

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG ELECTRONICS CO., LTD.;
SAMSUNG ELECTRONICS AMERICA, INC.,
Petitioner

v.

EMPIRE TECHNOLOGY DEVELOPMENT LLC,
Patent Owner.

Case No. IPR2024-00897
U.S. Patent No. 8,565,331

**DECLARATION OF MATTHEW C. VALENTI
IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 8,565,331**

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I. INTRODUCTION

1. I have been retained by Samsung Electronics Co., Ltd. and Samsung Electronics America, Inc. (collectively, “Samsung” or “Petitioner”), as an independent expert in this proceeding before the Patent Trial and Appeal Board (“PTAB” or “Board”). I understand that Samsung is requesting that the Board institute an inter partes review (“IPR”) proceeding of Claims 1-8 of U.S. Patent No. 8,565,331 (“the ’331 Patent”) (Ex-1001), currently assigned to Empire Technology Development LLC (“PO”).

2. I am not and have never been an employee of Samsung. I am being compensated at my usual and customary rate of \$550 per hour. No part of my compensation depends on the outcome of this proceeding, and I have no other interest in this proceeding.

3. I have been asked to provide my independent analysis of the ’331 Patent in light of the prior art publications cited below. I have also been asked to consider the state of the art and prior art available as of August 20, 2010, with respect to Ground 1 of the Petition, and July 1, 2008, with respect to Grounds 2 and 3 of the Petition. Based on the prior art discussed in this declaration, it is my opinion that Claims 1-8 of the ’331 Patent are unpatentable for the reasons provided below.

A. Qualifications

4. I received a Bachelor of Science degree in Electrical Engineering from Virginia Polytechnic Institute & State University (Virginia Tech) in May 1992. I received a Master of Science degree in Electrical Engineering from Johns Hopkins University in May 1995 and a Ph.D. in Electrical Engineering from Virginia Tech in 1999.

5. From 1992 to 1995 I served as an Electronics Engineer at the U.S. Naval Research Laboratory in Washington DC. During this time, I worked on signal processing systems, including systems that used adaptive antenna arrays.

6. From 1995 to 1999, I was a Graduate Research Assistant and Instructor in the Bradley Department of Electrical and Computer Engineering at Virginia Tech. For my Ph.D. research while working as a research assistant, I conducted in-depth investigations into signal processing and error-control coding techniques specifically tailored for mobile radio systems including cellular networks.

7. From 1999 to present, I have been a faculty member at West Virginia University in Morgantown, West Virginia. I was initially appointed as an Assistant Professor, was promoted to Associate Professor with tenure in 2005, and then was promoted to Professor in 2010. At WVU, I regularly teach the senior undergraduate course on Wireless Networking (CPE 462), which covers key concepts behind modern cellular networks, including orthogonal frequency division multiple access (OFDMA), multiple-input multiple-output (MIMO) antenna systems, and link

adaptation. I also teach graduate courses on Coding Theory (EE 567) and Communication Theory (EE 561). In addition to my teaching, I run an active funded research program focused on wireless communications and signal processing. I have advised over 50 graduate students who worked in my lab, including 10 Ph.D. students, to degree completing.

8. I have authored numerous technical papers on various aspects of mobile and wireless communication systems that have been published in well-respected, peer-reviewed journals, such as the *IEEE Transactions on Communications*, *IEEE Transactions on Wireless Communications*, and the *International Journal on Wireless Information Networks*.

9. I have extensive experience in developing software for the simulation and implementation of various aspects of wireless communication systems, including error-control coding and adaptive modulation. My software is freely available to the public in a package called the *Coded Modulation Library (CML)*¹. The software implements certain portions of several standardized systems including WiMAX, UMTS, HSDPA, and LTE.

10. I have experience designing transmission and reception schemes for MIMO communication systems. For instance, in the paper “Efficiently decoded full-rate space-time block codes,” published in the February 2010 issue of *IEEE*

¹ <https://github.com/wvu-wcrl/CML>.

Transactions on Communications, I devised a class of efficient space-time codes suitable for transmission from 3, 4, or 5 antennas.

11. I have experience designing systems involving the use of pilot symbols for the purpose of channel estimation. In a paper entitled “Refined channel estimation for coherent detection of turbo codes over flat-fading channel” published in 1998 in the journal *Electronics Letters*, I developed a strategy for iteratively estimating a wireless channel wherein a first initial channel estimate is obtained by using pilot symbols, data is decoded using that first estimate, and then the decoded data is used along with the pilots to perform a second estimation of the channel. That second estimation of the channel would then be used to improve a second decoding of the data. The process was iteratively performed several times until a final decoding result obtained. This work was further developed in a subsequent paper entitled “Iterative channel estimation and decoding of pilot symbol assisted turbo codes over flat-fading channels” published in 2001 in the *IEEE Journal on Selected Areas in Communications*. Ex-1034.

12. I have experience designing systems that involve the use of automatic repeat request (ARQ) and hybrid automatic repeat request (HARQ) protocols, wherein incorrectly decoded packets are retransmitted. For instance, in the paper “Practical relay networks: A generalization of hybrid-ARQ” published in 2005 in the *IEEE Journal on Selected Areas in Communications*, I extend traditional HARQ

protocols to a relay network that includes additional terminals called *relays* that can retransmit incorrectly decoded packets on behalf of the source transmitter.

13. I am an active member of the Institute for Electrical and Electronic Engineers (IEEE), the world's largest technical professional organization with the aims of fostering technological innovation and excellence. As an IEEE member, I have been involved in running some of the most impactful journals and conferences in the field of wireless communications. For instance, I have served in many roles for *IEEE Transactions on Wireless Communications*, including chairing the Executive Editorial Committee and chairing the Steering Committee. Moreover, I have served in various program committee roles including serving as Technical Program Chair, which is the top technical leadership position, for the *IEEE International Conference on Communications* (ICC), which is a flagship conference of the IEEE Communications Society that attracts thousands of papers and participants annually.

14. In 2018, my research achievements were honored with elevation to IEEE Fellow status. As the most prestigious level of membership within the IEEE, the Fellow grade recognizes individuals through a stringent selection process. No more than 0.1% of IEEE members are elevated to Fellow, underscoring the distinction and selectivity of this recognition.

15. Since 2011, I have been registered as a Professional Engineer (P.E.) in the state of West Virginia. This licensure affirmed my engineering proficiency through the successful completion of rigorous examinations and the attaining of sufficient experience. To retain this licensure, I remain committed to upholding these proficiencies by engaging in continuing education and contributing to the advancement of engineering knowledge.

16. Taken as a whole, my academic and practical experience have given me a substantial basis upon which to evaluate the technology that is in question in the claims of the '331 Patent. Based on my experience and education, and the acceptance of my publications and professional recognition by peers in my field, I believe that I am qualified to opine as to the knowledge and level of skill of one of ordinary skill in the art at the time of the alleged invention of the '331 Patent (which I further describe below) and what such a person would have understood at that time, and the state of the art during that time.

17. A complete copy of my curriculum vitae, which includes a list of my publications and contains further details on my education, experience, publications, patents, and other qualifications to render an expert opinion, is attached as Ex-1003.

B. Materials Considered

18. In forming my opinions, I reviewed the following documents, in addition to others I have cited in my declaration. I also relied on my own knowledge

of and experience in the field of wireless data communication systems at the physical layer.²

Ex. No.	Description
Ex-1001	U.S. Patent No. 8,565,331 (“the ’331 Patent”)
Ex 1003	Curriculum Vitae of Dr. Matthew C. Valenti
Ex-1004	Prosecution History of the ’331 Patent (Application No. 12/999,029)
Ex-1005	European Patent Application Publication No. EP 2114029 (“Haustein”)
Ex-1006	U.S. Patent App. Pub. No. 2008/0222482 (“Ban”)
Ex-1007	U.S. Patent App. Pub. No. 2002/0003774 (“Wang”)
Ex-1008	L. Tang & M. A. Abu-Rgheff, <i>Joint Pilot-Aided and Blind Decision-Directed Channel Estimation for MIMO-OFDM System</i> , The 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (2007) (“Tang”)
Ex-1020	Claim Mapping Table
Ex-1021	<i>Empire Technology Development LLC v. Samsung Electronics Co., Ltd., et al.</i> , Case No. 2-23-cv-00427, Infringement Contentions (E.D. Tex. Jan. 4, 2024).
Ex-1022	Declaration of Gordon Macpherson dated Apr. 27, 2024 (Institute of Electrical and Electronics Engineers, Incorporated)
Ex-1023	Siavash M. Alamouti, <i>A Simple Transmit Diversity Technique for Wireless Communications</i> , IEEE Journal on Select Areas in Communications, Vol. 16, No. 8, Oct. 1998.
Ex-1024	U.S. Patent No. 8,126,408 (“Ahrony”)

² Four-digit pin citations that begin with 0 are to the branded numbers added by Samsung in the bottom right corner of the exhibits. All other pin citations are to original page, column, paragraph, or line numbers.

Ex. No.	Description
Ex-1025	Andreas F. Molisch, <i>Wireless Communications</i> , IEEE (2 nd ed.)
Ex-1026	Tzi-Dar Chiueh and Pei-Yun Tsai, <i>OFDM Baseband Receiver Design for Wireless Communications</i>
Ex-1027	Andre Antonio dos Anjos et al., <i>Channel Estimation on MIMO-OFDM Systems</i>
Ex-1028	Anna Zhuang and Markku Renfors, <i>Combined Pilot Aided and Decision Directed Channel Estimation For The RAKE Receiver</i>
Ex-1029	Arogyaswami Paulraj et al., <i>Introduction to Space-Time Wireless Communications</i>
Ex-1030	F. Tufvesson and T. Maseng, <i>Pilot assisted channel estimation for OFDM in mobile cellular systems</i> , IEEE (2006)
Ex-1031	Alexandre Rodrigues Mesquita et al., <i>Redundant Data and Transmission in Control/Estimation Over Wireless Networks: Extended Version</i>
Ex-1032	U.S. Patent No. 7,039,001 (“Krishnan”)
Ex-1033	U.S. Patent App. Pub. No. 2008/0192842 (“Fei”)
Ex-1034	Matthew C. Valenti and Brian D. Woerner, <i>Iterative Channel Estimation and Decoding of Pilot Symbol Assisted Turbo Codes Over Flat-Fading Channels</i> , IEEE Journal on Selected Areas in Communications (2001)
Ex-1035	Ahmad R. S. Bahai, Burton R. Saltzberg, and Mustafa Ergen, <i>Multi-Carrier Digital Communications: Theory and Applications of OFDM Second Edition</i> (Springer 2004)

II. LEGAL STANDARDS

19. In forming my opinions and considering the subject matter of the '331 Patent and its claims in light of the prior art, I am relying on certain legal principles

that counsel in this case explained to me. My understanding of these concepts is summarized below.

20. I understand that earlier publications and patents may act to render a patent unpatentable for one of two reasons: (1) anticipation, and (2) obviousness.

A. Anticipation

21. It is my understanding that the claims of a patent are anticipated by a prior art reference if each and every element of the claim is found either explicitly or inherently in the reference. I understand that inherency requires a showing that the missing descriptive matter in the claim is necessarily present in the allegedly anticipating reference, and that it would have been so recognized by a person of ordinary skill in the art (“POSITA”).

22. I understand that when a challenged claim covers several structures, either generically or as alternatives, the claim is deemed anticipated if any of the structures within the scope of the claim is found in the prior art reference.

23. Although anticipation typically involves the analysis of a single prior art reference, I understand that additional references may be used to show that the prior art reference has enabling disclosure (i.e., allows a POSITA to make the invention without undue experimentation), to explain the meaning of a term used in the prior art reference, and/or to show that a characteristic is inherent in the prior art reference.

B. Obviousness

24. I understand that a claim is invalid as obvious if it would have been obvious to a person of ordinary skill in the art at the time the alleged invention was made. This means that even if all of the elements of the claim cannot be found in a single prior art reference that would anticipate the claim, a person of ordinary skill in the art who was aware of the prior art would have been able to come up with the claimed invention. This may be the case, for example, where the missing element represents only an insubstantial different over the prior art or a reconfiguration of a known system. I understand that in an obviousness determination, the person of ordinary skill in the art is presumed to have knowledge of all material prior art.

25. I understand that an obviousness analysis requires an understanding of the scope and content of the prior art, any differences between the alleged invention and the prior art, and the level of ordinary skill in evaluating the pertinent art.

26. I understand that when a product is available, design incentives and other market forces can prompt variations of it, either in the same field or a different one. If a person of ordinary skill in the art can implement a predictable variation, obviousness likely bars its patentability. For the same reason, 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 would have been obvious.

27. I understand that whether a prior art reference renders a patent claim unpatentable as obvious is determine from the perspective of a person of ordinary skill in the art at the time of the alleged invention. I have been told that there is not requirement that the prior art contain an express suggestion to combine known elements to achieve the claimed invention, but a suggestion to combine known elements to achieve the claimed invention may come from the prior art, as filtered through the knowledge of one skilled in the art. In addition, I have been told that the inferences and creative steps a person of ordinary skill in the art would employ are relevant to the determination of obviousness.

28. I understand that one may consider, e.g., whether (1) the change was merely the predictable result of using prior art elements according to their known functions, or whether it was the result of true inventiveness; (2) there is some teaching or suggestion in the prior art to make the modification or combination of elements claimed in the patent; (3) the claimed innovation applies a known technique that had been used to improve a similar device or method in a similar way; (4) the claimed invention would have been obvious to try, meaning that the claimed innovation was one of a relatively small number of possible approaches to the problem with a reasonable expectation of success by those skilled in the art; (5) the invention merely substituted one known element for another known element in order to obtain predictable results; (6) the invention merely applies a known technique to

a known device, method, or product to yield predictable results; or (7) known work in one field of endeavor may have prompted variations of it for use in either the same field or a different one based on design incentives or other market forces that would have been predictable to a person of ordinary skill in the art.

29. I further understand that certain factors may support or rebut the obviousness of a claim. I understand that such secondary considerations include, among other things, commercial success of the patented invention, skepticism of those having ordinary skill in the art at the time of the invention, unexpected results of the invention, any long-felt but unsolved need in the art that was satisfied by the alleged invention, the failure of others to make the alleged invention, praise of the alleged invention by those having ordinary skill in the art, and copying of the alleged invention by others in the field. I understand that there must be a nexus—that is, a connection—between any such secondary considerations and the alleged invention. I also understand that contemporaneous and independent invention by others is a secondary consideration tending to show obviousness.

30. I am not aware of any allegations by the named inventors of the '331 Patent or any assignee of the '331 Patent that any secondary considerations tend to rebut the obviousness of the '331 Patent.

31. Additionally, I understand that in considering obviousness, it is important not to use the benefit of hindsight derived from the patent under consideration.

C. Level of Ordinary Skill in the Art

32. When interpreting a patent, I understand that it is important to identify the relevant art pertaining to that patent, as well as the level of ordinary skill in that art at the time of the claimed invention. The “art” is the field of technology to which the patent is related.

33. I am informed and understand that the POSITA is a hypothetical person who is presumed to know the relevant prior art. I understand that the actual inventor’s skill is not determinative of the level of ordinary skill. I further understand that factors that may be considered in determining level of skill include: (i) the types of problems encountered in the art; (ii) prior art solutions to those problems; (iii) the rapidity with which innovations are made; (iv) the sophistication of the technology; and (v) the educational level of active workers in the field. I understand that not all such factors may be present in every case, and one or more of them may predominate.

34. I understand that a POSITA is one who is presumed to be aware of all pertinent art, thinks along conventional wisdom in the art, and is a person of ordinary creativity.

35. A person of ordinary skill in the art at the relevant time, which I have been told to consider as August 20, 2010, with respect to Ground 1 of the Petition, and July 1, 2008, with respect to Grounds 2 and 3 of the Petition, (“POSITA”) would have had a bachelor’s degree in electrical engineering, computer science, computer engineering, or a related field, and two-to-three years of experience in the research, design, development, or testing of wireless data communication systems at the physical layer, with additional education substituting for experience and vice versa.

36. Based on my education and experience, I would have, at least, met the criteria for a POSITA on July 1, 2008 and August 20, 2010, and I still exceed it today.

D. Claim Construction

37. I understand that the United States Patent and Trademark Office interprets claim terms in an *inter partes* review proceeding under the same claim construction standard that is used in a United States federal court. I understand that under this standard, the meaning of claim terms is considered from the viewpoint of a POSITA at the time of the alleged invention.

38. I have been informed that claim terms are generally given their ordinary and customary meaning as understood by one of ordinary skill in the art in light of the specification and the prosecution history pertaining to the patent. I understand,

however, that claims terms are generally not limited by the embodiments described in the specification.

39. I understand that in addition to the claims, specification, and prosecution history, other evidence may be considered to ascertain the meaning of claim terms, including textbooks, encyclopedias, articles, and dictionaries. I have been informed that this other evidence is often less significant and less reliable than the claims, specification, and prosecution history.

III. SUMMARY OF GROUNDS

40. I understand that Petitioner challenges the validity of Claims 1-8 of the '331 Patent. It is my opinion that the following grounds demonstrate that Claims 1-8 of the '331 Patent are invalid.

Ground	Summary
1	Claims 1-8 are obvious in view of European Patent Application Publication No. EP 2114029 ("Haustein," Ex-1005)
2	Claims 1-8 are obvious over U.S. Patent App. Pub. No. 2008/0222483 ("Ban," Ex-1006) in view of U.S. Patent App. Pub. No. 2002/0003774 ("Wang," Ex-1007)
3	Claims 1-8 are obvious over L. Tang & M. A. Abu-Rgheff, "Joint Pilot-Aided and Blind Decision-Directed Channel Estimation for MIMO-OFDM System," The 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (2007) ("Tang," Ex-1008)

IV. THE '331 PATENT

A. Overview of the '331 Patent

41. The '331 Patent, titled "Inserting and Decoding Replicated Data Symbols in Wireless Communications," describes the "use of replicated data as a pilot symbol in a communications system." Ex-1001, 4:3-5. In particular, the '331 Patent describes receiving multiple copies of data ("replicated data"), transmitted over multiple data streams, and using the "decoded replicated data as a pilot symbol to estimate the channel matrix." *Id.*, 5:47-50.

42. The '331 Patent explains that in prior art wireless communication systems that implement orthogonal frequency division multiplexing (OFDM) and block encoding techniques, such as "Alamouti space-time block coding," decoding transmissions at the receiver requires "knowledge of properties of the communications channel over which the transmission is received." Ex-1001, 1:37-63. This is because "[t]he communications channel [] may introduce a variety of non-idealities to a transmitted signal, such as may be caused by multipath interference, reflections, motion of one or more mobile stations, or other properties of a communications channel." Ex-1001, 1:27-31. Obtaining knowledge of the communications channel involves estimating the channel matrix, which "refers to a matrix of data which may represent the operation of the communication channel on the transmitted data symbols, including representations of such effects as reflections." Ex-1001, 1:33-36. Such channel matrix estimation is typically done by "insert[ing] pilot symbols into the transmitted data streams." Ex-1001, 1:66-2:1.

Because these pilot symbols are “known to the receiver,” they “may be compared with the received signals to generate an estimate of one or more properties of the communications channel.” Ex-1001, 2:1-4. The ’331 Patent purportedly seeks to address a problem with such prior art channel estimation techniques, in which “[t]he need to insert pilot symbols into the transmitted data streams may adversely [a]ffect a data rate attainable in the communications system” because the pilot symbols increase overhead. Ex-1001, 2:4-6.

43. Accordingly, the ’331 Patent describes using copied, or replicated, payload data to serve as pilot symbols such that the effective data rate is increased. *Id.*, 2:61-3:2. For example, Figure 5, annotated below, illustrates replicating payload data symbols S3 and S4 and inserting the copies at other frequencies within the same data stream 510, as shown by the circled portions below. Figure 5 also illustrates a second replication of the entire data stream from a first stream 510 to a spatially separated second stream 515 using the known technique of Alamouti space-frequency block coding.³ Ex-1001, 1:52-58, 8:1-9.

³ Note that Figure 5 contains a typographical error. The first “S4” in the “first stream 510” should be “-S4*,” and the first “S3” in the “second stream 515” should be “S3*,” consistent with the Alamouti code being applied.

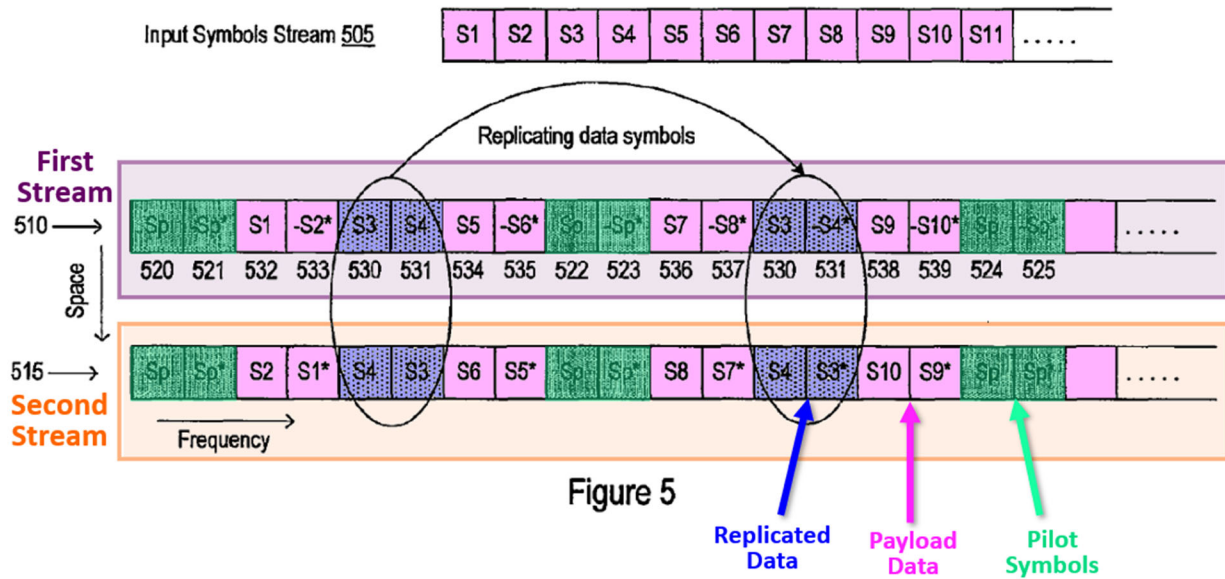
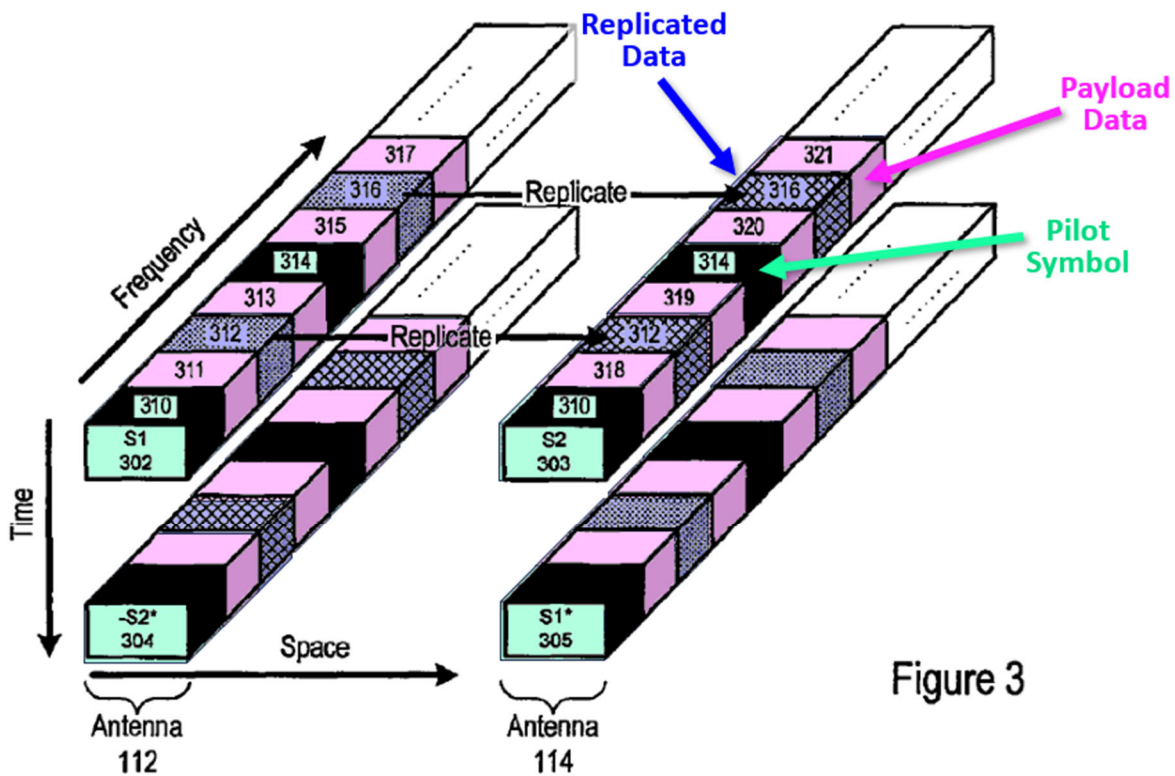


Figure 5

44. Alternatively, Figure 3, below, illustrates replicating data symbols from stream 302 to a second spatial stream 303 and using the known technique of Alamouti space-time block coding. Ex-1001, 1:45-52, 6:49-51.

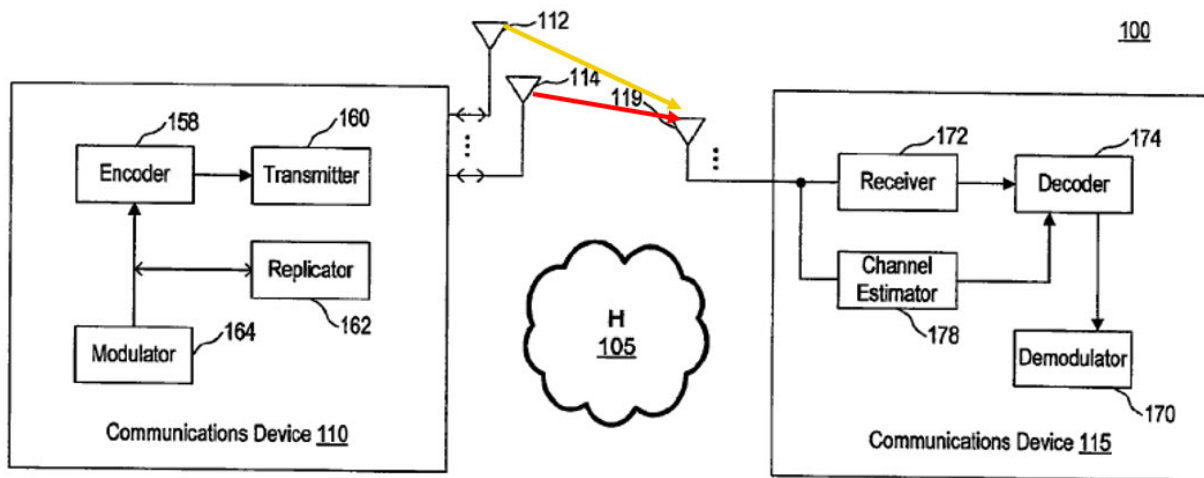


45. The '331 patent explains that Alamouti space-frequency and space-time block coding were known techniques by which a transmitter may send data using two or more antennas that are separated in space:

Block coding techniques may be used in communication systems to encode data and transmit multiple data streams over a communications channel, which may improve the reliability of data transfer. Block coding techniques include space-time block coding, which may transmit multiple data streams across multiple antennas. **Alamouti space time block coding** is one particular type of space-time block coding known in the art. Space-time block coding techniques may require that the communications channel be constant during consecutive data transmission times, which may not always be advantageous. Another type of block coding technique is space-frequency block coding. **Alamouti space-frequency block coding** is one particular type of space-frequency block coding known in the art. Space-frequency block coding techniques may require that different

frequencies experience similar communications channel properties, which may be more advantageous in some cases.

Ex-1001, 1:42-58. For example, annotated Figure 1, below, shows a first stream (yellow) transmitted through antenna 112 and a second stream (red) transmitted through antenna 114, both received at antenna 119. *Id.*, 4:59-67.



46. At the receiver, “the replicated data symbols may be utilized in a manner similar to pilot symbols to estimate the communications channel.” Ex-1001, 7:14-16. The ’331 Patent states that, “[b]y utilizing replicated data to generate or update an estimate of the channel matrix, the communications device 115 may in some examples require fewer pilot symbols to be inserted into signals communicated over the communications channel 105,” which “may advantageously improve the data rate of the communications system 100 in some examples.” Ex-1001, 5:50-57.

B. Prosecution History of the ’331 Patent

47. I understand that the ’331 Patent was filed August 20, 2010 as

international patent application PCT/US2010/046106.

48. I have reviewed the prosecution history of the application that led to the '331 Patent. During prosecution, the 20 pending claims were rejected twice over U.S. Patent Publication 2010/0202559 to Luo et al. Ex-1004, 0232, 0263-0264. The patentee overcame the rejections by requiring estimating the channel matrix based upon the replicated data and using that estimate to decode subsequently received signals. *Id.*, 0248-0250, 0275. The '331 Patent then issued on October 22, 2013. Ex-1001, Cover.

49. The prior art I apply to Claims 1-8 in my Declaration was not before the USPTO during prosecution of the '331 Patent. And as I discuss below, this art teaches or suggests the '331 Patent's Claims 1-8.

V. TECHNOLOGY BACKGROUND

A. Wireless Communication Networks

50. Wireless communication networks comprise one or more base stations, also known as access points, which provide wireless connectivity to various mobile stations. These base stations are connected to a core network, such as the Internet, and facilitate communication within designated areas called cells. Mobile stations, including devices like smartphones, tablets, and flip phones, rely on these base stations for access due to their lack of wired connectivity. Wireless networks support bi-directional communications, and thus base stations and mobile stations act as both

transmitters and receivers. The link from the base station down to the mobile station is called the *downlink* while the link from the mobile station up to the base station is called the *uplink*.

51. When a base station and mobile station communicate, they can each use one or multiple antennas, leading to configurations known as SISO, MIMO, SIMO, and MISO. In these abbreviations, “S” stands for *single*, and “M” stands for *multiple*, referring to the number of antennas and their corresponding transmitters or receivers. “I” denotes *input*, and “O” denotes *output*, indicating the respective ends of the wireless link. The wireless communication channel can be viewed as having one or more inputs and outputs, with the transmitter side being the input and the receiver side being the output. Thus, “SISO” (i.e., single input, single output) means a single antenna at both the transmit and receive sides, “MIMO” (i.e., multiple input, multiple output) means multiple antennas at both ends, “SIMO” (i.e., single input, multiple output) means a single antenna at the transmit side and multiple at the receive side, and finally “MISO” (i.e., multiple input, single output) means multiple antennas at the transmit side and a single antenna at the receive side.

52. Using multiple antennas at either end of the wireless link often leads to performance enhancements through benefits known as spatial multiplexing and diversity. Spatial multiplexing increases data throughput by allowing multiple data streams to be transmitted simultaneously over the same frequency channel,

effectively multiplying the channel's capacity. Diversity benefits improve signal quality and reliability by receiving the same signal through different paths, mitigating fading and enhancing overall connection stability. Together, these advantages generally lead to higher data rates and more robust wireless communication. *See, e.g.*, Ex-1029, 0017-0019.

B. Communication Channels

53. When a transmitter sends signals destined for a receiver, those signals travel through the wireless communication medium between the transmitter and receiver, before they are received at the receiver. This communication medium is referred to as the *communication channel*, and corresponds to the physical environment between the transmitter and receiver. This includes the atmosphere, objects such as buildings, cars, and trees, and anything else that may impact the propagation of the signals as they travel between the transmitter and the receiver. As the signal travels through the communication channel it is distorted, such that the received signal, y , is different from the transmitted signal, x , as illustrated below. For instance, reflections from objects, together with atmospheric scattering and refraction, results in the transmitted signal traveling over multiple paths that combine at the receiver. *See, e.g.*, Ex-1035, 0032.

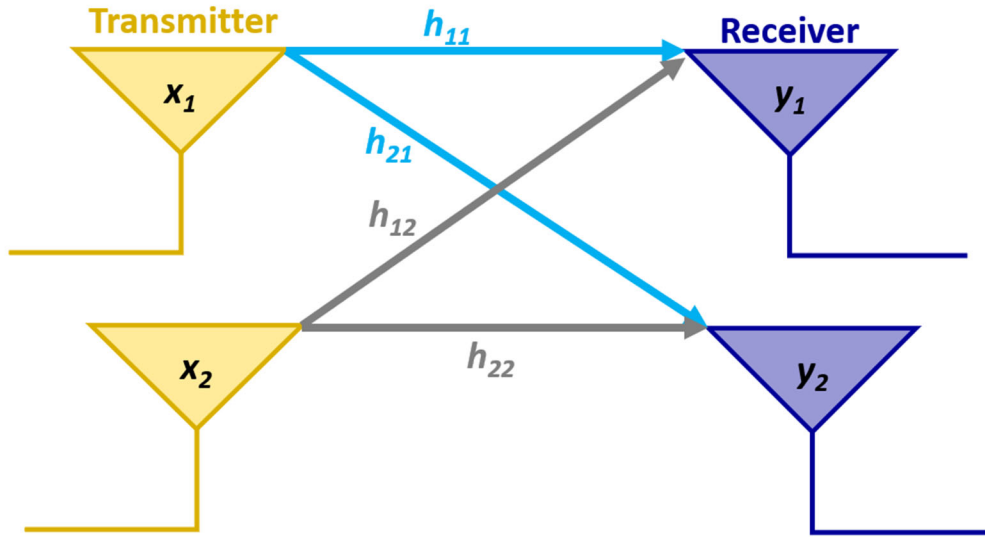


54. The channel may affect different signal frequencies differently. Thus, for a given frequency, f_N , the relationship between the transmitted signal, $x(f_N)$, and the received signal, $y(f_N)$, in a SISO system may be written as:

$$y(f_N) = h(f_N)x(f_N) + n(f_N),$$

where $h(f_N)$ is the channel function, and $n(f_N)$ corresponds to noise.

