetRestriction For a specific precoder codebook and associated transmission mode, the bitmap can specify all possible precoder codebook subsets from which the UE can assume the eNB may be using when the UE is configured in the relevant transmission mode. ... The bitmap forms the bit sequence $a_{A_c-1}, \dots, a_3, a_2, a_1, a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB and where a bit value of zero indicates that the PMI...reporting is not allowed to correspond to precoder(s) associated with the bit.*”)

- **TS36.213 Table 7.2-1b:** (“Number of bits in codebook subset restriction bitmap for applicable transmission modes.”)

		Number of bits A_c	
		2 antenna ports	4 antenna ports
	Transmission mode 3	2	4
	Transmission mode 4	6	64
	Transmission mode 5	4	16
	Transmission mode 6	4	16

- **TS36.213 Table 7.2-1c:** (“Association of bits in codebookSubSetRestriction bitmap to precoders in the 2 antenna port codebook of Table 6.3.4.2.3-1”)

Codebook index i_c	Number of layers ν	
	1	2
0	a_0	-
1	a_1	a_4
2	a_2	a_5
3	a_3	-

(b) Element [17.b]

197. Element [17.b] recites “each bit of the first bit sequence corresponding to one precoding matrix of the first precoding matrix group, respectively, the at least one precoding matrix of the first precoding matrix group being restricted from being used as a precoding matrix of a first precoder, each bit of the second bit sequence corresponding to one precoding

matrix of the second precoding matrix group, respectively, and the at least one precoding matrix of the second precoding matrix group being restricted from being used as a precoding matrix of a second precoder.” This limitation is met by **Sayana** in view of **TS36.213**.

198. **TS36.213** discloses each bit of the bit sequence corresponding to one precoding matrix of the precoding matrix group, respectively (*see* [17.a]).

199. See my discussion for element [17.a]. **TS36.213** teaches using a “bitmap parameter *codebookSubsetRestriction*.” **TS36.213**, pp. 34. The bitmap forms the bit sequence where a bit value of zero indicates that the PMI reporting is not allowed to correspond to precoder(s) associated with the bit “a bit value of zero indicates that the PMI . . . is not allowed to correspond to precoder(s) associated with the bit.” *Id.* As I discuss for [17.a], a person of ordinary skill in the art would have been motivated to modify **Sayana** to implement its “codebook subset restriction” information using **TS36.213**’s teachings of bitmaps to advantageously provide flexibility in the signaling of precoding matrices to UEs within a respective precoder codebook because **TS36.213**’s bitmaps “specif[ies] all possible precoder codebook subsets” “[f]or a specific precoder codebook.” *See* [17.a]; **TS36.213**, p.34.

(c) Claim 18

200. **Claim 18 recites “The method of claim 17, wherein the first matrix group includes N precoding matrices, and the first bit sequence is an N-bit sequence, where N is an integer.”** The additional limitation of this claim is met by **Sayana** in view of **TS 36.213**.

201. **TS36.213 teaches a matrix group includes N precoding matrices** (*e.g.*, “bitmap forms the bit sequence $a_{A_c-1}, \dots, a_3, a_2, a_1, a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB”), **and the first bit sequence** (*e.g.*, “bitmap”) **is an N-bit sequence, where N is an integer** (*e.g.*, a_{A_c-1} , integer values in Table 7.2-1b and Table 7.2-1c).

202. See my discussion for [17.a]. **TS36.213** also teaches that the “codebookSubSetRestriction bitmap” includes 2, 4, 6, 16, or 64 bits, corresponding to the same number of precoding matrices, specifically 2, 4, 6, 16, or 64 matrices per codebook, respectively, for “[a]ssociation of bits in codebookSubSetRestriction bitmap to precoders,” as shown in Tables 7.2-1b and 7.2-1c above. TS36.213, pp.33-35. As I further discuss for [17.a] and in Sections IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana)-IX.B.1 (Overview of TS36.213 and Motivation to Apply TS36.213’s Teachings to Sayana), a person of ordinary skill in the art would have been motivated to modify **Sayana** to implement its “codebook subset restriction” information for a “first component precoder” using

TS36.213's bitmaps, where the bitmap has a same number of bits as precoding matrices. See [17.a]; Sections IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689's Teachings to Sayana)-IX.B.1 (Overview of TS36.213 and Motivation to Apply TS36.213's Teachings to Sayana).

203. E.g., TS36.213:

- TS36.213 pp.33-34 (“§7.2 ...*The time and frequency resources that can be used by the UE to report ... PMI... A UE is restricted to report PMI ... within a precoder codebook subset specified by a bitmap parameter codebookSubsetRestriction For a specific precoder codebook and associated transmission mode, the bitmap can specify all possible precoder codebook subsets* from which the UE can assume the eNB may be using when the UE is configured in the relevant transmission mode. ... The bitmap forms the bit sequence $a_{A_c-1}, \dots, a_3, a_2, a_1, a_0$ where a_0 is the LSB and a_{A_c-1} is the MSB and where a bit value of zero indicates that the PMI ...reporting is not allowed to correspond to precoder(s) associated with the bit.”)
- TS36.213 Table 7.2-1b: (“Number of bits in codebook subset restriction bitmap for applicable transmission modes.”)

		Number of bits A_c	
		2 antenna ports	4 antenna ports
	Transmission mode 3	2	4
	Transmission mode 4	6	64
	Transmission mode 5	4	16
	Transmission mode 6	4	16

- **TS36.213 Table 7.2-1c:** (“Association of bits in codebookSubSetRestriction bitmap to precoders in the 2 antenna port codebook of Table 6.3.4.2.3-1”)

Codebook index i_c	Number of layers ν	
	1	2
0	a_0	-
1	a_1	a_4
2	a_2	a_5
3	a_3	-

(d) **Claim 19**

204. **Claim 19** recites “The method of claim 17, wherein the use of precoding matrices for the second precoder that make pairs with restricted precoding matrices of the first matrix group is restricted based on the first bit sequence, and the use of precoding matrices for the first precoder that make pairs with restricted precoding matrices of the second matrix group is restricted based on the second bit sequence.”¹³ The additional limitation of this claim is met by **Sayana** in view of **TS 36.213**.

205. **TS36.213** teaches the matrix group is restricted based on the bit sequence (*see* [17.a]; *e.g.*, “the bitmap”).

¹³ While limitation 17.a] and claim 19 require only “at least one of” a “first bit sequence” and a “second bit sequence,” Ground 2 nevertheless renders obvious both sequences.

206. See my discussion for element [17.a]. As I discuss for [17.a], when **TS36.213**'s teachings are applied to **Sayana**, a first bitmap (a first bit sequence), serving as codebook restriction information to restricts some entries of Sayana's "wideband" "first codebook," and a second bitmap (a second bit sequence), serving as codebook restriction information for Sayana's "subband" "second codebook" will be separately provided. *See* [17.a]. As discussed in Section IX.A.4(h), due to the use of first and second component precoders to obtain a final precoder, as **Sayana** teaches, the restriction of wideband precoding matrices of the "first codebook" as indicated by the first bit sequence also restricts the subband precoding matrices of the subband "second codebook" that makes pairs with the wideband precoding matrices as discussed above, and vice-versa, that restriction of a second precoding matrix from being used restricts the use of pairs of first precoding matrices with the restricted second precoding matrix. *See* Section IX.A.4(h).

C. Ground 3: Sayana in View of TS36.213 and TS36.211 (Claims 17-19, 22-24, 28)

207. **Sayana** in view of **TS36.213** and further in view of **TS36.211** teaches further details of claim limitations [17.b]/[23.b] ("each bit of the [first/second] bit sequence corresponding to one precoding matrix of the [first/second] precoding matrix group") and dependent claims 18/24 ("the first matrix group includes N precoding matrices, and the first bit sequence is an N-bit sequence, ...") and thus

render obvious claims 17-19, 22-24 and 28. In particular, **TS36.211** discloses that each claimed bit of a bit sequence is associated with a precoding matrix of a “Codebook.” TS36.211, pp.53-55.

208. **TS36.213** teaches with respect to the transmission modes 5-6 that the bitmaps of its codebooks are associated with the precoders of the codebooks in **TS36.211**’s Table 6.3.4.2.3-1 and Table 6.3.4.2.3-2, by expressly cross referencing the Tables 6.3.4.2.3-1 and 6.3.4.2.3-2. TS36.213, pp.34-35 (citing to reference “[3]” which is “3GPP TS 36.211”). TS36.211, pp.53-55. For example, **TS36.213**’s Table 7.2-1b, as annotated below, indicates a 16-bit bitmap is used for “4 antenna ports” that correspond to 16 precoder matrices (**light-orange**) for transmission modes 5 and 6. TS36.213, pp.34-35. **TS36.213** also teaches that, for transmission modes 5 and 6, where 4 antenna ports are used, each bit in the bitmap (a_{ic}) is “associated with the precoder for $v = 1$ layer with codebook index i_c in Table 6.3.4.2.3-2” of TS36.211. TS36.213, pp.34-35; TS36.211, p.53-54.

Table 7.2-1b: Number of bits in codebook subset restriction bitmap for applicable transmission modes.

		Number of bits A_c	
		2 antenna ports	4 antenna ports
	Transmission mode 3	2	4
	Transmission mode 4	6	64
	Transmission mode 5	4	16
	Transmission mode 6	4	16

TS36.213, p.35 (annotated). Table 6.3.4.2.3-2 of **TS36.211**, as shown below, includes the 16 precoder matrices, denoted by “Codebook index[es]” from “0” to “15” (black solid box) for layer $v = 1$ (**light-orange**). TS36.211, p.54.

Table 6.3.4.2.3-2: Codebook for transmission on antenna ports $\{0,1,2,3\}$.

Codebook index	u_n	Number of layers ν			
		1	2	3	4
0	$u_0 = [1 \ -1 \ -1 \ -1]^T$	$W_0^{(1)}$	$W_0^{(14)} / \sqrt{2}$	$W_0^{(124)} / \sqrt{3}$	$W_0^{(1234)} / 2$
1	$u_1 = [1 \ -j \ 1 \ j]^T$	$W_1^{(1)}$	$W_1^{(12)} / \sqrt{2}$	$W_1^{(123)} / \sqrt{3}$	$W_1^{(1234)} / 2$
2	$u_2 = [1 \ 1 \ -1 \ 1]^T$	$W_2^{(1)}$	$W_2^{(12)} / \sqrt{2}$	$W_2^{(123)} / \sqrt{3}$	$W_2^{(3214)} / 2$
3	$u_3 = [1 \ j \ 1 \ -j]^T$	$W_3^{(1)}$	$W_3^{(12)} / \sqrt{2}$	$W_3^{(123)} / \sqrt{3}$	$W_3^{(3214)} / 2$
4	$u_4 = [1 \ (-1-j)/\sqrt{2} \ -j \ (1-j)/\sqrt{2}]^T$	$W_4^{(1)}$	$W_4^{(14)} / \sqrt{2}$	$W_4^{(124)} / \sqrt{3}$	$W_4^{(1234)} / 2$
5	$u_5 = [1 \ (1-j)/\sqrt{2} \ j \ (-1-j)/\sqrt{2}]^T$	$W_5^{(1)}$	$W_5^{(14)} / \sqrt{2}$	$W_5^{(124)} / \sqrt{3}$	$W_5^{(1234)} / 2$
6	$u_6 = [1 \ (1+j)/\sqrt{2} \ -j \ (-1+j)/\sqrt{2}]^T$	$W_6^{(1)}$	$W_6^{(13)} / \sqrt{2}$	$W_6^{(134)} / \sqrt{3}$	$W_6^{(1324)} / 2$
7	$u_7 = [1 \ (-1+j)/\sqrt{2} \ j \ (1+j)/\sqrt{2}]^T$	$W_7^{(1)}$	$W_7^{(13)} / \sqrt{2}$	$W_7^{(134)} / \sqrt{3}$	$W_7^{(1324)} / 2$
8	$u_8 = [1 \ -1 \ 1 \ 1]^T$	$W_8^{(1)}$	$W_8^{(12)} / \sqrt{2}$	$W_8^{(124)} / \sqrt{3}$	$W_8^{(1234)} / 2$
9	$u_9 = [1 \ -j \ -1 \ -j]^T$	$W_9^{(1)}$	$W_9^{(14)} / \sqrt{2}$	$W_9^{(134)} / \sqrt{3}$	$W_9^{(1234)} / 2$
10	$u_{10} = [1 \ 1 \ 1 \ -1]^T$	$W_{10}^{(1)}$	$W_{10}^{(13)} / \sqrt{2}$	$W_{10}^{(123)} / \sqrt{3}$	$W_{10}^{(1324)} / 2$
11	$u_{11} = [1 \ j \ -1 \ j]^T$	$W_{11}^{(1)}$	$W_{11}^{(13)} / \sqrt{2}$	$W_{11}^{(134)} / \sqrt{3}$	$W_{11}^{(1324)} / 2$
12	$u_{12} = [1 \ -1 \ -1 \ 1]^T$	$W_{12}^{(1)}$	$W_{12}^{(12)} / \sqrt{2}$	$W_{12}^{(123)} / \sqrt{3}$	$W_{12}^{(1234)} / 2$
13	$u_{13} = [1 \ -1 \ 1 \ -1]^T$	$W_{13}^{(1)}$	$W_{13}^{(13)} / \sqrt{2}$	$W_{13}^{(123)} / \sqrt{3}$	$W_{13}^{(1324)} / 2$
14	$u_{14} = [1 \ 1 \ -1 \ -1]^T$	$W_{14}^{(1)}$	$W_{14}^{(13)} / \sqrt{2}$	$W_{14}^{(123)} / \sqrt{3}$	$W_{14}^{(3214)} / 2$
15	$u_{15} = [1 \ 1 \ 1 \ 1]^T$	$W_{15}^{(1)}$	$W_{15}^{(12)} / \sqrt{2}$	$W_{15}^{(123)} / \sqrt{3}$	$W_{15}^{(1234)} / 2$

209. Similarly, TS36.213's Table 7.2-1b, as annotated below, indicates a 4-bit bitmap (blue) is used for "2 antenna ports" (blue) that correspond to 4 precoder matrices for transmission modes 5 and 6. TS36.213, pp.34-35. TS36.213 also teaches that, for transmission modes 5 and 6, where 2 antenna ports are used, each bit in the bitmap (a_{ic}) is "associated with the precoder for $\nu = 1$ layer with codebook index i_c in Table 6.3.4.2.3-1" of TS36.211. TS36.213, pp.34-35; TS36.211, p.54.

Table 7.2-1b: Number of bits in codebook subset restriction bitmap for applicable transmission modes.

		Number of bits A_c	
		2 antenna ports	4 antenna ports
	Transmission mode 3	2	4
	Transmission mode 4	6	64
	Transmission mode 5	4	16
	Transmission mode 6	4	16

TS36.213, p.35 (annotated). Table 6.3.4.2.3-1 of **TS36.211**, as shown below, includes the 4 precoder matrices, denoted by “Codebook index[es]” from “0” to “3” for layer $v = 1$ (blue). TS36.211, p.53.

Table 6.3.4.2.3-1: Codebook for transmission on antenna ports {0,1}.

Codebook index	Number of layers v	
	1	2
0	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ 1 \end{bmatrix}$	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$
1	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$
2	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ j \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 1 \\ j & -j \end{bmatrix}$
3	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -j \end{bmatrix}$	-

210. Similarly, **TS36.213** teaches with respect to the transmission mode 4 for 2 antenna ports that the bitmap is provided by Table 7.2-1c and associated with the precoders of the codebooks in **TS36.211**'s Table 6.3.4.2.3-1, by expressly cross referencing the Table 6.3.4.2.3-1. TS36.213, pp.34-35 (citing to reference "[3]" which is "3GPP TS 36.211"); TS36.211, pp.53-55. TS36.213 shows that "Transmission mode" 4 is a "Closed-loop spatial multiplexing mode." TS36.213 p.48.

Table 7.2.3-0: PDSCH transmission scheme assumed for CQI reference resource

Transmission mode	Transmission scheme of PDSCH
1	Single-antenna port, port 0
2	Transmit diversity
3	Transmit diversity if the associated rank indicator is 1, otherwise large delay CDD
4	Closed-loop spatial multiplexing
5	Multi-user MIMO
6	Closed-loop spatial multiplexing with a single transmission layer
7	If the number of PBCH antenna ports is one, Single-antenna port, port 0; otherwise Transmit diversity

As shown in the excerpt below, **TS36.213** refers to Table 7.2-1c for "Transmission mode 4" and 2 antenna ports. TS36.213 pp.34.

2. Transmission mode 4

a. 2 antenna ports: see Table 7.2-1c

- b. 4 antenna ports: bit $a_{16(v-1)+i_c}$ is associated with the precoder for v layers and with codebook index i_c in Table 6.3.4.2.3-2 of [3].

211. **TS36.213's** Table 7.2-1c, as annotated below, indicates a 6-bit bitmap (a₀-a₅) (yellow highlight) is used that correspond to 6 precoder matrices for transmission mode 4, and refers to TS36.211 Table 6.3.4.2.3-1. TS36.213, pp.34-35.

Table 7.2-1c: Association of bits in *codebookSubSetRestriction* bitmap to precoders in the 2 antenna port codebook of Table 6.3.4.2.3-1 in [3].

Codebook index i_c	Number of layers v	
	1	2
0	a_0	-
1	a_1	a_4
2	a_2	a_5
3	a_3	-

TS36.213, p.35 (annotated). **TS36.211** section 6.3.4.2.3 states that for the “closed-loop spatial multiplexing transmission mode defined in [4] [3GPP TS 36.213], the codebook index 0 is not used when the number layers is $v = 2$.” TS36.211, p.53. Excluding codebook index 0 when number of layers $v = 2$ from Table 6.3.4.2.3-1 of **TS36.211**, as shown below, results in the 6 precoder matrices (yellow highlight) which are associated with the same codebook index and number of layers positions as Table 7.2-1c above.. TS36.211, p.53.

Table 6.3.4.2.3-1: Codebook for transmission on antenna ports {0,1}.

Codebook index	Number of layers v	
	1	2
0	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ 1 \end{bmatrix}$	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$
1	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -1 \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$
2	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ j \end{bmatrix}$	$\frac{1}{2} \begin{bmatrix} 1 & 1 \\ j & -j \end{bmatrix}$
3	$\frac{1}{\sqrt{2}} \begin{bmatrix} 1 \\ -j \end{bmatrix}$	-

212. Like **Sayana** and **TS36.213**, **TS36.211** is in the same field as the '924 patent which includes multiple input multiple output (MIMO) wireless communications, and reasonably pertinent to the alleged problems identified in the '924 patent—*e.g.*, improving communication efficiency. *See* Sections IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689's Teachings to Sayana), IX.B.1 (Overview of TS36.213 and Motivation to Apply TS36.213's Teachings to Sayana); TS36.211, pp.7 ("The present document describes the physical channels for evolved UTRA."), 53-54 (§6.3.4.2.3) (describes using multiple "antenna ports," which supports the MIMO operations of TS36.213). In addition, per my discussion above, **TS36.213** expressly references **TS36.211** in implementation of MIMO functionality. TS36.213, pp.34-35 (citing "[3] [TS 36.211]"). Because **TS36.213** states, "provisions which, through reference in this text, constitute provisions of the

present document,” the referenced **TS36.211** provisions are considered **TS36.213** provisions. TS36.213 pp,6.

213. A person of ordinary skill in the art would have been motivated to implement **Sayana’s** precoding functionality, as modified by **TS36.213’s** teachings, using **TS36.211’s** teachings of bitmap associated precoding matrices at least because **TS36.213** expressly references **TS36.211’s** teachings of bitmap associated precoding matrices, as I discuss above. TS36.213, pp.6 (citing TS36.211), 35-36; TS36.211, pp.53-54.