55. The relationship is similar in a MIMO system, except now multiple paths exist between the transmitters and receivers, which must be considered. For example, the image below illustrates a system with two transmit antennas and two receiver antennas:



In this system, the received signals, $y_1(f)$ and $y_2(f)$, may be written as:

$$y_1(f) = h_{11}(f)x_1(f) + h_{12}(f)x_2(f) + n_1(f)$$

$$y_2(f) = h_{21}(f)x_1(f) + h_{22}(f)x_2(f) + n_2(f)$$

In matrix form, these equations may be written as:

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n}, \text{ where}$$

$\mathbf{y} = \begin{bmatrix} y_1 \\ y_2 \end{bmatrix}$, $\mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$, $\mathbf{n} = \begin{bmatrix} n_1 \\ n_2 \end{bmatrix}$, and $\mathbf{H} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$, is referred to as the channel matrix.

C. Channel Estimation Using Pilot Symbols

56. In order to process the received signals, the channel response (i.e., channel matrix) must be estimated at the receiver. A variety of different channel estimation techniques exist. These may be broadly characterized as data-aided and non-data-aided techniques. Non-data-aided channel estimation techniques, also

known as blind channel estimation techniques, estimate the channel using statistical properties of the received signals. On the other hand, data-aided channel estimation techniques rely on the transmission of known reference signals (e.g., pilot symbols), and can achieve a better channel estimation accuracy, at the expense of higher overhead.

57. In data-aided channel estimation techniques, channel estimation is performed by sending pilot symbols from the transmitter and measuring those pilot symbols at the receiver. Since the pilot symbols are known a priori by the receiver, “the channel response can be estimated as the ratio of the received pilot symbol over the transmitted pilot symbol for each [frequency] subband used for pilot transmission.” Ex-1032, 1:52-61. The channel response for the entire transmission can then be estimated through interpolation. *See, e.g.*, Ex-1030, 0004.

58. The placement of pilot symbols within the transmission (i.e., the pilot symbol pattern) is chosen based on two competing concerns—improving the channel estimation accuracy versus reducing overhead. As U.S. Patent No. 7,039,001 explains for the use of pilot symbols in an OFDM system:

Pilot transmission represents overhead in the OFDM system. Thus, it is desirable to minimize pilot transmission to the extent possible. However, because of noise and other artifacts in the wireless channel, a sufficient amount of pilot [symbols] needs to be transmitted in order for the receiver to obtain a reasonably accurate estimate of the channel response. Moreover, the pilot transmissions need to be repeated to account for variations in the channel over time due to fading and changes in the multipath constituents.

Ex-1032, 1:62-2:3. Similarly, U.S. Patent Pub. No. 2008/0192842 (“Fei”) explains:

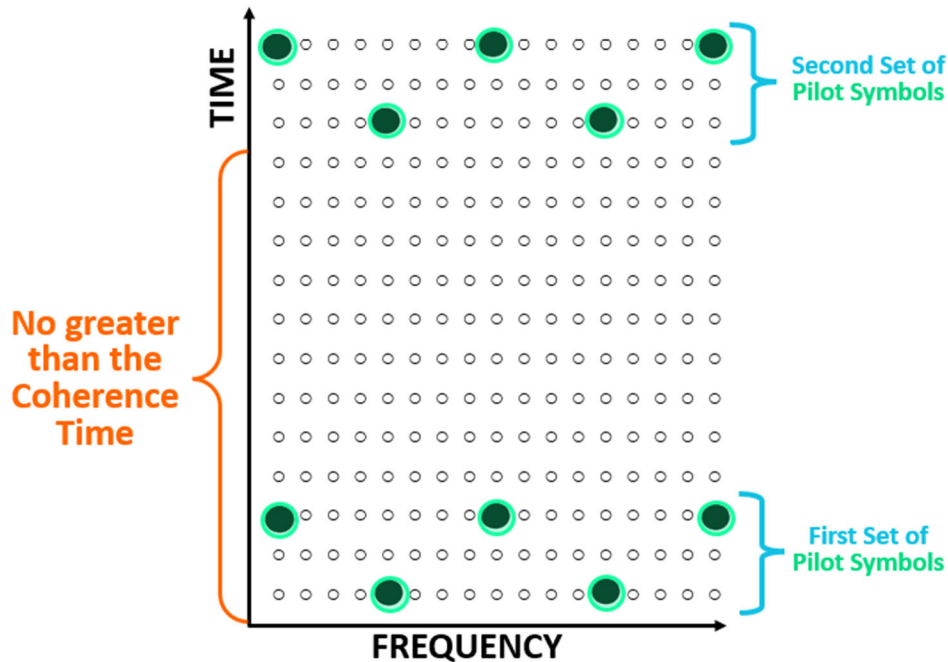
Generally, the more pilot data included in the transmitted signal, the more accurate channel response estimations can be performed in the receiver. However, increasing the pilot data content of the signal will reduce the information data throughput of the transmission since such pilot data content increase comes at the expense of the amount of (useful) information data that can be carried in the transmitted signal.

Ex-1033, ¶ 4.

59. Thus, “[t]he spacing between the pilot symbols [should] be chosen small enough to enable reliable channel estimates but large enough not to increase the overhead too much.” Ex-1030, 0004. For reliability, the pilot symbols should be inserted “according to the degree of channel variation” in both the frequency and time domains. Ex-1026, 0099. In particular, the spacing between pilots in the frequency direction should be smaller than the channel coherence bandwidth—the range in frequency over which the channel may be assumed to be approximately constant—and the spacing between pilots in the time direction should be smaller than the channel coherence time—the time period over which the channel characteristics may be assumed to be approximately constant. *See, e.g.*, Ex-1027, 0002 (explaining that for “slow fading channels”—i.e., channels with large coherence time—“several data symbols can be transmitted between two pilot symbols, reducing the impact of the pilot symbols in the system throughput”).

60. For example, the diagram below illustrates an example of the spacing that may be used between grids of pilot symbols (green, below), for a slowly-varying

channel.



As illustrated, the spacing in time between the transmission of the first set of pilot symbols and the second set of pilot symbols should be chosen to be no greater than the channel coherence time, to help ensure that the channel estimate obtained using the first set of pilot symbols remains suitable for decoding the subsequently received data symbols, prior to the reception of the second set of pilot symbols.

D. Methods for Improved Channel Estimation

61. At the same time, as noted by Fei, “much effort [has been invested in improving the channel response estimations without requiring an increase in pilot data content.” Ex-1033, ¶ 4. These efforts include my own iterative channel estimation (ICE) technique, which I described in the Qualifications section. Specifically, in the paper entitled “Refined channel estimation for coherent detection

of turbo codes over flat-fading channel” published in 1998 in the journal *Electronics Letters*, I developed a strategy for estimating a wireless channel wherein a first initial channel estimate is obtained by using pilot symbols, data is decoded using the channel estimate, and then the decoded data is used along with the pilots to perform a second estimation of the channel allowing for improved decoding in a subsequent iteration of decoding. Ex-1034. The decoded data effectively served as “virtual” pilot symbols and were used to iteratively re-estimate the channel until a final result was obtained.

62. As another example, in their article, “Combined Pilot Aided and Decision Directed Channel Estimation For The RAKE Receiver,” Anna Zhuang and Markku Renfors describe a method for two stage channel estimation. Ex-1028, 0002. This method involves determining a first channel estimate from reference pilot symbols, using that first channel estimate to estimate the received data symbols, making a decision about the received data symbols, and then using those decisions (as known reference) together with the received signals to determine a second channel estimate. *Id.*

63. Other methods for obtaining improved channel estimates without increasing pilot overhead leveraged the presence of redundant data received by the receiver. For example, Fei discloses a method for improved channel estimation in a system employing the Hybrid Automatic Repeat Request (HARQ) technique. Ex-

[Fei], ¶21. As Fei explains:

When th[e] receiver receives a first data block in a first transmission from the transmitter, the data block is provided to the channel estimator. **This estimator determines a channel response for the first data block, for example, by utilizing known pilot symbols included therein.** The resulting channel response is used for modulating the received data symbols of the first block to generate data symbol estimates. These symbol estimates are then demodulated and the resulting data bit estimates from the demodulation are provided to a decoder. This decoder tries to decode the bit estimates and, thus, the first data block. However, if the decoding is not successful, the receiver preferably notifies the transmitter accordingly. As a consequence, the transmitter can then retransmit the data block or transmit another data block that includes at least some of the data symbols found in the first block. In addition, **the decoder generates data bit hypotheses of the data bit estimates of the first block and temporarily stores them in a memory.**

Once the receiver receives this second data block, the data bit hypotheses can be fetched from the memory and modulated into data symbols hypotheses. **Since the first and second data block are based on common data bits, these data symbol hypotheses can be used as known reference symbols similar to pilot symbols when determining the channel response for the second data block.** If the second data block includes pilot symbols both the data symbol hypotheses of the first block and locally generated or stored reference pilot symbols can be used as known reference symbols.

Thus, **more reference symbols (the symbol hypotheses and the pilot symbols) are utilized in the channel estimation** than prior art solutions that only employ a few pilot symbols. Furthermore, this increase in the number of reference symbols for the purpose of channel estimation can be obtained without any increase in the number of pilot symbols that have to be included in the data block and, thus, without any reduction in the information data throughput. As a consequence, a much more accurate channel estimation for this second data block will be obtained, which in turn enables a more accurate estimation of the data bits of the block and increased probability of successful decoding.

Ex-1033, ¶¶15-17. Fei also describes another embodiment in which the pilot

symbols transmitted in the second data block are used to generate a preliminary estimate of the channel response, and then the data bit hypotheses of the first data block are used to refine that preliminary estimate:

In another embodiment of the invention, **an initial or preliminary channel response can first be estimated for the second data block by e.g. using pilot symbols included in the data block.** This preliminary channel response is used to determine (preliminary) data symbol estimates for the second data block. These symbol estimates are **combined with the modulated data bit hypotheses of the first block to obtain combined reference symbols.** Alternatively, the data symbol estimates of the second block could first be demodulated into (preliminary) data bit estimates and then the combination could be performed on the bit-level.

In either case, **the resulting combined reference information is input to the channel estimator of the receiver and is used in a refined channel response estimation for the second block.** Thus, since more reference data can now be used in the refined channel estimation than for the preliminary estimation, a more accurate channel response is obtained. This more accurate channel response in turn enables more accurate estimations of the data bits of the second data block and increased probability of successful decoding.

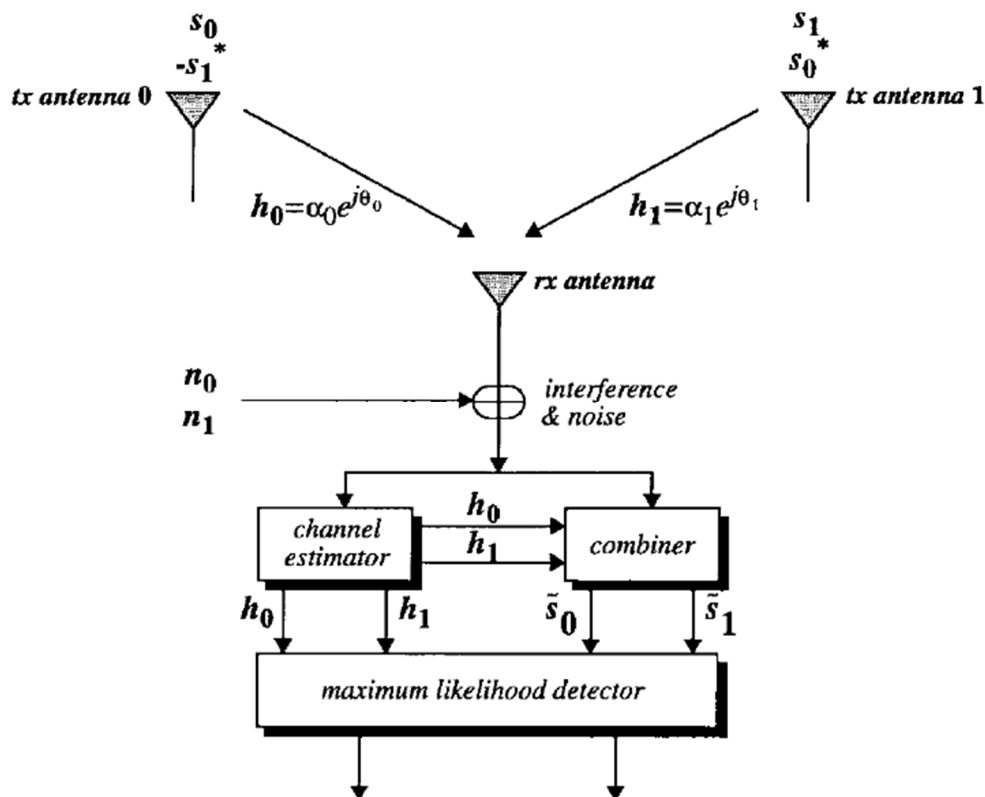
Ex-1033, ¶¶18-19.

E. Diversity Schemes and Alamouti Coding

64. Diversity schemes refer to schemes in which multiple, redundant copies of a single piece of data are transmitted, in order to increase the probability of successful reception. Ex-1026, 0146. These redundant copies may be generated by transmitting the same data “from different antennas, over different frequencies, at different time slots/symbols, or along different electromagnetic (EM) wave polarizations.” *Id.*; see also Ex-1031, 0001 (explaining that “multiple instances of a

same signal are sent at different time instants” in a “time diversity scheme,” and “multiple versions of the signal are spread over a wide spectrum” in a “frequency diversity scheme”).

65. When multiple transmit antennas exist, redundancy may be introduced “by sending from each transmit antenna a differently encoded (and fully redundant) version of the same signal.” Ex-1025, 0539. For example, Alamouti teaches a transmit diversity scheme that uses two transmit antennas and one receive antenna, as illustrated in the figure below.



Ex-1023, Fig. 2.

66. As Alamouti explains:

At a given symbol period, two signals are simultaneously transmitted from the two antennas. The signal transmitted from antenna zero is denoted by s_0 and from antenna one by s_1 . During the next symbol period signal $(-s_1^*)$ is transmitted from antenna zero, and signal s_0^* is transmitted from antenna one where $*$ is the complex conjugate operation.

Ex-1023, 0003. While Alamouti presents this encoding done in space and time (space-time coding), as illustrated in Table 1, reproduced below, Alamouti explains that “[t]he encoding, however, may also be done in space and frequency.” Ex-1023, 0003. In that situation, “[i]nstead of two adjacent symbol periods, two adjacent [frequency] carriers may be used (space-frequency coding).” Ex-1023, 0003.

TABLE I
THE ENCODING AND TRANSMISSION SEQUENCE FOR
THE TWO-BRANCH TRANSMIT DIVERSITY SCHEME

	antenna 0	antenna 1
time t	s_0	s_1
time $t + T$	$-s_1^*$	s_0^*

Ex-1023, 0004. Notably, the orthogonality of the code enables simple, linear decoding at the receiver. Ex-1025, 0539-0540.

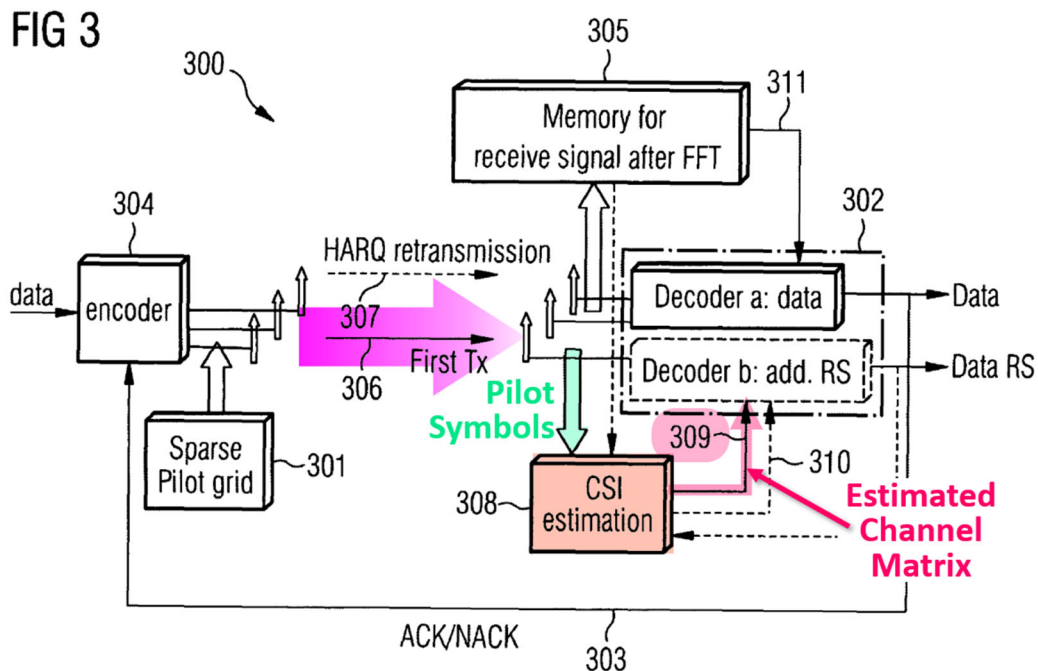
VI. THE PRIOR ART IN THE APPLIED INVALIDITY GROUNDS

A. Haustein (European Patent App. Pub. No. EP2114029) (Ex-1005)

67. Haustein, titled “Method of and device for transmission of data in a communication network,” was filed April 28, 2008, and published November 4, 2009. Ex-1005, Cover. I understand that Haustein is prior art under pre-AIA 35

U.S.C. § 102(a) based on its publication date.

68. Haustein teaches a method for “improved channel estimation” in an LTE (cellular phone) communication system that uses multiple antennas to transmit data. Ex-1005 ¶¶1, 8 (“MIMO”), 51. Haustein’s system is shown in Figure 1, annotated to show first data transmission 306 (pink):

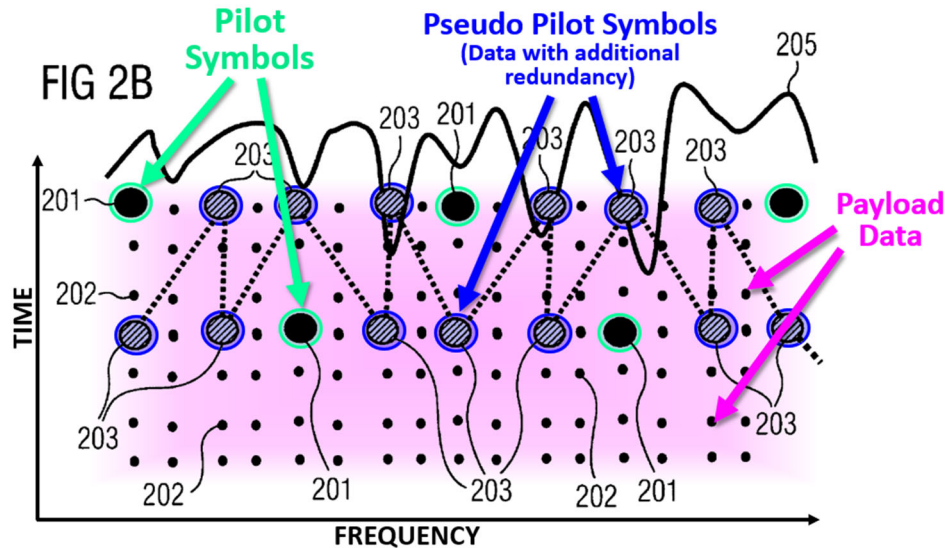


69. At the receiver, pilot symbols are used to estimate the channel matrix (above, red), and this channel estimate is used to decode the first data transmission. Ex-1005 ¶50. In some cases, however, the channel estimate is not adequate to decode the entire transmission. *Id.* ¶49.

70. Accordingly, as shown below in annotated Figure 2B, in addition to pilot symbols 201 (green) and regular payload data symbols 201 (black), Haustein

includes payload data symbols with additional redundancy 203 (blue). Ex-1005

¶¶48, 59.



71. In particular, Haustein explains that:

[I]n difference to Fig. 1 there is a different kind of data type, namely **payload data which are intended to be handled as pilot signals or reference signals in a retransmission**. These additional reference signals are indicated by the hatched dots 203 which are connected by the dashed line 204. The additional reference signals are **transmitted already in the first transmission with a higher redundancy so that they can be used as pseudo reference signals in a potential retransmission**.

Ex-1005, ¶48.

In a first step 401 data signals of a data packet are determined which are intended to represent pseudo pilot signals and **additional redundancy is added** to the respective data signals or data bins. Then the encoded data packet is transmitted 402 comprising a sparse pilot grid, normal data signals and the pseudo pilot signals.

Ex-1005, ¶59.

72. The additional redundancy of payload data symbols 203 may be achieved through repetition, which a POSITA would have recognized is a common way to add redundancy. For instance, as I described in the Background, it was well-known to create redundancy by transmitting multiple copies of the same data at different frequencies and/or times. *See, e.g.*, Ex-1031, 0001.

73. Haustein explains that the redundant payload data symbols 203 (i.e., replicated data) may then be sent over two separate streams using Alamouti block coding, just as in the '331 Patent. Ex-1005 ¶¶38 (“Alamouti processing may be used to insert extra diversity and/or different combinations of superposed signals”), 48.

74. In the event that not all first transmission data was decoded correctly, Haustein teaches retransmission of the data. However, because certain payload data 203 was already sent with higher redundancy to help ensure that it, at least, can be decoded, that data 203 is now assumed to be “known data,” which means it can be used as “pseudo pilot” data when the first data transmission is sent again in a retransmission. *Id.* ¶¶50, 52 (“So the strong redundancy for the pseudo RS’s makes out of the firstly unknown data bins known data, which is basically the main feature of pilots, i.e. that they are known transmit signals.”).

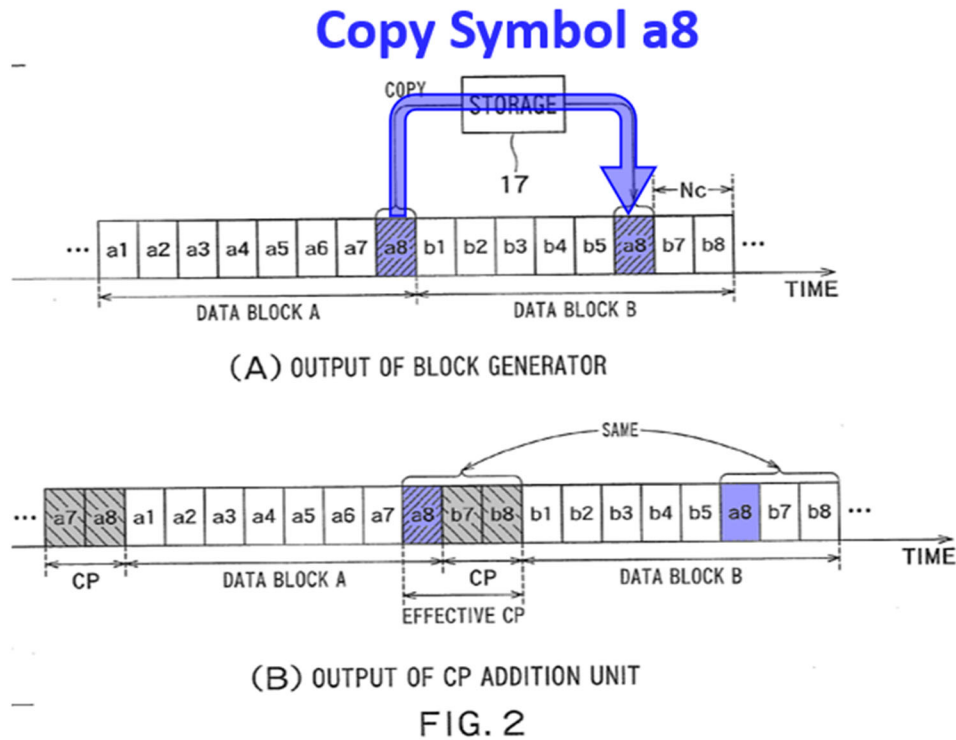
75. In such a case, where the first transmission is retransmitted, both pilot symbols 201 and redundant payload data/pseudo-pilot data 203 are used to update the channel estimate because redundant payload data/pseudo-pilot data 203 are now

“known data.” Ex-1005 ¶¶50-52. This updated channel estimate is then used to decode the retransmission (and subsequent signals until the next set of pilot symbols is sent). Ex-1005 ¶¶3, 50.

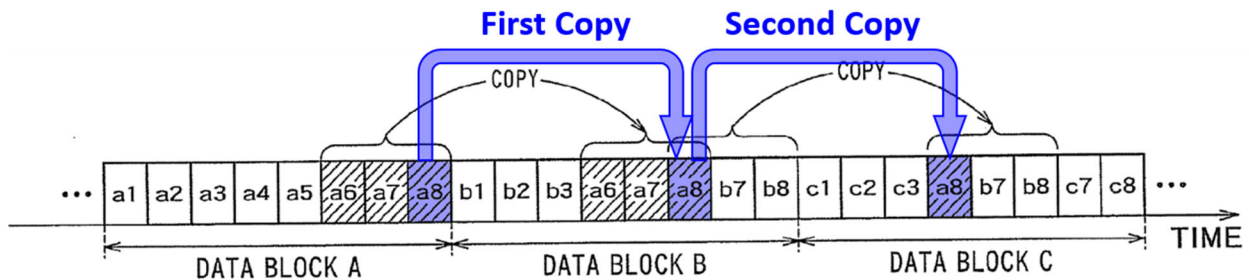
B. Ban (U.S. Patent App. No. 2008/0222482) (Ex-1006)

76. Ban, titled “Transmitter and Receiver,” was filed February 21, 2008, and published September 11, 2008. Ex-1006, Cover. I understand that Ban is prior art under pre-AIA 35 U.S.C. § 102(b) based on its publication date.

77. Ban discloses a communication system including a transmitter and a receiver for communicating a data stream. Ex-1006 ¶¶3-5. Ban teaches extending the size of the cyclic prefix (“CP”) associated with a given data block in the data stream. Ex-1006 ¶81. This is done by copying data symbols from the preceding data block into the current block, prior to generating its cyclic prefix, as illustrated in annotated Figure 2, below. Ex-1006 ¶90.



78. Ban explains that such copying may happen multiple times. For instance, Figure 3A (reproduced with annotations below) presents an example in which data symbol a8 is copied two times, from block A into both blocks B and C. Ex-1006 ¶97.



79. While Figures 2 and 3 illustrate examples in which a data symbol (a8) is copied from a block of data (block A) into one or more other blocks of data (block B for Figure 2; blocks B and C for Figure 3), Ban teaches that the disclosed method

may also be applied to “a data block composed of pilot symbols,” such that “some of [the] pilot symbols in the data block are replaced with data symbols of the preceding data block.” Ex-1006 ¶147. In particular, Ban explains that:

[W]hen substantially extending the CP size of a data block composed of pilot symbols, if some of [the] pilot symbols in the data block are replaced with data symbols of the preceding data block ... the following method may be used to estimate the channel from the data block. First, the above described **data symbols in the preceding data block are demodulated and data symbols in the data block are handled as known data using the demodulation result**. In this way, since all the pilot symbols and data symbols in the data block can be regarded as known data, the channel can be estimated using the entire data block.

Id. Thus, because these data symbols are received as part of the preceding data block, they may be treated as “known data” within the block of pilot symbols and used (together with the pilot symbols in the pilot block) to perform channel estimation.

Id.

C. Wang (U.S. Patent App. Pub. No. 2002/0003774) (Ex-1007)

80. Wang, titled “Pilot Pattern Design for a STTD Scheme in an OFDM System,” was filed July 3, 2001, and published January 10, 2002. Ex-1007, Cover. I understand that Wang is prior art under pre-AIA 35 U.S.C. § 102(b) based on its publication date.

81. Wang discloses a channel estimation method in “a wireless orthogonal frequency division multiplex (OFDM) communication system with space time diversity.” Ex-1007 ¶1. As Wang explains, when using only a single antenna on both

the transmission side and the receiving side, poor data transmission quality may result:

In wireless telecommunication, **the transmission quality** between a transmitting device, such as a base station, and a receiving device, such as a mobile terminal, depends strongly on the respective transmission environment and **is often deteriorated by fading effects and the like**. This often leads to poor speech and data transmission quality, particularly if only one single antenna is used on the transmission side and one single antenna is used on the receiving side.

Ex-1007, ¶2. At the same time, Wang explains that “it is desirable that modern mobile terminals are as small and light as possible and therefore it is an increasing interest to use only a single antenna in these mobile terminals.” *Id.* For such terminals, improvements can be made to the transmission quality by using more than one antenna to transmit the same data in parallel. *Id.* This may be accomplished using a “space time coding” scheme. *Id.* Wang describes such a scheme, and explains that it generates “[a] second data stream [that] contains ***the identical data content*** as the first data stream, but in a different arrangement.” *Id.* ¶23.

D. Tang (L. Tang & M.A. Abu-Rgheff, “Joint Pilot-Aided and Blind Decision-Directed Channel Estimation for MIMO-OFDM System,” the 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (2007)) (Ex-1008)

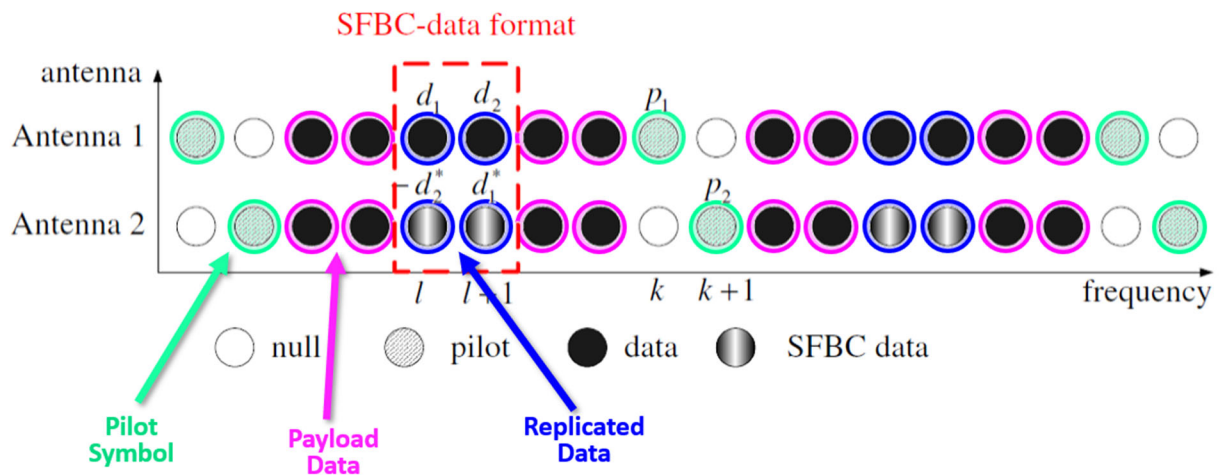
82. Tang, titled “Joint Pilot-Aided and Blind Decision-Directed Channel Estimation for MIMO-OFDM System,” was presented at the 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications,

held on September 3-7, 2007 in Athens, Greece, and published by the Institute of Electrical and Electronic Engineers (“IEEE”) on December 4, 2007. Ex-1022 (Declaration), 0004 (screenshot of website). I understand that Tang is prior art under at least pre-AIA 35 U.S.C. §102(b) because both its presentation date and its ACM publication date are more than a year before the filing date of the ’331 Patent. In my opinion, Tang would have been readily available to a POSITA at least a year before the August 2010 filing date of the ’331 Patent. For example, a POSITA would have been familiar with the IEEE website in 2009 and understood how to use the IEEE website to search for relevant papers.

83. Tang teaches a “joint pilot-aided and blind decision-directed channel estimation (PA-DDCE) scheme” for use in an “orthogonal frequency division multiplexing (OFDM) system” with “multiple antennas at both the transmitter and the receiver,” “which has a relative[ly] small pilot overhead but still guarantees the accuracy of the channel estimation.” Ex-1008, p.1. Tang’s disclosed method involves inserting “data symbols with the orthogonal format ... in the middle of any two adjacent pilot sub-carriers.” *Id.* These inserted symbols are decoded at the receiver using “conventional” pilot-based channel estimation, and then treated as “‘extra pilot symbols’ that are applied to estimate the channel on the whole frequency band” (*id.*), generating an “enhanced” channel estimate (*id.*, p.3).

84. As one of the orthogonal data formats that Tang teaches inserting

between adjacent pilot subcarriers, Tang discloses a “space frequency block code (SFBC)-data [] format.” *Id.* As illustrated in annotated Figure 5, below, generating this data format involves copying data symbols d_1 and d_2 from the data stream to be transmitted by one of Tang’s transmit antennas into the data stream to be transmitted by another transmit antenna. *Id.*



VII. CLAIM CONSTRUCTION

85. I do not believe that any claim term requires explicit construction to resolve the issues presented in this Petition. I apply the plain and ordinary meaning to each claim term, as that plain and ordinary meaning would have been understood by a POSITA.