214. In light of the above teachings, a person of ordinary skill in the art would have had a reasonable expectation of success in further modifying **Sayana’s** teachings, as modified by **TS36.213**, by applying **TS36.211’s** teachings of codebooks of precoding matrices associated with bitmaps, where a same number of matrices are used as the number of bits included in **TS36.213’s** codebook subset restriction bitmaps. Indeed, **TS36.213** teaches using bitmaps that have a same number of bits as associated precoding matrices (e.g., **TS36.211’s** precoding matrices) to implement codebooks of precoding matrices that are selectable by a UE for feedback to a base station. TS36.213, p.6, 34-36; Sayana, [0085]-[0092].

215. Based on my discussion above, a person of ordinary skill in the art would have been motivated to apply **TS36.211** and **TS36.213’s** collective teachings

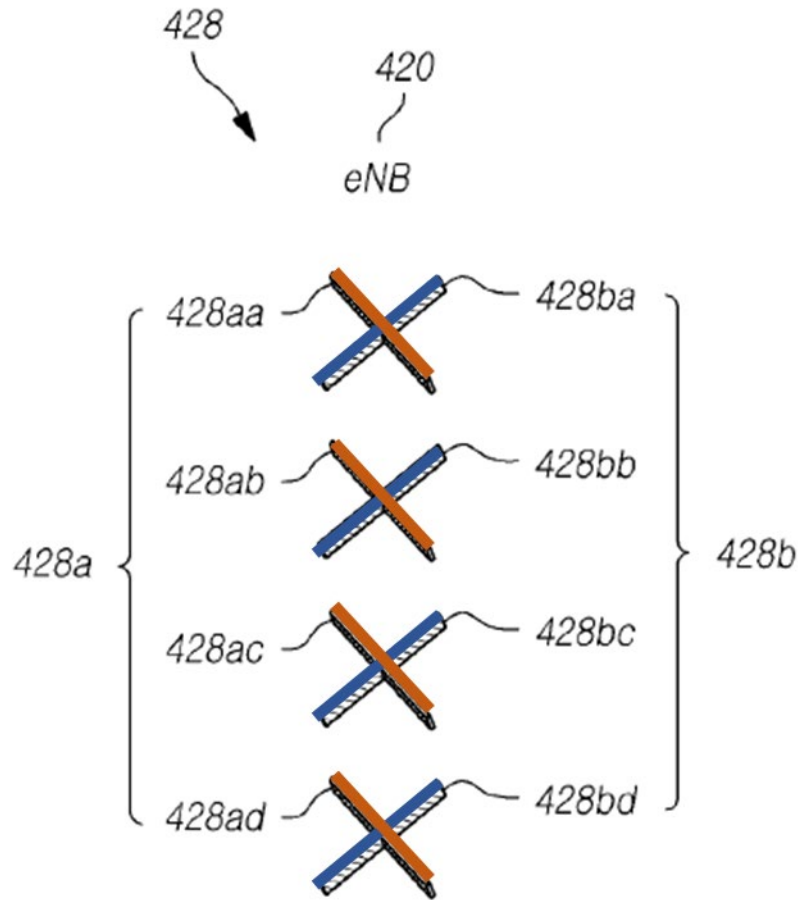
of using a bitmap that has the same number of bits as the number of precoding matrices in implementing **Sayana's** "codebook subset restriction" information for **Sayana's** "first" and "second" precoder such that any of the precoding matrices in **Sayana's** "first codebook" and "second codebook" advantageously is selected or restricted from feedback. TS36.213, p.34; Lee-689, 15:4-17:1, 18:5-15.

D. Grounds 4-6: Grounds 1-3 in Further View of Koivisto (Claims 20-21, 26-27)

216. In addition to the teachings I discussed above in Sections IX.A (Ground 1), IX.B (Ground 2) and IX.C (Ground 3), **Sayana** and **Koivisto** further render obvious the cross-polarization features recited in Challenged Claims 20-21, 26-27 (see Sections IX.B (Overview of Sayana and Koivisto's Cross-Polarization Teachings) to IX.B (Sayana and Koivisto Analysis)).

217. Challenged Claims 20-21 and 26-27 ("Cross-pol Claims") include three concepts: (a) "at least one antenna pair" having a "first domain" including an antenna polarized in a first direction and a "second domain" including an antenna polarized in a second direction intersecting the first direction at a transmitting device or BS, (b) a first "precoding matrix" that "performs precoding on the first domain and the second domain, separately," and (c) a second "precoding matrix" that "performs phase mismatch correction" "between the first domain and the second domain."

218. Figure 5 of the '924 patent, which I excerpt below, illustrates the first concept of “at least one antenna pair” having a first domain and second domain. Figure 5 illustrates a cross-polarization antenna array 428 that has two cross-polarization antennas (indicated by the two X) and that is associated with a BS 420. The antenna array includes a first domain “428a” composed of a first set of antennas “428aa” and “428ad” polarized in a first direction (indicated in **brown**). The antenna array also includes a second domain “428b” composed of a second set of antennas “428ba” and “428bd” polarized in a second direction (indicated in **blue**). '924, 8:29-47. The '924 patent refers to this arrangement of cross-polarization antennas as a “dual polarized antenna array.” The cross-polarization refers to arrangement of the antennas such that the two domains are “cross-polarized” whereby a first signal associated with a first polarization, and a second signal associated with a second polarization that is orthogonal to the first polarization are emitted from the antennas. '924, 8:29-47.



'924 Figure 5 (excerpt)

219. Equation 4 (also referred to as Equation 3) of the '924 patent, which I excerpt below, illustrates the second concept of a first “precoding matrix” that “performs precoding on the first domain and the second domain, separately.” The first precoding matrix (w_1) shown in the excerpt below separately precodes the first domain of the antenna array (e.g., first antennas polarized in a first direction, **428a** in Fig. 5), and the second domain of the antenna array (e.g., second antennas polarized in a second direction perpendicular to the first direction, **428b** in Fig. 5) as

“two independent domains.” This type of matrix, which has ‘0’ for elements off the diagonal, is referred to as a block diagonal matrix. ’924, 9:33-10:24. The structure of the block diagonal matrix results in the separate precoding of the first and second antenna domains, as I will describe further below.

$$\frac{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}{w_1}$$

’924 Equation 4 (excerpt)

220. Equation 4 (also referred to as Equation 3) of the ’924 patent, which I excerpt below, illustrates the third concept of a second “precoding matrix” that “performs phase mismatch correction” “between the first domain and the second domain.” The ’924 patent refers to “co-phasing” as “perform[ing] phase mismatch correction [] between domains.” ’924, 9:65-10:7, 17:61-18:12. The ’924 patent also describes co-phasing in reference to the second precoding matrix (w2) excerpted below from Equation 4 that performs “phase mismatch correction between domains”. The ‘Λ’ provides the phase correction. ’924, 8:48-10:24. The structure of this matrix results in correction of phase mismatch between the first and second antenna domains, as I will describe further below.

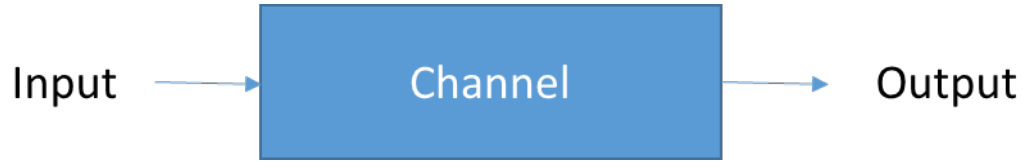
$$\frac{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}{w_2}$$

'924 Equation 4 (excerpt)

221. Based on my discussions herein, **Sayana** in view of **Lee-689** and **Koivisto** renders obvious each of the three aforementioned concepts and therefore the Cross-Pol claims.

222. To provide additional context for the discussion of the three concepts of the '924 Cross-pol Claims, and their relevant disclosures and teachings from the prior art, I provide an overview of how matrices are used to model effects of channels and precoding in wireless communications.

223. Provided below is a block diagram illustrating the transmitting of an input signal from a transmitter (e.g., a base station) to a receiving device (e.g., a UE). In this diagram, the “channel” refers to all of the operations that are applied to an input signal, including steps at the transmitter leading up to the transmitter antenna, and effects that occur after the signal is transmitted from the antenna over a wireless medium to a receiver.



(Fig. H01)

224. In wireless communications, the above block diagrams are often represented as equations to facilitate quantitative analysis. As I will discuss further below, each variable in the equation often refers to a matrix, or two dimensional array of numbers. For example, the above block diagram (Fig. H01) is represented by the following equation where the output matrix ‘y’ is equal to the channel matrix ‘C’ applied to the input ‘s’.

$$\mathbf{y} = \mathbf{C} \cdot \mathbf{s} \text{ (Equation E01)}$$

225. To facilitate additional quantitative analysis, the elements of (Equation E01) are often expressed in matrix form as shown in (Equation E01-A) below. In this form, the output is expressed as a 2 row by 1 column matrix $\begin{bmatrix} \mathbf{Y}_1 \\ \mathbf{Y}_2 \end{bmatrix}$, which for example applies when the output is sent on two separate antennas. The input is also expressed as a 2 row by 1 column matrix $\begin{bmatrix} \mathbf{S}_1 \\ \mathbf{S}_2 \end{bmatrix}$, which for example applies when the input corresponds to two data streams, which are also referred to as layers. The channel matrix that is applied to the input matrix to produce the output signal is

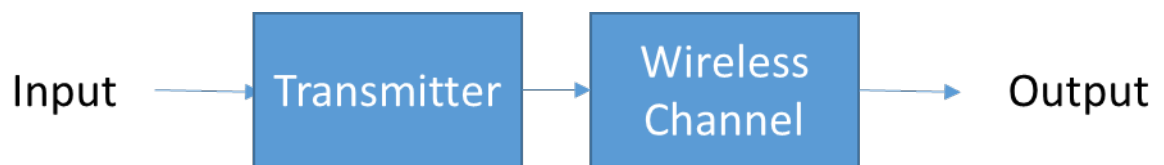
therefore a 2 row x 2 column matrix $\begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix}$ in order to match the dimensions of the input and output.

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} \cdot \begin{bmatrix} S_1 \\ S_2 \end{bmatrix} \text{ (Equation E01-A)}$$

226. In order to recover the input ‘s’ from the received signal ‘y’, an inverted channel matrix is applied to the received signal ‘y’ as shown below.

$$C^{-1} \cdot y = C^{-1} \cdot C \cdot s = s \text{ (Equation E02)}$$

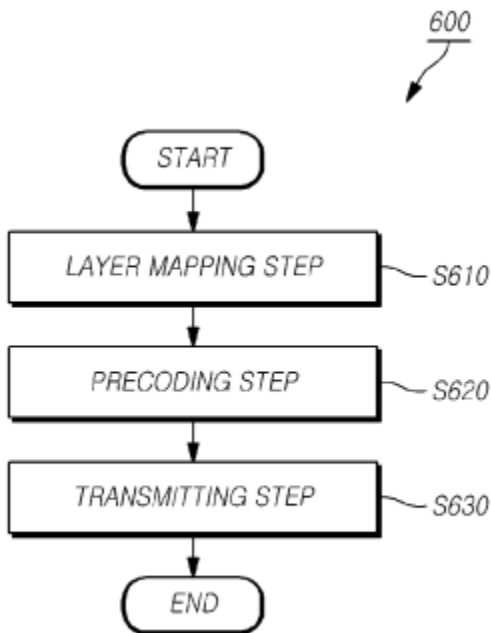
227. The above formulation of block diagrams and corresponding equations is useful because it enables successively and separately analyzing effects that contribute to the overall channel. In an example below, the block diagram of (Fig. H01) is partitioned to illustrate effects of transmitter processes (represented by the matrix ‘T’) and the wireless channel (represented by matrix ‘C’’) on the input signal. Note that the wireless channel matrix C’ is different than the overall channel matrix shown above in (Fig. H01), because it covers the transmission over the wireless medium and does not cover effects of the transmitter.



(Fig. H02)

$$\mathbf{y} = \mathbf{C}^H \cdot \mathbf{T} \cdot \mathbf{s} \text{ (Equation E03)}$$

228. Figure 6 of the '924 patent, reproduced below, provides an example of several steps that take place within a transmitter: a “layer mapping step,” “precoding step,” and “transmitting step.”

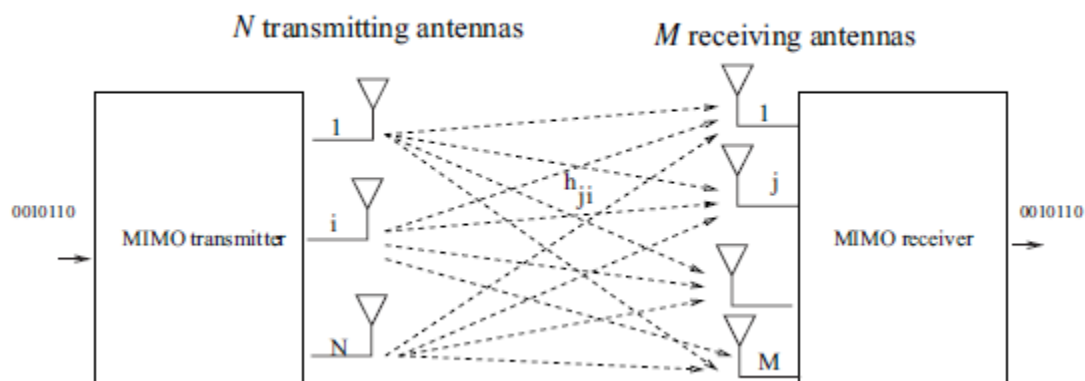
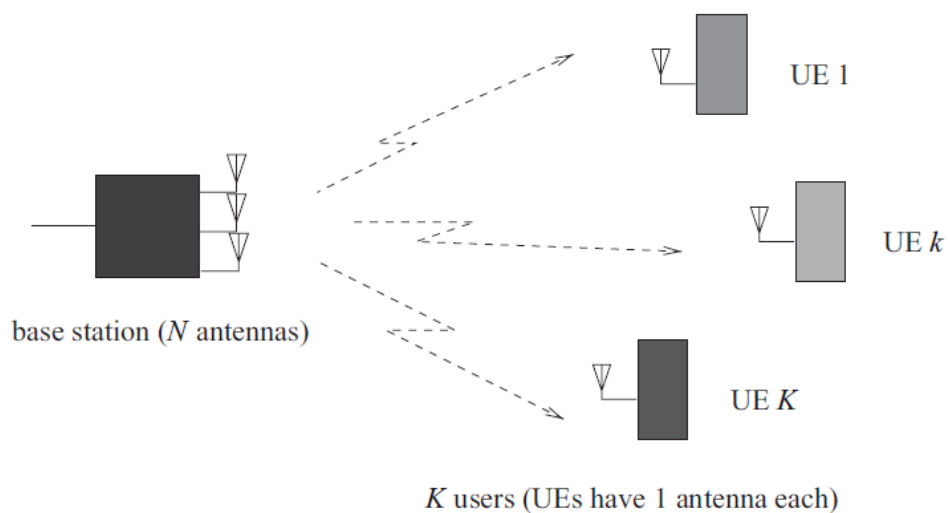


'924, Fig.6

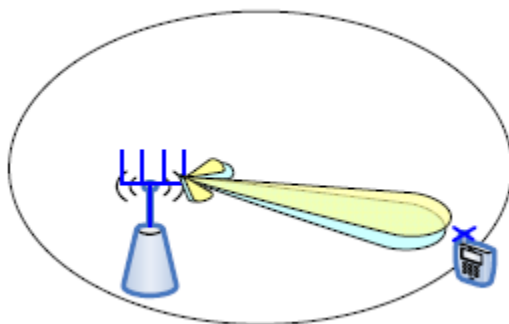
229. The “layer mapping step S610” of the '924 patent maps a codeword to a “layer” or data stream. '924, 15:15-27. For example, in a one layer input system, one data stream is processed for transmission using the transmitting device and is represented by a matrix having 1 row and 1 column. Sayana, [0026]. In a two layer input system, two data streams are processed for transmission using the transmitting

device, and are represented by a matrix having 2 rows (one for each of the two data streams) and 1 column. Sayana, [0027].

230. The “precoding step S620” of the ’924 patent “perform[s] precoding of symbols.” ’924, 15:15-27. For example, the precoding matrix pre-emptively tunes the layer mapped input signals to address for physical aspects of the channel. In some cases, the number of layers will be different from the number of antennas and the dimensions of the precoding matrix accounts for this difference. In some cases, the precoding matrix models directional effects, such as beam forming, between a transmitting device and receiving device, as illustrated below, in which arrows indicate directionality of signals transmitted to a respective UE. For example, the figure 11.5 reproduced below from a reference book, “LTE The UMTS Long Term Evolution From Theory to Practice,” shows precoding used in the downlink to direct signals to a UE; figure 11.2 shows a MIMO system in which multiple antennas are used at a transmitter and receiver and transmissions are precoded at the transmitter. Ex. 1026, Figs. 11.2 (top figure below), 11.5 (bottom figure below), pp.252-276 (e.g., 11.2.2.2-11.2.2.3).

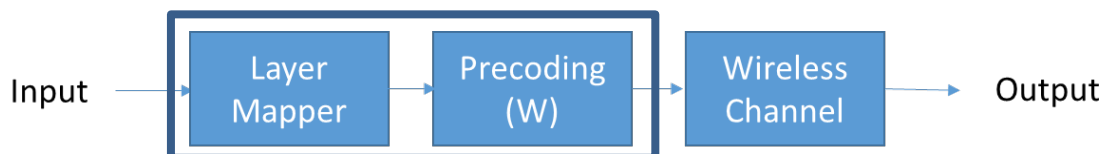


As another example, the publication “Coordinated Beamforming technology in TD-LTE-Advanced system” shows precoding used implement beamforming using a precoding matrix “ V ”. Ex. 1027.



231. The “transmitting step S630” of the ’924 patent refers to the transmission of the “precoded symbol into air through two or more antennas.” ’924, 15:15-27.

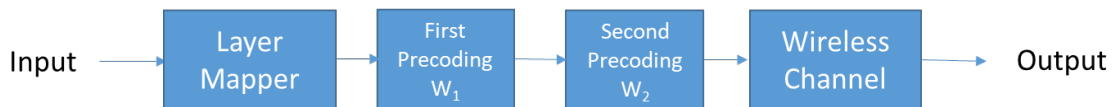
232. Applying the framework of block diagrams and equations discussed above to the steps described in Fig. 6 of the ’924 patent, the “transmitter” block is subdivided into two blocks (boxed) as shown below with a corresponding equation. The effect of the “layer mapper” step is represented in the equation (E04) by the size of the input signal ‘s’ (e.g., 1 row or 2 rows) and not an additional matrix. The effect of the precoding step is represented by the precoding matrix ‘W.’ There is no separate block for the “transmitting” step as that is already covered by the “wireless channel block.”



(Fig. H03)

$$\mathbf{y} = \mathbf{C}^H \cdot \mathbf{W} \cdot \mathbf{s} \text{ (Equation E04)}$$

233. In the context of the '924 patent, the above diagram is further modified as shown below to describe the case of using two precoders to form a multi-stage precoder. For example, the '924 patent illustrates in Fig. 4 a multistage precoder 425 formed from a first precoder 422 and second precoder 424. In the corresponding equation, the precoding matrix $\mathbf{W}$ that corresponds to the multistage precoder 425, is subdivided into a first precoding matrix $\mathbf{W}_1$ corresponding to the first precoder 422 and a second precoding matrix $\mathbf{W}_2$ corresponding to the second precoder 424.



(Fig. H04)

$$\mathbf{y} = \mathbf{C}^H \cdot \mathbf{W}_1 \cdot \mathbf{W}_2 \cdot \mathbf{s} \text{ (Equation E05)}$$

234. I will now explain the three concepts of the '924 Cross-pol Claims with reference to the above framework and matrix notation. When the input signal is one layer, the input signal 's' is represented by a 1x1 matrix, for example of the form $[\mathbf{s}]$. When the input signal is two layers, the input signal 's' is represented by a 2x1 matrix, for example of the form $\begin{bmatrix} \mathbf{s}_1 \\ \mathbf{s}_2 \end{bmatrix}$.

235. As I noted above, a first concept of the '924 patent is using cross-polarization antennas including “at least one antenna pair” having a “first domain” including an antenna polarized in a first direction and a “second domain” including an antenna polarized in a second direction intersecting the first direction. The '924 patent describes an example where the first domain is associated with a horizontal polarization, and the second domain is associated with a vertical polarization.

236. The '924 patent provides an example of a channel matrix in equation 1 that shows how the “overall channel H ” between the base station and user equipment may be expressed, assuming no “phase mismatch” between the antenna of the base station and the user equipment. '924, 8:48-57. The H_h matrix “denotes a channel between the “first domain” of the base station that is polarized in a horizontal direction, and the “first domain” of the user equipment, whereas the H_v matrix “denotes a channel between the first domain” of the base station that is polarized in a vertical direction, and the “first domain” of the user equipment. Thus the first domain represented by the upper left element (H_h), and the second domain is represented by the lower right element (H_v). '924, 8:58-63.

$$\begin{bmatrix} H_h & 0 \\ 0 & H_v \end{bmatrix}$$

'924 Equation 1

237. Also, as I noted above, a second concept of the '924 patent is using a first “precoding matrix” that “performs precoding on the first domain and the second domain, separately,” and a third concept is using a second “precoding matrix” that “performs phase mismatch correction” “between the first domain and the second domain.” The '924 patent provides an example of such a first matrix (W_1) and second matrix (W_2) in Equation 4, excerpted below.

$$\underbrace{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}_{W_1} \underbrace{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}_{W_2}$$

'924 Equation 4 (excerpt)

238. Provided below are the multiple matrices in '924 Equation 1 and Equation 4 collected together in the one equation based on (Equation E05):

$$y = \begin{bmatrix} H_h & 0 \\ 0 & H_v \end{bmatrix} \cdot \begin{bmatrix} R_0 & 0 \\ 0 & R_0 \end{bmatrix} \cdot \begin{bmatrix} I \\ \Lambda \end{bmatrix} \cdot [s]$$

(Equation E06)

239. As can be seen from above equation, the output signal is determined from the application of the channel matrix $C' \left(\begin{bmatrix} H_h & 0 \\ 0 & H_v \end{bmatrix} \right)$ to the first precoding matrix $W_1 \left(\begin{bmatrix} R_0 & 0 \\ 0 & R_0 \end{bmatrix} \right)$, which are then applied to the second precoding matrix $\left(\begin{bmatrix} I \\ \Lambda \end{bmatrix} \right)$, which are then applied to the input signal ($[s]$).

240. To explain the second claim concept of a first “precoding matrix” that “performs precoding on the first domain and the second domain, separately,” I will explain the interaction between the channel matrix $C' \begin{bmatrix} \mathbf{H}_h & 0 \\ 0 & \mathbf{H}_v \end{bmatrix}$ and the first precoding matrix $W_1 \begin{bmatrix} \mathbf{R}_0 & 0 \\ 0 & \mathbf{R}_0 \end{bmatrix}$.

241. The first precoding matrix is in the form of a “diagonal matrix” because the elements that are off the diagonal axis of the matrix are 0. This diagonal form of the first precoding matrix results in the separate precoding on the first domain and the second domain, required under the second concept of the Cross-Pol claims. For example, as I show below from the application of the Channel Matrix to the first precoding matrix, the result is that the precoding matrix R_0 (which is the same for the first precoding matrix and second precoding matrix) is applied separately to each of the horizontal polarization ($\mathbf{H}_h$) (upper left element corresponding to the first domain) and vertical polarization ($\mathbf{H}_v$) (lower right element corresponding to the second domain).

$$\begin{bmatrix} \mathbf{H}_h & 0 \\ 0 & \mathbf{H}_v \end{bmatrix} \cdot \begin{bmatrix} \mathbf{R}_0 & 0 \\ 0 & \mathbf{R}_0 \end{bmatrix} = \begin{bmatrix} \mathbf{H}_h \cdot \mathbf{R}_0 & 0 \\ 0 & \mathbf{H}_v \cdot \mathbf{R}_0 \end{bmatrix}$$

(Equation E07)

242. To explain the third claim concept of a second “precoding matrix” that “performs phase mismatch correction” “between the first domain and the second

domain,” I will explain the interaction between the channel matrix $C' \begin{bmatrix} \mathbf{H}_h & 0 \\ 0 & \mathbf{H}_v \end{bmatrix}$, first precoder matrix $W_1 \begin{bmatrix} \mathbf{R}_0 & 0 \\ 0 & \mathbf{R}_0 \end{bmatrix}$ and second precoder matrix $W_2 \begin{bmatrix} I \\ \Lambda \end{bmatrix}$. I will start my explanation from (Equation E07), which shows the result of applying the channel matrix C' to the first precoder matrix W_1 . When that result is further applied to the second precoding matrix W_2 , the result is shown below in (Equation E08).

$$\begin{bmatrix} \mathbf{H}_h \cdot \mathbf{R}_0 & 0 \\ 0 & \mathbf{H}_v \cdot \mathbf{R}_0 \end{bmatrix} \cdot \begin{bmatrix} I \\ \Lambda \end{bmatrix} = \begin{bmatrix} \mathbf{H}_h \cdot \mathbf{R}_0 \\ \mathbf{H}_v \cdot \mathbf{R}_0 \cdot \Lambda \end{bmatrix}$$

(Equation E08)

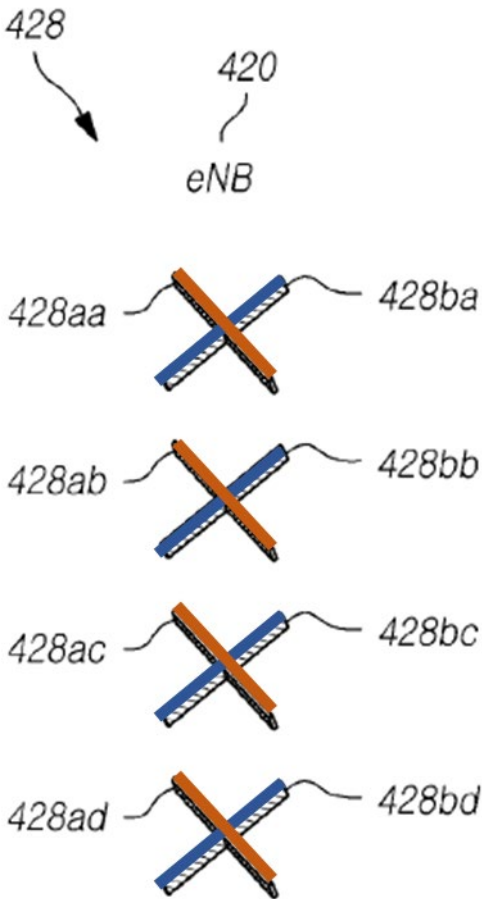
243. In the second precoder matrix, I represents a ‘unit’ or identity matrix, and operates as a ‘1’. ’924, 9:52-55. The result of multiplying any matrix by a unit matrix is the initial matrix itself. Λ represents a phase mismatch correction value between the first domain and second domain. *Id.* As seen in (Equation E07) and (Equation E08), because of the diagonal nature of the result of the channel matrix C' and the first precoding W_1 , the result of applying the second precoding matrix is that the phase mismatch correction Λ is applied only to the second domain (lower right element), and not the first domain (upper left element), thereby correcting a phase mismatch between the first domain and second domain.

244. Now that I have explained how the three claim concepts of the ’924 Cross-pol Claims are explained in the context of the ’924 patent, I will explain how

the prior art discloses and renders obvious the elements of the Cross-pol Claims in the same way.

1. Overview of Sayana and Koivisto's Cross-Polarization Teachings

245. **Sayana** discloses an antenna pair having a first and second domain. As I illustrate in the comparison of excerpts of '924's Fig. 5 and **Sayana's** Fig. 4 below, **Sayana** discloses the *first concept* of the Cross-pol Claims of an antenna pair having a first domain and second domain. Both the '924 and **Sayana** show a "cross-polarized configuration" of antennas, in which a first set of antennas are polarized in a first direction (indicated in **brown**), and a second set of antennas are polarized in a second direction (indicated in **blue**) that intersects the first direction. '924, 8:29-47, Fig. 5; Sayana, ¶[0040] (FIG. 4 illustrates some exemplary antenna configurations at a base unit. ... A cross-polarized configuration with two sets of cross-poles each with two antennas at $\pm 45^\circ$ polarizations is illustrated in **440**), Fig. 4.

'924 Cross-Pol Antennas (Fig. 5)	Sayana's Cross-Pol Antennas (Fig. 4)
	

246. **Koivisto** discloses both the second concept of the Cross-pol Claims--separately precoding antenna domains, and the third concept of the Cross-pol Claims--co-phasing. As I will explain, **Koivisto** teaches a “double codebook” feedback structure to send indications of a first precoder matrix (W_1) and a second precoder matrix (W_2) from a UE to a base station, where the first precoder matrix corresponds to separately precoding antenna domains, and the second precoder

matrix corresponds to co-phasing. Koivisto, Abstract, [0035], [0045], [0057], [0059], [0069], [0079], Fig. 9.

247. **Koivisto** teaches that a first precoder matrix W_1 is a “block diagonal” matrix that addresses “wideband” channel effects. Koivisto, [0045] (“In a first proposal for a codebook structure, *the precoder matrix W_1 is mainly handled in the wideband sense*, compressing the communication channel in the spatial dimension such that the resulting equivalent communication channel matrix $H \cdot W_1$ is of lower dimensionality than the physical transmission communication channel matrix H (e.g., of size N_r by N_t where N_t and N_r are the number of transmit and receive antennas, respectively). Further combining (co-phasing) of the two remaining dimensions (or beams) (for cross-polarized antennas) or orthogonalization between the streams is handled through the matrix W_2 , which is applied in a frequency selective fashion at a subband level. *The precoder matrix W_1 is block diagonal*, wherein each block includes columns of oversampled discrete Fourier transform matrices.”) **Koivisto’s** first precoding matrix and its block diagonal form separately precodes first and second antenna domains, which discloses the ’924’s first precoding matrix of the Cross-pol Claims for the same reasons I discussed above with respect to separate precoding of antenna domains in the ’924 patent. See paragraphs 217-241. **Koivisto** further discloses that a second precoder matrix W_2 is

a “co-phasing” matrix that addresses “subband” channel effects. Koivisto, [0045] (“Further *combining (co-phasing)* of the two remaining dimensions (or beams) (for cross-polarized antennas) or orthogonalization between the streams *is handled through the matrix W_2 , which is applied in a frequency selective fashion at a subband level.*”). Koivisto’s second precoding matrix that performs co-phasing discloses the ’924’s second precoding matrix of the Cross-pol Claims for the same reasons I discussed above with respect to co-phasing in the ’924 patent. See paragraphs 59, 220-244.

248. **Koivisto** also fully incorporates by reference Ericsson (and accordingly all of Ericsson’s teachings) in its discussions of the “block diagonal” and “co-phasing” precoder matrices.¹⁴ Koivisto, [0044]-[0046] (“3GPP TSG-RAN WG1 #61 document R1-102630 entitled “Refinements of Feedback and Codebook Design,” Montreal, Canada, May 10-14, 2010, which is incorporated herein by reference.”); Ericsson, §3.3. I understand that because **Koivisto** incorporates Ericsson by reference, the disclosures of Ericsson are a part of and fully included in

¹⁴ In my opinion, it also would have been obvious to apply Ericsson’s teachings to **Koivisto** for the same reasons that I have discussed herein, and for **Sayana, Lee-689** and **Koivisto**.

the disclosures of **Koivisto**. I will therefore refer to it using “Koivisto” even if it comes from the Ericsson document.

249. **Koivisto** teaches a form of a first precoder matrix ($W^{(1)}$) and second precoder matrix ($W^{(2)}$) in its equation (2) that I have reproduced these forms below. Ericsson’s Equation (2) corresponds to a “rank 1” case where the input is one layer or data stream, and Ericsson’s Equation (5) corresponds to a “rank 2” case where the input is two layers or two data streams. Ericsson, §§3.1, 3.3.1. In the equations below, the left matrix is the first precoder matrix, and the right matrix is the second precoder matrix.

$$W = \begin{bmatrix} \tilde{w} & 0 \\ 0 & \tilde{w} \end{bmatrix} \begin{bmatrix} 1 \\ \alpha \end{bmatrix}, \quad \alpha \in \{1, -1, j, -j\}$$

Koivisto/Ericsson Equation (2)

$$W = \begin{bmatrix} \tilde{w} & 0 \\ 0 & \tilde{w} \end{bmatrix} \begin{bmatrix} 1 & 1 \\ \alpha & -\alpha \end{bmatrix}, \quad \alpha \in \{1, j\}, \quad \tilde{w} \in G_q^{(1,2)}$$

Koivisto/Ericsson Equation (5)

250. **Koivisto** discloses the *second concept* of separately precoding the first and second domains. As I show below, **Koivisto** discloses a block diagonal form of a first precoding matrix that is the same as the one disclosed by the ’924 patent.

'924 First Precoding Matrix	Koivisto/Ericsson First Precoding Matrix
$\frac{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}{w_1}$	$\begin{bmatrix} \tilde{W}^{(1)} & 0 \\ 0 & \tilde{W}^{(1)} \end{bmatrix}$

Koivisto's first precoder matrix has a block diagonal form $\begin{bmatrix} \tilde{w} & 0 \\ 0 & \tilde{w} \end{bmatrix}$ which results in separately precoding a first domain and a second domain for the reasons I discussed above in the context of the '924 patent. See paragraphs 58, 217-241. For example as I explained above, the "block diagonal" form of Ericsson's first precoder matrix $W^{(1)}$ performs precoding separately on the first antenna domain and second antenna domain because the 0 values on the off-diagonal elements results in separate operations by the first row and second row of $W^{(1)}$ on respective antenna domains. For example, as shown in a modified version of (Equation E07) below to use the elements of Koivisto's block diagonal matrix, the precoding is applied separately to the first domain (upper left element) and second domain (lower right element).

$$\begin{bmatrix} H_h & 0 \\ 0 & H_v \end{bmatrix} \cdot \begin{bmatrix} W^{(1)} & 0 \\ 0 & W^{(1)} \end{bmatrix} = \begin{bmatrix} H_h \cdot W^{(1)} & 0 \\ 0 & H_v \cdot W^{(1)} \end{bmatrix}$$

(Equation E09)

251. **Koivisto** also expressly states that its “block diagonal” first precoder matrix “separately precodes each group of co-polarized and closely spaced antennas.” Ericsson, §3.1.

252. **Koivisto** discloses the *third concept* of “co-phasing.” As I show below, **Koivisto** discloses a form of a second precoding matrix that is substantially the same as the one disclosed by the '924 patent. Here, the top element of **Koivisto**'s second precoder matrix is a '1', which is an example of a unit matrix I in the '924's second precoder matrix because in both cases, the '1' or unit matrix multiplied by an element results in the same element. The bottom element of **Koivisto**'s second precoder matrix is α , which **Koivisto** discloses to be one of the values $\{1, -1, j, -j\}$, which corresponds to a change in phase of (0, -180 degrees, 90 degrees, or -90 degrees). α is a form of the '924's Λ , because both modify the phase of an element.

'924 Second Precoding Matrix	Koivisto Second Precoding Matrix
$\frac{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}{w_2}$	$\begin{bmatrix} 1 \\ \alpha \end{bmatrix}$

253. **Koivisto** further teaches that its second precoder matrix $W^{(2)}$ “adjusts the relative phase shift” between the first and second respective antenna domains. Ericsson, §3.3.1.

254. **Koivisto** also teaches that the “block diagonal” design of its first precoder matrix and the design of its co-phasing second precoder matrix are “well-matched” to use of “closely spaced cross-pole” antenna arrays, like those disclosed in **Sayana**. Ericsson, §3.3.1. For example, **Koivisto** states that the “precoder on the diagonal, $W^{(1)}$, is targeting a co-polarized antenna group.” *Id.*

2. Motivation to Apply Koivisto’s Teachings to Sayana and Lee-689

255. Like **Sayana** and **Lee-689**, **TS36.213**, **TS36.211**, and **Koivisto** are in the same field as the ’924 patent which includes multiple input multiple output (MIMO) wireless communications, and reasonably pertinent to the alleged problems identified in the ’924 patent—e.g., improving communication efficiency. *See* Sections IX.A.1 (Overview of Sayana) to IX.A.3 (Overview of Lee-689 and Motivation to Apply Lee-689’s Teachings to Sayana). As an example, **Koivisto** describes “feedback in support of downlink SU-/MU-MIMO operation” using a double codebook structure. Koivisto, [0035]-[0036], [0042]-[0043]. Koivisto’s double codebook structure combines “two feedback components from separate codebooks representing different characteristics of channel state information.” *Id.*

256. Each of **Sayana** and **Koivisto** (via incorporation by reference of **Ericsson**) teaches using a first precoder matrix to address wideband effects, and a second precoder matrix to address subband effects. For example, **Sayana** teaches two components of feedback where “[o]ne of the components representing the correlated channel characteristics can be fed back on a wideband basis and/or slowly in time, while the other component is fed back on a subband basis and/or more frequently in time,” and that “Codebook subset restriction can be used for both wideband and subband components.” Sayana, [0006], [0085]-[0086]. **Koivisto** teaches that “[o]ne feedback component targets wideband communication channel properties (also referred to as wideband properties) and/or long-term communication channel properties (also referred to as long-term properties), while the other targets frequency-selective communication channel properties (also referred to as frequency-selective properties) and/or short-term communication channel properties (also referred to as short-term properties).” Koivisto, [0035]-[0036], [0042]-[0046]. **Koivisto** teaches that a “precoder for a subband is composed of two matrices,” “two codebook indices together determine the precoder” and that “[o]ne of the two matrices targets wideband and/or long-term channel properties” and the “other matrix targets frequency-selective and/or short-term channel properties.” Ericsson, §1.

257. A person of ordinary skill in the art would have been motivated to modify **Sayana** in view of **Lee-689** (and **TS36.213** and **TS36.211**) to apply **Koivisto's** teachings of a block diagonal matrix for the first of **Sayana's** precoders, and **Koivisto's** teachings of a co-phasing matrix for the second of **Sayana's** precoders to form precoders that improve communications between a UE and BS. A person of ordinary skill in the art would have been motivated to do so in light of **Koivisto's** teachings that its first and second precoder matrices are “well-matched” for channel conditions of “closely spaced cross-pole” antennas like the polarized antenna arrays described in **Sayana**. **Koivisto**, §3.3.1; **Sayana**, 7:42-8:6, Fig. 5. The application of **Koivisto's** teachings to **Sayana** in view of **Lee-689** would have combined prior art elements and teachings according to known methods to yield predictable results of addressing wideband and narrowband interference, and would have been a simple substitution of one known element (one precoding matrix) for another (precoding matrix) to obtain predictable results. For example, a person of ordinary skill in the art would have been motivated to combine the known prior art elements and teachings such as codebooks for precoder matrices that address wideband/long-term variation in channels, and subband/short-term variation in channels as disclosed in **Sayana** and **Koivisto**, to apply **Koivisto's** precoding matrices in **Sayana**.