86. I respectfully reserve the right to offer opinions on any claim constructions proposed in this proceeding or to offer opinions on additional constructions in the district court.

VIII. DETAILED EXPLANATION OF THE UNPATENTABILITY

GROUND

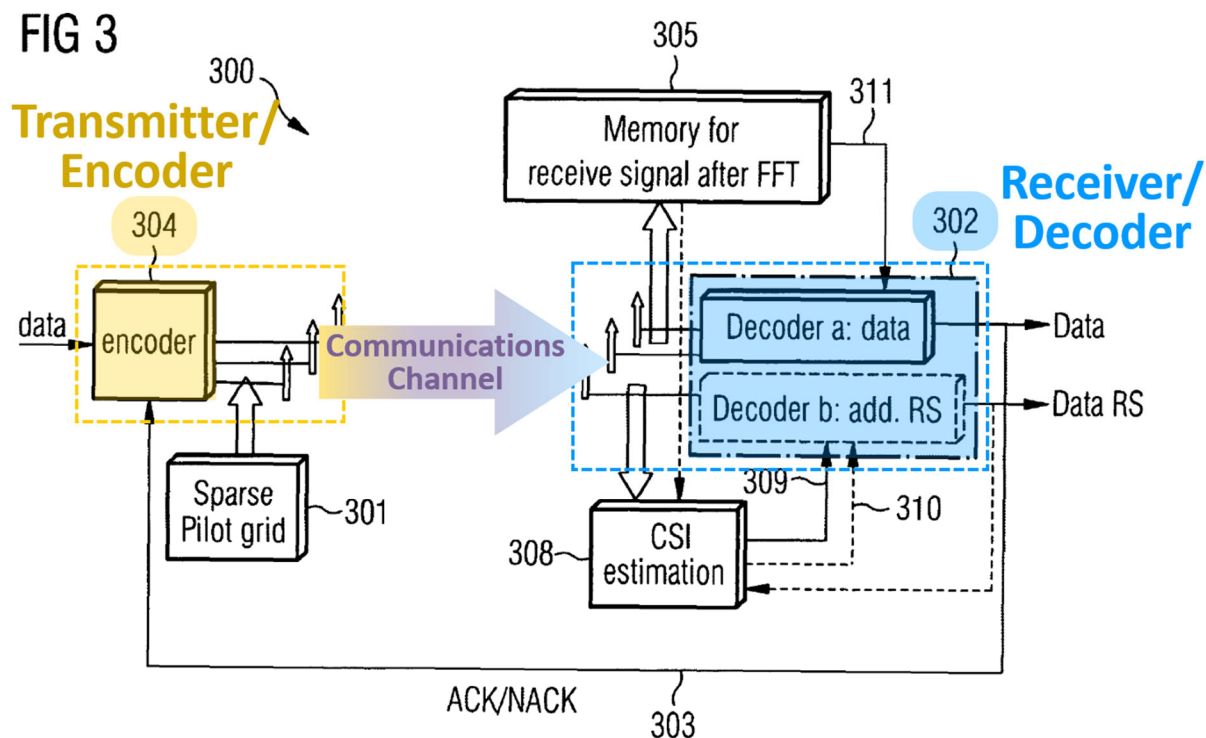
A. Ground 1: Claims 1-8 Are Obvious over Haustein

1. Independent Claim 1

- a. **Element 1[pre]: A method of decoding a signal transmitted over a communications channel, the method comprising:**

87. Haustein teaches or suggests the preamble, to the extent it is limiting.

88. Haustein teaches or suggests “a method of receiving and/or decoding a transmitted data packet” (Ex-1005 ¶10), where the data packet is encoded and modulated, into a “signal”, and then transmitted over a communications channel between transmitter/encoder 304 and receiver/decoder 302, as illustrated in annotated Figure 3, below:



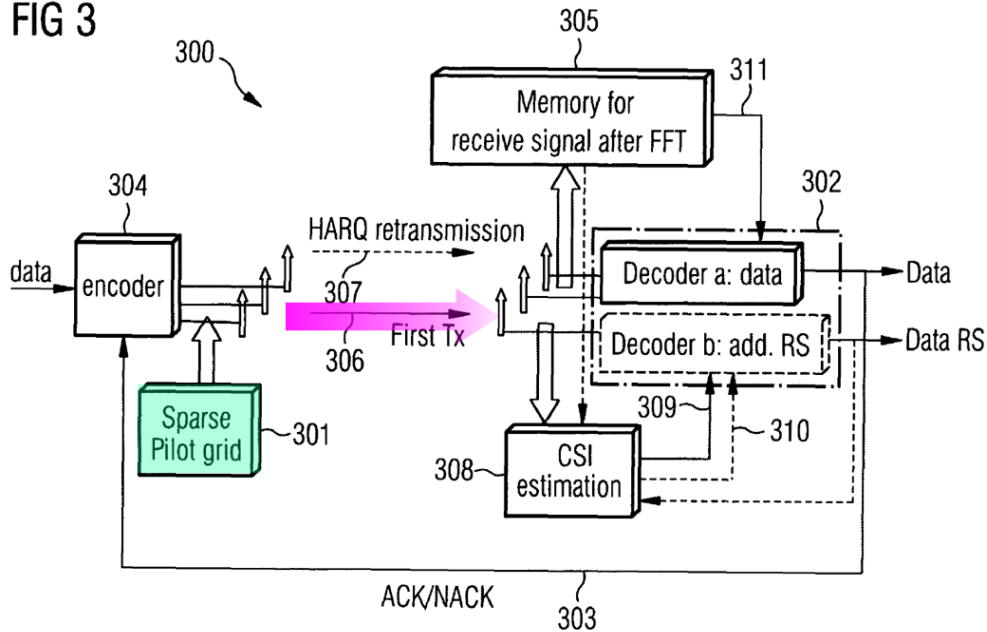
89. Properties of the communications channel are determined from known pilot symbols, and the rest of the data is then decoded based on the estimated channel properties: “the pilot signals are used for an estimation of a Channel State Information (CSI) 308. The estimated channel state is then used in the decoding which is indicated by the arrows 309 and 310.” Ex-1005 ¶ 50.

b. Element 1[a]: receiving a pilot symbol over the communications channel;

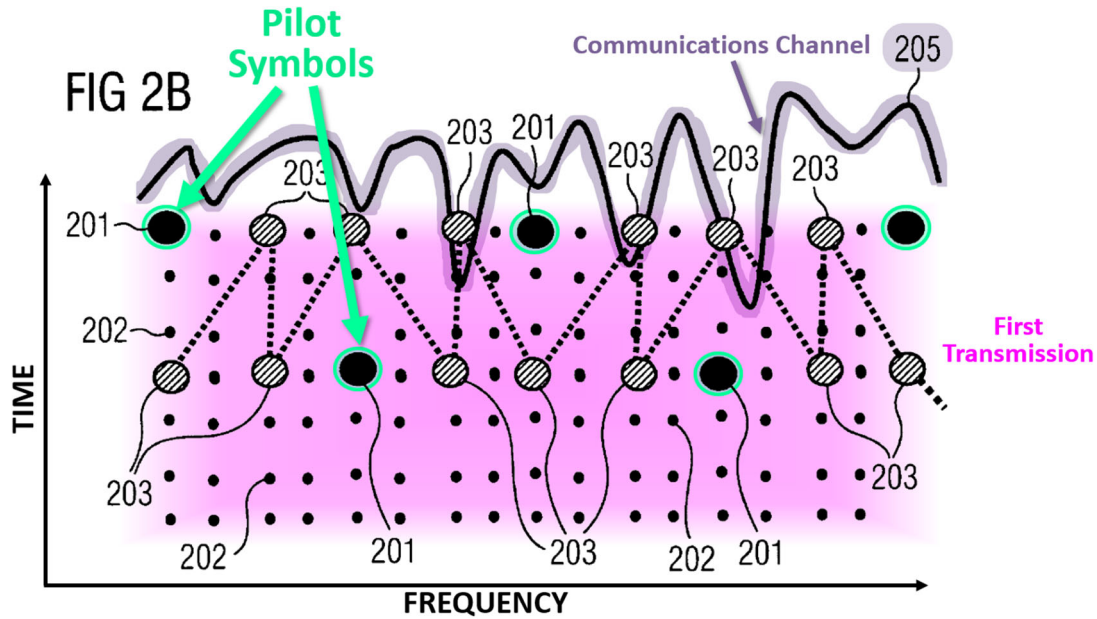
90. Haustein teaches or suggests Element 1[a].

91. As explained for Element 1[pre], Haustein teaches or suggests receiving a data packet over a “communications channel” between encoder/transmitter 304 and receiver/decoder 302. For instance, first transmission 306 of a data packet is received over the communication channel, as illustrated in annotated Figure 3, below:

FIG 3



92. Receiving first transmission 306 (pink) includes receiving a plurality of pilot symbols. Ex-1005 ¶13 (“the receiving device is adapted to receive a data packet comprising [a] first plurality of pilot data”). In particular, first transmission 306 includes a sparse grid 301 (Ex-1005 ¶49) of pilot symbols 201 inserted among payload data 202/203, as illustrated in annotated Figure 2B, below. Ex-1005 ¶48 (“Fig. 2B schematically show[s] a data grid in which pilot data or pilot signals are implemented.”).

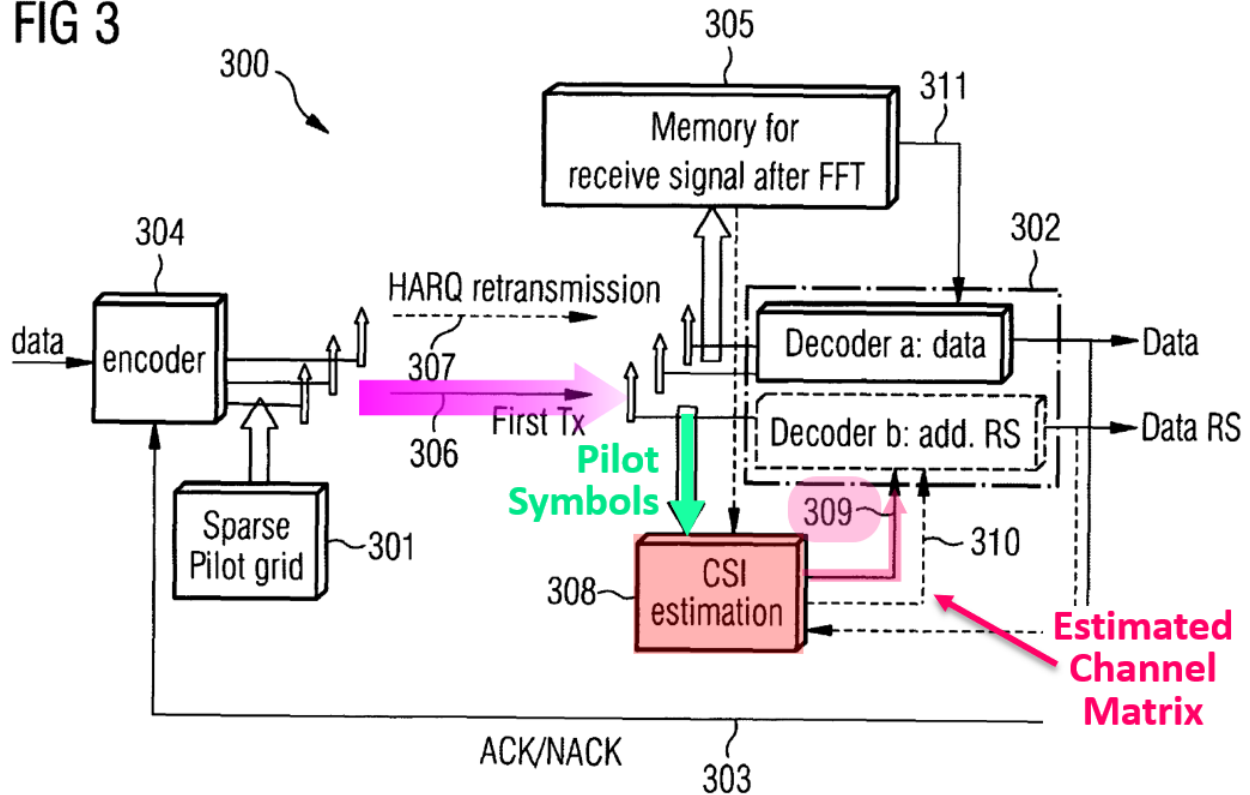


c. **Element 1[b]: estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol;**

93. Haustein teaches or suggests Element 1[b].

94. Haustein teaches or suggests that the received “pilot signals are used for an estimation of a Channel State Information (CSI) 308” (Ex-1005 ¶50), with “[t]he estimated channel state” then used in decoder 302, as illustrated in annotated Figure 3, below:

FIG 3



95. A POSITA would have recognized that estimating the channel state corresponds to estimating the channel matrix. Channel state information (CSI) is information about the properties of a communication link, describing how a signal propagates from transmitter to receiver and represents the effects of scattering, fading, etc. As I explained in the Background, in the case of multiple antennas, such as the MIMO system disclosed in Haustein (Ex-1005 ¶¶9, 11), the channel state information is modeled as a matrix (the channel matrix) representing the multiple communications links between the multiple antennas. For example, for a system with two transmit antennas (TX1 and TX2) and two receive antennas (RX1 and RX2), the channel matrix may be written as:

$$\mathbf{H} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix},$$

where h_{11} corresponds to the channel response between TX1 and RX1, h_{12} corresponds to the channel response between TX2 and RX1, h_{21} corresponds to the channel response between TX1 and RX2, and h_{22} corresponds to the channel response between TX2 and RX2.

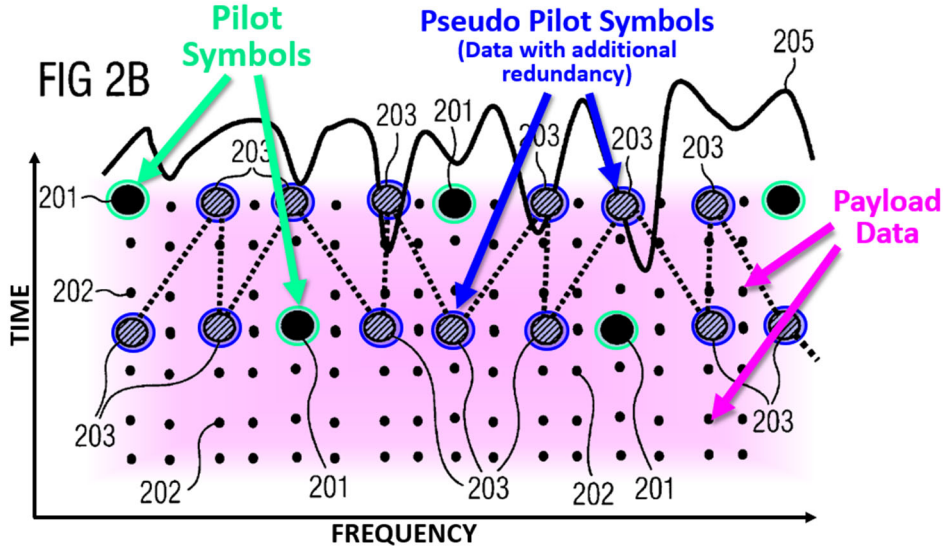
d. Element 1[c]: receiving replicated data from multiple data streams transmitted over the communications channel;

96. Haustein teaches or suggests Element 1[c].

97. Haustein teaches or suggests the claimed “replicated data” in the form of “additional redundancy” provided for certain payload data in a first transmission that is pre-designated to be repurposed as pilot data in a potential retransmission, further described below. Ex-1005 ¶¶48, 59. The entire data stream (already including replicated data) is then duplicated using Alamouti block coding such that the first transmission is sent through the communications channel via two separate transmit antennas in two separate streams, as also described in more detail below.

(1) Replication Though Additional Redundancy

98. Haustein’s first transmission is depicted in Figure 2B, annotated below.



99. This first transmission includes pilot symbols 201 (green) and payload data 202 (black) and 203 (blue). Ex-1005 ¶48. Payload data 202 are “normal payload data” (*id.*), while redundant payload data/pseudo-pilot data 203 are “payload data which are intended to be handled as pilot signals or reference signals in a retransmission.” *Id.* To ensure that they can be decoded successfully, these “additional reference [or pilot] signals [203] are ***transmitted already in the first transmission with a higher redundancy*** so that they can be used as pseudo reference [or pilot] signals in a potential retransmission.” *Id.*; *see also*:

In a first step 401 data signals of a data packet are determined which are intended to represent pseudo pilot signals and additional[] redundancy is added to the respective data signals or data bins. Then the encoded data packet is transmitted 402 comprising a sparse pilot grid, normal data signals and the pseudo pilot signals.

Id., ¶59.

The method (400) according to claim 1, further comprising:
predetermining (401) the some of the payload data which are intended

to be sent as pilot data in the retransmission before the data packet is transmitted the first time.

Id., Cl. 6.

100. Haustein explains that the “‘normal data,’ [202] i.e., the payload data not intended for improvement of the channel estimation,” is transmitted such that “the additional amount of redundancy is small or zero to minimize the overhead.” Ex-1005 ¶51. But the redundant payload data/pseudo-pilot data 203 is sent with “additional redundancy” that “allows the receiver to decode the data bins intended as ‘pseudo reference [or pilot] signals’ (RS) with high accuracy so that they can be used for an improved channel estimation.” *Id.* This “strong redundancy” of the data (203) designated as pseudo-pilot symbols “makes out of the firstly unknown data bins known data, which is basically the main feature of pilots, i.e., that they are known transmit signals.” Ex-1005 ¶52.

101. A POSITA would have recognized that the redundancy in redundant payload data/pseudo-pilot data 203 can be achieved by repeating certain data symbols in frequency and/or in time. In particular, as I explained in the Background, diversity schemes were well-known that relied on the transmission of redundant data at different frequencies and/or times. *See, e.g.*, Ex-1031, 0001. I have illustrated examples of such redundancy in annotated Figure 2B, below. The red shading of certain redundant payload data/pseudo-pilot data 203 is intended to show repeated symbols, separated (horizontally) in frequency or (vertically) in time, and the yellow

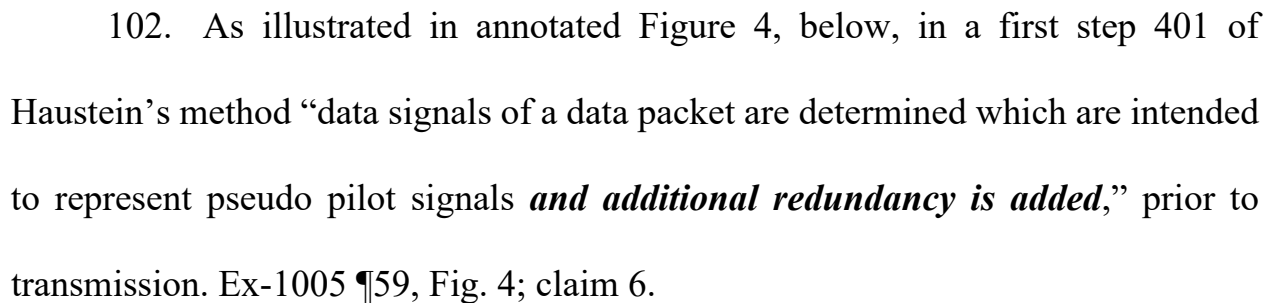
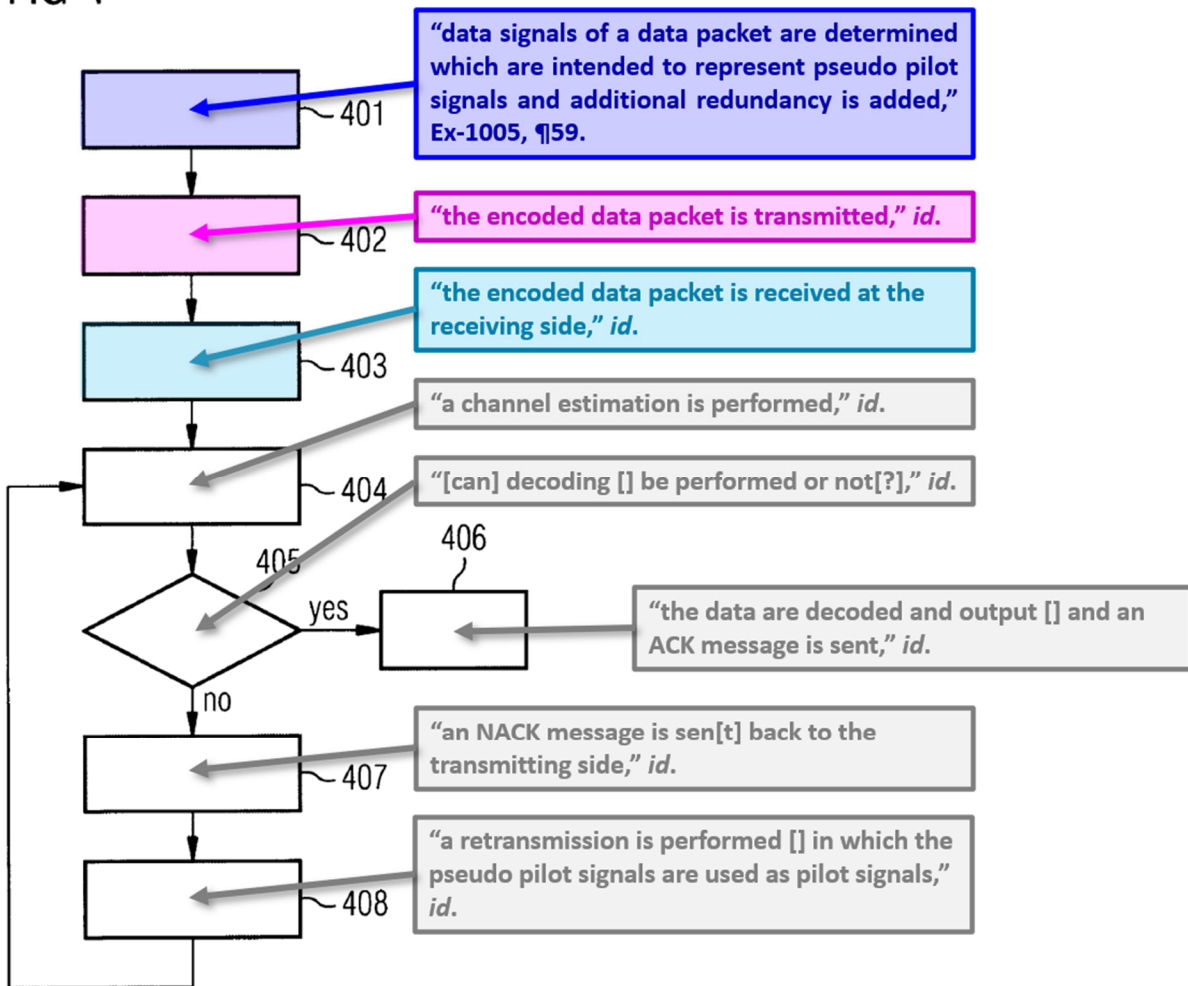


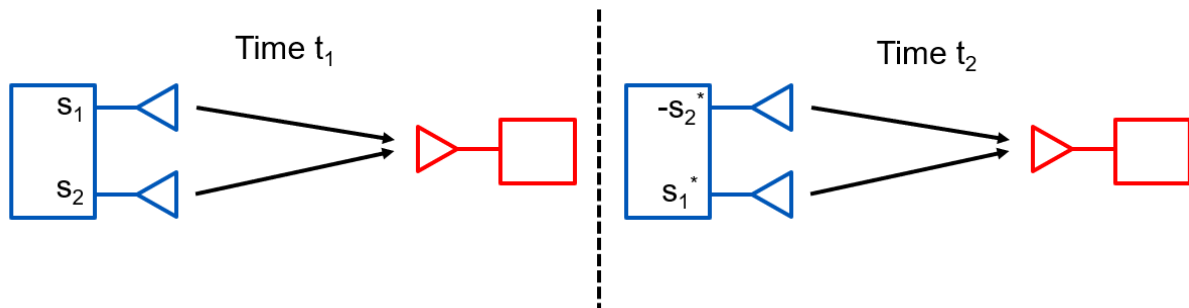
FIG 4



(2) Transmission Over Two Streams

103. Haustein teaches that the redundant data discussed above is transmitted over the communication channel in multiple data streams. Haustein uses “Alamouti processing ... to insert extra diversity ... e.g., on a second subcarrier or by using a second antenna element.” Ex-1005 ¶38. A POSITA would have understood that Alamouti processing is an example of space-time or space-frequency block coding, a technique whereby two copies of a data stream are transmitted across two antennas for improved reliability since the same data is sent over two spatially separated

streams. Indeed, as I explained in the Background section, Alamouti coding was a well-known scheme to achieve transmit diversity. *See, e.g.*, Ex-1023; Ex-1025, 0539. The diagram below shows Alamouti space-time block encoded transmission of data symbols s_1 and s_2 from a transmitter (blue) with two antennas to a receiver (red) with one antenna.⁴ At time t_1 , symbol s_1 is transmitted over the first antenna and symbol s_2 is transmitted over the second antenna. At time t_2 , the negative complex conjugate of symbol s_2 ($-s_2^*$) is transmitted over the first antenna, and the complex conjugate of s_1 (s_1^*) is transmitted over the second antenna.



104. This is no different from the Alamouti space-time block coding described in the '331 patent, which describes this technique as “known in the art.” Ex-1001, 1:42-49. Accordingly, Haustein teaches both adding redundant data into a data packet transmitted by a first antenna of transmitter/encoder 304 (a first data

⁴ Note that a receiver (red) with two antennas could also be used. In particular, in his paper describing Alamouti space-time block coding, in addition to describing the scheme for two transmit antennas and a single receive antenna, Alamouti also describes the case “of two transmit and two receive antennas.” Ex-1023, 0004.

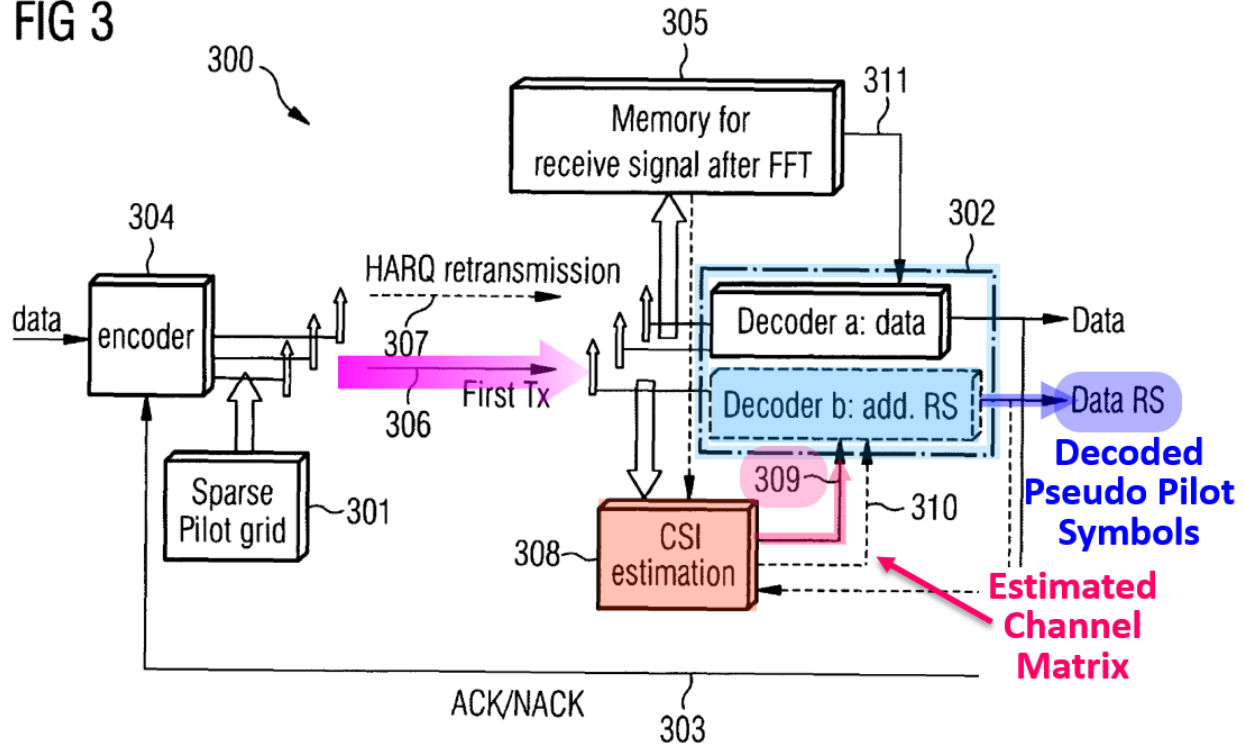
stream), and also sending that data (including the redundant data) via a second data stream transmitted by a second antenna of transmitter/encoder 304 using Alamouti block coding, and then receiving both streams at Haustein's receiver/decoder 302. *See* Ex-1005 ¶38, Fig.3.

e. Element 1[d]: decoding the replicated data using the estimated channel matrix;

105. Haustein teaches or suggests Element 1[d].

106. As explained for Element 1[b], the pilot signals that are received in first transmission 306 “are used for generation of a Channel State Information (CSI) 308” (Ex-1005 ¶50), or in other words, to generate a channel estimate (“estimated channel matrix”). Haustein teaches that “[t]he estimated channel state is then used in the decoding which is indicated by the arrows 309 and 310,” as illustrated in annotated Figure 3, below. *Id.* As explained above for Element 1[c], first transmission 306 includes the claimed “replicated data” (redundant payload data/pseudo-pilot data 203) because certain payload data intended as potential pseudo pilot data is replicated within the first transmission and then coded and transmitted as two streams over two antennas using Alamouti block coding.

FIG 3



107. During decoding, decoder 302 uses the channel estimate 309 to decode the redundant payload data/pseudo-pilot data 203 (designated as “additional reference [or pilot] signals” (Ex-1005 ¶48)) that are included in first transmission 306, as illustrated above. Ex-1005 ¶50 (“The estimated channel state is then used in the decoding which is indicated by the arrows 309 and 310.”). Thus, the replicated data (redundant payload data/pseudo-pilot data 203) is decoded using the estimated channel matrix.

- f. **Element 1[e]: generating an updated estimate of the channel matrix based, at least in part, on the replicated data; and**

108. Haustein teaches or suggests Element 1[e].

109. In case the first transmission cannot be fully decoded, “the data block is retransmitted using additional pilot signals which are formed by payload data of the original transmission.” Ex-1005 ¶22. This retransmission occurs when a “CRC,” or “Cyclic Redundancy Check” on the received data fails, indicating the presence of errors. Ex-1005 ¶49. A CRC is a cyclic error correcting code that is used to detect errors in a transmission.⁵ At a high level, this is done in the following manner: At the transmitter, the CRC algorithm is used to generate a checksum, which is a fixed-size value derived from the data being transmitted. The checksum is then appended to the data, and transmitted along with it. Upon receiving the transmission, the receiver performs the same CRC algorithm on the received data and compares the calculated checksum with the received one. If they match, the receiver assumes that the data was transmitted correctly. Otherwise, if the calculated checksum does not match the received checksum, the receiver assumes that errors have occurred during the transmission.

110. Haustein’s statement that “decoding cannot be performed,” thus does not mean that decoder 302 was unable to decode redundant payload data/pseudo-pilot data 203, but simply that error(s) were present (as indicated by the mismatch between the checksum calculated at the receiver and the received checksum), such that *some* of the received data was not properly decoded. Indeed, the additional

⁵ See https://en.wikipedia.org/wiki/Cyclic_redundancy_check.

redundancy provided to redundant payload data/pseudo-pilot data 203 in first transmission 306 is used to ensure that such data 203 *is likely to have been properly decoded*, thereby transforming decoded data 203 into “known data ... the main feature of pilots.” Ex-1005 ¶52. Thus, despite some payload decoding errors, the redundant data 203 is correctly decoded with high probability and is available for channel estimation as pseudo pilot symbols.

111. Indeed, it was well-known in systems implementing HARQ, that some data symbols transmitted within a first data block may be successfully decoded even though the decoder is unable to successfully decode the entire data block. For example, as I described in the Background, Fei discloses a method for improved channel estimation in a system employing the HARQ technique, in which data symbol hypotheses obtained for a first data block are “used as known reference symbols similar to pilot symbols” when determining the channel response for a second data block, that corresponds to a requested retransmission of the first data block, following unsuccessful decoding of the first data block. Ex-1033, ¶¶15-17.