258. **Sayana** teaches various codebook subset restriction methods that apply, depending on operating conditions, to various codebooks. Sayana, [0059]-[0063]. As an example, **Sayana** teaches that a “two-component feedback” of a “wideband and subband codebook” is implemented through a “product matrix based method of precoder matrix representation.” Sayana, [0079]-[0090]. **Sayana** teaches, as an example, using “closely spaced” cross-pol antennas to transmit information. Sayana, [0005], [0040]-[0043]; Fig. 4. **Sayana** teaches examples of “wideband” codebooks and “subband codebook[s]” that contain matrix forms that correspond to or are at least equivalent to the block diagonal first precoding matrix and co-phasing second precoding matrix disclosed in the ’924 patent, **Koivisto** and Ericsson. Sayana, [0063], [0084]; Koivisto, [0044]-[0046]; Ericsson, §§1-3, 3.3.1

259. For example, a person of ordinary skill would have understood that **Sayana’s** teachings of a “rank 1 or one-layer precoding” is equivalent to the form of the first precoding matrix that separately precodes first and second antenna domains, and a second precoding matrix that address co-phasing. Below I show how the equation for a rank 1 precoder at paragraph [0077] is equivalent in form to the first and second precoding matrices under the second and third concepts of the Cross-pol Claims of the ’924 patent.

$$\begin{bmatrix} \underline{v}_1^{nb} \\ \underline{v}_1^{nb} e^{j\theta_1} \end{bmatrix} = \begin{bmatrix} \underline{v}_1^{nb} & \underline{0} \\ \underline{0} & \underline{v}_1^{nb} \end{bmatrix} \begin{bmatrix} \underline{1} \\ e^{j\theta_1} \end{bmatrix} = \begin{bmatrix} R_0 & 0 \\ 0 & R_0 \end{bmatrix} \begin{bmatrix} \underline{1} \\ \underline{\Lambda} \end{bmatrix}$$

(Equation E10)

$$\text{where } R_0 = \underline{v}_1^{nb} \quad I = 1 \quad \Lambda = e^{j\theta_1}$$

260. As another example, a person of ordinary skill in the art would have understood that **Sayana's** teachings of a “rank 2” precoding matrix is equivalent to the form of the first precoding matrix that separately precodes first and second antenna domains, and a second precoding matrix that address co-phasing. Below I show how the equation for a second structure of a rank 2 precoder at paragraph [0072] is equivalent in form to the first and second precoding matrices under the second and third concepts of the Cross-pol Claims of the '924 patent.

$$\begin{bmatrix} \underline{v}_{nb}^1 \rho & \underline{v}_{nb}^2 \sqrt{1 - \rho^2} \\ \underline{v}_{nb}^1 \sqrt{1 - \rho^2} e^{j\theta_1} & \underline{v}_{nb}^2 \rho e^{j\theta_2} \end{bmatrix}$$

(Equation E11) (second structure of precoder matrix)

261. When $\rho = 1/\sqrt{2}$, and $(\rho^2 = \frac{1}{2})$, (Equation E11) becomes the following:

$$\frac{1}{\sqrt{2}} \begin{bmatrix} \underline{v}_{nb}^1 & \underline{v}_{nb}^2 \\ \underline{v}_{nb}^1 e^{j\theta_1} & \underline{v}_{nb}^2 e^{j\theta_2} \end{bmatrix}$$

(Equation E12)

262. (Equation E12) is rewritten in equivalent form to the first and second precoders under the second and third concepts of the Cross-pol Claims of the '924 patent, as shown below.

$$\frac{1}{\sqrt{2}} \begin{bmatrix} \underline{v}_{nb}^1 & \underline{v}_{nb}^2 & 0 \\ 0 & 0 & \underline{v}_{nb}^1 \\ 0 & \underline{v}_{nb}^2 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ e^{j\theta_1} & 0 \\ 0 & e^{j\theta_2} \end{bmatrix} = \begin{bmatrix} R_0 & 0 \\ 0 & R_0 \end{bmatrix} \begin{bmatrix} I \\ \Lambda \end{bmatrix}$$

(Equation E13)

263. In the above form, $R_0 = \frac{1}{\sqrt{2}} \begin{bmatrix} \underline{v}_{nb}^1 & \underline{v}_{nb}^2 \end{bmatrix}$, $\Lambda = \begin{bmatrix} e^{j\theta_1} & 0 \\ 0 & e^{j\theta_2} \end{bmatrix}$, and $I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$.

264. As a further example, a person of ordinary skill in the art would have understood that **Sayana's** teachings of a “rank 2” precoding matrix in a “two-component feedback” is equivalent to the form of the first precoding matrix that separately precodes first and second antenna domains, and a second precoding matrix that address co-phasing. Below I show how the equations for a first precoder for a wideband codebook and a second codebook in **Sayana** is equivalent in form to the first and second precoding matrices under the second and third concepts of the Cross-pol Claims of the '924 patent. Sayana, [0080]-[0081].

265. **Sayana** describes a first component for a wideband codebook in paragraph [0080]:

$$W_1 = \begin{bmatrix} 1 & 1 \\ e^{2\pi j n_1 / N_1} & e^{2\pi j n_2 / N_1} \\ \vdots & \vdots \\ e^{2\pi j L n_1 / N_1} & e^{2\pi j L n_2 / N_1} \end{bmatrix}$$

$$\frac{v_1}{v_2} \quad \frac{v_2}{v_1}$$

(Equation E14)

266. **Sayana** also describes a second component for a codebook in paragraph [0081]:

$$W_2 = \begin{bmatrix} 1 & e^{2\pi j k_1/4} & 1 & e^{2\pi j k_2/4} \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

(Equation E15)

267. The product of the matrix is expressed as:

$$W_1 W_2 = \begin{bmatrix} v_1 & v_1 e^{2\pi j k_1/4} & v_1 & v_1 e^{2\pi j k_2/4} \end{bmatrix}$$

(Equation E16)

268. **Sayana** teaches that to obtain the final precoder W , the above result is passed through a reshape function ($W = \text{reshape}(W_1 W_2)$), Sayana [0082]:

$$\text{Reshape}(X = [X_1 \ X_2 \ X_3 \ X_4]) = \begin{bmatrix} X_1 & X_2 \\ X_3 & X_4 \end{bmatrix}$$

(Equation E17)

269. When applying a reshaping function as taught by **Sayana** at paragraph [0082], the resulting precoding matrix is shown below:

$$W = \begin{bmatrix} \frac{v_1}{v_2} & \frac{v_1}{v_2} \\ v_1 e^{2\pi j k_1/4} & v_1 e^{2\pi j k_2/4} \end{bmatrix} = \begin{bmatrix} R_0 & 0 \\ 0 & R_0 \end{bmatrix} \begin{bmatrix} I \\ \Lambda \end{bmatrix}$$

(Equation E18)

270. When $R_0 = \begin{bmatrix} \underline{v_1} & \underline{v_1} \end{bmatrix}$ and $\Lambda = \begin{bmatrix} e^{2\pi j k_1/4} & 0 \\ 0 & e^{2\pi j k_2/4} \end{bmatrix}$, (Equation

E18) becomes the following form, which is the same as the second and third concepts of the Cross-pol Claims of the '924 patent:

$$W = \begin{bmatrix} R_0 & 0 \\ 0 & R_0 \end{bmatrix} \begin{bmatrix} I \\ \Lambda \end{bmatrix}$$

(Equation E19)

271. **Koivisto**, which incorporates by reference Ericsson, teaches first and second precoding matrix groups that are compatible and complementary with **Sayana's** teachings that I have discussed above. **Sayana** and **Koivisto**, all describe matrices that are the same as or equivalent to the form of the first and second precoder matrices that meet the second and third concepts of the Cross-pol Claims of the '924 patent. **Koivisto** teaches that when using "Closely Spaced Cross-Pole" antennas such as the "cross-polarized configuration" in **Sayana**, channel properties are "well-matched" to a "block diagonal" matrix form of a first precoder matrix ($W^{(1)}$), and a complex valued matrix form of a second precoder matrix ($W^{(2)}$) that adjusts a "relative phase shift" by co-phasing. Sayana, [0040], Fig. 4; Koivisto, [0044]; Ericsson, §3.3.1. Provided below is an example of **Koivisto's** matrix form, which is compatible with **Sayana's** disclosed matrices and cross-pol antennas. Sayana, [0040], Fig. 4; Koivisto, [0044]; Ericsson, §3.3.1. As I have explained

above, **Sayana's** disclosed precoding matrices are equivalent to the form of **Koivisto's** precoder matrix form shown below, and thus **Koivisto's** matrix form are compatible with **Sayana's** matrices.

$$\mathbf{W} = \underbrace{\begin{bmatrix} \tilde{\mathbf{w}} & 0 \\ 0 & \tilde{\mathbf{w}} \end{bmatrix}}_{\mathbf{W}^{(1)}} \underbrace{\begin{bmatrix} 1 \\ \alpha \end{bmatrix}}_{\mathbf{W}^{(2)}}, \quad \alpha \in \{1, -1, j, -j\}$$

(Equation E20)

272. Thus, a person having ordinary skill in the art would have been motivated to apply **Koivisto's** precoding matrix format teachings to **Sayana's** first precoder matrix and second precoder matrix because doing so would have been merely implementing known alternatives to achieve predictable results, in light of the compatibility of the precoding matrices taught by **Sayana**, and **Koivisto** to achieve predictable results.

273. In light of my discussion above, a person of ordinary skill in the art would have had a reasonable expectation of success in modifying **Sayana** and **Lee-689** with **Koivisto's** teachings by using **Koivisto's** teachings of a “block diagonal” first precoder matrix and a “co-phasing” second precoder matrix with **Sayana's** closely cross-polarization antennas to achieve a result in which a first precoder

matrix separately precodes first and second antenna domains, and a second precoder matrix correct a phase mismatch between the first and second domains.

3. Sayana and Koivisto Analysis

274. In addition to Sections IX.A.1(Overview of Sayana and Koivisto’s Cross-Polarization Teachings) to IX.D.2 (Motivation to Apply Koivisto’s Teachings to Sayana and Lee-689), my discussion below that follows bulleted excerpts explains that challenged claims 20-21 and 26-27 is disclosed and/or rendered obvious.

(a) Claim 20

275. **Claim 20 recites “The method of claim 17, wherein the transmitting device includes at least one antenna pair in which a first domain including at least one antenna polarized in one direction and a second domain including at least one antenna polarized in another direction intersect each other; and the precoding matrix of the first precoder performs precoding on the first domain and the second domain, separately, and the precoding matrix of the second precoder performs phase mismatch correction to remove an effect from a phase mismatch between the first domain and the second domain.” Sayana in view of Lee-689 and Koivisto meets this limitation.**

276. **Sayana discloses the transmitting device (*see* [17.c]) includes at least one antenna pair (*e.g.*, “two antennas” [0040], “antenna subsets” [0043], Fig.**

4) **in which a first domain** (*e.g.*, first “cross pole” [0040], Fig. 4) **including at least one antenna polarized in one direction and a second domain** (*e.g.*, second “cross pole” [0040], Fig. 4) **including at least one antenna polarized in another direction intersect each other** (*e.g.*, “cross-polarized configuration with two sets of cross-poles each with two antennas at $\pm 45^\circ$ polarizations” [0040]).

277. **Koivisto discloses the precoding matrix of the first precoder** (*e.g.*, “precoder matrix W_1 ”) **performs precoding on the first domain and the second domain, separately** (*e.g.*, “precoder matrix W_1 is block diagonal” and “separately precodes each group of co-polarized and closely spaced antennas”), **and the precoding matrix of the second precoder** (*e.g.*, precoder matrix W_2) **performs phase mismatch correction to remove an effect from a phase mismatch between the first domain and the second domain** (*e.g.*, “handle the cross-polarized combining (co-phasing and orthogonalization)” and “adjusts the relative phase shift between polarizations”).

278. **Sayana discloses a “cross-polarized configuration”** in which “two antennas at $\pm 45^\circ$ polarizations” each have an associated “cross pole.” Sayana, [0040]. For example, **Sayana teaches, as a claimed first antenna pair, a 2 antenna cross pole** (*e.g.*, which I have boxed in Fig. 4 above). Fig. 4 refers to a “4 antenna xpol closely spaced” which includes 2 of the 2 antenna cross pole that I boxed in the

figure above. Sayana, Fig. 4. **Sayana** teaches that a first antenna of the cross pole (e.g., which I marked with a red solid line above, angled at 45 degrees to the left from vertical) which acts as a first domain, and a second antenna of the cross pole (e.g., which I have marked with a red dotted line above angled at 45 degrees to the right from vertical) which acts as a second domain and intersects the first antenna/domain. Sayana, Figure 4, [0040], [0043].

279. **Koivisto** discloses that a first “precoder matrix W_1 is block diagonal” and is “handled in the wideband.” Koivisto, [0040], [0044]-[0045]. **Koivisto** also teaches that a second “precoder matrix W_2 ” “handle[s] the cross-polarized combining (*co-phasing* and orthogonalization) after the W_1 matrix structure has been applied to the communication channel.” Koivisto, [0040], [0044]-[0045]. **Koivisto**, including Ericsson’s incorporated teachings, teaches that the first precoder matrix “ $W^{(1)}$ separately precodes each group of co-polarized and closely spaced antennas,” and that the second precoder matrix “ $W^{(2)}$ ” “adjusts the relative phase shift between polarizations.” Koivisto, [0044]; Ericsson, §3.3.1. As I have explained above in Section IX.D (Grounds 4-6: Grounds 1-3 in Further View of Koivisto (Claims 20-21, 26-27)) at paragraphs 217-241, 247-251, the block diagonal form of a first precoder matrix separately precodes a first antenna domain and a second antenna domain. As I have also explained above in Section IX.D.1

(Overview of Sayana and Koivisto's Cross-Polarization Teachings) at paragraphs 242-244, 252-254, the form of the second precoder matrix which includes an unit matrix as a top element and a phase adjustment matrix as a bottom element adjusts a phase between the first antenna domain and second antenna domain.

280. I had previously described a difference between cases where the input is one layer or one data stream, also referred to as “rank 1” inputs, and cases where the input is two layers or two data streams, also referred to as “rank 2” inputs. *See* Section IX.D.1 (Overview of Sayana and Koivisto's Cross-Polarization Teachings) at paragraph 249 and Section IX.D.1 (Motivation to Apply Koivisto's Teachings to Sayana and Lee-689) at paragraphs 259-270. The difference between these two cases is the form of the input matrix. A “rank 1” input has a size that is 1 row by 1 column. A “rank 2” input has a size that is 2 rows by 1 column. **Koivisto**, by incorporating Ericsson by reference, teaches two forms of a co-phasing matrix. In the rank 1 case, Ericsson teaches a 2 row by 1 column matrix, that when multiplied by a 1 row by 1 column matrix input, associated with “rank 1” input results in a 2 row by 1 column matrix, to which the first precoder and then channel matrix is applied, as shown below.

$$y = \begin{bmatrix} H_h & 0 \\ 0 & H_v \end{bmatrix} \cdot \begin{bmatrix} R_0 & 0 \\ 0 & R_0 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ \alpha \end{bmatrix} \cdot [s] = \begin{bmatrix} H_h & 0 \\ 0 & H_v \end{bmatrix} \cdot \begin{bmatrix} R_0 \\ \alpha \cdot R_0 \end{bmatrix} \cdot [s]$$

(Equation E21)

281. In the rank 2 case, Ericsson teaches a 2 rows by 2 column matrix, that when multiplied by a 2 row by 1 column matrix input, associated with “rank 2” input results in a 2 row by 1 column matrix, to which the first precoder and then channel matrix is applied, as shown below.

$$\begin{aligned} y &= \begin{bmatrix} H_h & 0 \\ 0 & H_v \end{bmatrix} \cdot \begin{bmatrix} R_0 & 0 \\ 0 & R_0 \end{bmatrix} \cdot \begin{bmatrix} 1 & 1 \\ \alpha & -\alpha \end{bmatrix} \cdot \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} \\ &= \begin{bmatrix} H_h & 0 \\ 0 & H_v \end{bmatrix} \cdot \begin{bmatrix} R_0 & R_0 \\ \alpha \cdot R_0 & -\alpha \cdot R_0 \end{bmatrix} \cdot \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} \end{aligned}$$

(Equation E22)

282. As I have explained above in Section IX.D.2 (Motivation to Apply Koivisto’s Teachings to Sayana and Lee-689), a person of ordinary skill in the art would have been motivated to modify **Sayana** and **Lee-689** with **Koivisto’s** teachings of first and second precoder matrices because doing so would have combined prior art elements and teachings according to known methods to yield predictable results. For example, a person of ordinary skill in the art would have been motivated to combine the known prior art elements and teachings such as codebooks for precoder matrices that address wideband/long-term variation in channels, and subband/short-term variation in channels as disclosed in **Sayana** and **Koivisto** and Ericsson, to apply **Koivisto’s** precoding matrices in **Sayana**. The modification of **Sayana** by **Koivisto’s** precoding matrices teachings would have been a simple substitution of one known element for another to obtain predictable

results. Each of the codebooks in **Sayana** and **Koivisto** (and Ericsson incorporated by reference) were known to be implementations for precoding, and as I have explained above, the forms of matrices in **Sayana** are equivalent to those in **Koivisto** and Ericsson, therefore compatible with them. Moreover, **Koivisto** teaches that its precoder matrices are well-suited to channel conditions of closely spaced cross-polarization antennas, as used in **Sayana**. Koivisto, [0044]-[0046]; Ericsson, §3.1.

283. *E.g., Sayana:*

- Sayana Figure 4

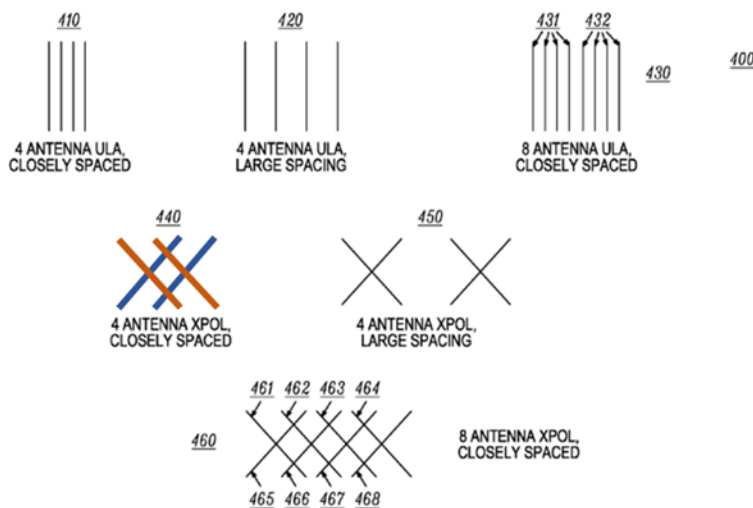


FIG. 4

- **Sayana [0040]** (“FIG. 4 illustrates some exemplary antenna configurations at a base unit. ... A cross-polarized configuration with two sets of cross-poles each with two antennas at $\pm 45^\circ$ polarizations is illustrated in 440.”)
- **Sayana [0043]** (“The polarization Kronecker component R_{Pol} captures the correlation submatrix between subsets with similar cross-polarized configuration, namely antenna subsets (461,465), (462,466), (463,467) and (464,468) in FIG. 4. The above representation in the covariance matrix also translates to similar structure for the precoder.”)