112. And, as Haustein explains, adding redundancy is one of several methods Haustein discloses to ensure that redundant payload data/pseudo-pilot data 203 of first transmission 306 is properly decoded for use at the receiver as known pilot signals to decode retransmission 307. For example, Haustein also discloses using specific modulation schemes for this data:

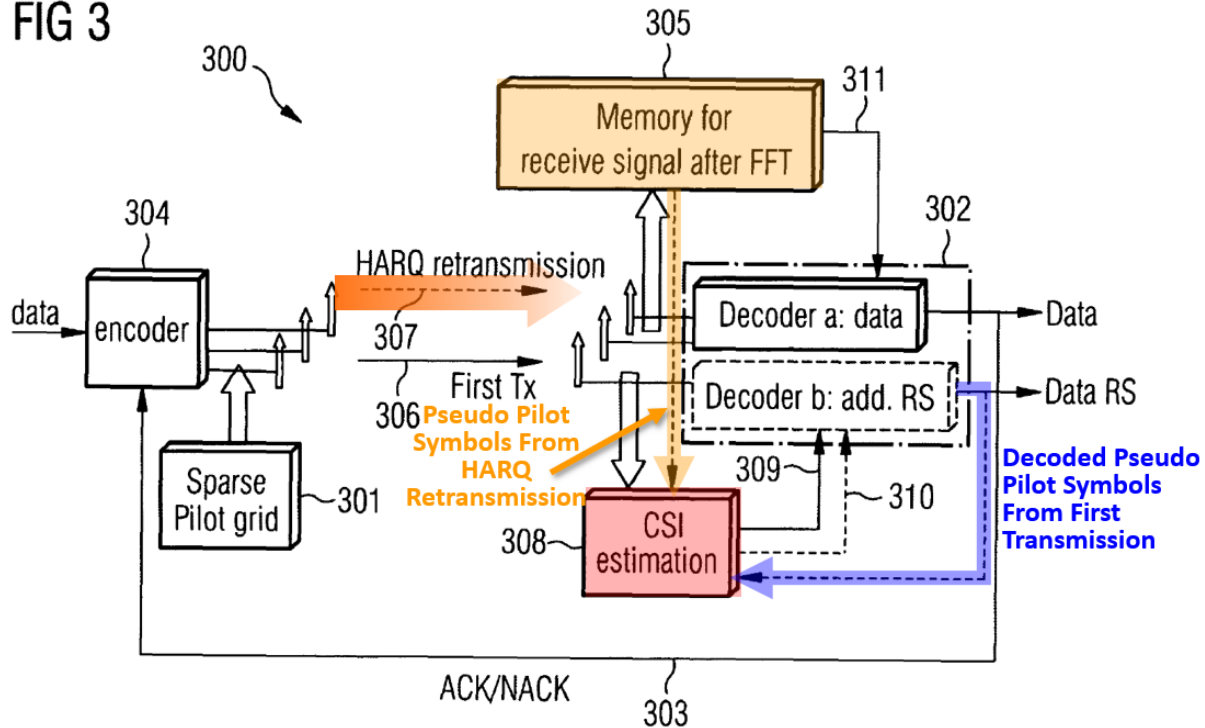
According to another exemplary embodiment the method further comprises predetermining the some of the payload data which are intended to be sent as pilot data in the retransmission before the data packet is transmitted the first time. In particular, QAM4 modulation schemes may be used for transmitting of the predetermined payload data intended to be sent as pilot data in the retransmission.

By predetermining specific payload data as possible candidates for converted payload data, i.e. additional pilot data, for a retransmission it may be possible to use specific modulation schemes, e.g. QAM4 modulation schemes, for the respective payload data intended as possible further reference or pilot signals already at the original or first transmission, which may ensure that the respective future reference signals are transmitted with increased or maximum power, possibly leading to the effect that the channel estimation may be eased or ensured.

Ex-1033, ¶¶32-33.

113. Upon CRC failure, the first transmission is retransmitted as retransmission 307. Retransmission 307 includes the same pilot 201 and data 202/203 symbols as the first transmission 306 and is also sent over two antennas via Alamouti block coding. Ex-1005 ¶¶38, 50. CSI estimation block 308 uses the decoded redundant payload data/pseudo-pilot data 203 of first transmission 306 (“replicated data”) as known pilot symbols to generate an updated channel estimate (“updated estimate of the channel matrix”) to decode retransmission 307, as shown in Figure 3. Ex-1005 ¶50 (“in the case of retransmission the pilots of the original sparse pilot grid [201] and the pseudo pilot signals [203] are used in the CS[I] estimation and thus for the decoding.”); *id.* ¶¶51-52.

FIG 3



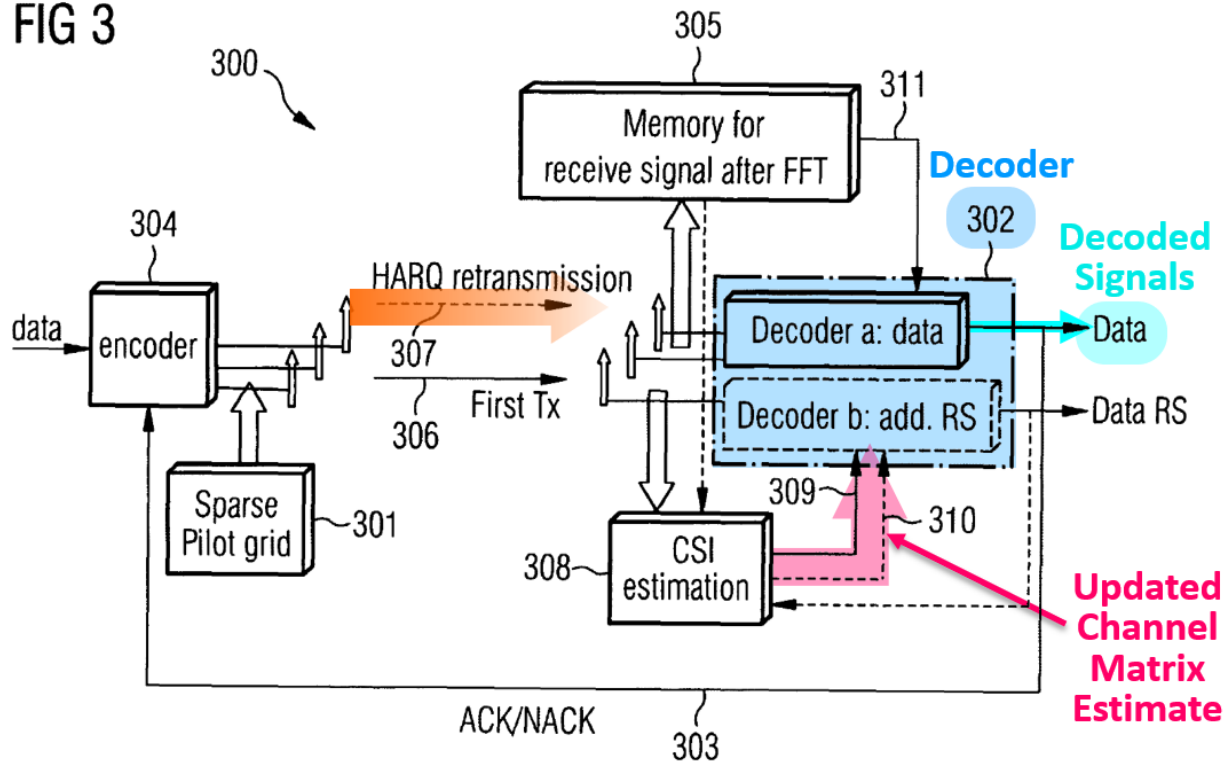
114. Thus, an updated estimate of the channel matrix is based, at least in part, on the redundant payload data/pseudo-pilot data 203 received in the first transmission 306.

- g. **Element 1[f]: decoding subsequently received signals over the communications channel using the updated estimate of the channel matrix.**

115. Haustein teaches or suggests Element 1[f]. As illustrated in annotated Figure 3, below, CSI estimation block 308 provides the updated estimate of the channel matrix to decoder 302, which uses it to decode retransmission 307, which comprises subsequently received signals that arrive at the receiver after first transmission 306, which includes the replicated data. *See also* Ex-1005 ¶51 (use of the “pseudo reference signals” provides an “improved channel estimation, which in

turn will increase the decoding probability of the rest of the data bins significantly”). Thus, the updated estimate of the channel matrix is used to decode subsequently received signals over the communication channel, teaching or suggesting Element 1[f].

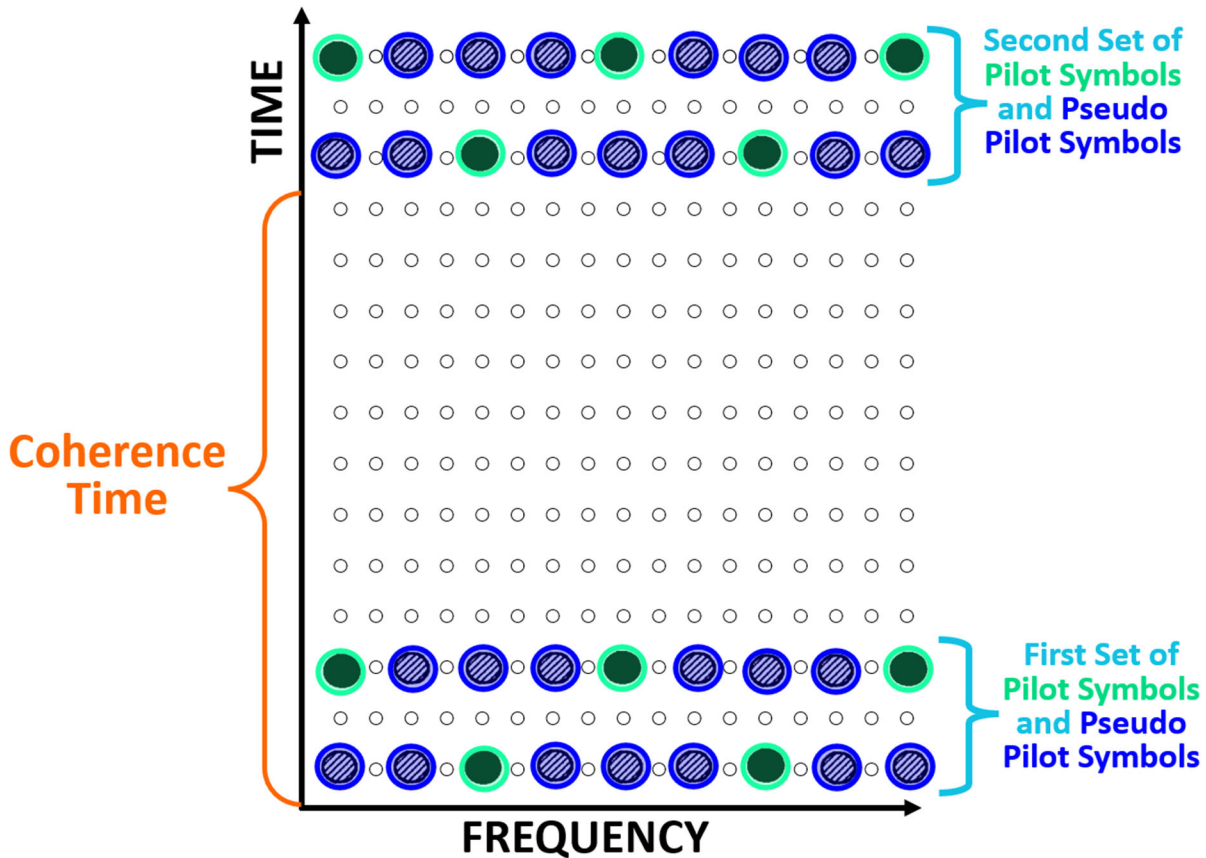
FIG 3



Although not required by the claim, Haustein also teaches or suggests using the updated channel estimate to decode additional subsequently received signals. For example, Haustein discloses inserting the sparse pilot grid into the data packet “with certain spacing in time.” Ex-1005 ¶3. Haustein also explains that the spacing in time between sets of pilot signals depends on the channel “coherence time.” *Id.* As I explained in the Background section, it was well-known that the channel “coherence time” is the time during which the channel does not vary, such that a single channel

estimate may be used to decode the data received over the channel during that time.

As I also explained in the Background section, the spacing between pilot symbols is typically chosen by balancing the competing concerns of improving the accuracy of the channel estimation and reducing pilot overhead. *See, e.g.*, Ex-1032, 1:62-2:3; Ex-1033, ¶4. Thus, for a slowly fading channel (i.e., a channel with a large coherence time), a POSITA would have recognized that both of these competing concerns may be addressed by setting the spacing between pilot grid transmissions large enough to enable the transmission of payload-only data between pilot grid transmissions (thereby reducing the pilot overhead), but small enough so as to be less than the channel coherence time (thereby ensuring reliable channel estimation), as illustrated in the image below. *See, e.g.*, Ex-1027, 0002-0003 (explaining that for channels with “a large coherence time,” “several data symbols can be transmitted” between transmissions that include pilot symbols, “reducing the impact of the pilot symbols in the system throughput”).



116. In particular, as illustrated in the diagram above, a first set of pilot / pseudo-pilot symbols at the bottom is followed by several sets of data and then and a second set of pilot / pseudo-pilot symbols. The two sets of pilots are separated by Haustein's "certain spacing in time," which is chosen to be less than or equal to the estimated channel coherence time, over which the channel is assumed not to be varying (i.e., the channel matrix is assumed not to change). Thus, after estimating the channel matrix using the first set of pilot symbols (and potentially re-estimating it based on a retransmission), that estimated channel matrix is used to decode

subsequently received data symbols for a period of time less than or equal to the channel coherence time, until the next set of pilot symbols is received.

117. Accordingly, a POSITA would have recognized that, for a slowly varying channel (i.e., a channel with a large coherence time), the updated estimate of the channel matrix determined using the pilot symbols and pseudo pilot symbols in retransmission 307 will be used not only to decode retransmission 307, but also subsequently received signals (until a new grid of pilot symbols is received).

118. Thus, Haustein renders claim 1 obvious.

2. Dependent Claim 2: The method of claim 1 wherein said decoding the replicated data comprises using a joint detection technique.

119. Haustein teaches or suggests Claim 2.

120. As explained for Elements 1[c]-[d], Haustein's redundant payload data/pseudo-pilot data 203 corresponds to "replicated data." Haustein explains this data may be transmitted and received using "Alamouti processing." Ex-1005 ¶38. A POSITA would have understood that Alamouti block decoding is a joint detection technique. For example, U.S. Patent No. 8,126,408 describes several examples of "joint detection method[s]," including Alamouti block decoding:

Output module 56 accepts the received signals from receivers 52A and 52B, and performs joint detection of DATA1 and DATA2. Any suitable **joint detection method** can be used for this purpose. For example, the output module may apply **Maximum Ratio Combining (MRC)**. Alternatively, the system may use a Space-Time Trellis Code (STTC).... Further alternatively, a **Space-Time Block Code (STBC)**

can be used. **STBCs are described, for example, by Alamouti** in “A Simple Transmit Diversity Technique for Wireless Communication.” IEEE Journal on Select Areas in Communications, volume 16, number 8, October 1998, pages 1451 1458, which is incorporated herein by reference. Alternatively, module 56 may use **any other suitable joint detection method**. Module 56 reconstructs the original input data sequence from DATA1 and DATA2, and provides the data sequence as output.

Ex-1024, 8:4-24.

Moreover, as explained for Element 1[c], Haustein teaches that data is replicated through the inclusion of additional redundancy. A POSITA would have understood that receiving Haustein’s replicated data symbols would have involved “maximal ratio combining” them. *See, e.g.,* Ex-1024, 8:4-24 (describing the maximal ratio combining technique). The ’331 Patent also specifically identifies this as a “joint detection technique” (Ex-1001, 10:28-30). In particular, the ’331 Patent states that “a joint detection technique is used to decode the replicated data, *such as max-ratio combining.*” *Id.*

121. Thus Haustein teaches or suggests the replicated data is decoded using a joint detection technique.

3. **Dependent Claim 3: The method of claim 1, wherein said decoding the replicated data comprises using a space-time block decoding technique. / Dependent Claim 4: The method of claim 1, wherein said decoding the replicated data comprises using a space-frequency block decoding technique.**

122. Haustein teaches or suggests Claims 3-4. As explained for claim 2, above, Haustein teaches or suggests decoding replicated data using Alamouti

decoding. Ex-1005 ¶38. A POSITA would have understood that Alamouti processing is an example of space-time or space-frequency block coding. In particular, Alamouti's paper describes both "space-time coding," where "the encoding is done in space and time," as well as "space-frequency coding," where "two adjacent carriers may be used." Ex-1023, 0002-0003.

123. At the receiver, Alamouti block decoding would be performed to combine the redundant copies, helping to ensure that the "pseudo reference signals" are decoded "with high accuracy." Ex-1005, ¶51. In particular, Alamouti explains that, at the receiver, the "combined signals are then sent to the maximum likelihood detector," with "[t]he resulting combined signals [being] equivalent to that obtained from two-branch MRRC [(maximal-ratio receiver combining)]." Ex-1023, 0004.

4. Dependent Claim 5: The method of claim 1, wherein the replicated data includes same data symbols in multiple data streams.

124. Haustein teaches or suggests Claim 5. As explained for Element 1[c], Haustein teaches "replicated data" in the form of "additional redundancy" provided for redundant payload data/pseudo-pilot data 203 included in a data packet transmitted in a data stream of first transmission 306. Ex-1005 ¶¶48, 59 (same). As also explained for Element 1[c], Haustein teaches the use of Alamouti block coding (Ex-1005 ¶38) to transmit two copies of the data stream (already including replicated data), using two transmit antennas. A POSITA would have understood that Alamouti

block coding is an example of space-time or space-frequency block coding, a technique whereby multiple copies of a data stream are transmitted across multiple antennas for improved reliability. Ex-1025, 0539 (describing Alamouti block coding as an example in which redundancy is introduced “by sending from each transmit antenna a differently encoded (and fully redundant) version of the same signal”).

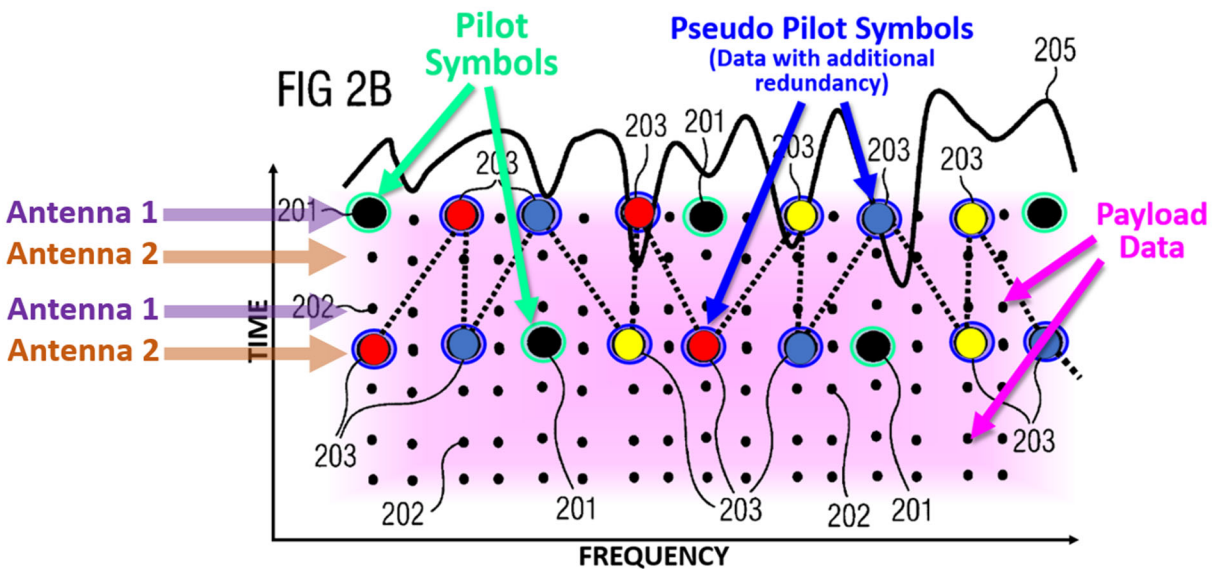
Indeed, the '331 Patent describes Alamouti coding as “known in the art”:

Block coding techniques may be used in communication systems to encode data and transmit multiple data streams over a communications channel, which may improve the reliability of data transfer. Block coding techniques include space-time block coding, which may transmit multiple data streams across multiple antennas. **Alamouti space time block coding** is one particular type of space-time block coding known in the art. Space-time block coding techniques may require that the communications channel be constant during consecutive data transmission times, which may not always be advantageous. Another type of block coding technique is space-frequency block coding. **Alamouti space-frequency block coding** is one particular type of space-frequency block coding known in the art. Space-frequency block coding techniques may require that different frequencies experience similar communications channel properties, which may be more advantageous in some cases.

Ex-1001, 1:42-58.

125. To see how Haustein meets this claim, consider the application of Alamouti space-time block coding using two antennas to the data illustrated in annotated Figure 2B. At any given time, the Alamouti code will be sending a symbol “S1” over one antenna and a symbol “S2” over the other antenna. Prior to space-time coding, the symbol “S1” will be an odd-indexed symbol in time, while “S2”

will be an even-indexed symbol in time. Thus, because the red data 203 is included in both the top row (odd-indexed in time), and the fourth row (even-indexed in time) it would be transmitted on both the first antenna and on the second antenna. Since each antenna corresponds to a stream, it follows that the same data symbol is sent over two streams. As can be seen below, using the colored examples, red, blue, and yellow data is sent at least once in each data stream sent to each antenna.



126. Accordingly, Haustein teaches or suggests sending first transmission 306, which includes redundant payload data/pseudo-pilot data 203, over each of two spatially separated data streams, each transmitted over a separate antenna such that both data streams include same replicated data symbols.

127. Thus, Haustein renders claim 5 obvious.

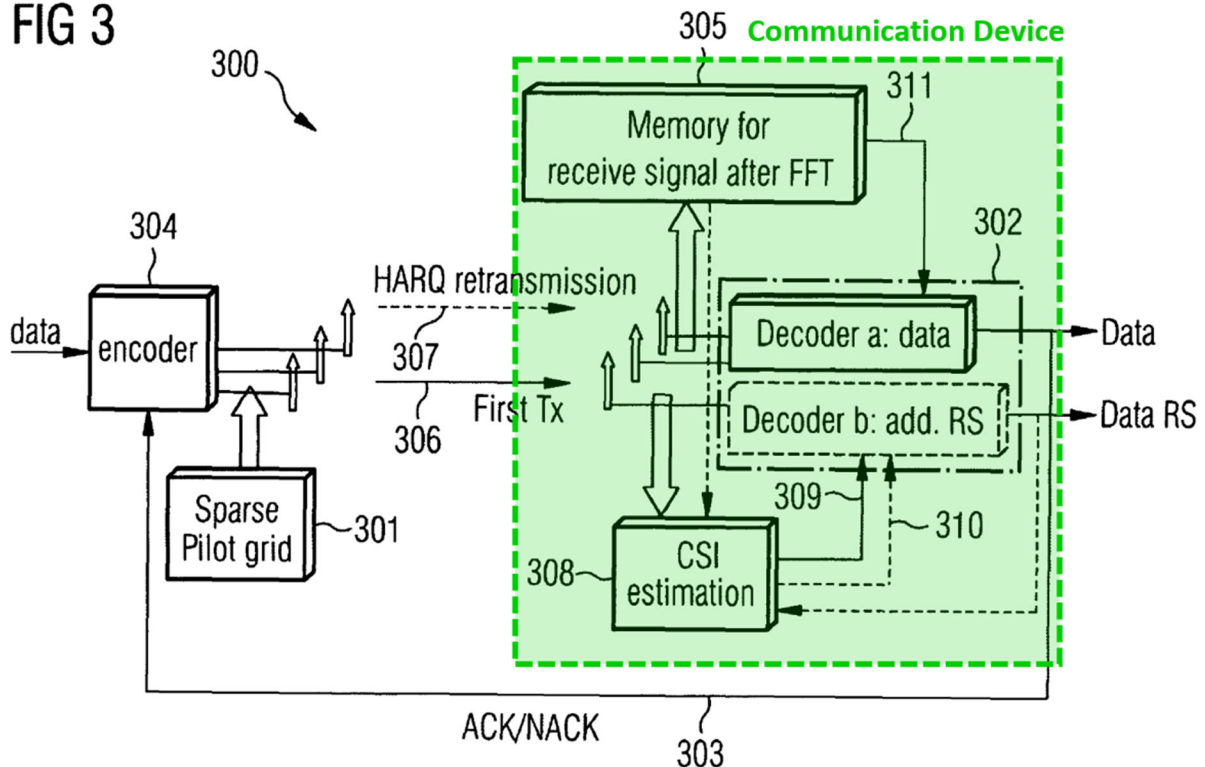
5. Independent Claim 6:

a. Element 6[pre]: A communication device comprising:

128. Haustein teaches or suggests the preamble, to the extent it is limiting.

129. Haustein's "receiving device [] adapted to receive a data packet" transmitted by a "sending device" (Ex-1005, Cl. 13) is a "communication device," as illustrated in annotated Figure 3, below.

FIG 3

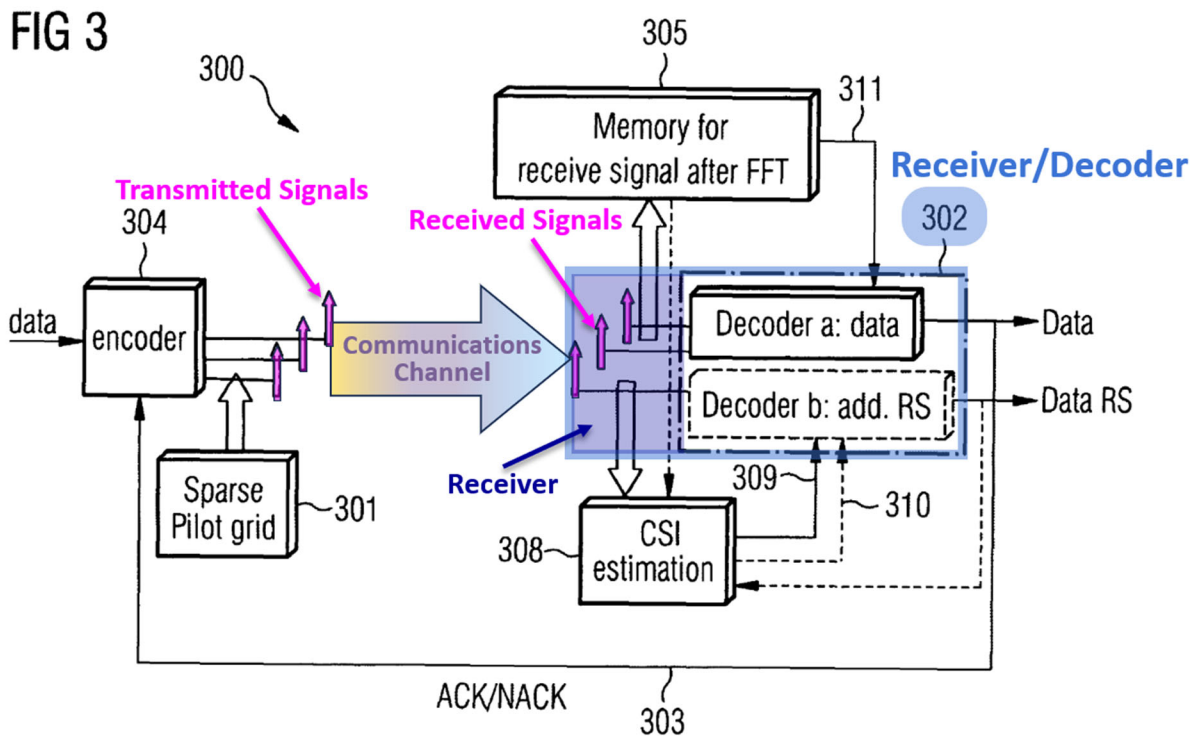


b. Element 6[a]: a receiver configured to receive signals over a communications channel,

130. Haustein teaches or suggests Element 6[a]. In particular, the pilot symbols 201 and redundant payload data/pseudo-pilot data 203 of Haustein's first

transmission 306 correspond to the claimed “receive[d] signals.” Ex-1005 ¶¶49 (receiver/decoder 302); Fig. 3.

131. Haustein discloses a receiver/decoder 302 configured to receive signals transmitted by transmitter/encoder 304 over a “communications channel” between the receiver/decoder and the transmitter/encoder, as illustrated in annotated/excerpted Figure 3, below. *See also* Ex-1005 ¶¶39, 59.



- c. **Element 6[a][i]: wherein the signals are based at least in part on first and second data streams transmitted over a communications channel,**

132. Haustein teaches or suggests Element 6[a][i]. As explained for Element 1[c], Haustein’s transmitter/encoder 304 uses two transmit antennas to transmit two data streams to receiver/decoder 302, by using “Alamouti processing ... to insert

extra diversity ... e.g., on a second subcarrier or by using a second antenna element.”

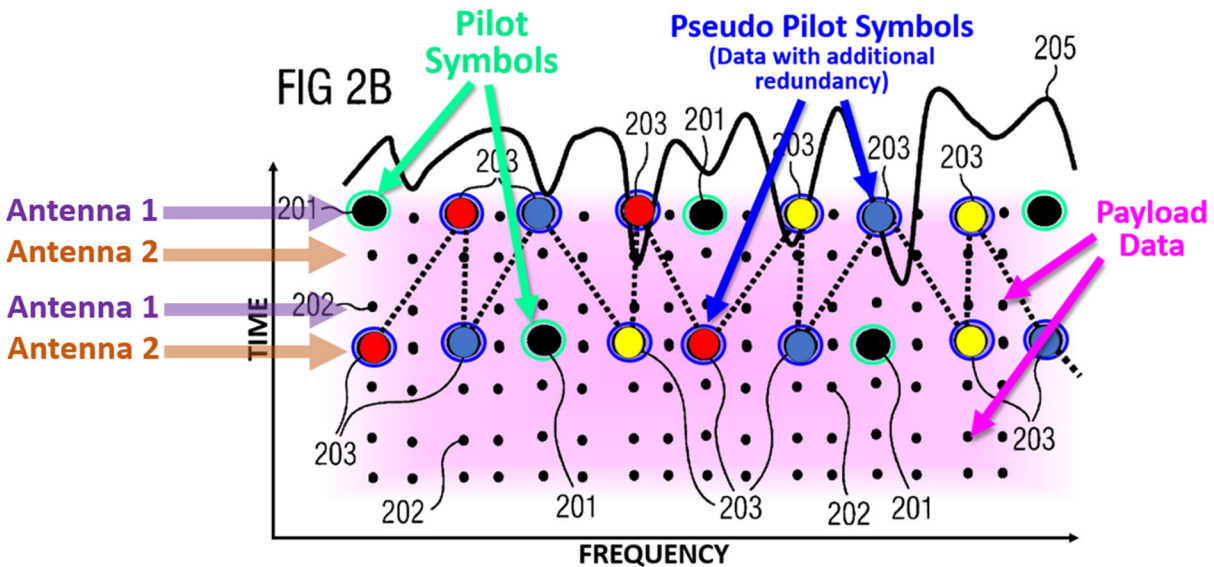
Ex-1005 ¶38.

d. Element 6[a][ii]: wherein the second data stream includes at least one data symbol replicated from the first data stream;

133. Haustein teaches or suggests Element 6[a][ii]. Haustein’s redundant payload data/pseudo-pilot data 203 in transmission 306 corresponds to the claimed at least one data symbol.

134. As explained for Element 1[c], first transmission 306 of a data packet includes a set of “pseudo pilot signals” 203 corresponding to replicated data signals that are pre-designated to be used as known pilot symbols in a potential subsequent retransmission. Ex-1005 ¶¶50-51. As explained for Element 6[a][i], this stream including replicated data is Alamouti space-frequency block coded to create two streams transmitted over separate antennas as transmission 306. Ex-1005 ¶38 (“Alamouti processing may be used to insert extra diversity ... e.g., on a second subcarrier or by using a second antenna element.”).

135. Alternatively, if Alamouti space-time block coding is to be used, Haustein’s symbol grid shows that symbols are repeated in the first and fourth rows. If odd rows, under Alamouti space-time block coding, are transmitted on the first antenna, even rows will be transmitted on the second antenna, so data symbols replicated from the first stream will also be transmitted on the second stream.



136. In particular, as can be seen in annotated Figure 2B, above, because the red data 203 is included in both the top row (odd-indexed in time), and the fourth row (even-indexed in time) it would be transmitted on both the first antenna and the second antenna. Thus, the second data stream includes at least one data symbol replicated from the first data stream when Alamouti space-time block coding is applied.

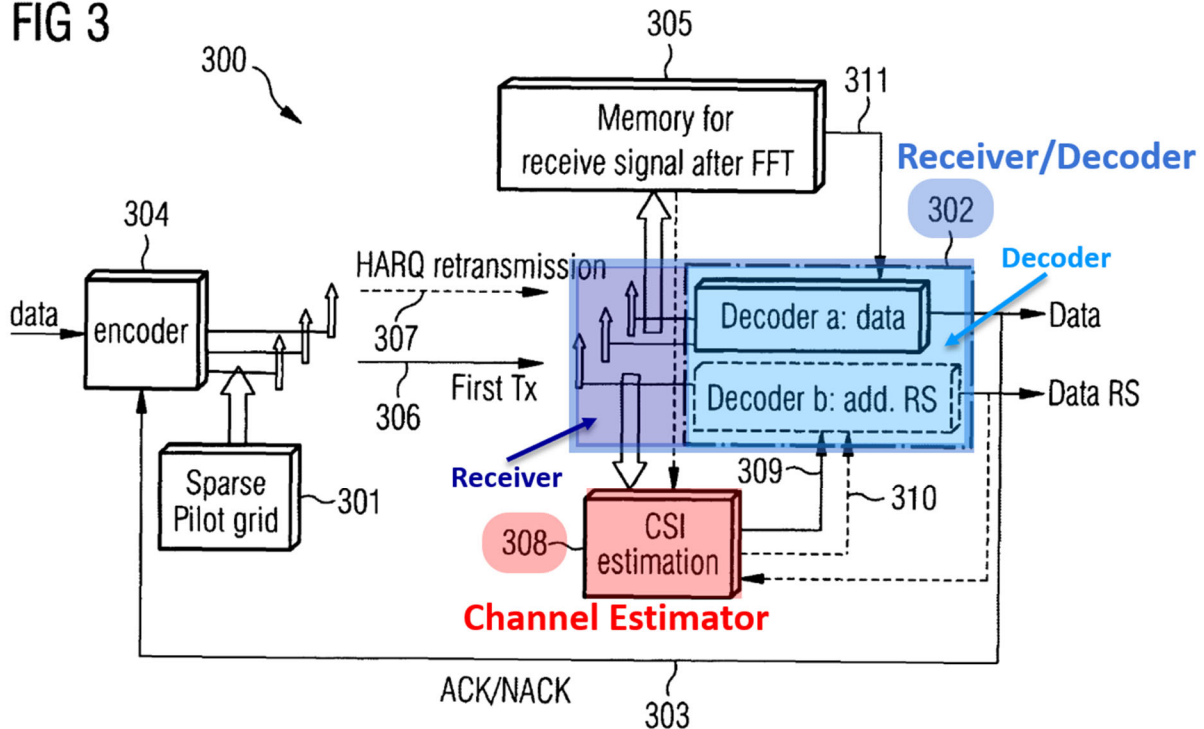
- e. **Element 6[b]: a decoder coupled to the receiver and the channel estimator, wherein the decoder is configured to receive the received signals and decode the at least one data symbol replicated from the first data stream;**

137. Haustein teaches or suggests Element 6[b].

138. As illustrated in annotated Figure 3, below, Haustein's receiving device includes a decoder (light blue) coupled to a receiver (dark blue), and a channel estimator (red). Received signals "are stored in a memory 305" and then provided to

decoder 302 for decoding, demonstrating the coupling between the receiver and the decoder. Ex-1005 ¶50. Such decoding is performed using an estimated channel state 309/310 determined by CSI estimation 308 (“channel estimator”), demonstrating the coupling between the decoder and the channel estimator. Ex-1005 ¶50.

FIG 3



139. As explained for claim elements 1[b]-1[d], above, the redundant “pseudo pilot signals” 203 replicated from the first to second Alamouti stream are received and decoded by Haustein’s receiver and decoder 302. Ex-1005 ¶51 (“[t]his allows the receiver to decode the data bins intended as ‘pseudo reference [or pilot] symbols’ (RS) with high accuracy.”).

f. Element 6[c]: a channel estimator coupled to the decoder and the receiver,

140. Haustein teaches or suggests Element 6[c]. As explained for Element 6[b], Haustein's CSI estimation block 308 teaches or suggests a channel estimator coupled to decoder 302. CSI estimation block 308 is also coupled to the receiver, because it receives pilot signals (both pilot symbols 201 and redundant payload data/pseudo-pilot data 203 intended for use as known pilot signals in the retransmission), and uses them to generate estimated channel state 309/310, as explained for Elements 1[b] and 1[e]. *See also* Ex-1005 ¶50.

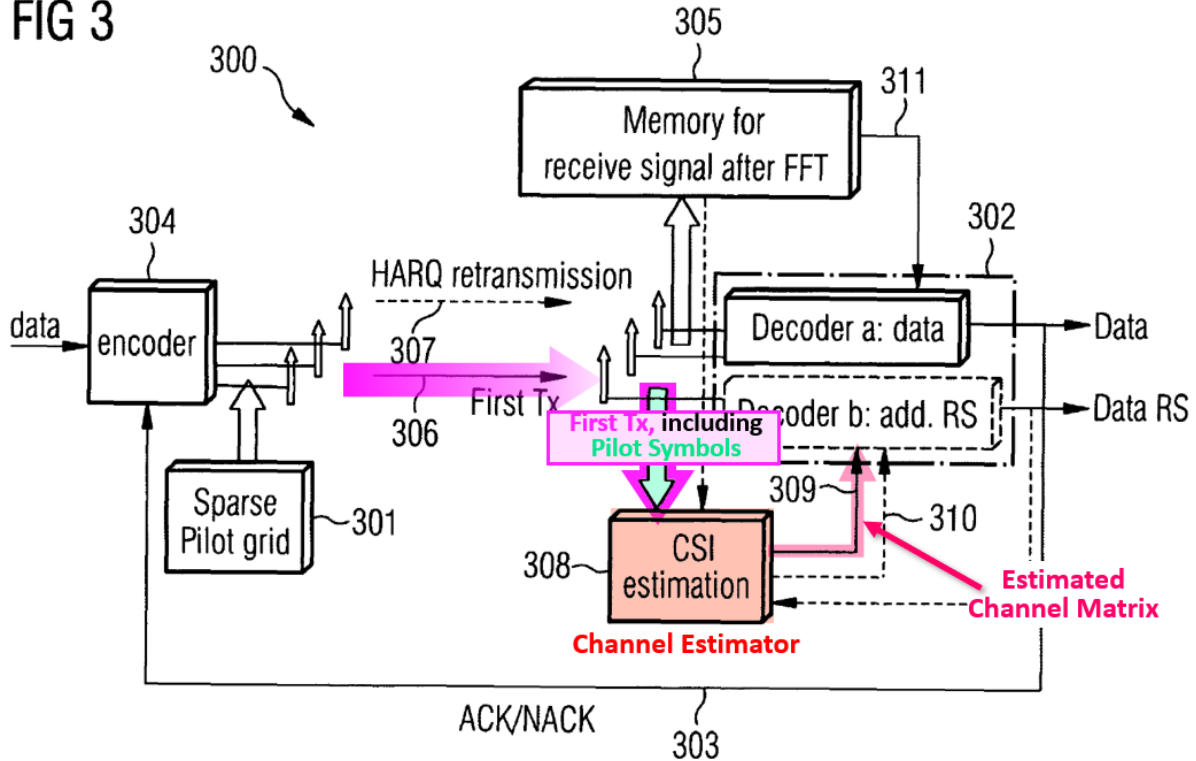
g. Element 6[c][i]: wherein the channel estimator is configured to receive the received signals and the decoded at least one data symbol,

141. Haustein teaches or suggests Element 6[c][i].

142. As explained for Element 6[a], the pilot symbols 201 and redundant payload data/pseudo-pilot data 203 of Haustein's first transmission 306 correspond to the claimed "received signals."

143. As illustrated in annotated Figure 1, below, Haustein's CSI estimation block 308 receives first transmission 306 and uses the pilot symbols 201 included within first transmission 306 to generate a channel matrix estimate, as explained for Element 1[b]. *See also* Ex-1005 ¶50. Thus, the channel estimator receives the "received signals."

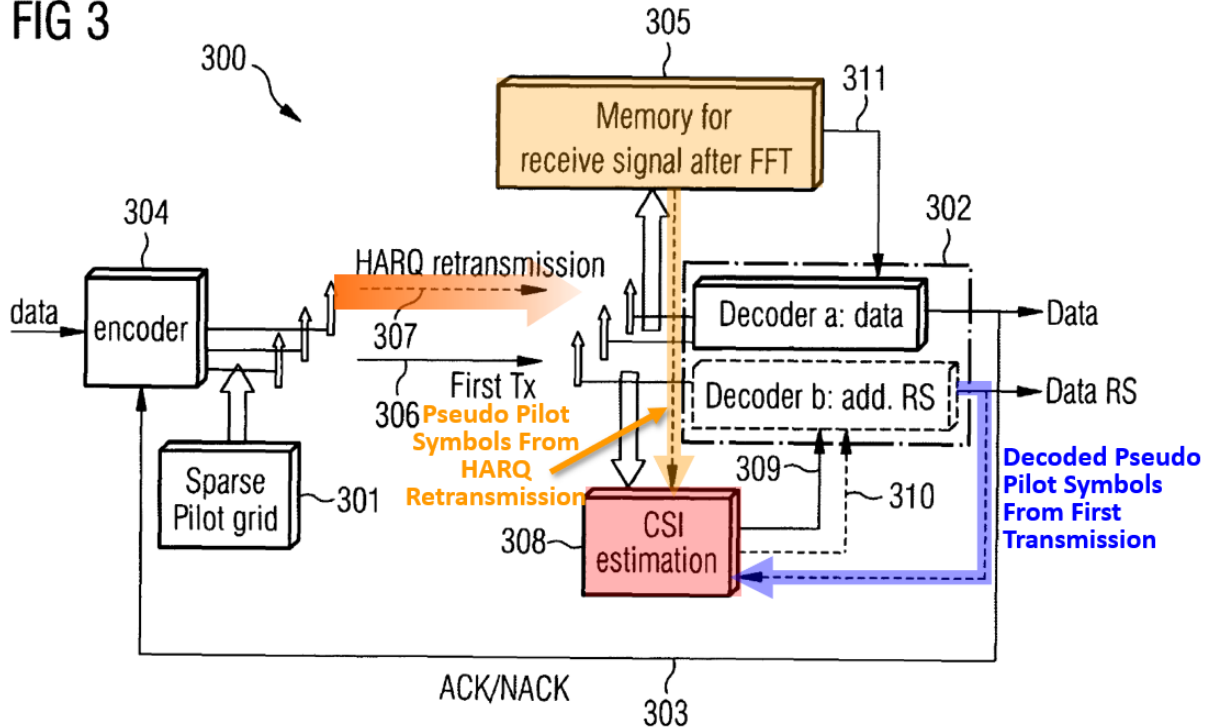
FIG 3



144. As explained for Element 6[b], the decoded redundant payload data/pseudo-pilot data 203 of first transmission 306 correspond to the claimed “decoded at least one data symbol.” In particular, as explained for Element 6[b], decoder 302 is used to decode the redundant payload data/pseudo-pilot data 203, which were transmitted with “additional redundancy” in transmission 306, enabling decoder 302 to decode them with “high accuracy.” Ex-1005 ¶51. As illustrated in annotated Figure 3, below, if decoder 302 determines that first transmission 306 cannot be fully decoded using the estimated channel matrix, these decoded redundant payload data/pseudo-pilot data 203 are then provided to CSI estimation

block 308 where they are used as known pilot symbols for retransmission 307, as explained for Element 1[e].

FIG 3



- h. Element 6[c][ii]: wherein the channel estimator is configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded at least one data symbol; and**

145. Haustein teaches or suggests Element 6[c][ii]. As explained for Element 6[b], the decoded redundant payload data/pseudo-pilot data 203 of first transmission 306 correspond to the claimed “decoded at least one data symbol.” As explained for Element 6[c], CSI estimation block 308 uses these redundant payload data/pseudo-pilot data 203 as “known data” references, in conjunction with the redundant payload data/pseudo-pilot data 203 received as part of retransmission 307,

to generate estimated channel state 310 (an estimate of the “channel matrix”) for use by decoder 302 in decoding retransmission 307, as described for Element 1[f].

146. That is, in response to receiving first transmission 306 (including “the received signals”), decoder 302 decides “whether the decoding can be performed or not.” Ex-1005 ¶59; *id.* ¶50 (similar). “In case a decoding cannot be performed ... a retransmission is performed 408 in which the pseudo pilot signals are used a pilot signals.” Ex-1005 ¶59. For the reasons explained in addressing Element 1[d], even though decoder 302 is unable to decode *all* of the received data, the decoder is assumed to be able to reliably decode redundant payload data/pseudo-pilot data 203 because of their added redundancy, in order to enable their use as known pilot signals for retransmission 307 such that the channel matrix estimate can be updated. Ex-1005 ¶59.

- i. Element 6[d]: wherein the decoder is further configured to decode subsequent received signals based, at least in part, on the estimate of the channel matrix.**

147. Haustein teaches or suggests Element 6[d], as explained previously for Element 1[f]. In particular, claim element 6[b] recites “the decoder is configured to receive the received signals,” which is met when the decoder receives Haustein’s first transmission 306. Haustein’s retransmission 307, thus, comprises “subsequent received signals,” recited in element 6[d], which are decoded based, at least in part, on the estimate of the channel matrix based, at least in part, on the “decoded at least

one data symbol,” recited in claim element 6[c][ii] and met by Haustein’s decoded redundant payload data/pseudo-pilot data 203.

148. This estimate of the channel matrix is also used to decode additional subsequently received signal that arrive during the coherence time period, as discussed with reference to Element 1[f], above.

149. Thus, Haustein renders claim 6 obvious.

6. Dependent Claim 7: The communication device of claim 6 wherein the decoder is configured to decode the at least one data symbol using a joint detection technique.

150. Haustein teaches or suggests Claim 7. As explained for Element 6[c][ii], Haustein’s redundant payload data/pseudo-pilot data 203 corresponds to the at least one data symbol. As explained for Claim 2, when this data is sent using Alamouti block coding (Ex-1005, ¶38), Alamouti block decoding will be applied at the receiver. A POSITA would understand Alamouti block decoding is a type of joint detection technique. For example, U.S. Patent No. 8,126,408 describes several examples of “joint detection method[s],” including Alamouti block decoding:

Output module 56 accepts the received signals from receivers 52A and 52B, and performs joint detection of DATA1 and DATA2. Any suitable **joint detection method** can be used for this purpose. For example, the output module may apply **Maximum Ratio Combining (MRC)**. Alternatively, the system may use a Space-Time Trellis Code (STTC).... Further alternatively, a **Space-Time Block Code (STBC)** can be used. **STBCs are described, for example, by Alamouti** in “A Simple Transmit Diversity Technique for Wireless Communication.” IEEE Journal on Select Areas in Communications, volume 16, number 8, October 1998, pages 1451 1458, which is incorporated herein by

reference. Alternatively, module 56 may use **any other suitable joint detection method**. Module 56 reconstructs the original input data sequence from DATA1 and DATA2, and provides the data sequence as output.

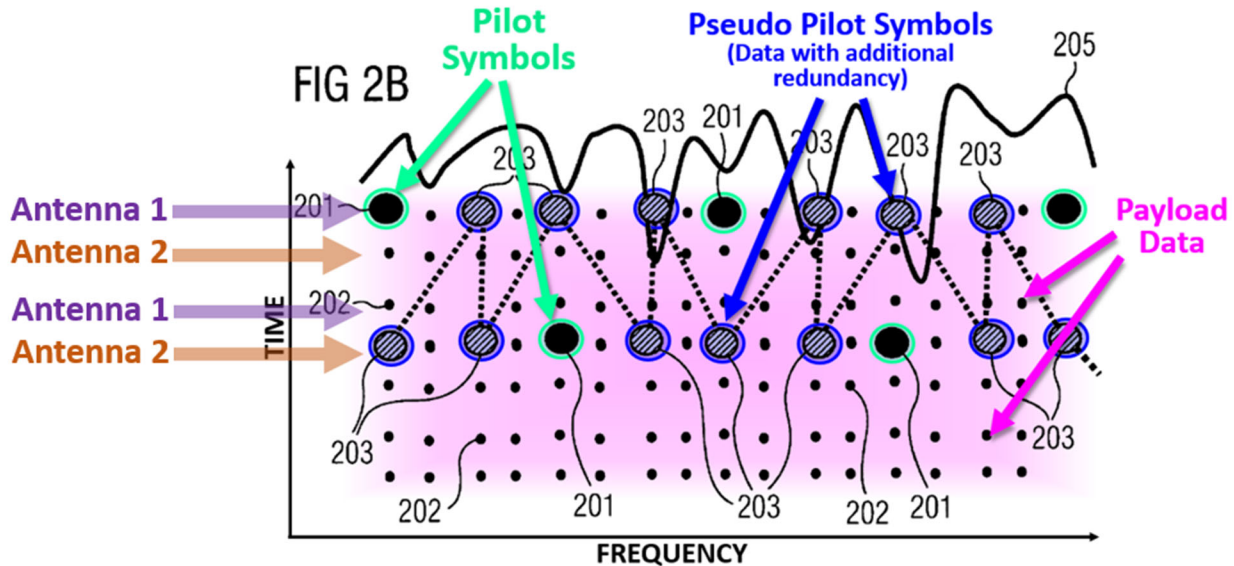
Ex-1024, 8:4-24.

7. Dependent Claim 8

- a. Element 8[a]: The communication device of claim 6 wherein the first and second data streams each further include at least one pilot symbol, and**

151. Haustein teaches or suggests Element 8[a].

152. As explained for Element 6[a][i], following Alamouti block coding, Haustein's first transmission 306, comprises first and second streams. Each stream of first transmission 306 includes at least one pilot symbol 201, as explained for Element 1[e]. In particular, because pilot symbols 201 are present in both odd (first) and even (fourth) rows of the symbol matrix shown in Figure 2B, below, Alamouti space-time block coding ensures they are transmitted in both the first and second data streams. Specifically, under Alamouti space-time block coding, if odd rows (in time) are transmitted on the first antenna, then even rows will be transmitted on the second antenna, such that rows 1, 3, 5, etc. will be transmitted on the first antenna, and rows 2, 4, 6, etc. will be transmitted on the second antenna, as illustrated below:



- b. **Element 8[b]: wherein the channel estimator is configured to receive the at least one pilot symbol and generate an initial estimate of the channel matrix based, at least in part on the at least one pilot symbol.**

153. Haustein teaches or suggests Element 8[b]. As explained for Element 1[b], pilot signals 201 in first transmission 306 are used by CSI estimation block 308 (“channel estimator”) to estimate the channel state (“the channel matrix”). Ex-1005 ¶¶13, 48-49, Fig. 2B. This channel matrix estimation is performed prior to the channel matrix estimation performed using the redundant payload data/pseudo-pilot data 203 as pilots to decode retransmission 307, and thus corresponds to “an initial estimate of the channel matrix.”

B. Ground 2: Claims 1-8 Are Obvious over Ban in view of Wang

1. A POSITA would have been motivated to combine Ban and Wang and would have had a reasonable expectation of success

154. A POSITA would have been motivated to combine the teachings of Ban and Wang and would have had a reasonable expectation of success in doing so, because both relate to the transmission of OFDM symbols (Ex-1006 ¶81; Ex-1007 ¶1), and the use of pilot symbols for channel estimation (Ex-1006 ¶134; Ex-1007 ¶1).

155. Ban teaches a method for effectively extending the size of the cyclic prefix associated with a given data block within a data block stream (Ex-1006 ¶81) by copying into that data block data symbols from the preceding data block, prior to generating the cyclic prefix (Ex-1006 ¶90). A POSITA would have understood that a cyclic prefix is used to separate data blocks from one another, thereby reducing potential inter-block interference, and increasing the reliability of decoding at the receiver. Ex-1026, 0033 (explaining that a cyclic prefix is a “guard interval” used to prevent inter-symbol interference, which takes the form of “an exact copy of a segment of the OFDM symbol located toward the symbol end”). A POSITA seeking to implement Ban’s system for the purpose of increasing the reliability of decoding would have been motivated to search for additional techniques to further improve the reliability of the decoding. Wang discloses one such well-known method.

156. Wang teaches the use of space-time coding to transmit a stream of data over two different spatial streams, thereby creating spatial diversity “for a better transmission quality.” Ex-1007 ¶2. As Wang explains, when using only a single antenna on both the transmit and receive sides, poor data transmission quality may result:

In wireless telecommunication, **the transmission quality** between a transmitting device, such as a base station, and a receiving device, such as a mobile terminal, depends strongly on the respective transmission environment and **is often deteriorated by fading effects and the like**. This often leads to poor speech and data transmission quality, particularly if only one single antenna is used on the transmission side and one single antenna is used on the receiving side.

Id. To mitigate this problem while still preserving a mobile terminal that is “small and light as possible,” Wang proposes to add transmit diversity by adding two antennas at the base station transmitter such that “more than one antenna, e.g. two antennas, transmit data simultaneously to a receiving device.” Ex-1007 ¶2. “If the same data are transmitted in parallel by two antennas, the receiving side has a chance to receive signals at least from one of the antennas with an acceptable transmission quality so that a good connection can be ensured.” *Id.*

157. A POSITA would have recognized that by applying Wang’s teaching to Ban’s system (by adding a second transmit antenna and using space-time coding to add spatial diversity), Ban’s system performance would be improved in the same manner as taught by Wang. In the combined Ban-Wang system, Ban’s transmitter

would be modified according to Wang, as illustrated below, to include two transmit antennas and to encode using space-time block coding (specifically, Alamouti coding⁶), to transmit the same data over two data streams that are orthogonal to one another.

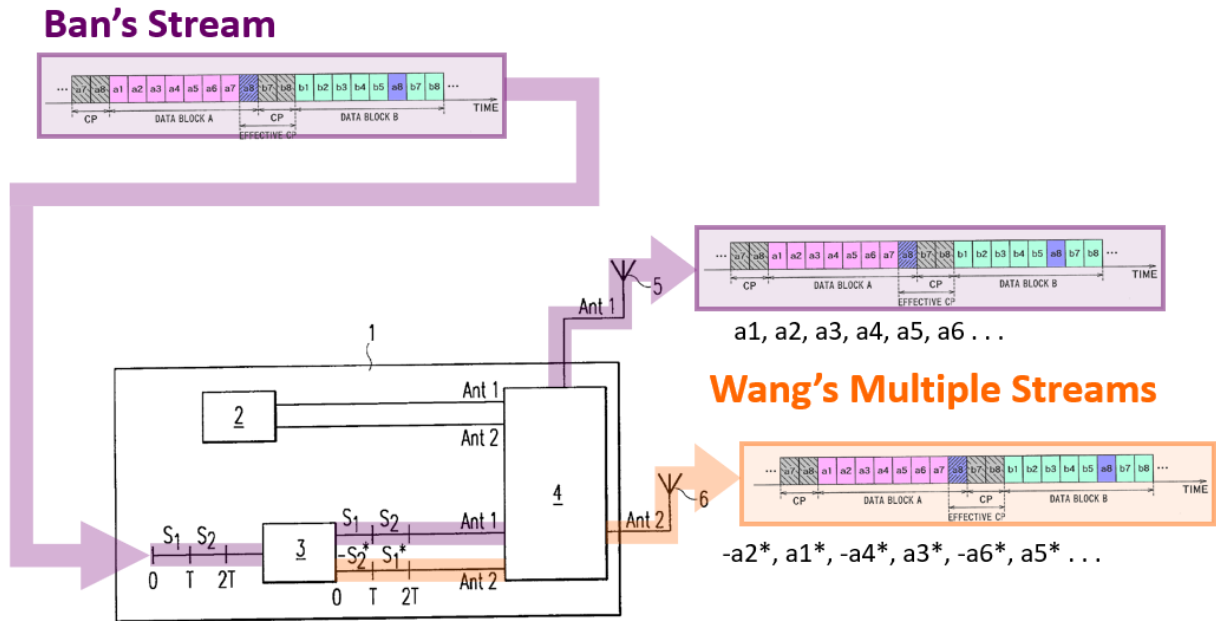
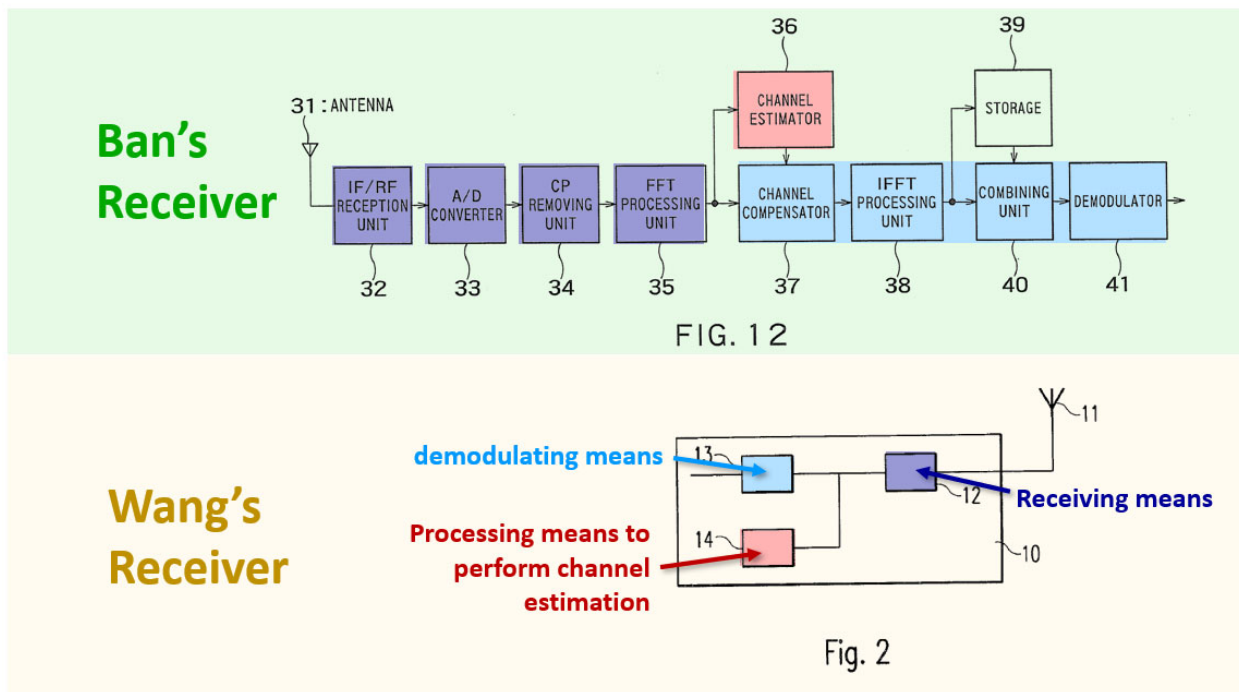


Fig. 1

158. In the combined system, Ban's receiver would also have been modified to receive the pilots and data over two spatial streams, as in done in Wang: "In other words, by processing the received pilot symbols, ... the processing means 14 is able to separately determine the transmission quality of the signals transmitted from the first antenna 5 and the transmission quality of the signals transmitted from the

⁶ The well-known Alamouti block code $\begin{bmatrix} S_1 & S_2 \\ -S_2^* & S_1^* \end{bmatrix}$ is depicted to the right of element 3 in Figure 1 and in the description of paragraph 27 of Wang. See, e.g., Ex1023, 0004, Table 1.

second antenna 6. On the basis of this channel estimation result, both the STTD encoded signals from the first antenna 5 and from the second antenna 6 are further processed and used as communication data in the mobile terminal 10.” Ex-1007, ¶27. As can be seen by comparing Ban’s Figure 12 receiver and Wang’s Figure 2 receiver, this would have involved modifying Ban’s channel estimator 36 (analogous to Wang’s processing means 14) to perform channel estimation using pilot symbols received over the block-coded streams, as taught by Wang (Ex-1007, ¶27), and modifying Ban’s channel compensator (which, together with IFFT processing unit 38, combining unit 40, and demodulator 41, is analogous to Wang’s demodulating means 13) to use that channel estimation to decode and demodulate the data from the two transmitted streams. Ex-1006, ¶¶136-137.



159. A POSITA would have expected such a combination to be successful because adding spatial diversity to a transmission, such as by using Alamouti coding, as described in Wang, was a well-known technique for increasing reliability of data transmission through a noisy or fading channel. *See, e.g.*, Ex-1023, 0002 (explaining the Alamouti coding “can improve the error performance, data rate, or capacity of wireless communication systems”); *see also* Ex-1001, 1:45-58 (describing Alamouti space-time and space-frequency block codes as “known in the art”). Thus, a POSITA would have expected Ban’s communication system to have been improved by adding the type of spatial diversity described in Wang and would have predicted the combined system to operate as expected.

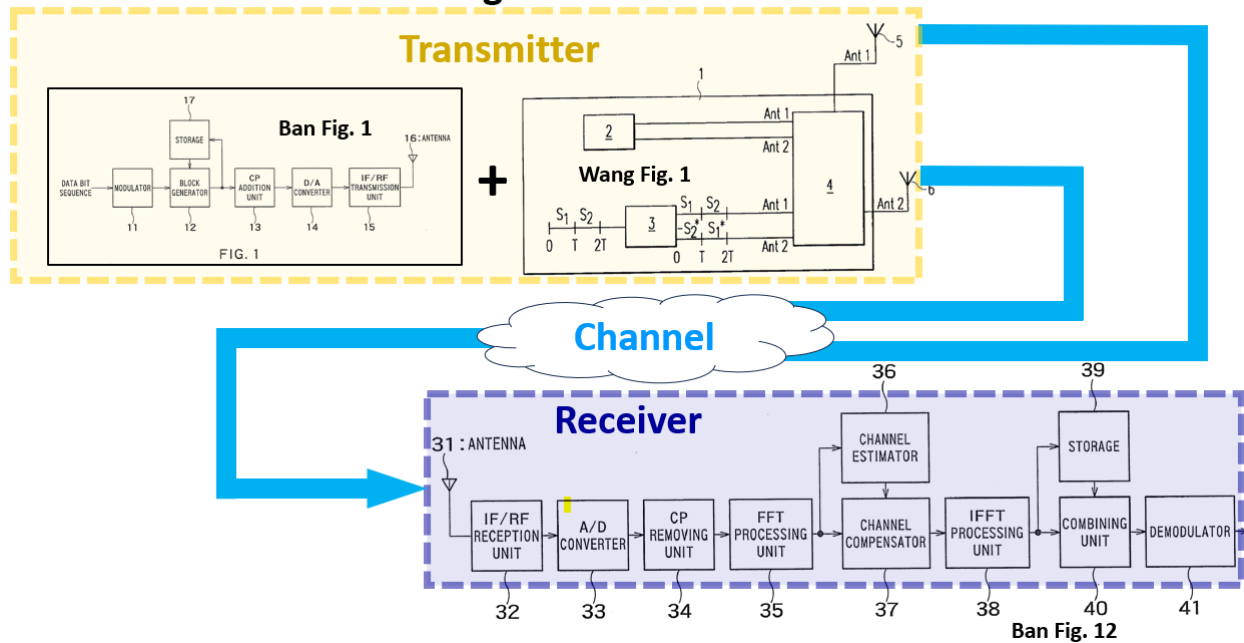
2. Independent Claim 1

a. Element 1[pre]: A method of decoding a signal transmitted over a communications channel, the method comprising:

160. Ban-Wang teaches or suggests the preamble, to the extent it is limiting.

161. Ban teaches a method for decoding data blocks (i.e., “signal[s]”) transmitted over a communication channel between a transmitter (Ban’s Figure 1 embodiment combined with Wang’s Figure 1 embodiment) and a receiver (Ban’s Figure 12 embodiment, modified to receive Wang’s two data streams), as illustrated below:

Ban + Wang



162. Specifically, Ban’s Figures 1 and 12 show that Ban’s transmitter and receiver include multiple processing blocks that take a “data bit sequence” through modulation and encoding before transmission through antenna 16, and then, following reception via antenna 31, through multiple steps for decoding and demodulation to recover the data bit sequence at the receiver. *See, e.g.,* Ex-1006 ¶¶81-88 (transmitter), ¶¶130-131 (receiver). In the Ban-Wang system, the receiver decodes the combined signal received from the two transmit antennas.

163. Ban explains that, by using the disclosed method of copying data from the preceding block, “it is thereby possible to obtain the same effect as extending the CP size while preventing the occurrence of interference among signals” (Ex-1006 ¶81), thereby enabling successful decoding of those signals at the receiver (Ex-1006 ¶129).

b. Element 1[a]: receiving a pilot symbol over the communications channel;

164. Ban-Wang teaches or suggests Element 1[a]. Ban teaches receiving a “data block composed of pilot symbols” over the communication channel between the transmitter of Figure 1 and the receiver of Figure 12. Ex-1006 ¶134. Wang also teaches receiving pilot symbols in the combined, block-coded signal. Ex-1007 ¶¶27-28. In the combined Ban-Wang system, the pilot symbols are received in space-time block-coded (e.g., Alamouti-coded) form.

c. Element 1[b]: estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol;

165. Ban-Wang teaches or suggests Element 1[b]. Figure 12’s receiver includes “channel estimator 36,” as illustrated in annotated Figure 12, below.

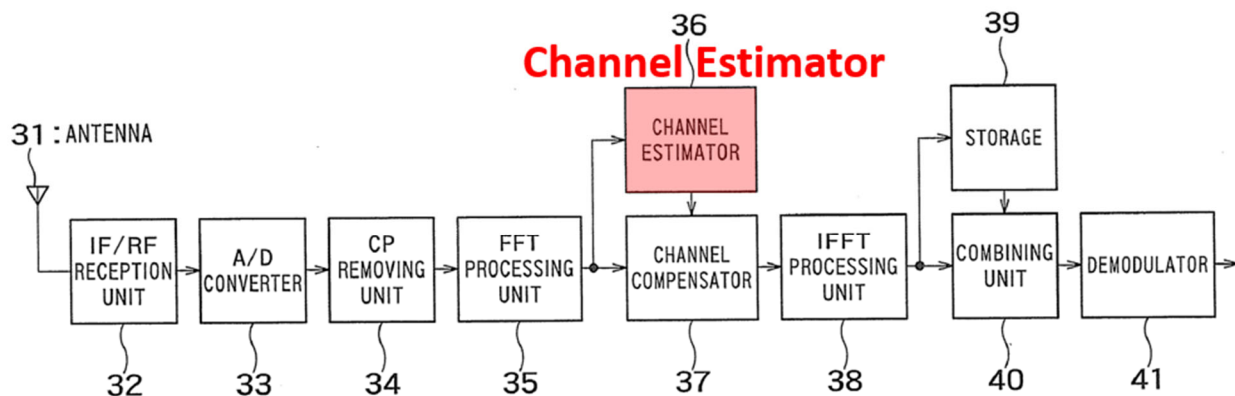


FIG. 12

166. Ban explains that, “[b]ased on signals of a plurality of frequency components obtained from the data block composed of pilot symbols, channel estimator 36 estimates channel responses of the respective frequency components.”