284. *E.g., Koivisto:*

- **Koivisto [0045]** (“*[T]he precoder matrix W_1 is mainly handled in the wideband sense, compressing the communication channel in the spatial dimension Further combining (co-phasing) of the two remaining dimensions (or beams) (for cross-polarized antennas) or orthogonalization between the streams is handled through the matrix W_2 , which is applied ...at a subband level. The precoder matrix W_1 is block diagonal.... The purpose of the precoder matrix W_2 is to handle the cross-polarized combining (co-phasing and orthogonalization) after the W_1 matrix structure has been applied to the communication channel....*”)
- **Ericsson, §3.1** (“This structure is well-suited for efficiently supporting common antenna setups such as closely spaced cross-poles or closely spaced ULA. ...[C]onsider the common case of an array of closely spaced cross-poles. *The antennas can then be divided into two groups based on polarization and the corresponding channels are denoted H_1 and H_2 , respectively.* Assuming for example that the inner precoder $W^{(1)}$ has a block diagonal structure,

$$W^{(1)} = \begin{bmatrix} \tilde{W}^{(1)} & 0 \\ 0 & \tilde{W}^{(1)} \end{bmatrix} \quad (1)$$

The product of the MIMO channel and the overall precoder can then be written as

$$HW = [H_1 \quad H_2] W^{(1)} W^{(2)} = [H_1 \quad H_2] \begin{bmatrix} \tilde{W}^{(1)} & 0 \\ 0 & \tilde{W}^{(1)} \end{bmatrix} W^{(2)} = [H_1 \tilde{W}^{(1)} \quad H_2 \tilde{W}^{(1)}] W^{(2)} = H_{\text{eff}} W^{(2)}$$

As seen, $\tilde{W}^{(1)}$ *separately precodes each group of co-polarized and closely spaced antennas* forming a smaller and improved effective channel H_{eff} .”)

- **Ericsson, §3.3.1** (“The *closely spaced cross-pole is a common antenna array setup, ..., the antennas can then be divided into two separate groups depending on the polarization direction of the antenna.* ... Such an antenna setup thus creates quite pronounced channel properties, *which are well-matched to a block diagonal design* along the lines of

$$W = \begin{bmatrix} \tilde{W}^{(1)} & 0 \\ 0 & \tilde{W}^{(1)} \end{bmatrix} W^{(2)}$$

very well. *The precoder on the diagonal, $\tilde{W}^{(1)}$, is targeting a co-polarized antenna group. ... The outer precoder, $W^{(2)}$, adjusts the relative phase*

shift between polarizations, at least for rank 1 and 2 where the 2 Tx Rel-8 codebook could be re-used. For rank 1, the precoder could for example be formed as

$$\mathbf{W} = \begin{bmatrix} \tilde{\mathbf{w}} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{w}} \end{bmatrix} \begin{bmatrix} 1 \\ \alpha \end{bmatrix}, \quad \alpha \in \{1, -1, j, -j\}$$

...

The rank 2 case would follow similarly as

$$\mathbf{W} = \begin{bmatrix} \tilde{\mathbf{w}} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{w}} \end{bmatrix} \begin{bmatrix} 1 & 1 \\ \alpha & -\alpha \end{bmatrix}, \quad \alpha \in \{1, j\}, \quad \tilde{\mathbf{w}} \in G_q^{(1,2)}$$

(b) Claim 21

285. Claim 21 recites “The method of claim 20, wherein the precoding matrix of the first precoder corresponds to W1 in the following Equation and the precoding matrix of the second precoder corresponds to W2 in the following Equation:

$$\mathbf{W} = \underbrace{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}_{\mathbf{W}_1} \underbrace{\begin{pmatrix} \mathbf{I} \\ \Lambda \end{pmatrix}}_{\mathbf{W}_2},$$

wherein R0 denotes a value determined by a precoding gain when the first domain and the second domain have an identical spatial channel status, I denotes a unit matrix, and Λ denotes a phase mismatch correction value between the first domain and the second domain.” Sayana in view of Lee-689 and Koivisto meets this limitation.

286. **Koivisto** discloses the precoding matrix of the first precoder

corresponds to W_1 (e.g., $\begin{bmatrix} \tilde{W}^{(1)} & 0 \\ 0 & \tilde{W}^{(1)} \end{bmatrix}$) in the following Equation and the

precoding matrix of the second precoder corresponds to W_2 (e.g., $\begin{bmatrix} 1 \\ \alpha \end{bmatrix} \begin{bmatrix} 1 & 1 \\ \alpha & -\alpha \end{bmatrix}$)

in the following Equation
$$W = \underbrace{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}_{w_1} \underbrace{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}_{w_2},$$
 wherein R_0 denotes a value determined by a precoding gain when the first domain and the second domain have an identical spatial channel status (e.g., “closely spaced cross-poles”), I denotes a unit matrix, and Λ denotes a phase mismatch correction value between the first domain and the second domain (e.g., see claim 20).

287. **Koivisto**, including Ericsson’s teachings incorporated by reference, discloses that a first “precoder matrix W_1 is block diagonal” in the form of

$\begin{bmatrix} \tilde{W}^{(1)} & 0 \\ 0 & \tilde{W}^{(1)} \end{bmatrix}$. Koivisto, [0044] incorporating Ericsson, §3.3.1. **Koivisto** teaches,

incorporating Ericsson by reference, that in “closely spaced cross-pol” antenna configurations, the value on the block diagonal is a same precoding gain $W^{(1)}$.

Koivisto, [0043]-[0044]; Ericsson, §3.1. **Koivisto**, incorporating Ericsson by reference, explains that in the “common case of an array of closely spaced cross-

poles” that “antennas can then be divided into two groups based on polarization and the corresponding channels are denoted $H_{\backslash}$ and $H_{/}$. *Id.* **Koivisto**, including **Ericsson’s** incorporated teachings, further states that “such an antenna setup [] creates quite pronounced channel properties, which are well-matched to a block diagonal design,” in which a common precoder on the diagonal is “targeting a co-polarized antenna group.” Koivisto, [0043]-[0044]; Ericsson, §§3.1, 3.3.1. **Koivisto**, incorporating Ericsson by reference, also teaches that a second “precoder matrix W_2 ” “adjusts the relative phase shift between polarizations” and is in the form $\begin{bmatrix} 1 \\ \alpha \end{bmatrix}$ in the case of 1 layer input, or $\begin{bmatrix} 1 & 1 \\ \alpha & -\alpha \end{bmatrix}$ in the case of 2 layer input. Koivisto, [0044]-[0045]; Ericsson, §3.3, 3.3.1. The value “1” is a an example of the unit matrix “I”, because as I explained above in Section IX.D.2 (Grounds 4-6: Grounds 1-3 in Further View of Koivisto (Claims 20-21, 26-27)) at paragraph 243, multiplying a number by 1 or the unit matrix returns the same number. The value “ α ” in the second “precoder matrix W_2 ” represents an adjusted relative phase shift, as shown by the values that “ α ” can take $\{1, -1, j, -j\}$ which corresponds to $\{0, -180, 90, \text{ or } -90 \text{ degrees}\}$ as I discussed above. *See* Sections IX.D.2 (Motivation to Apply Koivisto’s Teachings to Sayana and Lee-689) at paragraph 271, IX.D.2 (Motivation to Apply Koivisto’s Teachings to Sayana and Lee-689) at paragraph 243; Koivisto,

[0044]-[0045]; Ericsson, §3.3, 3.3.1. As explained above in Section IX.D.2 (Motivation to Apply Koivisto's Teachings to Sayana and Lee-689), a person of ordinary skill in the art would have been motivated to modify **Sayana** and **Lee-689** with **Koivisto's** teachings of first and second precoder matrices because doing so would have combined prior art elements and teachings according to known methods to yield predictable results. For example, a person of ordinary skill in the art would have been motivated to combine the known prior art elements and teachings such as codebooks for precoder matrices that address wideband/long-term variation in channels, and subband/short-term variation in channels as disclosed in **Sayana** and **Koivisto** (incorporating Ericsson by reference), to apply **Koivisto's** precoding matrices in **Sayana**. The modification of **Sayana** with **Koivisto's** precoding matrices teachings would have been a simple substitution of one known element for another to obtain predictable results. Each of the codebooks in **Sayana** and **Koivisto** (and Ericsson incorporated by reference) were known to be implementations for precoding, and as I have explained above, the forms of matrices in **Sayana** are equivalent to those in Koivisto and Ericsson, therefore compatible with them. Moreover, **Koivisto** teaches that its precoder matrices are well-suited to channel conditions of closely spaced cross-polarization antennas, as used in **Sayana**. Sayana, [0040], Fig. 4; Koivisto, [0044]-[0046]; Ericsson, §3.1.

288. *E.g., Koivisto:*

- **Koivisto [0045]** (“*[T]he precoder matrix W_1 is mainly handled in the wideband sense, compressing the communication channel in the spatial dimension Further **combining (co-phasing) of the two remaining dimensions (or beams) (for cross-polarized antennas) or orthogonalization between the streams is handled through the matrix W_2 , which is applied ...at a subband level.** The precoder matrix W_1 is block diagonal.... **The purpose of the precoder matrix W_2 is to handle the cross-polarized combining (co-phasing and orthogonalization) after the W_1 matrix structure has been applied to the communication channel....**”).*
- **Koivisto [0046]** (“Additionally/alternatively, some user equipment feedback reporting modes (e.g., over a physical uplink control channel (“PUCCH”)) may be designed under the constraint of very low associated feedback overhead. In the latter case, it would make sense for instance, to consider W_1 and W_2 matrix selection and reporting both in a wideband fashion. The main difference compared to the usual grid of beams is that the feedback is based on the double codebook format or structure, wherein the format is used to provide a grid of beams-like operation for both uniform linear array and cross-polarized-type of arrays with the same feedback. The issue with this scheme is exactly the one referred to previously hereinabove (i.e., the scheme does not allow improved SU-MIMO performance when azimuthal spread is higher).”)
- **Ericsson, §3.1** (“This structure is well-suited for efficiently supporting common antenna setups such as closely spaced cross-poles or closely spaced ULA. ...[C]onsider the common case of an array of closely spaced cross-poles. **The antennas can then be divided into two groups based on polarization and the corresponding channels are denoted H_1 and H_2 , respectively.** Assuming for example that the inner precoder $W^{(1)}$ has a block diagonal structure,

$$W^{(1)} = \begin{bmatrix} \tilde{W}^{(1)} & \mathbf{0} \\ \mathbf{0} & \tilde{W}^{(1)} \end{bmatrix} \quad (2)$$

The product of the MIMO channel and the overall precoder can then be written as

$$HW = \begin{bmatrix} H_1 & H_2 \end{bmatrix} W^{(1)} W^{(2)} = \begin{bmatrix} H_1 & H_2 \end{bmatrix} \begin{bmatrix} \tilde{W}^{(1)} & \mathbf{0} \\ \mathbf{0} & \tilde{W}^{(1)} \end{bmatrix} W^{(2)} = \begin{bmatrix} H_1 \tilde{W}^{(1)} & H_2 \tilde{W}^{(1)} \end{bmatrix} W^{(2)} = H_{\text{eff}} W^{(2)}$$

As seen, $\tilde{\mathbf{W}}^{(1)}$ *separately precodes each group of co-polarized and closely spaced antennas* forming a smaller and improved effective channel $\mathbf{H}_{\text{eff}}$.”)

- Ericsson, §3.3.1 (“The *closely spaced cross-pole is a common antenna array setup*, ..., *the antennas can then be divided into two separate groups depending on the polarization direction of the antenna*. ... Such an antenna setup thus creates quite pronounced channel properties, *which are well-matched to a block diagonal design* along the lines of

$$\mathbf{W} = \begin{bmatrix} \tilde{\mathbf{W}}^{(1)} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{W}}^{(1)} \end{bmatrix} \mathbf{W}^{(2)}$$

very well. *The precoder on the diagonal, $\tilde{\mathbf{W}}^{(1)}$, is targeting a co-polarized antenna group*. ... *The outer precoder, $\mathbf{W}^{(2)}$, adjusts the relative phase shift between polarizations*, at least for rank 1 and 2 where the 2 Tx Rel-8 codebook could be re-used. For rank 1, the precoder could for example be formed as

$$\mathbf{W} = \begin{bmatrix} \tilde{\mathbf{w}} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{w}} \end{bmatrix} \begin{bmatrix} 1 \\ \alpha \end{bmatrix}, \quad \alpha \in \{1, -1, j, -j\}$$

...

The rank 2 case would follow similarly as

$$\mathbf{W} = \begin{bmatrix} \tilde{\mathbf{w}} & \mathbf{0} \\ \mathbf{0} & \tilde{\mathbf{w}} \end{bmatrix} \begin{bmatrix} 1 & 1 \\ \alpha & -\alpha \end{bmatrix}, \quad \alpha \in \{1, j\}, \quad \tilde{\mathbf{w}} \in G_q^{(1,2)}”))$$

- *See also [0044].*

(c) Claim 26

289. Claim 26 recites the same limitations as claim 20, except that it depends on claim 23 instead of claim 17. See my discussion for claims 20 and 23.

(d) Claim 27

290. Claim 27 recites the same limitations as claim 21, except that it depends on claim 23 instead of claim 17. See my discussion for claims 21 and 23.

X. SECONDARY CONSIDERATIONS

291. I have reviewed the '924 patent's prosecution history and have not uncovered any evidence of secondary considerations of non-obviousness, or evidence of nexus to any challenged Claim. *See generally* '924 File History. Indeed, as I have explained in my declaration with respect to the prior art referenced herein, any purported solutions to problems or unexpected results in the '924 were already well known.

XI. CONCLUSION

292. In summary, I have concluded that Challenged Claims 17-24 and 26-28 are rendered obvious over the prior art references as discussed above. For at least the reasons discussed above, Challenged Claims 17-24 and 26-28 are rendered obvious as follows:

Ground (§103)	Claims	References
1	17-19, 22-24, 28	Sayana in view of Lee-689
2		Sayana in view of TS36.213
3		Sayana in view of TS36.213 and TS36.211
4	20-21, 26-27	Sayana in view of Lee-689 and Koivisto

Ground (§103)	Claims	References
5		Sayana in view of TS36.213 and Koivisto
6		Sayana in view of TS36.213 , TS36.211 , and Koivisto

293. To the extent it is argued that any further disclosure is required for an element in the Challenged Claims 17-24 and 26-28 that I have identified as being disclosed, a person of ordinary skill in the art would certainly have found that element obvious to include based on the same explicit disclosure or inherent disclosures and analysis I have identified above.

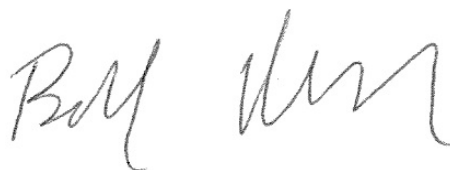
294. I reserve the right to supplement my opinions in the future to respond to any arguments that Patent Owner or its expert(s) may raise and to take into account new information as it becomes available to me.

295. In signing this declaration, I recognize 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 also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

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

Executed this 10th day of August 2023, in South Bend, Indiana

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Bertrand Hochwald", written in a cursive style.

Dr. Bertrand Hochwald

Appendix A

Bertrand M. Hochwald

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Degrees:

BS (Engineering) 1984, Swarthmore College
MS (Electrical Engineering) 1986, Duke University
MA (Statistics) 1993, Yale University
PhD (Electrical Engineering) 1995, Yale University

Experience:

Department of Defense, Fort Meade, Maryland. *Electrical Engineer*, 1986–1989.
Yale University, New Haven, Connecticut. *Teaching assistant*, 1990–1994.
University of Illinois, Urbana-Champaign
Postdoctoral Research Associate in data compression, 1995.
Visiting Faculty in Department of Electrical Engineering, 1996.
Bell Laboratories, Lucent Technologies, Murray Hill, New Jersey
Member of Technical Staff, 1996–2002.
Distinguished Member of Technical Staff, 2002–2005.
Columbia University, New York
Visiting Faculty in Department of Electrical Engineering, 2005.
Beceem Communications, Santa Clara, California
Chief Scientist, 2005–2009,
Vice-President Systems Engineering, 2009–2010.
Stanford University, Palo Alto, California
Consulting Professor of Electrical Engineering, 2006–2010.
University of Notre Dame, Notre Dame, Indiana
Frank M. Freimann Professor of Electrical Engineering, 2011–present.
University of Notre Dame, Notre Dame, Indiana
Co-Director of The Wireless Institute, 2016–present.

Honors:

New York State: *Regents Scholarship*, 1980.
Pennsylvania ACM computer programming competition: *Winner*, 1983.
Duke University: *Eta Kappa Nu engineering honor society*, 1985.
Department of Defense: *Special Achievement Awards*, 1988, 1989.
Yale University: *Prize Teaching Fellowship teaching award*, 1993.
Bell Laboratories: *President's Gold Award*, 2002.
Thomson Essential Science Indicators
Top one-tenth of one percent referenced papers, 2002 and 2003.
IEEE Transactions on Communications
Stephen O. Rice Best Paper Award, 2006.
IEEE
Fellow, 2008.
Thomson Reuters
World's Most Influential Scientific Minds, multiple years.

Honors (cont'd):

IEEE Transactions on Circuits and Systems
Young Author Best Paper Award, 2016 (my PhD student).
IEEE Transactions on Antennas and Propagation
H. A. Wheeler Prize Paper Award, 2018.
The Marconi Society
Paul Baran Young Scholar Award, 2018 (my PhD student).
National Academy of Inventors
Fellow, 2019.

Research Gifts, Grants and Contracts:

Principal Investigator, “NSF EAGER: Multiple Transmitter Chains to Minimize Exposure to Electromagnetic Radiation in Portable Devices,” National Science Foundation CCF-1141868, August 1, 2011–July 31, 2013, \$200,000.
Co-Principal Investigator, “Planning Grant: I/UCRC in Broadband Wireless Technologies and Applications,” National Science Foundation IIP-1266124, April 1, 2013–March 31, 2014, \$14,544.
Co-Principal Investigator, “I/UCRC Phase I: BWAC@NDWI: Broadband Wireless Access and Applications at the Notre Dame Wireless Institute,” National Science Foundation, IIP-1439682, August 1, 2014–July 31, 2019, \$325,000.
Principal Investigator, “Modeling, Analysis, and Code Design for Portable Wireless Transmitters Subject to an Electromagnetic Exposure Constraint,” National Science Foundation, CCF-1403458, September 1, 2014–August 31, 2018, \$1,200,000.
Principal Investigator, “Notre Dame Millimeter-Band Capability,” Equipment Restoration and Renewal Grant, May 31, 2015–May 31, 2016, \$183,000.
Principal Investigator, “Channel Estimation Technologies based on AoA/AoD in High-Frequency Wireless Communication Systems,” Huawei Technologies, June 22, 2015–October 31, 2016, \$181,217.
Principal Investigator, “*Radiohound*: A Low-Cost Spectrum Beacon/Sensor with Millimeter Wave Capability,” Alcatel-Lucent and Interdigital Corporations, June 1, 2015–May 31, 2018, \$240,000.
Principal Investigator, “Low-Complexity High-Bandwidth Multiport Matching Networks for Coupled Loads,” National Science Foundation, ECCS-1509188, August 1, 2015–July 31, 2018, \$400,000.
Principal Investigator, “Notre Dame Coherent RadioHound: A Distributed Spectrum Sensor Network,” Laboratory for Telecommunications Sciences, May 6, 2016–May 5, 2017, \$187,124.
Co-Principal Investigator, “Wideband Time-Domain Millimeter-Wave Device and Channel Characterization Testbed,” Department of the Navy, July 15, 2016–July 14, 2017, \$326,573.
Principal Investigator, “SpecEES: Wideband Wireless Communications with Low-Power Transceiver-Cell Circuits,” National Science Foundation, ECCS-1731056, August 15, 2017–August 14, 2020, \$650,000.
Principal Investigator, “Data Gathering Plan for Radio-Frequency Machine-Learning Systems,” Defense Advanced Research Projects Agency, October 1, 2017–June 1, 2018, \$149,332.
Principal Investigator, “REU Site: AWaRE Advanced Wireless Research Experiences at the University of Notre Dame,” National Science Foundation CNS-1757804, January 15, 2018–December 31, 2020, \$359,789.
Co-Principal Investigator, “Physical Layer Signature Discrimination of Transmitters,” The George J Kostas Research Institute for Homeland Security at Northeastern University (KRI), March 30, 2018–October 29, 2020, \$100,000.

Research Gifts, Grants and Contracts (cont'd):

- Co-Principal Investigator, "An Infrastructure-less and Heterogeneous Distributed Sensor for Electromagnetic Spectrum Sensing and Emitter Geolocation," Department of the Army, June 15, 2018–June 14, 2019, \$370,234.
- Co-Principal Investigator, "Improving STEM Retention Through Hands-On Implementation and Red-Teaming," Office of Naval Research, August 15, 2018–August 14, 2021, \$735,830.
- Principal Investigator, "Ultra Low Cost/Power Massive MIMO Architecture and Algorithm," Futurewei Technologies, Inc, Gift, September 13, 2018, \$200,000.
- Principal Investigator, "Ultra Low-Cost Low-Power Millimeter-Wave Transceiver," AT&T Innovation Lab, September 15, 2018–September 14, 2020, \$220,000.
- Principal Investigator, "MLWiNS: Quality Versus Quantity in Spectrum Sensing with Distributed Sensors," National Science Foundation jointly with Intel Corporation, July 1, 2020–June 30, 2023, \$665,000.
- Principal Investigator, "Low-Cost Low-Power Millimeter-Wave Transceiver," AT&T Innovation Lab, January 1, 2021–December 31, 2021, \$110,000.
- Co-Principal Investigator, "Stationary and Aerial-Based RF/Radar Detection of Drones, Concealed Threats and Anomalous Communications," Department of Homeland Security, October 1, 2021–September 30, 2031, \$1,000,000.
- Senior Personnel, "SpectrumX - An NSF Spectrum Innovation Center," National Science Foundation, September 15, 2021–September 14, 2026, \$25,000,000.
- Co-Principal Investigator, "Self-Powered Wireless Sensor System for Health Monitoring of Liquid-Sodium Cooled Fast Reactors," Department of Energy, October 1, 2021–September 30, 2024, \$640,000.
- Principal Investigator, "Ultra Low-Cost Low-Power Millimeter-Wave Transceiver," AT&T Innovation Lab, January 1, 2022–December 31, 2022, \$110,000.

Patents:

- “Multiple Antenna Communication System and Method Thereof,” #6058105, May 2, 2000.
- “Wireless Transmission Method for Antenna Arrays, Having Improved Resistance to Fading,” #6327310, December 4, 2001.
- “Antenna Array Having Reduced Sensitivity to Frequency-Shift Effects,” #6349219, February 19, 2002.
- “Wireless Transmission Method for Antenna Arrays Using Unitary Space-Time Signals,” #6363121, March 26, 2002.
- “Space-Time Spreading Method of CDMA Wireless Communication,” #6452916, September 17, 2002.
- “Method of Wireless Communication Using Structured Unitary Space-Time Signal Constellations,” #6693976, February 17, 2004.
- “Method for Wireless Differential Communication Using Multiple Transmitter Antennas,” #6724842, April 20, 2004.
- “Method for Wireless Communication using Unitary Space-Time Signal Constellations,” #6801579, October 5, 2004.
- “Method of Multiple-Antenna Wireless Communication Using Space-Time Codes,” #6944236, September 13, 2005.
- “Cayley-Encoding of Unitary Matrices for Differential Communication,” #7170954, January 30, 2007.
- “Method and Apparatus for Detection and Decoding of Signals Received from a Linear Propagation Channel,” #7236536, June 26, 2007.
- “Method of Signal Transmission to Multiple Users From a Multi-Element Array,” #7317764, January 08, 2008.
- “Downlink Coordinated Transmission in OFDMA Systems,” #7706335, April 27, 2010.
- “Downlink Coordinated Transmission in OFDMA Systems, Including WiMax Systems,” #7764658, July 27, 2010.
- “Spherical Decoder for Wireless Communications,” #7822150, October 26, 2010.
- “Method for Estimating Frequency Offset at a Subscriber Station Receiver in a Multi-Carrier System,” #7916800, March 29, 2011.
- “Estimating Frequency Offset at a Subscriber Station Receiver,” #7929595, April 19, 2011.
- “Method of a Receiver Estimating a Plurality of Channels,” #8194774, June 5, 2012.
- “Method of Aiding Uplink Beamforming Transmission,” #8259672, September 4, 2012.
- “Multi-Stream Priority-Based Space-Time Coding,” #8284693, October 9, 2012.
- “Estimating a Subscriber Location,” #8290508, October 16, 2012.
- “Selecting a Transmission Mode Between a Subscriber and a Base Station,” #8311003, November 13, 2012.
- “Noninvasive Characterization of Electrical Power Distribution Systems,” #8427169, April 23, 2013.
- “Method and System of Beamforming a Broadband Signal Through a Multiport Network,” #8432997, April 30, 2013.
- “Estimating a Subscriber Location,” #8611925, December 17, 2013.
- “Characterization of Electrical Power Distribution Systems,” #8633705, January 21, 2014.
- “Allocating Antennas for Cyclic Delay Diversity,” #8675761, March 18, 2014.
- “Wireless Transceivers with Filter Arrangement for WiFi and WiMax coexistence,” #8681748, March 25, 2014.
- “Multiple Antenna Signal Transmission,” #8737529, May 27, 2014.
- “Selecting a Transmission Mode Between a Subscriber and a Base Station,” #8750236, June 10, 2014.
- “Multiple Antenna Transceiver,” #8761694, June 24, 2014.

Patents (cont'd):

- “Characterization of Electrical Power Distribution Systems Using Characterization Matrices,” #8810253, August 19, 2014.
- “Method and System of Beamforming a Broadband Signal Through a Multiport Network,” #8811530, August 19, 2014.
- “Distribution of Transmit Signal to Multiple Transmit Antennas for Reduction, of Measured Specific Absorption Rate,” #8811918, August 19, 2014.
- “Method of Transmission from Multiple Transmit Chains Based on a Cost Function” for Electromagnetic Radiation,” #8818294, August 26, 2014.
- “Method and System for Uplink Coordinated Reception in Orthogonal Frequency Division Multiple Access Systems,” #8855046, October 7, 2014.
- “Method of Coding Using Multiple Transmit Chains for Reduced Exposure to Electromagnetic Radiation,” #8929828, January 6, 2015.
- “Method and Apparatus for Link Adaptation in a Wireless Communication Network,” #8942184, January 27, 2015.
- “Method and Apparatus for Managing Uplink Communication in Wireless Network,” #9026123, May 5, 2015.
- “Method of Updating Transmission of Channel Information Based on Eaves-Dropping of Beamformed Signals,” #9178597, December 8, 2015.
- “Adaptive Transmit Beamforming,” #9209876, December 8, 2015.
- “Method and Apparatus for Managing Uplink Communication in a Wireless Communication Network,” #9210716, December 8, 2015.
- “Wireless Transceivers with Filter Arrangement for WiFi and LTE coexistence,” #9232564, January 5, 2016.
- “Mobile Subscriber Information Transmission Over Multiple Uplink Frames,” #9236975, January 12, 2016.
- “Method of Aiding Uplink Beamforming Transmission,” #9344178, May 17, 2016.
- “Adaptive Transmit Beamforming for Frequency Division Duplexing Systems,” #9537684, January 3, 2017.
- “Mitigating Beam Squint in Millimeter Wave Wireless Communication Systems,” #10819405, October 27, 2020.
- “Low-Resolution, Low-Power, Radio-Frequency Receiver,” #11121896, September 14, 2021.
- “Ultra-Low-Power Millimeter-Wave to Baseband Receiver Module for Scalable Massive MIMO,” #11296742, April 5, 2022.
- “Low-Power, Self-Referenced Receiver,” #11303347, April 12, 2022.

Professional Feature Videos, Projects, Web-pages, and Plenary Talks

“Multiple Antennas: How a Point-to-Point Advantage Becomes a Multi-user Advantage.” Plenary Speaker at the *22nd Biennial Symposium on Communications*, Queens University, Kingston, Ontario, June 2004.

“A Random-Channel Graph-Theoretic Perspective of Wireless Networks.” Plenary Speaker at the *2006 Seventh Annual IEEE Workshop on Signal Processing Advances in Wireless Communication*, Cannes, France, July 2006.

“The Role of MIMO in Fourth-Generation Mobile Wireless Systems and Beyond.” Plenary Speaker at the *2009 IEEE Communication Theory Workshop*, Napa, California, May 2009.

“What Have We Learned So Far About MIMO in Mobile Wireless Systems?” Plenary Speaker at the *2009 Tenth Annual IEEE Workshop on Signal Processing Advances in Wireless Communication*, Perugia, Italy, June 2009.

“Bandwidth of Large-Scale Multiport Radio-Frequency Systems.” Plenary Speaker at the *20th International ITG Workshop on Smart Antennas*, Munich, Germany, March 2016.

“Building a Better Phone,” University of Notre Dame web page feature story, 2016:
<https://www.nd.edu/stories/building-a-better-phone/>

“Notre Dame Researchers Target Cell Phone Radiation,” WSBT television feature story, 2016:
<https://wsbt.com/news/local/notre-dame-researchers-target-cell-phone-radiation>.
<https://engineering.nd.edu/news-publications/engineering-in-the-news/notre-dame-researchers-target-cell-phone-radiation>

Principle Investigator for the *RadioHound Spectrum Sensing System*, 2015–present:
<https://wireless.nd.edu/research/radiohound-distributed-spectrum-sensing>

Editorial, Panelist, and Professional Service Activities

Owner and Editor of <http://mars.bell-labs.com>, the *Multiple-Antenna Research and Solutions* web-site dedicated to promoting research into space-time techniques, 1998–2005. (800 subscribers)

Guest Associate Editor, *IEEE Transactions on Signal Processing Special Issue on Signal Processing for Communications*, with N. Al-Dhahir, G. Giannakis, B. Hughes and T. Marzetta, vol. 50, October 2002.

Guest Editor, *IEEE Transactions on Information Theory Special Issue on Space-Time Transmission, Reception, Coding and Signal Design*, with G. Caire, B. Hassibi and T. Marzetta, vol. 49, October 2003.

Associate Editor for MIMO Techniques, *IEEE Transactions on Communications*, November 2003–2005.

Associate Editor for *IEEE Transactions on Information Theory*, 2011–2012.

IEEE Fellows Committee for the Information Theory Society, 2016–2017.

Panelist, National Science Foundation Signal Processing Systems Faculty Early Career Development Program (CAREER), November 2002; Computer and Information Science Communications/Signal-Processing Research Program, April 2004; Theoretical Foundations of Communications and Signal-Processing Research Program, May 2007; Computing and Communication Foundations (CCF): Core Programs, February 2010; Communications and Information Foundations (CIF), December 2011; Communications and Signal Processing, April 2014; Computer and Network Systems Research Experience for Undergraduates (CNS-REU), November 2018.

Technical Program Chair, *2018 IEEE Communication Theory Workshop*, Miramar Beach, Florida, May 2018.

University Service Activities

Graduate Admissions Committee, 2012–present.

Graduate Committee, 2012–2013, 2016–2018.

College Council, 2014–2017.

Committee for Appointments and Promotions, 2016–2017.

CRADA (Cooperative Research and Development Agreement) between University of Notre Dame and Crane Naval Base, Crane, Indiana, 2016–present.

Co-Director, University of Notre Dame Wireless Institute, 2016–present. In 2017–2018, approximately \$4M/yr in expenditures was routed through the Institute in various projects, including *RadioHound*.

Principal Investigator of an ongoing (2018–) National Science Foundation-funded Research Experience for Undergraduates (REU), sponsoring ten undergraduates from around the United States that visit the University of Notre Dame Wireless Institute for a ten-week research program every summer.

Past Co-Advised PhD Students:

Ibrahim Abou-Faycal (Massachusetts Institute of Technology), 1998
Sriram Vishwanath (Stanford University), 2002
Christian Peel (Brigham-Young University), 2003
Radhika Gowaikar (Caltech), 2005
Heunchul Lee and Kyoung Jae Lee (Korea University), 2007

MS and PhD Students at University of Notre Dame:

Luyu Zhao, MS 2013
Ding Nie, PhD 2015
Kang Gao, PhD 2020
Arash EbadiShahrivar, PhD 2021
Abbas Termos, PhD 2022
Mir Sahariyat, MS 2022
Xiangbo Meng, PhD
Christopher Wahl, PhD

Courses, Book Chapters, Tutorials

- “Probabilistic Methods in Signal and System Analysis.” Senior-level undergraduate course, University of Illinois, Urbana-Champaign, January–May 1996.
- “Multi-Antenna Wireless Communications—from Theory to Algorithms,” with B. Hassibi and T. Marzetta. Tutorial at *IEEE Conference on Acoustics, Speech and Signal Processing*, Orlando, FL, May 2002.
- “Communication Theory.” Senior-level undergraduate course, Columbia University, September–December 2005.
- “Linear and Dirty-Paper Techniques for the Multiuser MIMO Downlink,” with Christian B. Peel, Quentin H. Spencer, A. Lee Swindlehurst and Martin Haardt. Book chapter in *Space-Time Processing for MIMO Communications*, A. B. Gershman and N. D. Sidiropoulos (editors), Chichester: John Wiley & Sons, 2005.

Theses and Journal Papers

- “Aspects of Vector-Sensor Processing.” PhD thesis, Yale University, 1995.
- B. Hochwald and A. Nehorai, “Concentrated Cramér-Rao bound expressions,” *IEEE Transactions on Information Theory*, vol. 40, pp. 363–371, March 1994.
- B. Hochwald and A. Nehorai, “Minimum bias priors for estimating additive terms in state-space models,” *IEEE Transactions on Automatic Control*, vol. 40, pp. 684–693, April 1995.
- B. Hochwald and A. Nehorai, “Polarimetric modeling and parameter estimation with applications to remote sensing,” *IEEE Transactions on Signal Processing*, vol. 43, pp. 1923–1935, August 1995.
- B. Hochwald and A. Nehorai, “Identifiability in array processing models with vector-sensor applications,” *IEEE Transactions on Signal Processing*, vol. 44, pp. 83–95, January 1996.
- B. Hochwald and A. Nehorai, “On identifiability and information-regularity in parameterized normal distributions,” *Circuits, Systems, and Signal Processing*, vol. 16, pp. 83–89, January 1997.
- B. Hochwald and A. Nehorai, “Magnetoencephalography with diversely-oriented and multi-component sensors,” *IEEE Transactions on Biomedical Engineering*, vol. 44, pp. 40–50, January 1997.
- B. Hochwald and K. Zeger, “Tradeoff between source and channel coding,” *IEEE Transactions on Information Theory*, vol. 43, pp. 1412–1424, September 1997.
- B. Hochwald, “Tradeoff between source and channel coding on a Gaussian channel,” *IEEE Transactions on Information Theory*, vol. 44, pp. 3044–3055, November 1998.
- B. Hochwald and P. Jelenković, “State Learning and Mixing in Entropy of Hidden Markov Processes and the Gilbert-Elliott Channel,” *IEEE Transactions on Information Theory*, vol. 45, pp. 128–138, January 1999.
- T. Marzetta and B. Hochwald, “Capacity of a mobile multiple-antenna communication link in Rayleigh flat fading,” *IEEE Transactions on Information Theory*, vol. 45, pp. 139–157, January 1999.
- B. Hochwald and T. Marzetta, “Unitary space-time modulation for multiple-antenna communications in Rayleigh flat fading,” *IEEE Transactions on Information Theory*, vol. 46, pp. 543–564, March 2000.
- B. Hochwald, T. Marzetta, T. Richardson, W. Sweldens, and R. Urbanke, “Systematic design of unitary space-time constellations,” *IEEE Transactions on Information Theory*, vol. 46, pp. 1962–1973, September 2000.
- B. Hochwald and W. Sweldens, “Differential unitary space-time modulation,” *IEEE Transactions on Communications*, vol. 48, pp. 2041–2052, December 2000.
- B. Hochwald and T. Marzetta, “Adapting a downlink array from uplink measurements,” *IEEE Transactions on Signal Processing*, vol. 49, pp. 642–653, March 2001.
- B. Hochwald, T. Marzetta, and C. Papadias, “A transmitter diversity scheme for wideband CDMA systems based on space-time spreading,” *IEEE Journal on Selected Areas of Communication: Special Issue on Wideband CDMA*, vol. 19, pp. 48–60, March 2001.
- A. Shokrollahi, B. Hassibi, B. Hochwald, and W. Sweldens, “Representation theory for high-rate multiple-antenna code design,” *IEEE Transactions on Information Theory*, vol. 47, pp. 2335–2367, September 2001.