Ex-1006 ¶134. In the Ban-Wang combination, the received, block-coded pilot symbols are output at FFT processing unit 35 prior to being input to channel estimator 36. *Id.* A POSITA would have understood that estimating these channel responses corresponds to estimating the channel matrix, given the two antenna transmission to one antenna reception in the Ban-Wang combination. In particular, as I explained in the Background, in the case of multiple antennas, such as Ban-Wang's MISO system, the channel state information is modeled as a matrix (the channel matrix) representing the multiple communications links between the multiple antennas. For example, for a system with two transmit antennas (TX1 and TX2) and one receive antenna (RX1), the 2-by-2 channel matrix may be written as:

$$\mathbf{H} = \begin{bmatrix} h_{11} & h_{12} \\ 0 & 0 \end{bmatrix},$$

where h_{11} corresponds to the channel response between TX1 and RX1, and h_{12} corresponds to the channel response between TX2 and RX1. The last row of this 2-by-2 matrix is zeros corresponding to the absence of a second receive antenna. Alternatively, the channel matrix may be written as a 1-by-2 channel matrix with a single row corresponding to the single receive antenna.

- d. Element 1[c]: receiving replicated data from multiple data streams transmitted over the communications channel;**

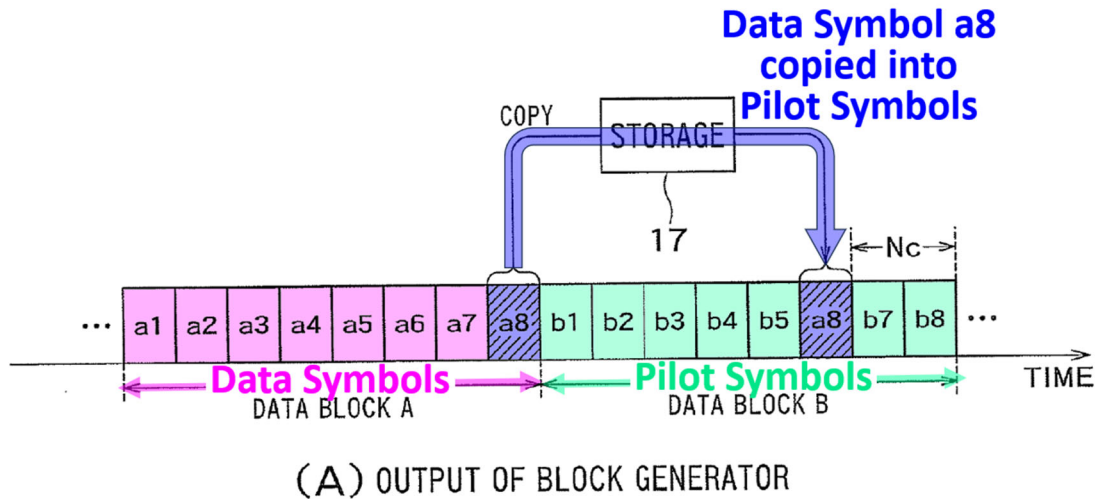
167. Ban-Wang teaches or suggests Element 1[c].

168. Ban-Wang teaches or suggests the claimed “replicated data” by copying data within a data stream (Ex-1006 ¶90) as part of Ban’s method for effectively extending the cyclic prefix length (Ex-1006 ¶81). Ban-Wang then teaches applying Alamouti coding to the data stream (already including replicated data) to transmit two separate, spatially-diverse streams over the communications channel. These methods are described in more detail below.

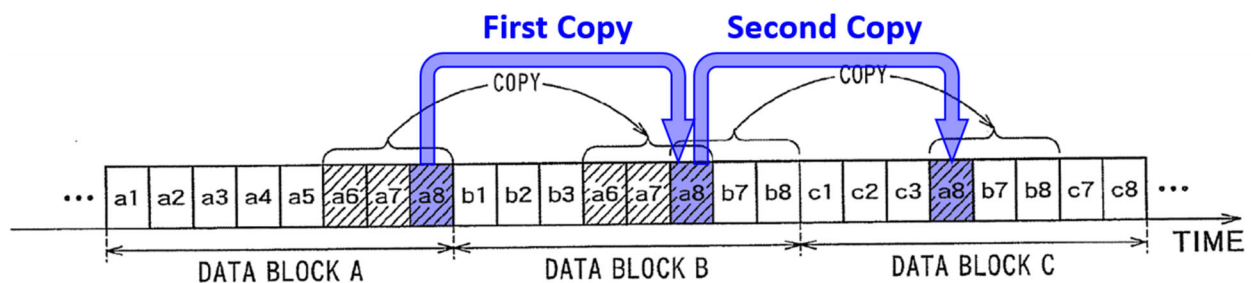
(1) Replication Within Ban’s Data Stream

169. As explained for Element 1[pre], Ban teaches effectively extending the cyclic prefix length of a data block B (Ex-1006 ¶81), by copying (i.e., replicating) data from the preceding data block A into block B, before generating the cyclic prefix for block B. Ex-1006 ¶90. This is illustrated below, in annotated Figure 2A, where data symbol a8 is copied from block A into block B. Notably, while Figure 2A illustrates blocks A and B that both contain data symbols (Ex-1006 ¶93), Ban teaches that this same copying process may also be used to effectively extend the cyclic prefix size of a block composed of pilot symbols. Ex-1006 ¶147. This is reflected in annotated Figure 2A, below, in which block B is illustrated as including pilot symbols:⁷

⁷ Note that while Ban’s paragraph 147 appears in a section generally discussing a different embodiment, it expressly states that the modification whereby pilot symbols are replaced by data symbols copied from the prior data block is intended to be used with the transmitter of Figure 1.

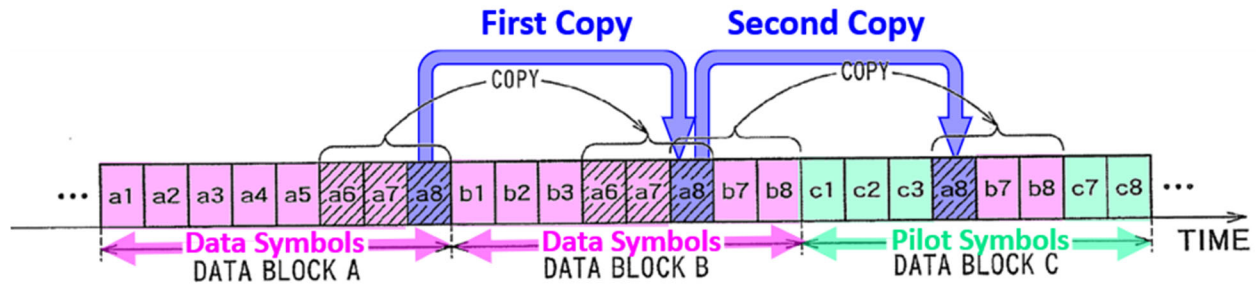


170. While annotated Figure 2A, above, illustrates a single instance in which data symbol a8 is copied (from block A of data symbols into block B of pilot symbols), Ban explains that such copying may happen multiple times. For instance, Figure 3A (reproduced below with annotations), presents an example in which data symbol a8 is copied two times, from block A into both blocks B and C. Ex-1006 ¶97.

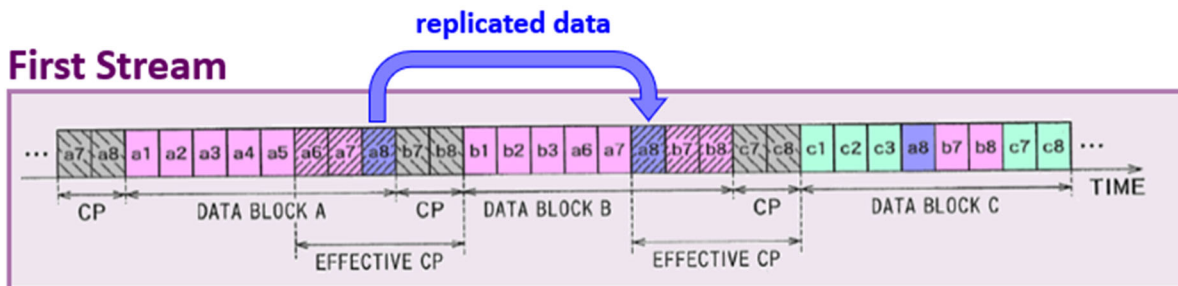


171. And, similar to the discussion of Figure 2A, above, based on Ban's disclosure that a block into which data is copied may be a block of pilot symbols (Ex-1006 ¶147), a POSITA would have recognized that data blocks A and B may be

blocks of data symbols, while data block C may be a block of pilot symbols into which data symbols from the preceding blocks are copied:



172. Thus, Ban teaches receiving replicated data (e.g., symbol a8) copied from one block of data symbols into another block of data symbols and transmitted within a stream of data blocks received by Ban's receiver (Figure 12):



(2) Transmission Over Two Streams

173. Ban-Wang further teaches or suggests that the copied data symbols (e.g., symbol a8) copied within the same data stream from one block of data symbols into another block of data symbols, are transmitted over the communication channel in multiple data streams. In particular, Wang teaches the use of “space time transmit diversity (STTD)” (Ex-1007 ¶1) in which “[a] stream of data to be transmitted to a receiving device ... is encoded and processed so that two parallel data streams are

generated” (Ex-1007 ¶3). As Wang explains, “the second data stream *contains the identical data content* as the first data stream, but in a different arrangement.” Ex-1007 ¶23.

174. As explained above (motivation to combine Ban and Wang), in the combined Ban-Wang system, Ban’s transmitter would have included a second antenna, and would have been configured to implement Wang’s STTD to generate a second data stream (containing identical data content to the first stream, though with sign change and complex conjugate operation) for transmission over the second antenna (Ex-1007 ¶23), in order to increase the reliability of data decoding at the receiver (Ex-1007 ¶2), as illustrated below.

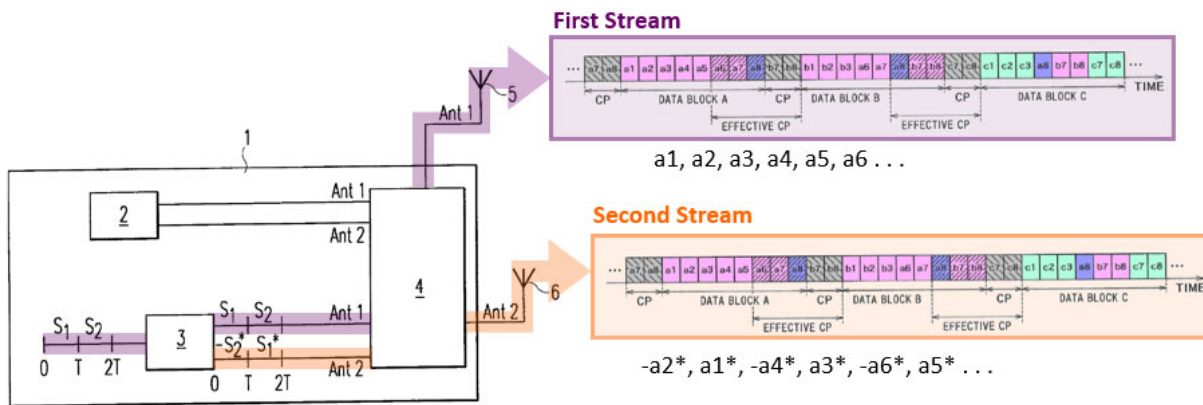
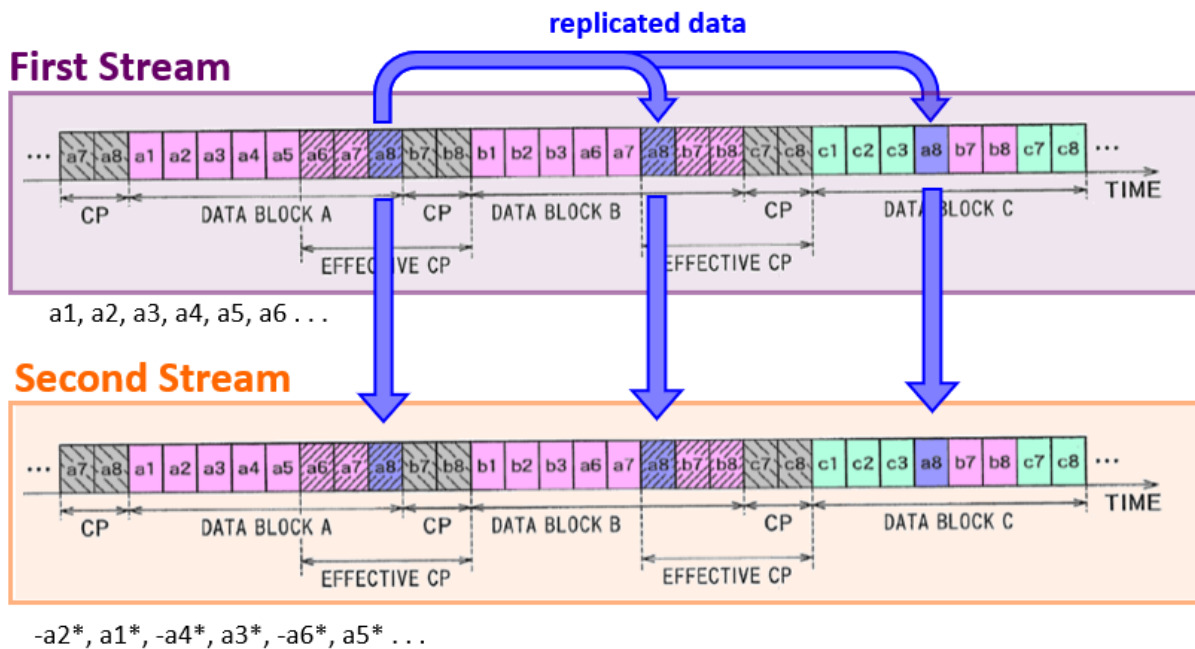


Fig. 1

175. And Ban’s receiver (Figure 12) would have been modified according to Wang to receive the pilot and data signals from the two spatially diverse streams, perform channel estimation, and decode the streams to output the decoded symbols. Ex-1007 ¶27. As explained above (motivation to combine), this would have been

done by modifying Ban's "channel estimator 36" and "channel compensator 37" to use that channel estimation to decode and demodulate the data from the two transmitted streams. Ex-1006, ¶¶136-137.

176. Accordingly, in the combined Ban-Wang system, data symbols replicated within Ban's data stream (a first data stream) are transmitted over both a first data stream and a second data stream using Wang's STTD, as illustrated below:



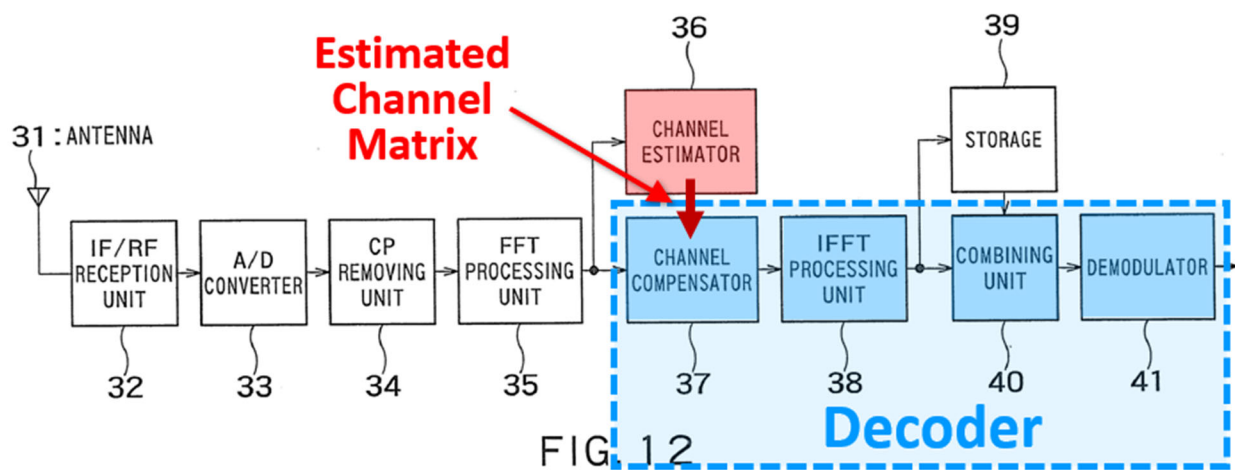
177. The second stream will "contain[] the identical data content as the first data stream, but in a different arrangement" (Ex-1007 ¶23), which is represented in the above figure by the notations indicating that symbols a1, a2, etc. are sent as -a2*, a1*, etc. in the second stream and received by Ban-Wang's receive antenna.

178. Thus, Ban-Wang teaches receiving replicated data from multiple data streams transmitted over the communications channel.

e. Element 1[d]: decoding the replicated data using the estimated channel matrix;

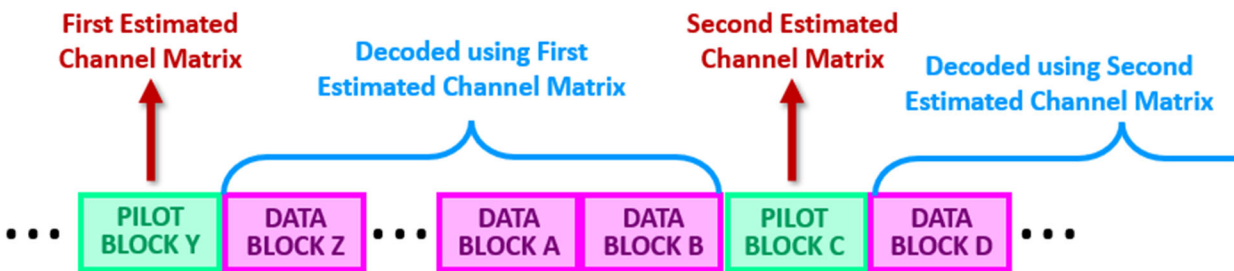
179. Ban-Wang teaches or suggests Element 1[d].

180. As explained for Elements 1[a] and 1[b], both Ban and Wang teach receiving “pilot symbols” and using those pilot symbols to estimate the channel matrix. Ex-1006 ¶134; Ex-1007 ¶27. Ban explains that “channel compensator 37” uses the estimated channel matrix to “correct[] distortion ... produced in the channels (equalization processing)” (Ex-1006 ¶135), as part of a decoding process performed by channel compensator 37, IFFT processing unit 38, combining unit 40, and demodulator 41 (Ex-1006 ¶¶135-137), illustrated in annotated Figure 12, below, to generate demodulated received data symbols.



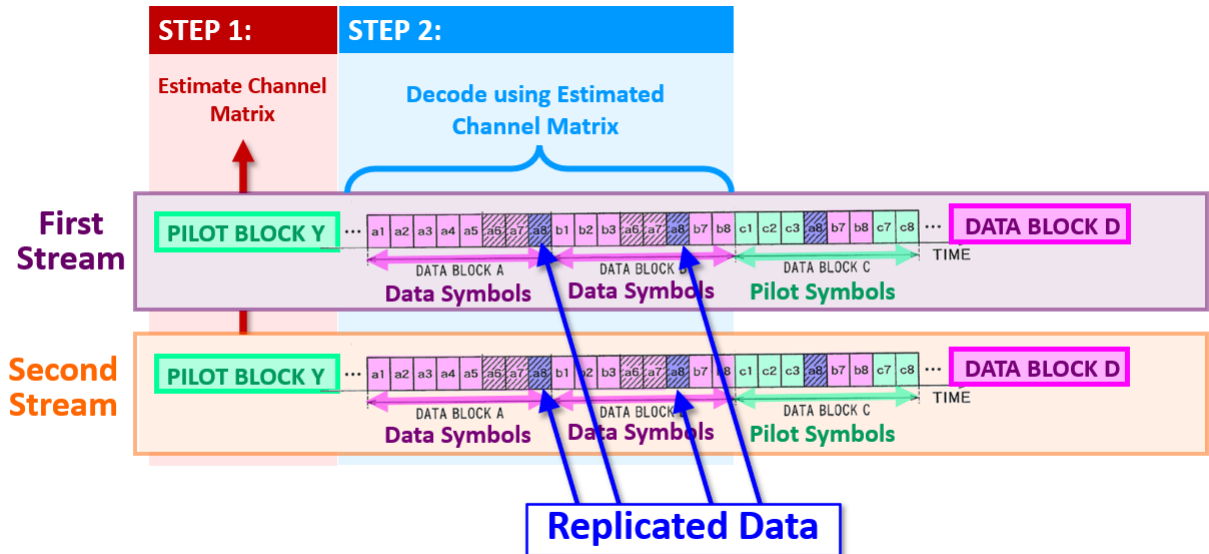
181. A POSITA would have understood that the channel estimate from a first set of pilot symbols may be used to decode several data blocks. For example, after receiving a first block of pilot symbols (Pilot Block Y, below) and using those

pilot symbols to generate a first estimated channel matrix, that first estimated channel matrix would be used in the decoding process to decode some number of subsequently received blocks of data symbols (Data Blocks Z, A, B, below). *Id.* When the next block of pilot symbols (Pilot Block C, below) is received, it would be used to generate a new estimated channel matrix, which would be used to decode the next several blocks of data. This process is illustrated below:



182. As illustrated below, in the combined Ban-Wang system, prior to receiving data blocks A and B (which include replicated data symbol a8), Ban-Wang's receiver would receive pilot symbols of block Y (*see* Ex-1006 ¶134), transmitted via Wang's multiple streams (Ex-1007, Cl. 13 ("transmitting ... pilot symbols via said first and said second antenna means" and "receiving said pilot symbols in a single antenna of a receiving device")). Ban's modified channel estimator 36 would use these pilot symbols to generate an estimated channel matrix (step 1, below). Ex-1006 ¶134; Ex-1007, Cl. 13 ("processing received pilot symbols and performing a channel estimation on the basis of said processing"). Ban's modified channel compensator 37 would then use this estimated channel matrix to

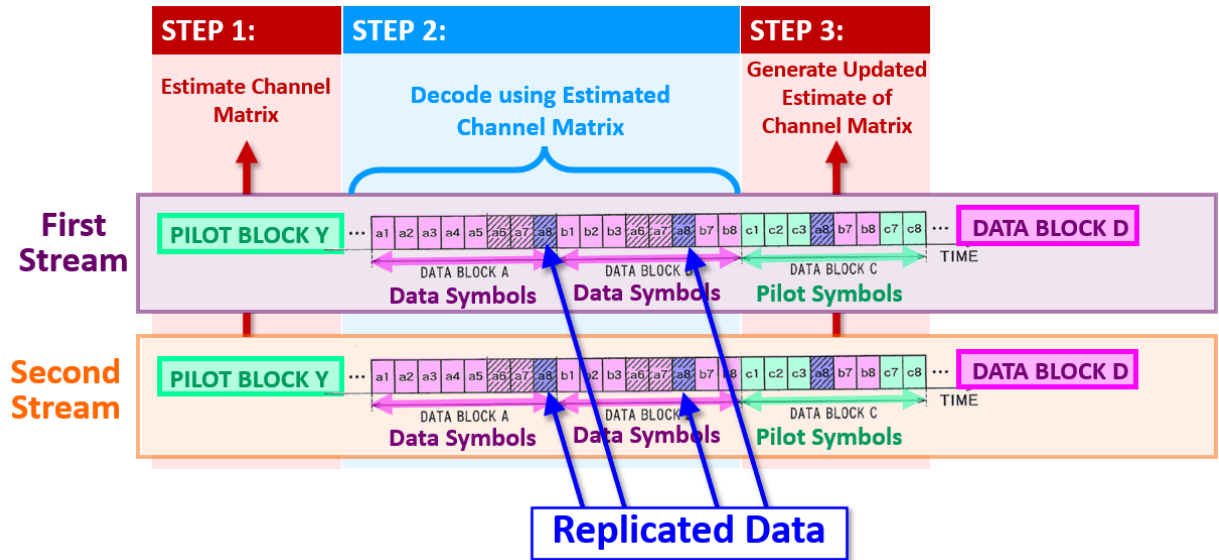
perform equalization processing (Ex-1006, ¶135; §XII.B.1 *supra*) on replicated symbols a8 (Ex-1006 ¶135) of subsequently received data blocks A and B, as part of the decoding process (step 2, below). Thus, the replicated data is decoded using the estimated channel matrix.



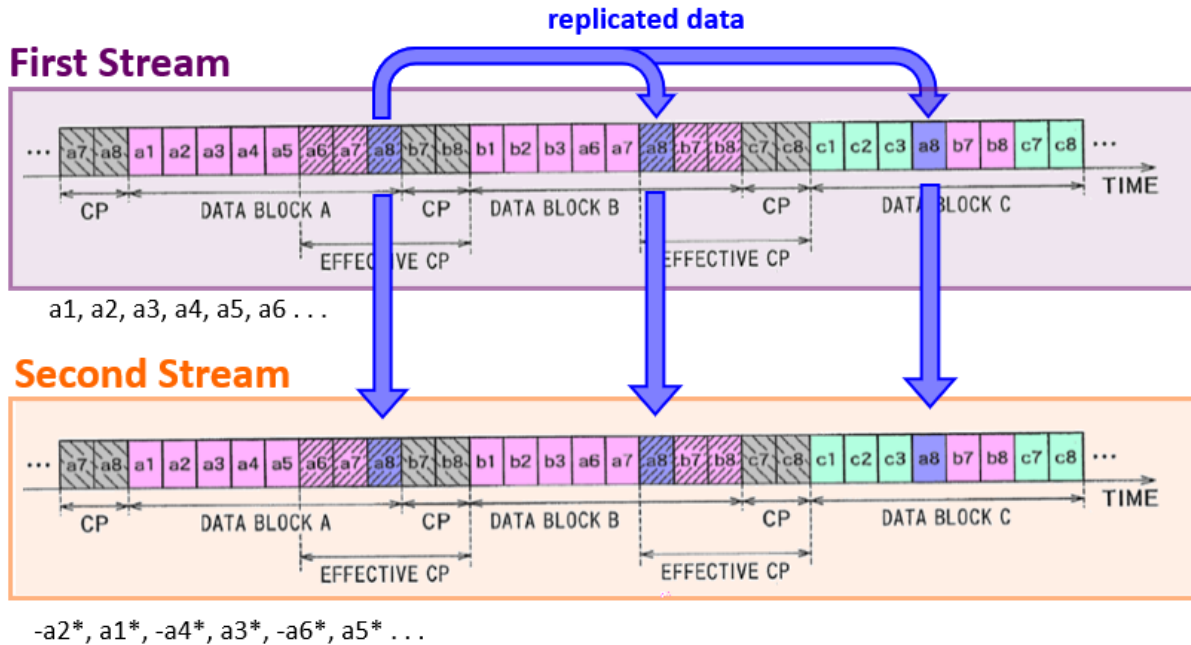
- f. **Element 1[e]: generating an updated estimate of the channel matrix based, at least in part, on the replicated data; and**

183. Ban-Wang teaches or suggests Element 1[e].

184. As illustrated below, after receiving data blocks A and B, Ban-Wang's receiver will receive data block C, which includes pilot symbols, as well as data symbols replicated from prior data blocks A and B. Ex-1006 ¶147 ("some of pilot symbols in the data block are replaced with data symbols of the preceding data block"):



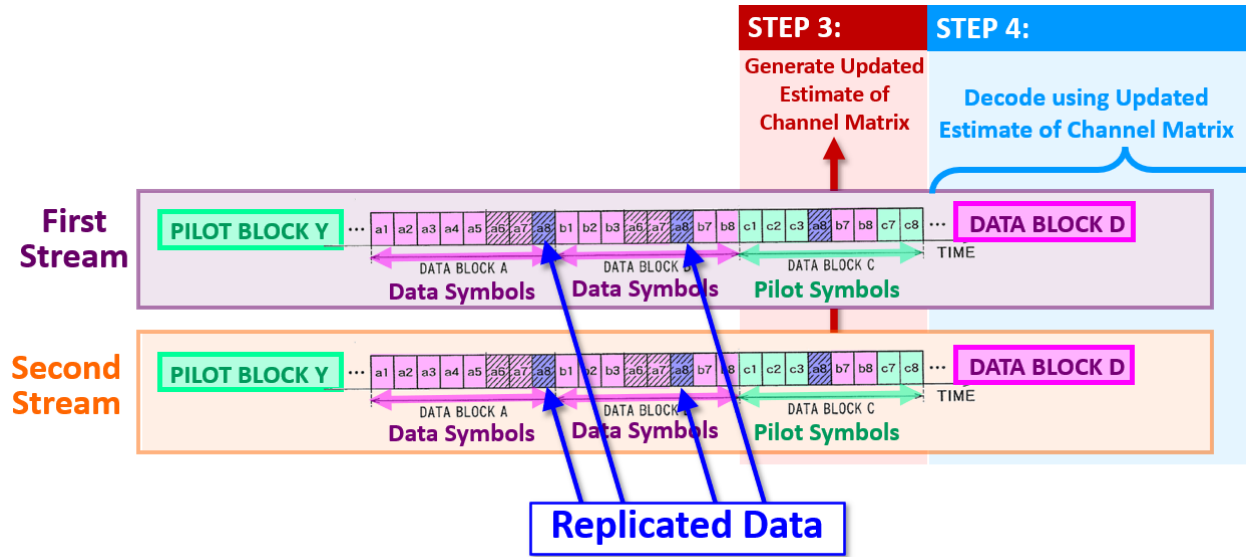
185. Ban teaches using the data symbols received in block C, in addition to the pilot symbols within that block, to perform a new channel estimation (“generat[e] an updated estimate of the channel matrix,” step 3, above), by treating those data symbols as known data (i.e., in the same manner as pilot symbols), based on the demodulated copies of those data symbols that were received in the preceding data blocks (“replicated data” received in blocks A and B). Ex-1006 ¶147. Data copied into block C are “handled as known data using the demodulation result.” *Id.* Thus, “since all the pilot symbols and data symbols in the data block can be regarded as known data, the channel can be estimated using the entire data block.” *Id.* Thus, the updated channel estimate is based, in part, on the replicated data (e.g., symbol a8), as illustrated below.



- g. Element 1[f]: decoding subsequently received signals over the communications channel using the updated estimate of the channel matrix.**

186. Ban-Wang teaches or suggests Element 1[f].

187. As explained for Element 1[d], after receiving a block of pilot symbols (block C, below) and using those symbols to generate an updated estimate of the channel matrix, that updated estimate of the channel matrix is used in the decoding process to decode subsequently received blocks of data symbols (e.g., data block D, below), until the next block of pilot symbols is received and used to generate a new estimate of the channel matrix.



188. Thus, Ban-Wang renders claim 1 obvious.

3. **Dependent Claim 2: The method of claim 1 wherein said decoding the replicated data comprises using a joint detection technique.**

189. Ban-Wang teaches or suggests Claim 2.

190. As part of the decoding process, Ban’s “combining unit 40” is used to combine copies of the replicated a8 symbols into a single data symbol. Ex-1006 ¶136, Cl. 20 (same). Ban explains that this may be done using “maximum ratio combining” (Ex-1006 ¶136), which the ’331 Patent specifically identifies as a “joint detection technique” (Ex-1001, 10:28-30). In particular, the ’331 Patent states that “a joint detection technique is used to decode the replicated data, *such as max-ratio combining.*” *Id.*

191. Additionally/alternatively, as will be explained for Claims 3-4 below, Ban-Wang teaches or suggests decoding the replicated data using Alamouti block

decoding, which, as explained above, applying Haustein to claim 2, is another type of joint detection technique. For example, U.S. Patent No. 8,126,408 describes several examples of “joint detection method[s],” including Alamouti block decoding:

Output module 56 accepts the received signals from receivers 52A and 52B, and performs joint detection of DATA1 and DATA2. Any suitable **joint detection method** can be used for this purpose. For example, the output module may apply **Maximum Ratio Combining (MRC)**. Alternatively, the system may use a Space-Time Trellis Code (STTC).... Further alternatively, a **Space-Time Block Code (STBC)** can be used. **STBCs are described, for example, by Alamouti** in “A Simple Transmit Diversity Technique for Wireless Communication.” IEEE Journal on Select Areas in Communications, volume 16, number 8, October 1998, pages 1451 1458, which is incorporated herein by reference. Alternatively, module 56 may use **any other suitable joint detection method**. Module 56 reconstructs the original input data sequence from DATA1 and DATA2, and provides the data sequence as output.

Ex-1024, 8:4-24.

4. Dependent Claim 3: The method of claim 1, wherein said decoding the replicated data comprises using a space-time block decoding technique.

192. Ban-Wang teaches or suggests Claim 3.

193. As explained for Element 1[e], in the Ban-Wang system, decoding the replicated data involves decoding data received over two spatially diverse streams (Ex-1007 ¶¶23, 27), which, as explained for Element 1[c], were generated at the transmitter by applying Alamouti space-time block coding. A POSITA would have understood that Alamouti space-time block decoding would be used to decode

Alamouti-encoded spatially diverse streams. *See* Ex-1023, 0004 (describing decoding by sending the Alamouti-encoded combined signals to a “maximum likelihood detector”).

5. Dependent Claim 4: The method of claim 1, wherein said decoding the replicated data comprises using a space-frequency block decoding technique.

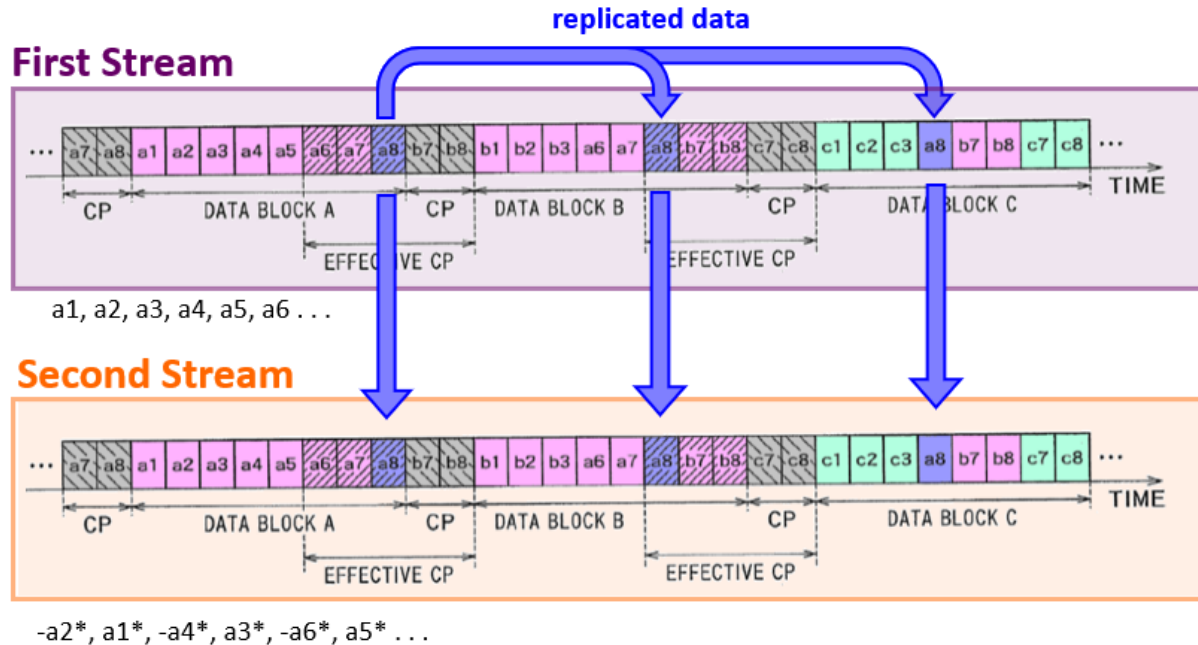
194. Ban-Wang teaches or suggests Claim 4.

195. As explained for Claim 3, Ban-Wang teaches Alamouti space-time block decoding. A POSITA would have recognized that Alamouti coding/decoding can be applied either as space-time blocks or space-frequency blocks as a matter of design choice. In particular, Alamouti’s paper describes both “space-time coding,” where “the encoding is done in space and time,” as well as “space-frequency coding,” where “two adjacent carriers may be used.” Ex-1023, 0002-0003.

6. Dependent Claim 5: The method of claim 1, wherein the replicated data includes same data symbols in multiple data streams.

196. Ban-Wang teaches or suggests Claim 5.

197. As explained for Element 1[c], Ban-Wang teaches or suggests replicated data received over multiple data streams because Ban-Wang teaches transmitting Ban’s entire data stream (already including replicated data) in two separate, spatially-diverse streams, as illustrated below.



198. In particular, Wang teaches the use of “space time transmit diversity (STTD)” (Ex-1007 ¶1) in which “[a] stream of data to be transmitted to a receiving device ... is encoded and processed so that *two parallel data streams are generated*” (Ex-1007 ¶¶1, 3). As Wang explains, “the second data stream *contains the identical data content* as the first data stream, but in a different arrangement.”⁸ Ex-1007 ¶23. Thus, Ban-Wang teaches or suggests that the replicated data includes same data symbols in multiple data streams. So Ban-Wang renders obvious claim 5.

⁸ The '331 Patent also contemplates that symbols s_1 and s_1^* are “same symbols.” See, e.g., Ex-1001, Fig. 5 (equating s_3 and s_3^*). Indeed, a POSITA would have understood that, despite being differently encoded, s_1 and s_1^* correspond to the same signal. See, e.g., Ex-1025, 0539 (explaining that redundancy may be introduced in a system with multiple transmit antennas “by sending from each transmit antenna a differently encoded (and fully redundant) version of *the same signal*”). Moreover, certain modulation schemes, e.g., BPSK, use real symbols for which $s_1 = s_1^*$. See, e.g., https://en.wikipedia.org/wiki/Phase-shift_keying

7. Independent Claim 6:

a. Element 6[pre]: A communication device comprising:

199. Ban-Wang teaches or suggests the preamble, to the extent it is limiting.

200. Ban's receiver, illustrated below, is a communication device, because it includes "a reception unit configured to sequentially receive data blocks" (Ex-1006 ¶31) transmitted by a transmitter (Ex-1006 ¶29).

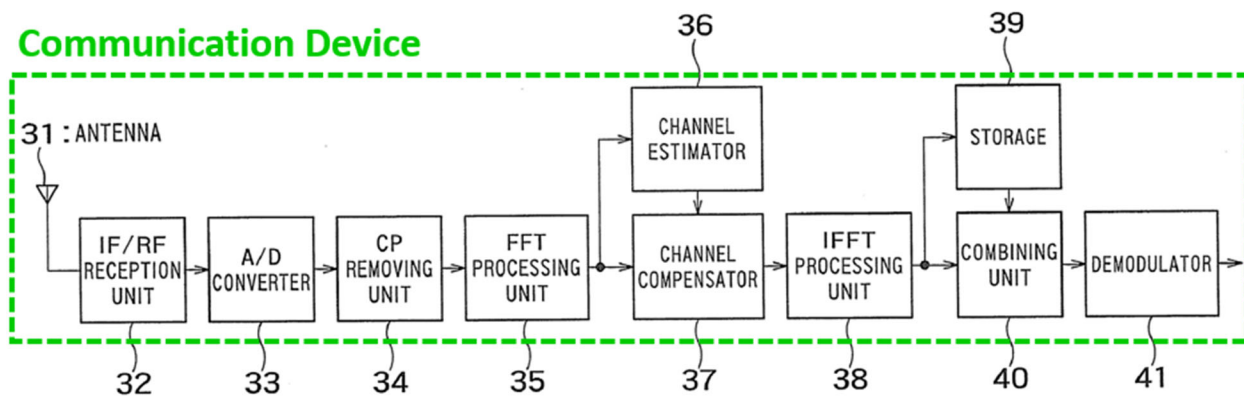


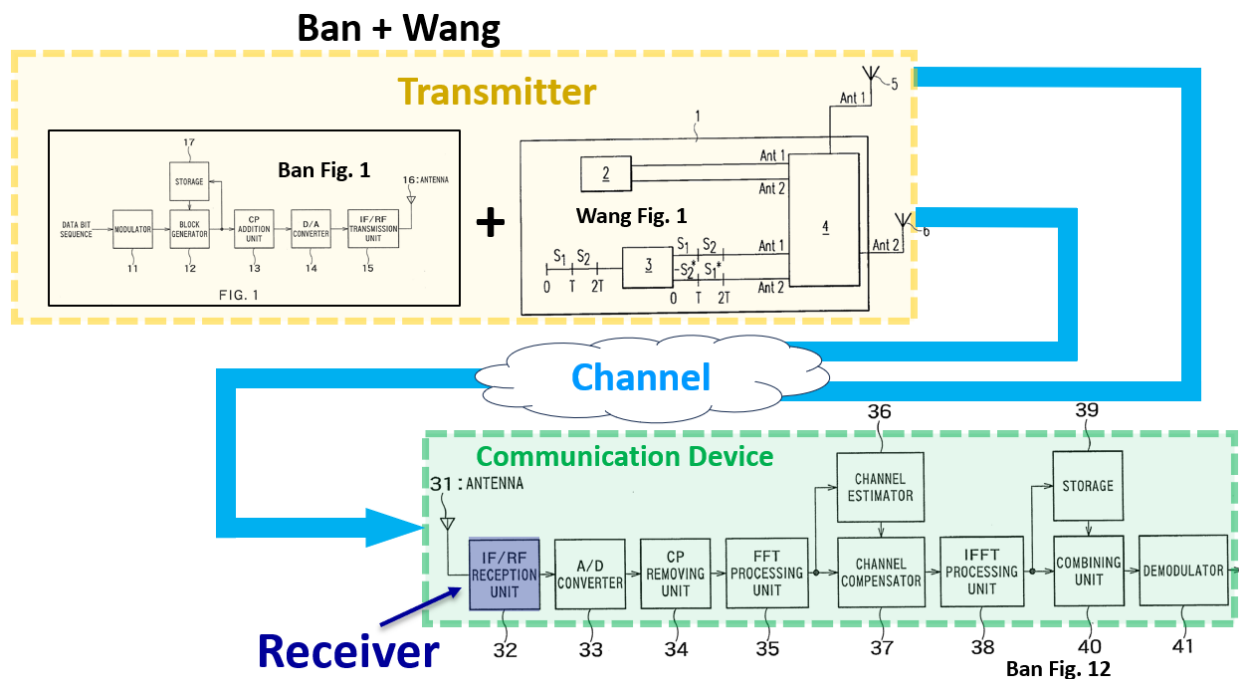
FIG. 12

b. Element 6[a]: a receiver configured to receive signals over a communications channel,

201. Ban-Wang teaches or suggests Element 6[a].

202. Figure 12 depicts a "first embodiment" of Ban's "receiver." Ex-1006 ¶130. In particular, an incoming RF signal arriving at antenna 31 is received and down-converted by IF/RF reception unit 32, which corresponds to the claimed "receiver" analogous to "receiver 172" in Figure 1 of the '331 Patent (separate from channel estimator 178, decoder 174, and demodulator 170). Ex-1001, Fig. 1. In particular, in Ban, "[a] *signal* received by antenna 31 is converted to a baseband

signal at an IF/RF reception unit 32 and then converted to a digital signal at an A/D converter 33.” *Id.* ¶131. The “signal” takes the form of data blocks (Ex-1006 ¶29) transmitted by Ban-Wang’s transmitter (Ex-1006 ¶25, Ex-1007 ¶23), over a communication channel between Ban-Wang’s receiver and transmitter, as illustrated below, based on Ban’s Figures 1 and 12 and Wang’s Figure 1. *See* Ex-1006 ¶135 (discussing properties of the communication channel).



- c. **Element 6[a][i]: wherein the signals are based at least in part on first and second data streams transmitted over a communications channel,**

203. Ban-Wang teaches or suggests Element 6[a][i]. As explained for Element 1[c], Ban-Wang’s receiver receives signals transmitted as first and second data streams. Specifically, Wang teaches the use of “space time transmit diversity (STTD)” (Ex-1007 ¶1) in which “[a] stream of data to be transmitted to a receiving

device ... is encoded and processed that *two parallel data streams* are generated.”

Ex-1007 ¶¶1, 3. As Wang explains, “the second data stream *contains the identical data content* as the first data stream, but in a different arrangement.” Ex-1007 ¶23.

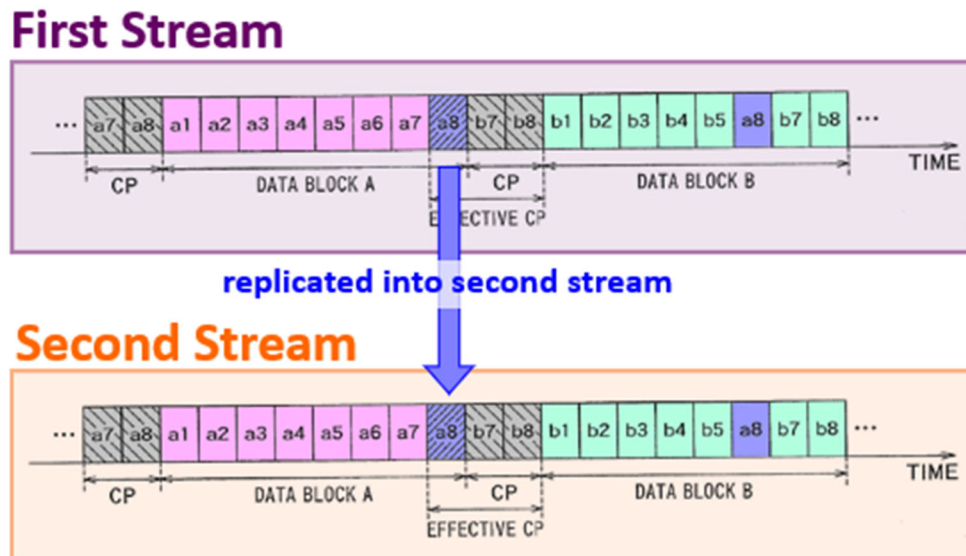
Thus, the received signals are based on the first and second data streams transmitted via STTD over the communications channel.

d. Element 6[a][ii]: wherein the second data stream includes at least one data symbol replicated from the first data stream;

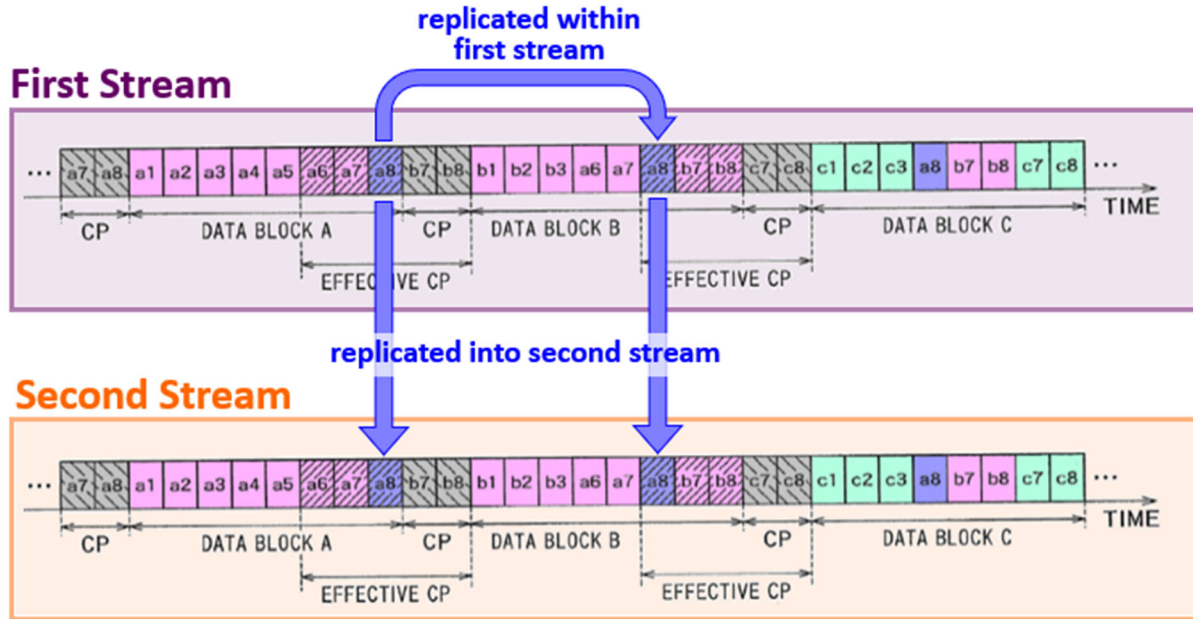
204. Ban-Wang teaches or suggests Element 6[a][ii]. As explained for Element 1[c], in the combined Ban-Wang system, data symbols within Ban’s data stream (the first data stream) are replicated into the second data stream through STTD (as taught by Wang). Ex-1007 ¶¶1, 3, 23. For instance, as illustrated below, data symbol a8 is replicated from block A of the first data stream into block A of the second data stream. Ex-1007 ¶23 (“the second data stream contains the identical data content as the first data stream, but in a different arrangement.”). For example, applying an Alamouti code generates copies of symbols in the second data stream that are complex conjugated or negative but are nonetheless replicated symbols.⁹ See, e.g., Ex-1025, 0539-0540 (describing Alamouti coding as an example in which redundancy may be introduced in a system with multiple transmit antennas “by

⁹ Furthermore, for certain modulations such as BPSK, the symbols have real values and the complex conjugate is the same as the original symbol. See, e.g., https://en.wikipedia.org/wiki/Phase-shift_keying

sending from each transmit antenna a differently encoded (and fully redundant) version of *the same signal*"). Indeed, Wang explains that the implemented "space time coding" scheme generates "[a] second data stream [that] contains *the identical data content* as the first data stream, but in a different arrangement." Ex-1007, ¶23. And, the '331 Patent also contemplates that a symbol and its complex conjugate are "same symbols." See, e.g., Ex-1001, Fig. 5 (equating s_3 and s_3^*).



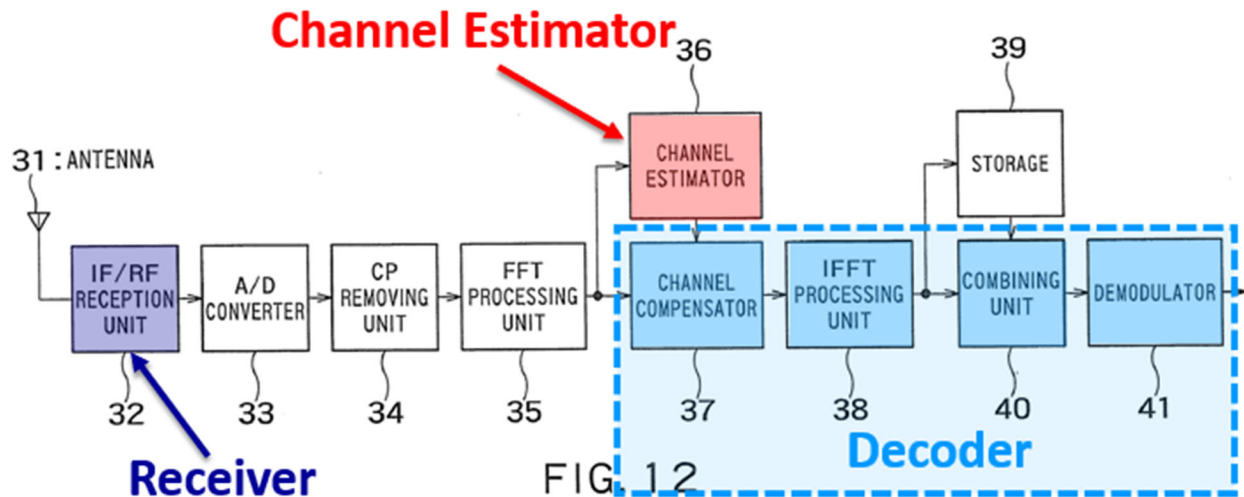
205. The "at least one data symbol replicated from the first data stream" into the second data stream may also have been replicated within the first data stream, as illustrated below:



- e. **Element 6[b]: a decoder coupled to the receiver and the channel estimator, wherein the decoder is configured to receive the received signals and decode the at least one data symbol replicated from the first data stream;**

206. Ban-Wang teaches or suggests Element 6[b].

207. Together, Ban's channel compensator 37, IFFT processing unit 38, combining unit 40, and demodulator 41 correspond to the claimed "decoder," because they are configured to use an estimated channel matrix to perform equalization processing (Ex-1006 ¶135) and convert the received signals into demodulated data symbols, as explained for Element 1[d]. As illustrated in annotated Figure 12, below, this decoder is coupled directly to channel estimator 36, and to Ban's reception unit 32 (claimed "receiver") through A/D converter 33, CP removing unit 34, and FFT processing unit 35, from which it "receives the received signals," as claimed.

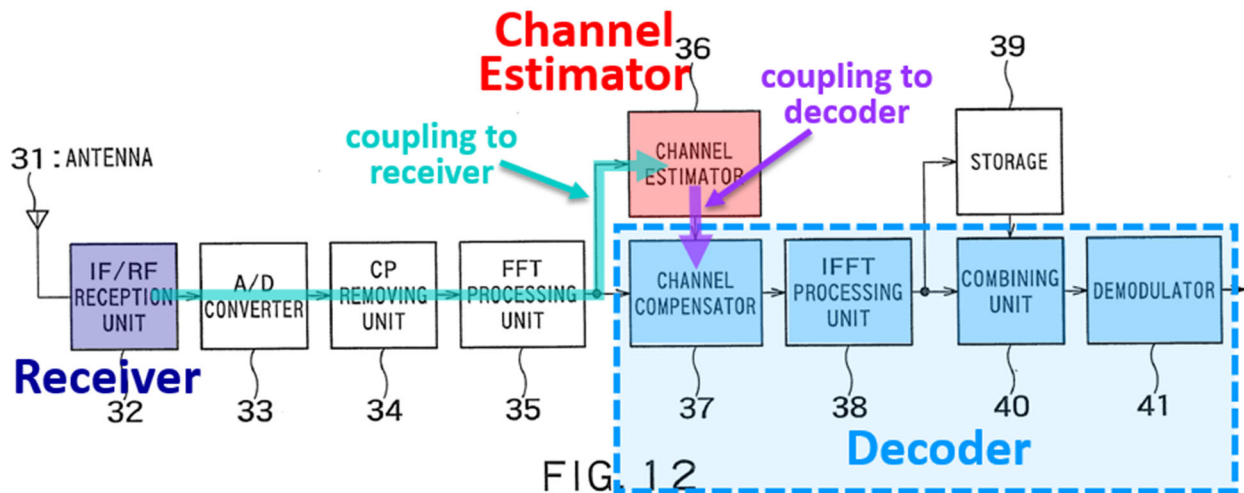


208. As explained for Element 1[e], in the combined Ban-Wang system, data symbols transmitted in multiple streams are received and passed to Ban's decoder, which is configured to perform equalization processing (Ex-1006 ¶135) and decoding of the data. Ex-1006 ¶136. The signals received from the two streams (including data symbol a8, "replicated from the first data stream") are subsequently demodulated ("decode[d]") by demodulator 41. Ex-1006 ¶137.

f. Element 6[c]: a channel estimator coupled to the decoder and the receiver,

209. Ban-Wang teaches or suggests Element 6[c].

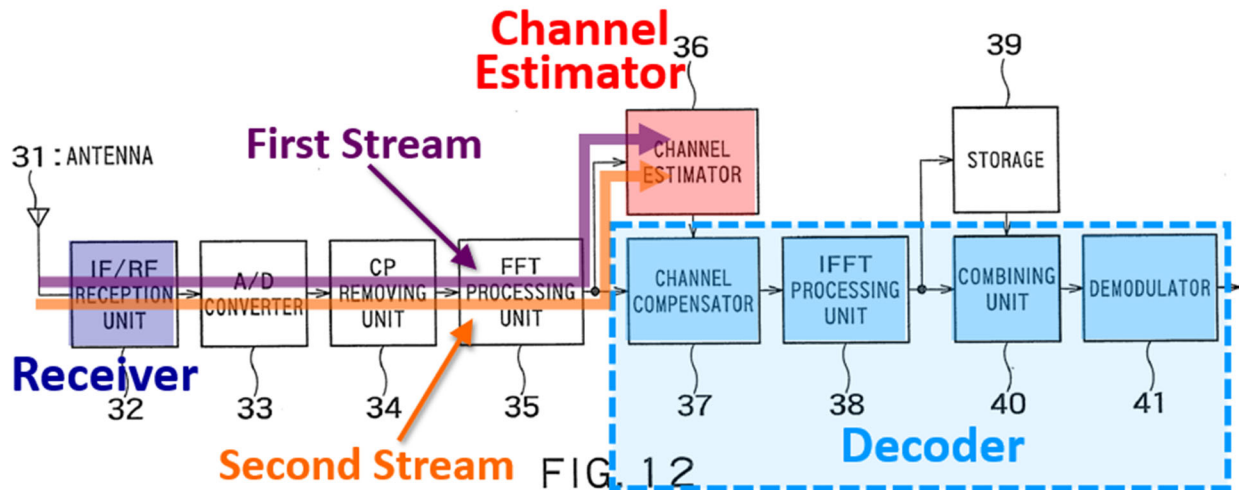
210. As illustrated below, Ban's channel estimator 36 is coupled both to reception unit 32 ("receiver") and to channel compensator 37 (forming part of the claimed "decoder," as explained for Element 6[b]). Ex-1006 ¶135.



- g. Element 6[c][i]: wherein the channel estimator is configured to receive the received signals and the decoded at least one data symbol, / Element 6[c][ii]: wherein the channel estimator is configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded at least one data symbol; and

211. Ban-Wang teaches or suggests Elements 6[c][i] and 6[c][ii].

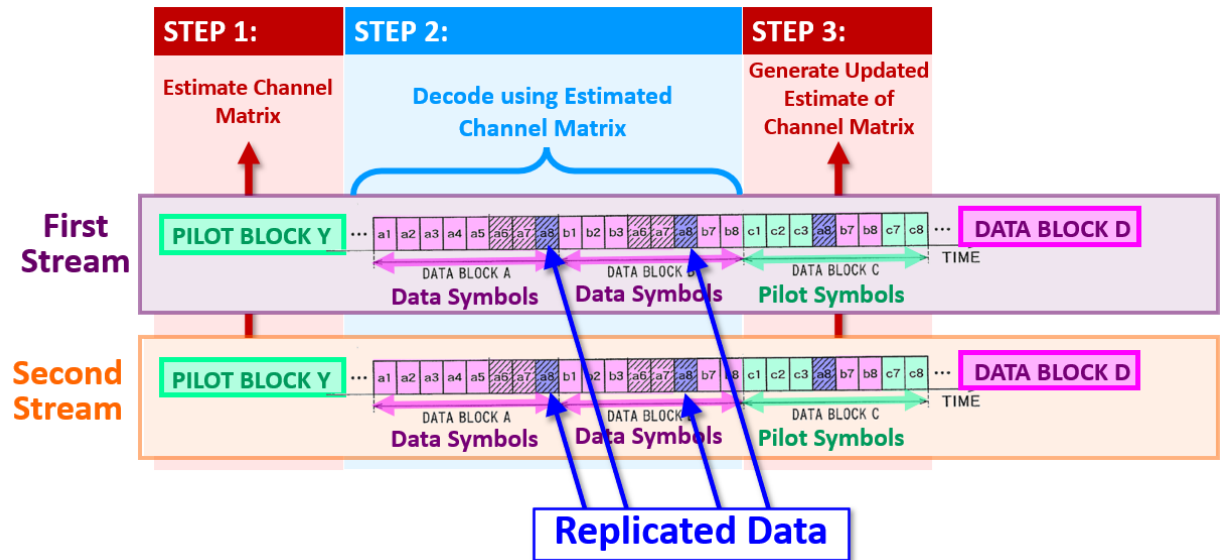
212. As illustrated in annotated Figure 12, below, in the combined Ban-Wang system, channel estimator 36 is configured to receive the signals transmitted in the first and second streams (“received signal”):



213. In particular, Ban discloses that channel estimator 36 operates on “signals ... from the data block composed of pilot symbols.” Ex-1006 ¶134. A POSITA would have understood that Ban’s channel estimator 36 would be configured to receive the first and second data streams (“receive the received signals”), and to identify and extract, from those streams, the data blocks composed of pilot symbols, on which the channel estimator operates. In particular, a POSITA would have recognized that, because Ban’s Figure 12 does not separately illustrate logic to identify and extract pilot symbol data blocks from the received data streams, such logic would have been included within channel estimator 36.

214. Ban also teaches that the channel estimator is configured to receive the decoded at least one data symbol. Ex-1006, ¶147. As explained for Element 1[e], after receiving data blocks A and B, Ban’s modified receiver will receive data block C, which includes pilot symbols, as well as data symbols replicated from prior data

blocks A and B, as illustrated below. *Id.* (“some of [the] pilot symbols in the data block are replaced with data symbols of the preceding data block”):

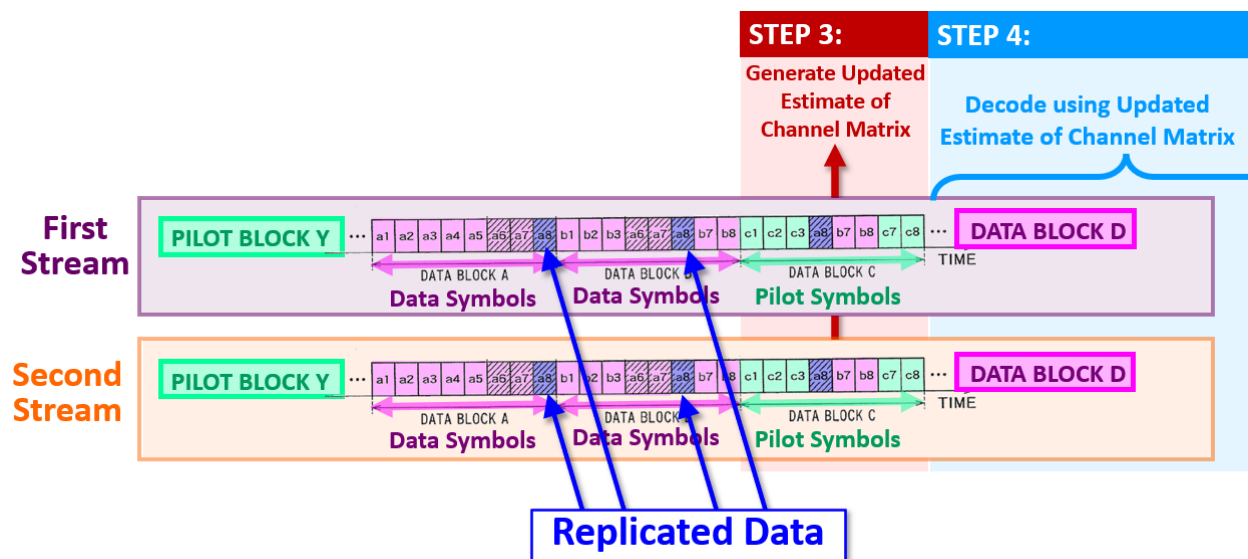


215. Ban uses copied data symbols (e.g., a8) received in block C, in addition to the pilot symbols in block C, to perform a new channel estimation (step 3, above), by treating the copied data symbols as known data (i.e., in the same manner as pilot symbols), since copies of those data symbols were received in the preceding data blocks. Ex-1006 ¶147 (“In this way, since all the pilot symbols and data symbols in the data block can be regarded as known data, the channel can be estimated using the entire data block.”).

216. Because channel estimator 36 must first receive demodulated symbol a8 before it can use it, Ban-Wang teaches that “the channel estimator is configured to receive ... the decoded at least one data symbol.”

- h. Element 6[d]: wherein the decoder is further configured to decode subsequent received signals based, at least in part, on the estimate of the channel matrix.**

217. Ban-Wang teaches or suggests Element 6[d]. As explained for Element 1[f], after receiving a block of pilot symbols (block C, below) and using those symbols to generate an updated estimate of the channel matrix, that updated estimate of the channel matrix is used in the decoding process to decode subsequently received blocks of data symbols (e.g., data block D, below), until the next block of pilot symbols is received and used to generate a new estimate of the channel matrix.



218. Thus, Ban-Wang renders claim 6 obvious.

- 8. Dependent Claim 7: The communication device of claim 6 wherein the decoder is configured to decode the at least one data symbol using a joint detection technique.**

219. Ban-Wang teaches or suggests Claim 7.

220. As explained for Claim 2, as part of the process of decoding replicated a8 data symbols (the claimed “at least one data symbol”), Ban’s “combining unit 40” is used to combine copies of the replicated a8 symbols into a single data symbol. Ex-1006 ¶136, Cl. 20 (same). Ban explains that this may be done using “maximum ratio combining” (Ex-1006 ¶136), which the ’331 Patent identifies as an example of a “joint detection technique” (Ex-1001, 10:28-30).

221. Additionally/alternatively, as explained for Claims 3-4, in the Ban-Wang system, decoding the replicated data involves decoding two spatially diverse received streams (Ex-1007 ¶¶23, 27) by using Alamouti block decoding, which, as explained in §XII.A.2, is another type of joint detection technique.

9. Dependent Claim 8

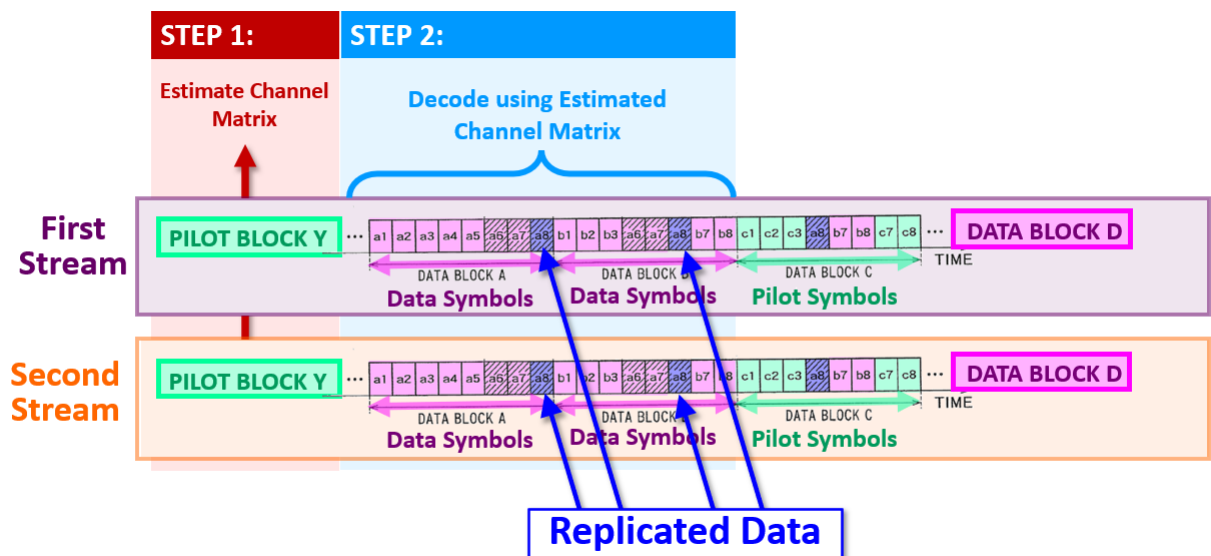
a. Element 8[a]: The communication device of claim 6 wherein the first and second data streams each further include at least one pilot symbol, and

222. Ban-Wang teaches or suggests Element 8[a].

223. As explained for Element 1[a], Ban teaches receiving a “data block composed of pilot symbols.” Ex-1006 ¶134. As explained for Element 1[c], in the combined Ban-Wang system, this block of pilot symbols was replicated into a “second data stream [that] contains the identical data content as the first data stream, but in a different arrangement.” Ex-1007 ¶23. Thus, Ban-Wang teaches or suggests receiving pilot symbols in the first and second data streams.