Journal Papers (cont'd)

- B. Hochwald, T. Marzetta, and B. Hassibi, "Space-time autocoding," *IEEE Transactions on Information Theory*, vol. 47, pp. 2761–2781, November 2001.
- T. Marzetta, B. Hassibi, and B. Hochwald, "Structured unitary space-time autocoding constellations," *IEEE Transactions on Information Theory*, vol. 48, pp. 942–950, April 2002.
- B. Hassibi and B. Hochwald, "Cayley differential unitary space-time codes," *IEEE Transactions on Information Theory*, vol. 48, pp. 1485–1503, June 2002.
- B. Hassibi and B. Hochwald, "High-rate codes that are linear in space and time," *IEEE Transactions on Information Theory*, vol. 48, pp. 1804–1824, July 2002.
- N. Al-Dhahir, G. Giannakis, B. Hochwald, B. Hughes, and T. Marzetta, "Guest editorial," *IEEE Transactions on Signal Processing*, vol. 50, pp. 2381–2384, October 2002.
- B. Hochwald and S. ten Brink, "Achieving near-capacity on a multiple-antenna channel," *IEEE Transactions on Communications*, vol. 53, pp. 389–399, March 2003.
- B. Hassibi and B. Hochwald, "How much training is needed in multiple-antenna wireless links?" *IEEE Transactions on Information Theory*, vol. 49, pp. 951–963, April 2003.
- B. Hochwald, G. Caire, B. Hassibi, and T. Marzetta, "The academic and industrial embrace of space-time methods," *IEEE Transactions on Information Theory: Special Issue on Space-Time Transmission, Reception, Coding and Signal Processing*, vol. 49, pp. 2329–2331, October 2003.
- B. Hochwald, T. Marzetta, and V. Tarokh, "Multiple-antenna channel hardening and its implications for rate-feedback and scheduling," *IEEE Transactions on Information Theory*, vol. 50, pp. 1893–1909, September 2004.
- H. Vikalo, B. Hassibi, B. Hochwald, and T. Kailath, "On the capacity of frequency-selective channels in training-based transmission schemes," *IEEE Transactions on Signal Processing*, vol. 52, pp. 2572–2583, September 2004.
- D. Garrett, L. Davis, S. ten Brink, B. Hochwald, and G. Knagge, "Silicon complexity for maximum-likelihood MIMO detection using spherical decoding," *IEEE Journal of Solid State Circuits*, vol. 39, pp. 1544–1552, September 2004.
- A. Alexiou, D. Avidor, P. Bosch, S. Das, P. Gupta, B. Hochwald, T. Klein, J. Ling, A. Lozano, T. Marzetta, S. Mukherjee, C. Papadias, R. Valenzuela, and H. Viswanathan, "Duplexing, resource allocation, and inter-cell coordination: design recommendations for next-generation wireless systems," *Wireless Communications and Mobile Computing*, vol. 5, pp. 77–93, May 2005.
- T. Marzetta and B. Hochwald, "Fast transfer of channel state information in wireless systems," *IEEE Transactions on Signal Processing*, vol. 54, pp. 1268–1278, April 2006.
- R. Gowaikar, B. Hochwald, and B. Hassibi, "Communication over a wireless network with random connections," *IEEE Transactions on Information Theory*, vol. 52, pp. 2857–2871, July 2006.
- C. Peel, B. Hochwald and A. L. Swindlehurst, "A vector-perturbation technique for near-capacity multi-antenna multi-user communication—Part I: Channel inversion and regularization," *IEEE Transactions on Communications*, vol. 53, pp. 195–202, January 2005. **Winner of the 2006 IEEE Transactions on Communications Stephen O. Rice Best Paper Award.**

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- B. Hochwald, C. Peel, and A. L. Swindlehurst, "A vector-perturbation technique for near-capacity multi-antenna multi-user communication—Part II: Perturbation," *IEEE Transactions on Communications*, vol. 53, pp. 537–544, March 2005. **Winner of the 2006 IEEE Transactions on Communications Stephen O. Rice Best Paper Award.**
- A. Ashikhmin, A. van Wijngaarden, Z. Haibo, B. Hochwald, T. Marzetta, V. Purohit, C. Qinghong, P. Wilford, S-R. Zhou, M. Zuniga, E. Zuranski, "Design and development of a terrestrial digital video broadcast demodulation core: An international collaborative effort," *Bell Labs Technical Journal*, vol. 12, pp. 97–118, 2007.
- B. Hochwald and H. Artés, "Orthogonalizing beams to train unscheduled terminals," *IEEE Transactions on Signal Processing*, vol. 57, pp. 3063–3074, August 2009.
- E. Stauffer and B. Hochwald, "Low-complexity multi-stream space-time codes—Part I: Direct-sum codes and design criteria," *IEEE Transactions on Communications*, vol. 60, pp. 81–88, January 2012.
- B. Hochwald and E. Stauffer, "Low-complexity multi-stream space-time codes—Part II: Unitary-transform codes," *IEEE Transactions on Communications*, vol. 60, pp. 375–383, February 2012.
- D. Nie, B. Hochwald, and E. Stauffer, "Systematic design of large-scale multiport decoupling networks," *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 61, pp. 2172–2181, July 2014.
- B. Hochwald, D. Love, S. Yan, P. Fay, J-M. Jin, "Incorporating specific absorption rate constraints into wireless signal design," *IEEE Communications Magazine*, vol. 52, pp. 126–133, September, 2014.
- D. Nie and B. Hochwald, "Broadband matching bounds for coupled loads," *IEEE Transactions of Circuits and Systems I: Regular Papers*, vol. 62, pp. 995–1004, April 2015. **Winner of the 2016 IEEE Transactions on Circuits and Systems Best Paper Award by a Young Author.**
- D. Ying, D. Love, and B. Hochwald, "Closed-loop precoding and capacity analysis for multiple antenna wireless systems with user radiation exposure constraints," *IEEE Transactions on Wireless Communications*, vol. 14, pp. 5859–5870, October 2015.
- D. Nie and B. Hochwald, "Bandwidth analysis of multiport radio-frequency systems—Part I," *IEEE Transactions on Antennas and Propagation*, vol. 65, pp. 1081–1092, March 2017. **Winner of the 2018 IEEE Transactions on Antennas and Propagation H. A. Wheeler Prize Paper Award.**
- D. Nie and B. Hochwald, "Bandwidth analysis of multiport radio-frequency systems—Part II," *IEEE Transactions on Antennas and Propagation*, vol. 65, pp. 1093–1107, March 2017.
- D. Ying, D. Love, and B. Hochwald, "Sum-rate analysis for multi-user MIMO systems with user exposure constraints," *IEEE Transactions on Wireless Communications*, vol. 16, pp. 7376–7388, November 2017.
- D. Nie and B. Hochwald, "Improved broadband matching bound," *IEEE Transactions on Antennas and Propagation*, vol. 65, pp. 5878–5885, November 2017.
- J. Li, S. Yan, Y. Liu, B. Hochwald, and J-M. Jin, "A high-order model for fast estimation of electromagnetic absorption induced by multiple transmitters in portable devices," *IEEE Transactions on Antennas and Propagation*, vol. 65, pp. 6768–6778, December 2017.
- A. Ebadi-Shahrivar, P. Fay, D.J. Love, and B. Hochwald, "Determining electromagnetic exposure compliance of multi-antenna devices in linear time," *IEEE Transactions on Antennas and Propagation*, vol. 67, pp. 7585–7596, December 2019.

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- M. Castellanos, Y. Liu, D. Love, B. Peleato, J.-M. Jin, and B. Hochwald, "Signal-level models of pointwise electromagnetic exposure for millimeter-wave communication," *IEEE Transactions on Antennas and Propagation*, pp. 3963–3977, May 2020.
- A. Molev-Shteiman, X-F. Qi, L. Mailander, N. Prasad, and B. Hochwald, "New equivalent model of a quantizer with noisy input and its applications for MIMO system analysis and design," *IEEE Access*, September 2020.
- M. Castellanos, D. Ying, D. Love, B. Peleato, and B. Hochwald, "Dynamic electromagnetic exposure allocation for Rayleigh fading MIMO channels," *IEEE Transactions on Wireless Communications*, pp. 728–740, February 2021.
- N. Estes, K. Gao, B. Hochwald, J. N. Laneman, and J. Chisum, "Efficient modeling of low-resolution millimeter-wave transceivers for massive MIMO wireless communications systems," *Microwave and Optical Technology Letters*, pp. 1134–1140, April 2021.
- N. Kleber, J. Chisum, B. Hochwald, J. N. Laneman, "Three-dimensional RF sensor networks for widespread spectrum monitoring," *IEEE Transactions on Cognitive Communications and Networking*, pp. 763–777, vol. 8, no. 2, June 2022.
- N. Kleber, M. Haenggi, J. Chisum, B. Hochwald, J. N. Laneman, "Directivity in RF sensor networks for widespread spectrum monitoring," *IEEE Transactions on Cognitive Communications and Networking*, pp. 778–792, vol. 8, no. 2, June 2022.
- K. Gao, X. Meng, J.N. Laneman, J. Chisum, R. Bendlin, A. Chopra, B. Hochwald, "A training-based mutual information lower bound for large-scale systems," *IEEE Transactions on Communications*, pp. 5151–5163, vol. 70, no. 8, August 2022.
- N. Estes, X. Kang, X. Meng, R. Bendlin, A. Chopra, J.N. Laneman, B. Hochwald, J. Chisum, "A 0.71mW antenna-coupled on-off-key receiver for Gbps millimeter-wave wireless communication," *IEEE Transactions on Microwave Theory and Techniques*, vol. 71, no. 4, April 2023.

Conference Papers

- B. Hochwald and A. Nehorai, "Minimum bias priors for estimating additive terms in state-space models," *Proceedings of the Twenty-Sixth Asilomar Conference on Signals, Systems, and Computers*, pp. 836–840, Pacific Grove, CA, October 1992 (Invited).
- B. Hochwald and A. Nehorai, "Electromagnetic vector sensors and active target localization and identification," *IEEE International Conference on Acoustics, Speech, and Signal Processing*, pp. IV 25–28, Minneapolis, MN, April 1993.
- B. Hochwald and A. Nehorai, "Identifiability in array processing models with vector-sensor applications," *Proceedings of the IEEE Seventh Signal Processing Workshop on Statistical Signal and Array Processing*, pp. 121–124, Québec City, Canada, June 1994.
- B. Hochwald and A. Nehorai, "Polarimetric modeling and parameter estimation with electromagnetic vector sensors," *Proceedings of the 1994 IEEE International Geoscience and Remote Sensing Symposium*, pp. 1129–1132, Caltech, Pasadena, CA, August 1994 (Invited).
- B. Hochwald and A. Nehorai, "Optimizing an array of sensors for magnetoencephalography," *Proceedings of the 17th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pp. 861–862, Montréal, Canada, September 1995.
- B. Hochwald and K. Zeger, "Bounds on the tradeoff between source and channel coding with a delay constraint," *Proceedings of 1996 International Symposium on Information Theory and its Applications*, pp. 755–758, Victoria, Canada, September 1996.
- B. Hochwald and K. Zeger, "Tradeoff between source and channel coding," *Proceedings of 1997 International Symposium on Information Theory*, pg. 335, Ulm, Germany, June 1997.
- B. Hochwald and T. Marzetta, "Multiple-antenna communications when nobody knows the Rayleigh fading coefficients," *Proceedings of Thirty-Fifth Annual Allerton Conference on Communication, Control and Computing*, pp. 1033–1042, Monticello, IL, September 1997.
- B. Hochwald and P. Jelenković, "The role of memory in entropy approximation for hidden Markov models," *Proceedings of Thirty-Fifth Annual Allerton Conference on Communication, Control and Computing*, pp. 1013–1022, Monticello, IL, September 1997.
- T. Marzetta and B. Hochwald, "Fundamental limitations on multiple-antenna wireless links in Rayleigh fading," *Proceedings of 1998 International Symposium on Information Theory*, pg. 310, Boston, MA, August 1998.
- B. Hochwald, "Source and channel coding tradeoff on a Gaussian channel," *Proceedings of 1998 International Symposium on Information Theory*, pg. 248, Boston, MA, August 1998.
- B. Hochwald and T. Marzetta, "Space-time modulation scheme for unknown Rayleigh fading environments," *Proceedings of Thirty-Sixth Annual Allerton Conference on Communication, Control and Computing*, pp. 431–440, Monticello, IL, September 1998.
- B. Hochwald and T. Marzetta, "Space-time modulation for unknown fading," *Proceedings of SPIE, Digital Wireless Communication*, pp. 10–19, Orlando, FL, April 1999.
- B. Hochwald, C. Papadias, T. Marzetta, M. Buehrer and R. Soni, "Space-time spreading for CDMA systems," *Sixth workshop on Smart Antennas in Wireless Mobile Communications*, Stanford University, Stanford, CA, July 1999.

Conference Papers (cont'd)

- B. Hochwald and W. Sweldens, "Multiple-antenna differential modulation," *Proceedings of Thirty-Seventh Annual Allerton Conference on Communication, Control, and Computing*, pp. 1266–1273, Monticello, IL, September 1999.
- B. Hochwald, T. Marzetta, and C. Papadias, "A novel space-time spreading scheme for wireless CDMA systems," *Proceedings of Thirty-Seventh Annual Allerton Conference on Communication, Control, and Computing*, pp. 1284–1293, Monticello, IL, September 1999.
- T. Marzetta, B. Hochwald, and B. Hassibi, "A new approach to single-user multiple-antenna wireless communication," *Proceedings of the 2000 Conference on Information Sciences and Systems*, pp. WA4-16–WA4-21, Princeton, NJ, March 2000.
- T. Marzetta, B. Hochwald, and B. Hassibi, "Space-time autocoding: arbitrarily reliable communication in a single fading interval," *Proceedings of the 2000 International Symposium on Information Theory*, pg. 313, Sorrento, Italy, June 2000.
- B. Hassibi, B. Hochwald, A. Shokrollahi, and W. Sweldens, "Multiple antennas and representation theory," *Proceedings of the 2000 International Symposium on Information Theory*, pg. 337, Sorrento, Italy, June 2000.
- B. Hochwald and W. Sweldens, "A method of differential transmission with multiple antennas," *Proceedings of the IEEE Sixth International Symposium on Spread-Spectrum Techniques and Applications*, pg. 122, Parsippany, NJ, September 2000.
- B. Hassibi, B. Hochwald, A. Shokrollahi, and W. Sweldens, "Codes for differential signaling with many antennas," *Wireless Communications and Networking Conference*, pp. 23–24, vol. 1, 2000.
- B. Hassibi and B. Hochwald, "Optimal training in space-time systems," *Conference Record of the Thirty-Fourth Asilomar Conference on Signals, Systems and Computers*, pp. 743–747, vol. 1, Asilomar, CA, October 2000.
- B. Hassibi and B. Hochwald, "High-rate linear space-time codes," *Proceedings of the Thirty-Eighth Annual Allerton Conference on Communication, Control and Computing*, pp. 1047–1056, Monticello, IL, October 2000.
- H. Vikalo, B. Hassibi, B. Hochwald, and T. Kailath, "Optimal training for frequency-selective fading channels," *Proceedings of the 2001 IEEE International Conference on Acoustics, Speech and Signal Processing*, pp. 2105–2108, vol. 4, Salt Lake City, UT, May 2001.
- B. Hassibi and B. Hochwald, "High-rate linear space-time codes," *Proceedings of the 2001 IEEE International Conference on Acoustics, Speech and Signal Processing*, pp. 2461–2464, vol. 4, Salt Lake City, UT, May 2001.
- B. Hassibi and B. Hochwald, "Linear dispersion codes," *Proceedings of the IEEE International Symposium on Information Theory*, pg. 325, Washington, D.C., June 2001.
- T. Marzetta, B. Hassibi, and B. Hochwald, "Space-time autocoding constellations with pairwise-independent signals," *Proceedings of the IEEE International Symposium on Information Theory*, pg. 326, Washington, D.C., June 2001.
- B. Hochwald and S. ten Brink, "Iterative list sphere decoding to attain capacity on a multi-antenna link," *Proceedings of the Thirty-Ninth Annual Allerton Conference on Communication, Control and Computing*, pp. 815–824, Monticello, IL, October 2001.

Conference Papers (cont'd)

- B. Hochwald and B. Hassibi, "Cayley codes for multi-antenna differential modulation," *Conference Record of the Thirty-Fifth Asilomar Conference on Signals, Systems and Computers*, pp. 232–235, vol. 1, Asilomar, CA, October 2001.
- V. Tarokh and B. Hochwald, "Existence and construction of block interleavers," *IEEE International Conference on Communications*, pp. 1855–1857, vol. 3, New York, NY, April 2002.
- S. ten Brink and B. Hochwald, "Detection thresholds of iterative MIMO processing," *Proceedings of the 2002 International Symposium on Information Theory*, pg. 22, Lausanne, Switzerland, June 2002.
- B. Hochwald and S. Vishwanath, "Space-Time Multiple Access: Linear growth in the sum-rate," *Proceedings of the Fortieth Annual Allerton Conference on Communication, Control and Computing*, Monticello, IL, October 2002.
- B. Hochwald, T. Marzetta, and V. Tarokh, "Multi-antenna channel hardening and its implications for rate feedback and scheduling," *DIMACS Workshop on Signal Processing for Wireless Transmission*, Piscataway, NJ, October 2002.
- D. Garrett, L. Davis, B. Hochwald, and S. ten Brink, "APP processing for high-performance MIMO systems," *Proceedings of the Twenty-Fifth IEEE Custom Integrated Circuits Conference*, San Jose, CA, September 2003.
- B. Hochwald, C. Peel, and L. Swindlehurst, "Achieving near-capacity in multi-antenna multi-user systems," *Proceedings of the Forty-First Annual Allerton Conference on Communication, Control and Computing*, Monticello, IL, October 2003.
- T. Marzetta and B. Hochwald, "Learning the channel at the transmitter," *Proceedings of the Forty-Second Annual Allerton Conference on Communication, Control and Computing*, Monticello, IL, October 2004.
- R. Gowaikar, B. Hochwald and B. Hassibi, "An Achievability result for random networks," *Proceedings of the 2005 International Symposium on Information Theory*, Adelaide, Australia, September 2005.
- C. Yuen and B. Hochwald, "Dropping users in a multi-antenna broadcast channel," *Proceedings of the Information Theory and Applications Workshop*, San Diego, CA, February 2006.
- R. Gowaikar, B. Hochwald and B. Hassibi, "Throughput scaling in random wireless networks," *Proceedings of the Information Theory and Applications Workshop*, San Diego, CA, February 2006.
- C. Yuen and B. Hochwald, "How to gain 1.5 dB in vector precoding" *Proceedings of the 2006 IEEE Global Telecommunications Conference*, San Francisco, CA, November 2006.
- D. Love, B. Hochwald and K. Krishnamurthy, "Exchanging third-party information in a network," *Proceedings of the Information Theory and Applications Workshop*, San Diego, CA, February 2007.
- B. Hochwald and H. Artés, "Orthogonalizing a random set of beams," *Proceedings of the Information Theory and Applications Workshop*, San Diego, CA, February 2008.
- E. Stauffer and B. Hochwald, "Low-complexity space-time codes for high and low-priority streams," *Proceedings of the Information Theory and Applications Workshop*, San Diego, CA, February 2009.
- A. Jalali, D. Love, S. Sanghavi, and B. Hochwald, "Conferencing on trees," *Proceedings of Conference on Information Sciences and Systems*, Baltimore, MD, pp. 763-768, March 18-20, 2009.

Conference Papers (cont'd)

- L. Jalloul, N. Czink, B. Hochwald, and A. Paulraj, "Why downlink cyclic delay diversity helps uplink transmit diversity," *Proceedings of the 69th IEEE Vehicular Technology Conference*, Barcelona, Spain, April 2009.
- B. Hochwald and L. Jalloul, "Statistical distributions that arise in constrained beamforming with incomplete channel information," *Proceedings of the Information Theory and Applications Workshop*, San Diego, CA, February 2010.
- B. Hochwald and D. Love, "Minimizing exposure to electromagnetic radiation in portable devices," *Proceedings of the Information Theory and Applications Workshop*, San Diego, CA, February 2012.
- B. Hochwald, D. Love, S. Yan and J-M. Jin, "SAR codes," *Proceedings of the Information Theory and Applications Workshop*, San Diego, CA, February 2013.
- D. Ying, D. Love and B. Hochwald, "Beamformer optimization with a constraint on user electromagnetic exposure," *Proceedings of 2013 47th Annual Conference on Information Sciences and Systems*, March 2013, pp. 1–6.
- D. Ying, D. Love and B. Hochwald, "Transmit covariance optimization with a constraint on user electromagnetic radiation exposure," *Proceedings 2013 Globecom Wireless Communications Symposium*, December 2013, pp. 4104–4109.
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- D. Nie, B. Hochwald, and E. Stauffer, "Minimum complexity decoupling networks for arbitrary coupled loads," *Proceedings of the 2014 International Symposium on Antennas and Propagation*, Memphis, TN, July 2014, pp. 460–461.
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- D. Nie and B. Hochwald, "Bandwidth as a function of number of sources and loads in multiport radio-frequency systems," *Proceedings of the 2016 IEEE International Symposium on Antennas and Propagation*, Fajardo, Puerto Rico, June 2016.
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- K. Gao, N. Estes, B. Hochwald, J. Chisum and J. N. Laneman, “Power-performance analysis of a simple one-bit transceiver,” *Proceedings of the 2017 Information Theory and Applications Workshop*, San Diego, CA, February 2017.
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- J. Li, S. Yan, Y. Liu, B. Hochwald and J-M. Jin, “A high-order model for fast estimation of specific absorption rate induced by multiple transmitters in portable devices,” *Proceedings of the IEEE AP-S Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting*, San Diego, July 9–14, 2017.
- M. Cai, J. N. Laneman, B. Hochwald, “Carrier aggregation for phased-array analog beamforming with beam squint,” *Proceedings of 2017 IEEE Global Communications Conference (GLOBECOM)*, Singapore, December 2017.
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- A. Ebadi-Shahrivar, P. Fay, D. J. Love, and B. Hochwald, “Multi-antenna SAR estimation in linear time,” *Proceedings of the 2018 IEEE International Symposium on Antennas and Propagation*, Boston, July 2018.
- K. Gao, J. N. Laneman, N. Estes, J. Chisum, and B. Hochwald, “Training for channel estimation in nonlinear multi-antenna transceivers,” *Proceedings of the 2019 Information Theory and Applications Workshop*, San Diego, CA, February 2019.
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- A. Termos and B. Hochwald, "Robust Neural Network-Based Spectrum Occupancy Mapping," *IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks*, December 2021.
- X. Meng, N. Estes, J.N. Laneman, J. Chisum, R. Bendlin, B. Hochwald, "Spectral efficiency with one-bit transmitters under out-of-band power constraints," *Proceedings of the 2022 IEEE Global Communications Conference (GLOBECOM)*, Rio de Janeiro, Brazil, December 2022.

Appendix B

List of Materials Considered

Exhibit ("Ex.")	Description
Ex. 1001	U.S. Patent No. 9,136,924 ("924")
Ex. 1002	File History of U.S. Patent No. 9,136,924 ("924FH")
Ex. 1004	Declaration of Friedhelm Rodermund in Support of Petition for <i>Inter Partes</i> Review of U.S. Patent No. 9,136,924 ("Rodermund")
Ex. 1005	U.S. Patent App. Pub. 2011/0274188 ("Sayana")
Ex. 1006	U.S. Provisional App. No. 61/331,818 ("Sayana-Prov")
Ex. 1007	International Patent App. Pub. WO2010/050689 ("Lee-689")
Ex. 1008	LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (3GPP TS 36.213 version 8.8.0 Release 8) ("TS36.213")
Ex. 1009	LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (3GPP TS 36.211 version 8.8.0 Release 8) ("TS36.211")
Ex. 1010	U.S. Patent App. Pub. 2013/0064129 ("Koivisto")
Ex. 1011	R1-102630, "Refinements of Feedback and Codebook Design," submitted by Ericsson for 3GPP Meeting WG1 #61 (May 10-14, 2010) ("Ericsson")
Ex. 1012	U.S. Patent App. Pub. 2011/0249713 ("Hammarwall")
Ex. 1013	U.S. Patent App. Pub. 2011/0305263 ("Jongren")
Ex. 1014	U.S. Patent App. Pub. 2011/0034192 ("Lim")

Exhibit ("Ex.")	Description
Ex. 1017	Expert Report of Todor Cooklev, Ph.D. [Claim Construction] dated June 23, 2023
Ex. 1018	Joint Claim Construction and Prehearing Statement, <i>Pantech Corp. et al. v. LG Electronics Inc. et al.</i> , Case 5:22-cv-00113-RWS-JBB (E.D. Texas), Dkt. No. 118.
Ex. 1019	Redline Comparison between U.S. Patent App. Pub. 2011/0274188 and U.S. Provisional App. No. 61/331,818
Ex. 1020	International Patent App. Pub. WO2009/025619 ("Göransson-619")
Ex. 1021	U.S. Patent No. 9,078,236 ("Chun")
Ex. 1022	U.S. Patent No. 9,247,420 ("Jung")
Ex. 1023	U.S. Patent No. 9,083,411 ("Li")
Ex. 1024	U.S. Patent No. 7,369,511 ("Utsunomiya")
Ex. 1025	U.S. Patent No. 8,649,456 ("Xia")
Ex. 1026	Sesia, Stefania et al. LTE - The UMTS Long Term Evolution: From Theory to Practice. United Kingdom, Wiley, 2011.
Ex. 1027	Hui, Lin, and Wang Wen Bo. "Coordinated Beamforming technology in TD-LTE-Advanced system." 2010 International Conference on Communications and Mobile Computing. Vol. 2. IEEE, 2010.
Ex. 1051	Webpage, available at https://archive.org/legal/affidavit.php
Ex. 1052	Internet Archive Capture, available at https://web.archive.org/web/20110509054716/http://3gpp.org/Specification-Groups
Ex. 1053	Internet Archive Capture, available at https://web.archive.org/web/20090802220720/http://www.3gpp.org/

Exhibit ("Ex.")	Description
Ex. 1054	Internet Archive Capture, available at https://web.archive.org/web/20130812132958/http://3gpp.org/RAN1-Radio-layer-1
Ex. 1055	Internet Archive Capture, available at https://web.archive.org/web/20080917042036/http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/
Ex. 1056	Internet Archive Capture, available at https://web.archive.org/web/20080803190713/http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_55/
Ex. 1057	Webpage, available at https://www.3gpp.org/ftp/Specs
Ex. 1058	Internet Archive Capture, available at https://web.archive.org/web/20130110164645/http://www.3gpp.org/specifications
Ex. 1059	Internet Archive Capture, available at https://web.archive.org/web/20081201021150/http://www.3gpp.org/Specification-Numbering
Ex. 1060	Internet Archive Capture, available at https://web.archive.org/web/20081207063329/http://www.3gpp.org/ftp/Specs/html-info/36-series.htm
Ex. 1061	Internet Archive Capture, available at https://web.archive.org/web/20080612010911/http://www.3gpp.org/ftp/Specs/html-info/TSG-WG--r1.htm
Ex. 1062	Internet Archive Capture, available at https://web.archive.org/web/20081201145114/http://www.3gpp.org/ftp/specs/html-info/36213.htm
Ex. 1063	Internet Archive Capture, available at https://web.archive.org/web/20140326211003/http://3gpp.org/DynaReport/TSG-WG--R1.htm
Ex. 1064	Internet Archive Capture, available at https://web.archive.org/web/20140217112636/http://www.3gpp.org/DynaReport/36-series.htm

Exhibit ("Ex.")	Description
Ex. 1065	Internet Archive Capture, available at https://web.archive.org/web/20140326220443/http://3gpp.org/DynaReport/36213.htm
Ex. 1066	Internet Archive Capture, available at https://web.archive.org/web/20140326193752/http://3gpp.org/DynaReport/36211.htm
Ex. 1067	3GPP TS 36.211 V8.1.0 (2007-11), retrieved from https://web.archive.org/web/20140724150608/http://www.3gpp.org/ftp/Specs/archive/36_series/36.211/36211-810.zip (36211-810.doc in 36211-810.zip)
Ex. 1068	Internet Archive Capture, available at https://web.archive.org/web/20141014200927/http://www.3gpp.org/ftp/Specs/latest/Rel-8/
Ex. 1069	Internet Archive Capture, available at https://web.archive.org/web/20080706152214/http://www.3gpp.org/ftp/Specs/latest/Rel-8/36_series/
Ex. 1071	Internet Archive Capture, available at https://web.archive.org/web/20190529145715/https://list.etsi.org/scripts/wa.exe?SUBED1=3gpp_tsg_ran_wg1&A=1
Ex. 1072	Webpage, available at https://www.3gpp.org/ftp/Specs/archive/36_series/36.213
Ex. 1073	Webpage, available at https://www.etsi.org/deliver/etsi_ts/136200_136299/136213/08.08.00_60/
Ex. 1074	ETSI TS 136 213 V8.8.0 (2009-10), retrieved from https://www.etsi.org/deliver/etsi_ts/136200_136299/136213/08.08.00_60/ts_136213v080800p.pdf
Ex. 1075	Internet Archive Capture, available at http://web.archive.org/web/20081201081622/http://www.3gpp.org/ftp/specs/archive/36_series/36.213/

Exhibit ("Ex.")	Description
Ex. 1076	Internet Archive Capture, available at http://web.archive.org/web/20140601044332/http://www.3gpp.org:80/ftp/specs/archive/36_series/36.213
Ex. 1077	3GPP TS 36.213 V8.8.0 (2009-09), retrieved from https://www.3gpp.org/ftp/specs/archive/36_series/36.213/36213-880.zip (36213-880.doc in 36213-880.zip)
Ex. 1078	Internet Archive Capture, available at https://web.archive.org/web/20081113150830/http://www.3gpp.org/ftp/Specs/
Ex. 1079	Internet Archive Capture, available at https://web.archive.org/web/20081013132648/http://www.3gpp.org/ftp/Specs/archive/
Ex. 1080	Internet Archive Capture, available at https://web.archive.org/web/20081012223857/http://www.3gpp.org/ftp/specs/archive/36_series/
Ex. 1081	Internet Archive Capture, available at https://web.archive.org/web/20140601044332/http://www.3gpp.org:80/ftp/specs/archive/36_series/36.213
Ex. 1082	Internet Archive Capture, available at https://web.archive.org/web/20081201231313/http://www.3gpp.org/ftp/Specs/latest
Ex. 1083	Internet Archive Capture, available at https://web.archive.org/web/20081208085335/http://www.3gpp.org:80/ftp/Specs/latest/Rel-8/
Ex. 1084	Internet Archive Capture, available at https://web.archive.org/web/20081209045248/http://www.3gpp.org/ftp/Specs/latest/Rel-8/36_series/
Ex. 1085	A. Müller and P. Frank, "Cooperative Interference Prediction for Enhanced Link Adaptation in the 3GPP LTE Uplink," 2010 IEEE 71st Vehicular Technology Conference (VTC), Taipei, Taiwan, 2010, pp. 1-5, doi: 10.1109/VETECS.2010.5493598, May 16-19, 2010

Exhibit ("Ex.")	Description
Ex. 1086	Webpage, available at https://ieeexplore.ieee.org/document/5493598
Ex. 1087	Webpage, available at https://www.3gpp.org/ftp/Specs/archive/36_series/36.211
Ex. 1088	Webpage, available at https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.08.00_60/
Ex. 1089	ETSI TS 136 211 V8.8.0 (2009-10), retrieved from https://www.etsi.org/deliver/etsi_ts/136200_136299/136211/08.08.00_60/ts_136211v080800p.pdf
Ex. 1090	Webpage, available at https://web.archive.org/web/20170404095635/http://webapp.etsi.org/key/key.asp?full_list=y
Ex. 1091	Internet Archive Capture, available at https://web.archive.org/web/20140801181746/http://3gpp.org/ftp/specs/archive/36_series/36.211/
Ex. 1092	Internet Archive Capture, available at http://web.archive.org/web/20081201192809/http://www.3gpp.org/ftp/Specs/archive/36_series/36.211/
Ex. 1093	3GPP TS 36.211 V8.8.0 (2009-09), retrieved from https://www.3gpp.org/ftp/specs/archive/36_series/36.211/36211-880.zip (36211-880.doc in 36211-880.zip)
Ex. 1094	Internet Archive Capture, available at https://web.archive.org/web/20081201152358/http://www.3gpp.org/ftp/specs/html-info/36211.htm
Ex. 1095	Internet Archive Capture, available at https://web.archive.org/web/20140315022717/http://www.3gpp.org:80/DynaReport/36211.htm

Exhibit ("Ex.")	Description
Ex. 1096	Jae-Hyuk Lee, Jun-Ho Baek, Seung-Hoon Hwang and Byoung-Jo Choi, "On the selection of training sequence code pair for MIMO technology in 3GPP GERAN system," 2010 The 12th International Conference on Advanced Communication Technology (ICACT), Phoenix Park, February 7-10, 2010, pp. 537-540
Ex. 1097	Webpage, available at https://ieeexplore.ieee.org/document/5440406
Ex. 1098	Yanguang Liu, Wenjing Li, Heng Zhang and Weihao Lu, "Graph based automatic centralized PCI assignment in LTE," The IEEE symposium on Computers and Communications, Riccione, June 22-25, 2010, pp. 919-921, doi: 10.1109/ISCC.2010.5546812
Ex. 1099	Webpage, available at https://ieeexplore.ieee.org/document/5546812
Ex. 1100	Webpage, available at http://3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_61/Docs/
Ex. 1101	3GPP R1-102630, retrieved from https://list.etsi.org/scripts/wa.exe?A3=ind1005A&L=3GPP_TSG_RAN_WG1&E=base64&P=85459760&B=--_007_E4CE3BC64C3AB6488038754A0E419DE11C0173F846ESES_SCMS0365e_&T=application%2Fzip-compressed;%20name=%22R1-102630.zip%22&N=R1-102630.zip&attachment=q&XSS=3 (R1-102630_refinements_of_fb_and_cb_design.doc in R1-102630.zip)
Ex. 1102	Webpage, available at https://list.etsi.org/scripts/wa.exe?A2=3GPP_TSG_RAN_WG1;a370e470.1005A&S=
Ex. 1103	Internet Archive Capture, available at https://web.archive.org/web/20100326093131/http://list.etsi.org/
Ex. 1104	Internet Archive Capture, available at https://web.archive.org/web/20120309181952/http://list.etsi.org:80/
Ex. 1105	Internet Archive Capture, available at https://web.archive.org/web/20140328154821/http://3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_61/Docs/

Exhibit ("Ex.")	Description
Ex. 1106	R1-102630, retrieved from https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_61/Docs/R1-102630.zip (R1-102630_refinements_of_fb_and_cb_design.doc in R1-102630.zip)
Ex. 1107	Draft Report of 3GPP TSG RAN WG1 #61 v0.1.0 (Montreal, Canada, 10th – 14th May, 2010), retrieved from https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_61/Report/Draft_ReportWG1%2361_v010.zip (Draft_ReportWG1#61_v010.doc in Draft_ReportWG1%2361_v010.zip)
Ex. 1108	Webpage, available at https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_61/Report
Ex. 1109	Excel file "Tdoclist_RAN1#61(May_2010).xls," retrieved from https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_61/Report/Draft_ReportWG1%2361_v010.zip
Ex. 1110	R1-103333, retrieved from https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_61/Docs/R1-103333.zip (R1-103333_refinements_of_fb_and_cb_design.doc in R1-103333.zip)
Ex. 1111	Redline comparing disclosures of R1-102630 and R1-103333.
Ex. 1112	Patent Application No. 13/698,419
Ex. 1113	Excel file "3gppRAN1_61.xls," retrieved from https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_61/Report/Final_ReportWG1%2361_v300.zip

Appendix C

LIST OF CHALLENGED CLAIMS:

[17.pre] A communication method of a receiving device in a wireless communication system, the method comprising:

[17.a] receiving codebook restricting information including at least one of a first bit sequence to restrict at least one precoding matrix from a first precoding matrix group and a second bit sequence to restrict at least one precoding matrix from a second precoding matrix group,

[17.b] each bit of the first bit sequence corresponding to one precoding matrix of the first precoding matrix group, respectively, the at least one precoding matrix of the first precoding matrix group being restricted from being used as a precoding matrix of a first precoder, each bit of the second bit sequence corresponding to one precoding matrix of the second precoding matrix group, respectively, and the at least one precoding matrix of the second precoding matrix group being restricted from being used as a precoding matrix of a second precoder; and

[17.c] transmitting, to a transmitting device, 1st channel status information indicating the precoding matrix of the first precoder and 2nd channel status information indicating the precoding matrix of the second precoder,

[17.d] the precoding matrix of the first precoder and the precoding matrix of the second precoder being selected, based on the codebook restricting information, from among precoding matrices that are not restricted, [17.e] wherein a period of transmitting the information relating to the precoding matrix of the first precoder and a period of transmitting the information relating to the precoding matrix of the second precoder are different from each other.

Claim 18: The method of claim 17, wherein the first matrix group includes N precoding matrices, and the first bit sequence is an N-bit sequence, where N is an integer.

Claim 19: The method of claim 17, wherein the use of precoding matrices for the second precoder that make pairs with restricted precoding matrices of the first matrix group is restricted based on the first bit sequence, and the use of precoding matrices for the first precoder that make pairs with restricted precoding matrices of the second matrix group is restricted based on the second bit sequence.

Claim 20: The method of claim 17, wherein the transmitting device includes at least one antenna pair in which a first domain including at least one antenna polarized in one direction and a second domain including at least one antenna polarized in another direction intersect each other; and

the precoding matrix of the first precoder performs precoding on the first domain and the second domain, separately, and the precoding matrix of the second precoder performs phase mismatch correction to remove an effect from a phase mismatch between the first domain and the second domain.

Claim 21: The method of claim 20, wherein the precoding matrix of the first precoder corresponds to W_1 in the following Equation and the precoding matrix of the second precoder corresponds to W_2 in the following Equation:

$$W = \underbrace{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}_{W_1} \underbrace{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}_{W_2},$$

wherein R_0 denotes a value determined by a precoding gain when the first domain and the second domain have an identical spatial channel status, I denotes a unit matrix, and Λ denotes a phase mismatch correction value between the first domain and the second domain.

Claim 22: The method of claim 17, wherein the period of transmitting the information relating to the precoding matrix of the first precoder is longer than the period of transmitting the information relating to the precoding matrix of the second precoder.

[23.pre] A receiving device in a wireless communication system, the receiving device comprising:

[23.a] an antenna array to receive, as codebook restricting information, at least one of a first bit sequence to restrict at least one precoding matrix from a first precoding matrix group and a second bit sequence to restrict at least one precoding matrix from a second precoding matrix group,

[23.b] each bit of the first bit sequence corresponding to one precoding matrix of the first precoding matrix group, respectively, the at least one precoding matrix of the first precoding matrix group being restricted from being used as a precoding matrix of a first precoder, each bit of the second bit sequence corresponding to one precoding matrix of the second precoding matrix group, respectively, and the at least one precoding matrix of the second precoding matrix group being restricted from being used as a precoding matrix of a second precoder; and

[23.c] a channel information feedback device to transmit, to a transmitting device, information relating to the precoding matrix of the first precoder and information relating to the precoding matrix of the second precoder,

[23.d] the precoding matrix of the first precoder and the precoding matrix of the second precoder being selected, based on the codebook restricting information, from among precoding matrices that are not restricted, [23.e] wherein a period of transmitting the information relating to the precoding matrix of the first precoder and a period of transmitting the information relating to the precoding matrix of the second precoder are different from each other.

Claim 24: The device of claim 23, wherein the first matrix group includes N precoding matrices, and the first bit sequence is an N-bit sequence, where N is an integer.

Claim 26: The device of claim 23, wherein the transmitting device includes at least one antenna pair in which a first domain including at least one antenna polarized in one direction and a second domain including at least one antenna polarized in another direction intersect each other; and the precoding matrix of the first precoder performs precoding on the first domain and the second domain, separately, and the precoding matrix of the second precoder performs phase mismatch correction to remove an effect from a phase mismatch between the first domain and the second domain.

Claim 27: The device of claim 26, wherein the precoding matrix of the first precoder corresponds to W_1 in the following Equation, and the precoding matrix of the second precoder corresponds to W_2 in the following Equation:

$$W = \underbrace{\begin{pmatrix} R_0 & 0 \\ 0 & R_0 \end{pmatrix}}_{W_1} \underbrace{\begin{pmatrix} I \\ \Lambda \end{pmatrix}}_{W_2},$$

wherein R_0 denotes a value determined by a precoding gain when the first domain and the second domain have an identical spatial channel status, I denotes a unit matrix, and Λ denotes a phase mismatch correction value between the first domain and the second domain.

Claim 28: The device of claim 23, wherein the period of transmitting the information relating to the precoding matrix of the first precoder is longer than the period of transmitting the information relating to the precoding matrix of the second precoder.