- b. **Element 8[b]: wherein the channel estimator is configured to receive the at least one pilot symbol and generate an initial estimate of the channel matrix based, at least in part on the at least one pilot symbol.**

224. Ban-Wang teaches or suggests Element 8[b]. As explained for Element 1[b], Ban discloses receiving “a block composed of pilot symbols” and using those pilot symbols to estimate the channel matrix. Ex-1006 ¶134. As illustrated below, in the combined Ban-Wang system, prior to receiving data blocks A and B (which include replicated data symbol a8), the Ban-Wang receiver would receive pilot symbols of block Y, transmitted via Wang’s multiple streams (Ex-1007, Cl. 13). Ban’s channel estimator 36 would then use these pilot symbols to generate an initial estimate of the channel matrix (step 1, below) (Ex-1006 ¶134; Ex-1007, Cl. 13), which would be used to decode replicated symbols a8 of subsequently received data blocks A and B, as explained for Element 1[d].



225. Thus, Ban-Wang teaches or suggests that the channel estimator is configured to generate an initial estimate of the channel matrix based, at least in part on the received at least one pilot symbol.

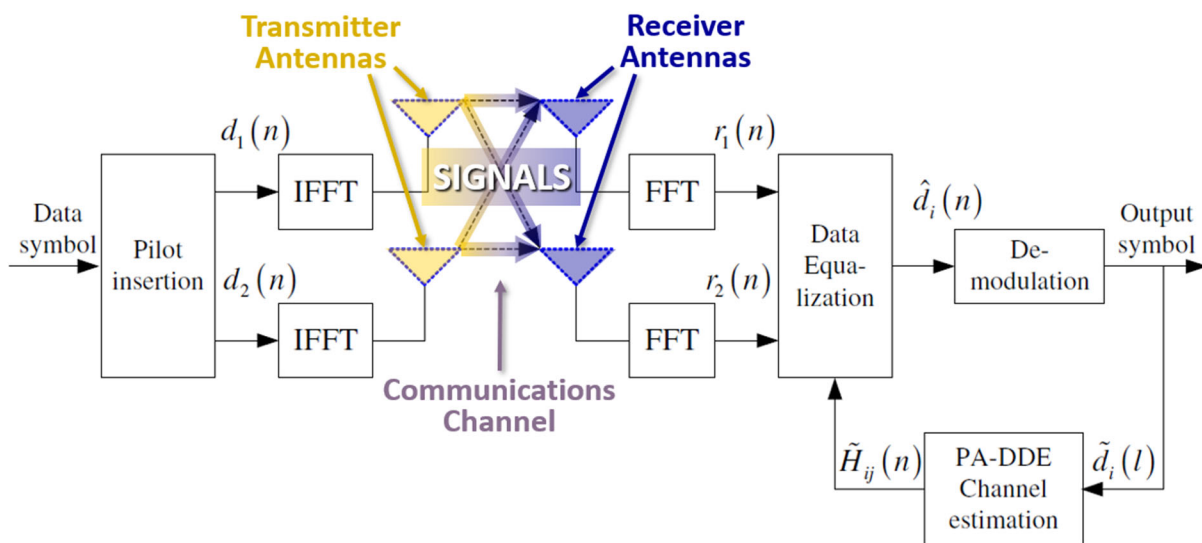
C. Ground 3: Claims 1-8 Are Obvious over Tang

1. Independent Claim 1

- a. **Element 1[pre]: A method of decoding a signal transmitted over a communications channel, the method comprising:**

226. Tang teaches or suggests the preamble, to the extent it is limiting.

227. Tang discloses a method for decoding OFDM symbols (i.e., “signal[s]”) transmitted over a communication channel between multiple transmit and receive antennas, as illustrated in annotated Figure 1, below:



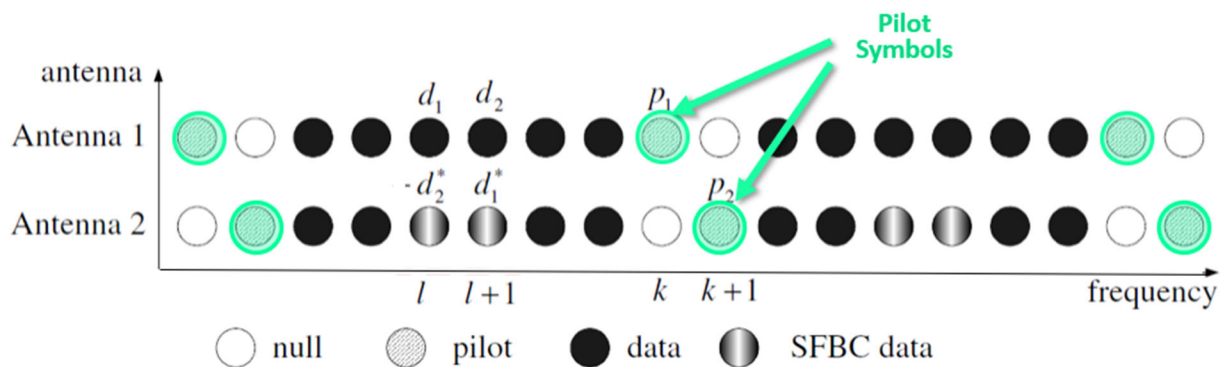
228. Specifically, Figure 1 shows that Tang’s transmitter and receiver include multiple processing blocks that take a “data symbol” through “pilot

insertion” and “modulat[ion] by inverse fast Fourier transform (IFFT)” before transmission through “two transmit antennas,” and then, following reception via “two receive antennas,” through multiple steps for decoding (including channel estimation, equalization, and demodulation) to recover the “output symbol” at the receiver. Ex-1008, pp.2-3.

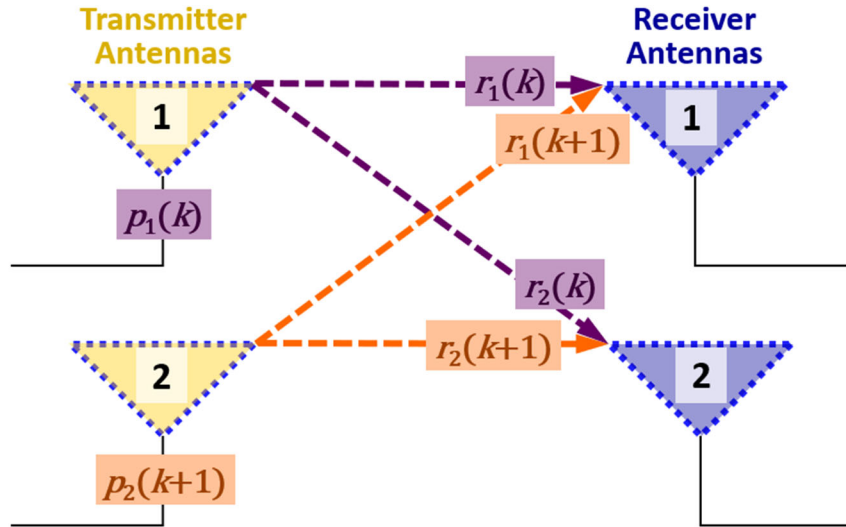
229. In particular, to enhance decoding, by “guarantee[ing] the accuracy of the channel estimation,” while nevertheless “achiev[ing] a good tradeoff between the pilots overhead and the system performance,” Tang teaches a “joint point-aided and blind decision-directed channel estimation (PA-DDCE) scheme.” Ex-1008, p.1.

b. Element 1[a]: receiving a pilot symbol over the communications channel;

230. Tang teaches or suggests Element 1[a]. Tang teaches that the data streams transmitted by Tang’s first and second transmit antennas include pilot symbols (p_1 and p_2 , respectively), as illustrated in annotated Figure 2 below. Ex-1008, p.2.



231. Each of these transmitted streams is received by Tang's receive antennas. Ex-1008, pp.1-2. Thus, as illustrated in the figure below, Tang's j th receive antenna receives signals $r_j(k)$ and $r_j(k + 1)$, corresponding to transmitted pilot symbols $p_1(k)$ and $p_2(k + 1)$, respectively.



- c. **Element 1[b]: estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol;**

232. Tang teaches or suggests Element 1[b]. Tang explains that Step 1 of the disclosed channel estimation method involves using Least Square (LS) channel estimation to calculate “the estimated channel frequency response $\hat{H}_{ij}(k)$ on the pilot sub-carriers $[(k)]$,” for the i th transmit antenna and the j th receive antenna. Ex-1008, p.2. A POSITA would have understood that the channel matrix $\mathbf{H}$ (*id.*) is derived from the channel frequency responses $\hat{H}_{ij}(k)$ as follows.

233. In step 1, Tang's LS channel estimation is based on the received pilot symbols. As explained for Element 1[a], the transmitted pilot symbols $p_1(k)$ and $p_2(k + 1)$ are received at Tang's j th receive antenna as signals $r_j(k)$ and $r_j(k + 1)$, respectively. Ex-1008, p.2. Tang explains that for a MIMO-OFDM system with two transmit antennas and two receive antennas, the components of the estimated channel matrix are calculated using these received pilot symbols, as follows:

The diagram illustrates the calculation of channel matrix components $\hat{H}_{ij}$ for a MIMO-OFDM system. It features four equations arranged vertically:

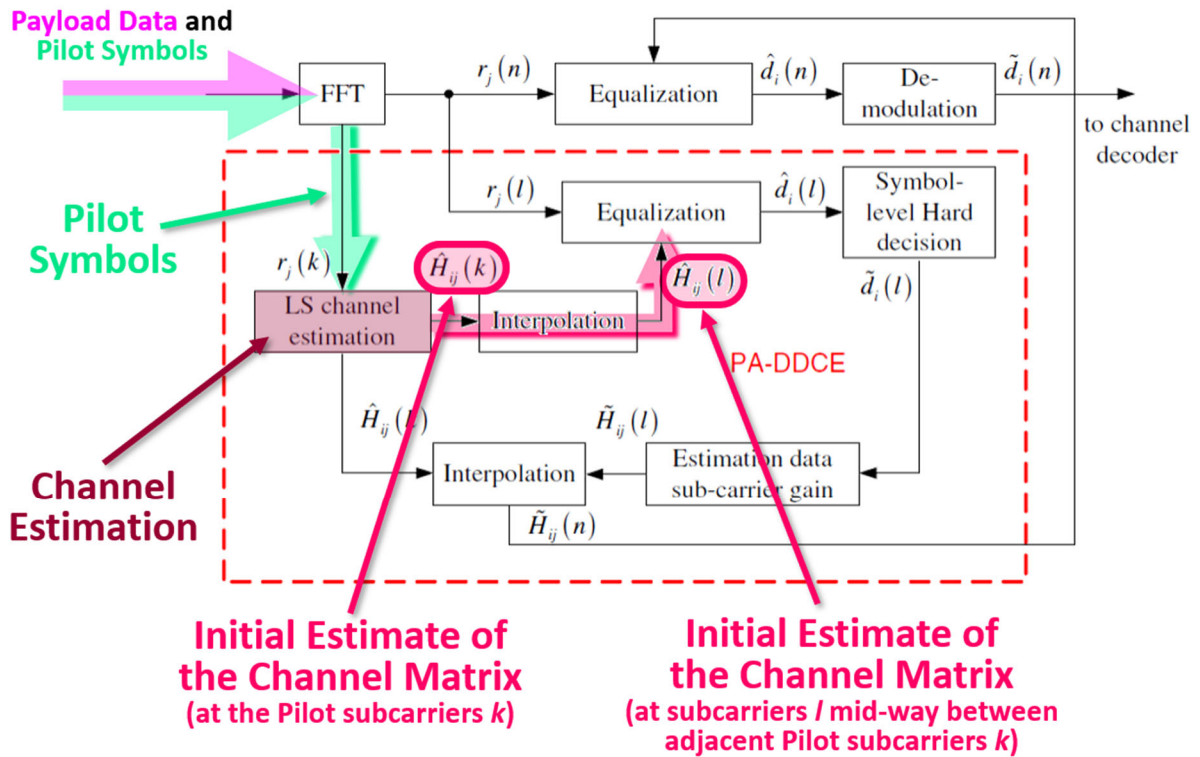
$$\begin{aligned}\hat{H}_{11}(k) &= r_1(k) / p_1(k) \\ \hat{H}_{12}(k) &= r_2(k) / p_1(k) \\ \hat{H}_{21}(k+1) &= r_1(k+1) / p_2(k+1) \\ \hat{H}_{22}(k+1) &= r_2(k+1) / p_2(k+1).\end{aligned}$$

Annotations include:

- A green box highlights the numerators $r_1(k)$ and $r_2(k)$ in the first two equations, with an arrow pointing to the text "Pilot Symbols Received at Subcarrier k ".
- A green box highlights the denominator $p_1(k)$ in the first two equations, with an arrow pointing to the text "Pilot Symbol Transmitted at Subcarrier k ".
- A blue box highlights the numerators $r_1(k+1)$ and $r_2(k+1)$ in the last two equations, with an arrow pointing to the text "Pilot Symbols Received at Subcarrier $k+1$ ".
- A blue box highlights the denominator $p_2(k+1)$ in the last two equations, with an arrow pointing to the text "Pilot Symbol Transmitted at Subcarrier $k+1$ ".

Ex-1008, p.2, equation 2 (annotated).

234. In Step 2 of Tang's disclosed channel estimation method, "[l]inear or other interpolation methods" are used "to obtain the estimated channel frequency response on the non-pilot sub-carriers $\hat{H}_{ij}(l)$, where l is defined as the middle sub-carriers between any two adjacent pilot sub-carriers." Ex-1008, p.2. This is illustrated in annotated Figure 3, below.



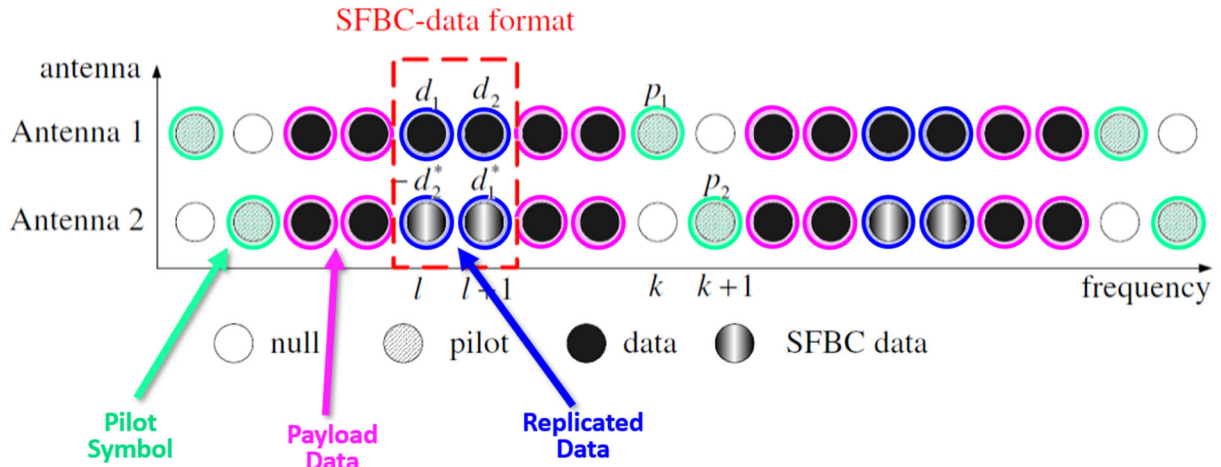
235. Thus, Tang teaches or suggests estimating a channel matrix H of the communications channel ($\hat{H}_{ij}(l)$) based, at least in part, on the received pilot symbols $r_j(k)$ and $r_j(k + 1)$.

- d. **Element 1[c]: receiving replicated data from multiple data streams transmitted over the communications channel;**

236. Tang teaches or suggests Element 1[c].

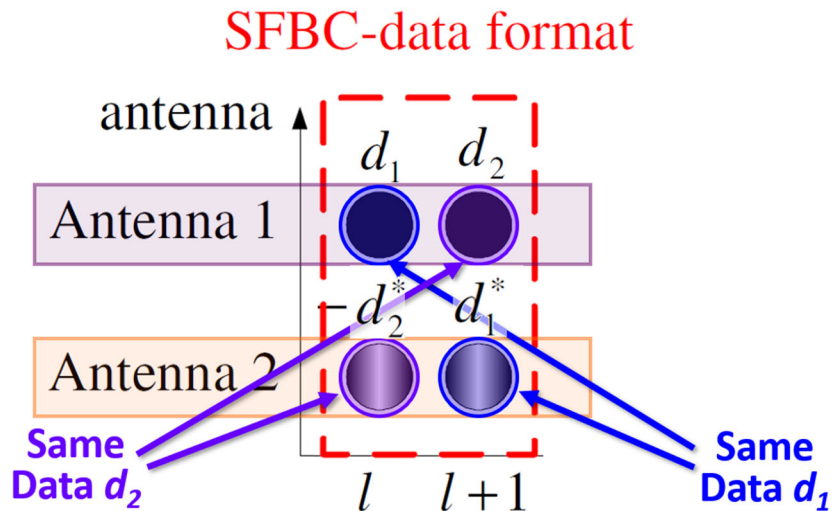
237. Tang discloses inserting “data symbols with the orthogonal format ... in the middle of any two adjacent pilot sub-carriers,” so they can be used for improved channel estimation. Ex-1008, p.1. As one of the disclosed orthogonal data

formats, Tang presents a “space frequency block code (SFBC)-data [] format,” as illustrated in annotated Figure 5, below. *Id.*



As illustrated further in excerpted Figure 5 below, in the SFBC-data format, data symbol d_1 , to be transmitted in sub-carrier l by antenna 1, is copied into sub-carrier $l + 1$ of the data stream to be transmitted by antenna 2. Similarly, data symbol d_2 is copied from sub-carrier $l + 1$ of antenna 1’s data stream into sub-carrier l of antenna 2’s data stream. Ex-1008, p.3. Here, while complex conjugates of d_1 and d_2 are transmitted by the second antenna (to achieve orthogonality), a POSITA would have understood that d_i and its complex conjugate, d_i^* , correspond to two representations of the same underlying data symbol. *See, e.g.,* Ex-1025, 0539-0540 (describing block coding techniques, such as Alamouti encoding, and explaining that in such techniques, redundancy may be introduced in a system with multiple transmit antennas “by sending from each transmit antenna a differently encoded (and fully

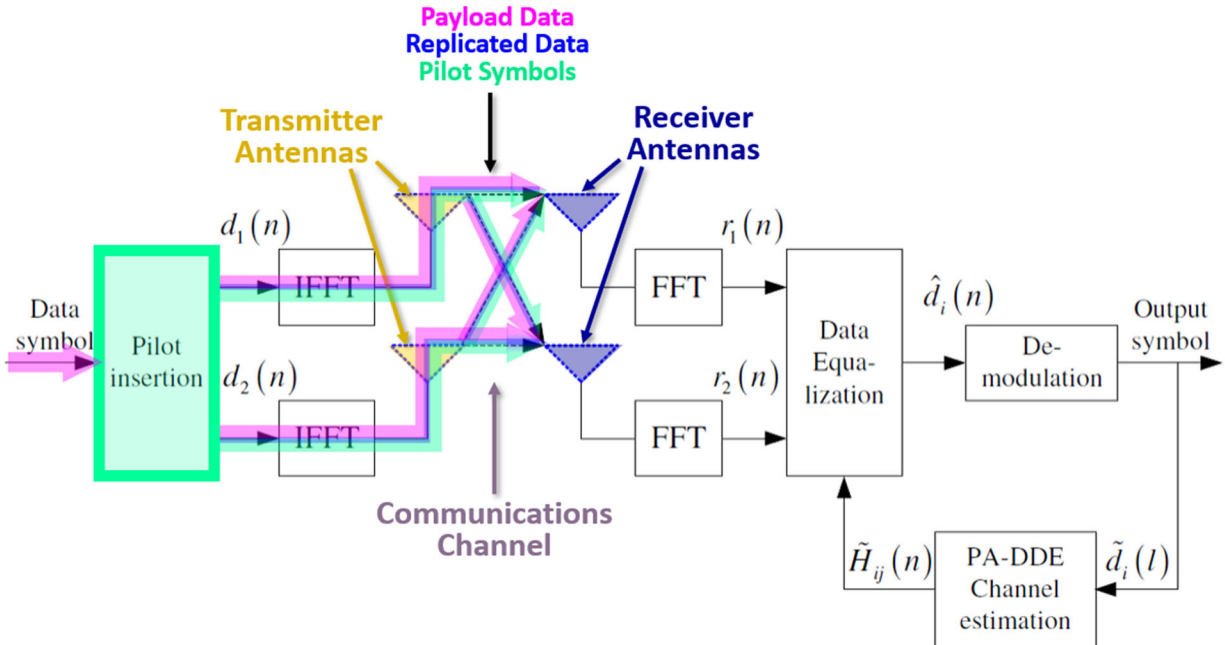
redundant) version of *the same signal*"). For example, Wang explains that its "space time coding" scheme (corresponding to the Alamouti space-time coding scheme) generates "[a] second data stream [that] contains *the identical data content* as the first data stream, but in a different arrangement," and a POSITA would have understood that the same would be true of Tang's SFBC-data format (which is equivalent to Alamouti's space-frequency coding scheme). Ex-1007, ¶23; Ex-1023, 0003-0004. Further, the '331 Patent also contemplates that d_i and its complex conjugate, d_i^* , correspond to two representations of the same underlying data symbol. See, e.g., Ex-1001, Fig. 5 (equating s_3 and s_3^*). Moreover, certain modulation schemes, e.g., BPSK, use real symbols for which $s_1 = s_1^*$.¹⁰



238. These replicated data symbols are received by each receive antenna j , as received data symbols $r_j(l)$. Ex-1008, p.2. Thus, Tang teaches or suggests

¹⁰ See, e.g., https://en.wikipedia.org/wiki/Phase-shift_keying

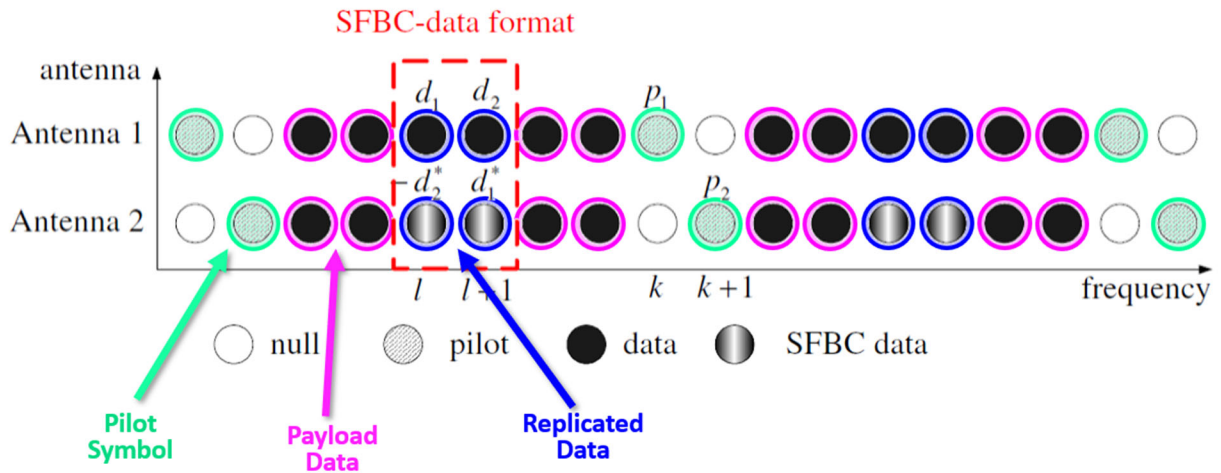
receiving replicated data from multiple data streams transmitted over the communications channel, as illustrated in annotated Figure 3, below.



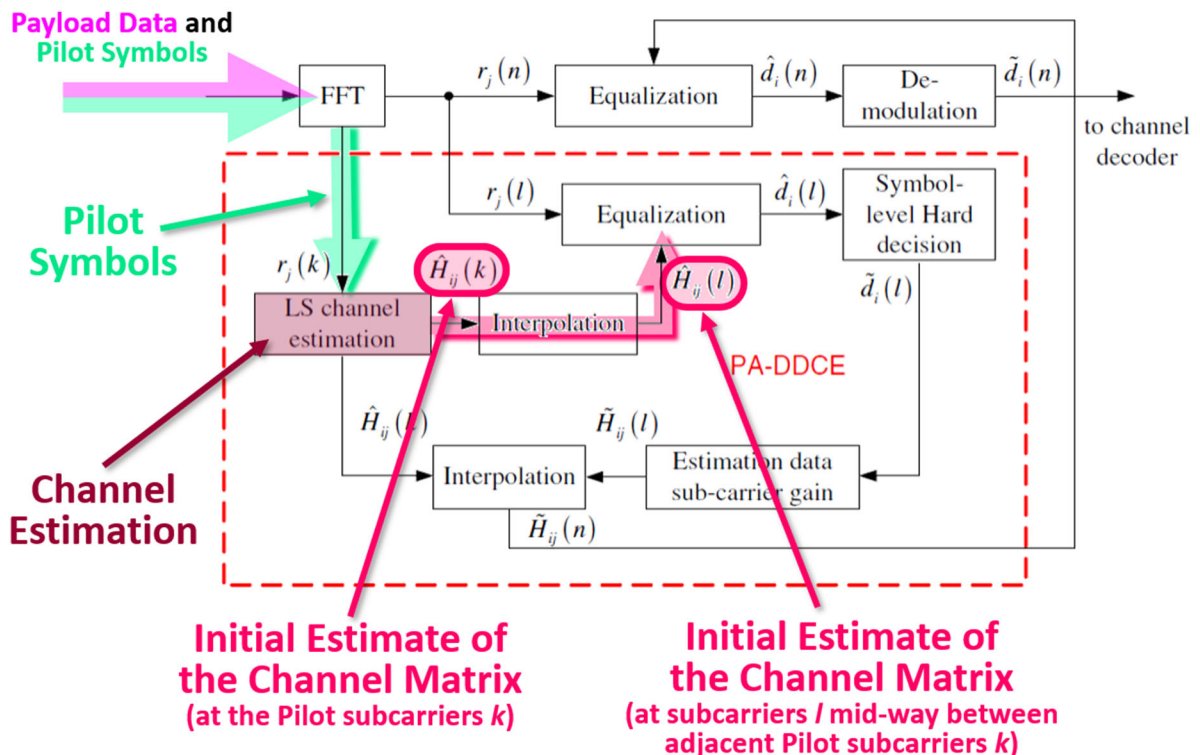
e. Element 1[d]: decoding the replicated data using the estimated channel matrix;

239. Tang teaches or suggests Element 1[d].

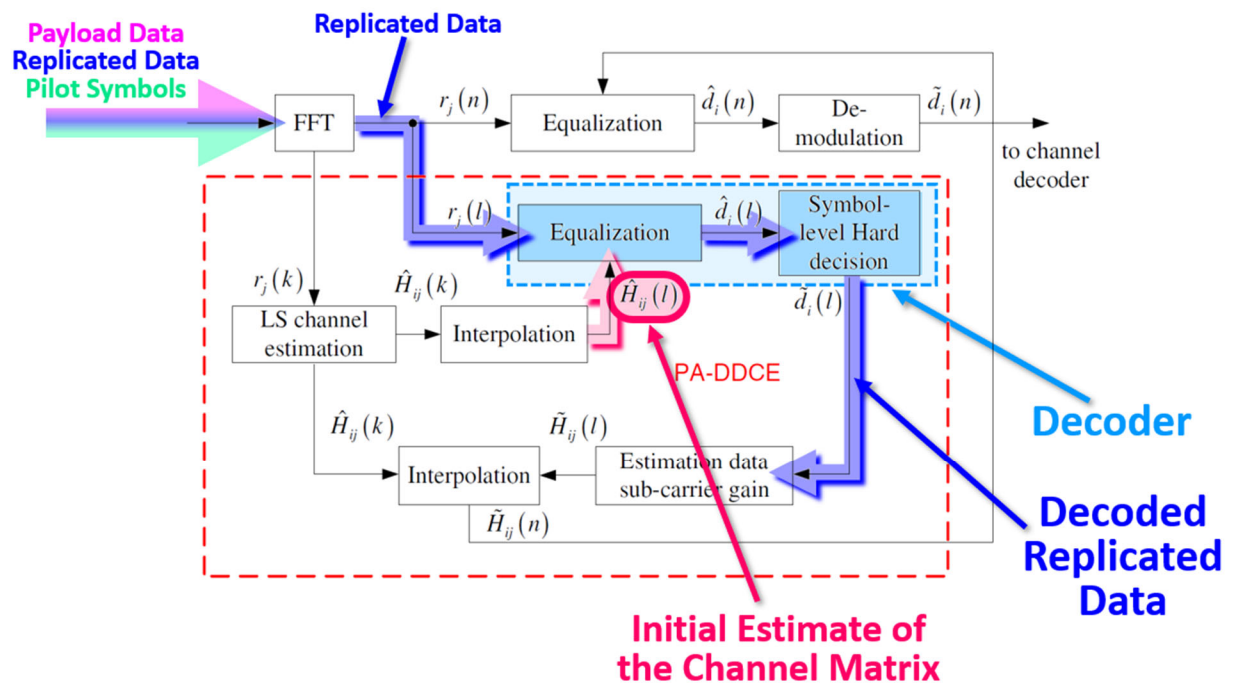
240. As explained for Elements 1[b] and [c] and illustrated in annotated Figure 5, below, Tang discloses transmitting pilot symbols (p_1 and p_2) at subcarriers k and $k+1$ and replicated data (d_1 and d_2) at subcarriers l and $l+1$:



241. As explained for Element 1[b] and illustrated in annotated Figure 3 below, in Steps 1 and 2 of Tang's method, the received pilot symbols are used to generate channel estimates at the pilot subcarriers k , from which channel estimates at the replicated data subcarriers l , $\hat{H}_{ij}(l)$, are obtained through interpolation:



242. In Steps 3 and 4 of Tang’s method, the estimated channel frequency response $\hat{H}_{ij}(l)$ (interpolated to the replicated data subcarriers l) is used to decode the received replicated data symbols $r_j(l)$, through “equalization” and “symbol-level Hard decision” decoding, as illustrated in annotated Figure 3 below, resulting in decoded replicated data $\tilde{d}_i(l)$. Ex-1008, p.2.

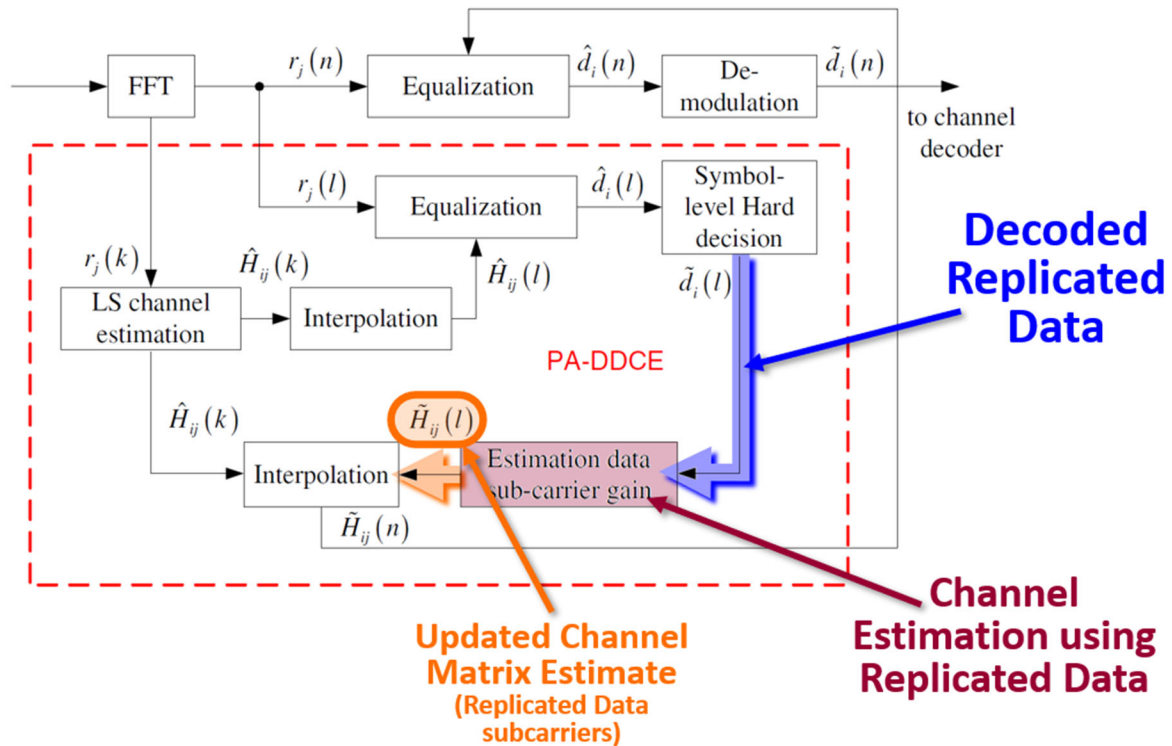


- f. **Element 1[e]: generating an updated estimate of the channel matrix based, at least in part, on the replicated data; and**

243. Tang teaches or suggests Element 1[e].

244. Tang discloses using the decoded replicated data symbols $\tilde{d}_i(l)$ in Step 5 of Tang’s channel estimation method, to calculate a “new data subcarrier channel

frequency response $\tilde{H}_{ij}(l)$ ” at the replicated data subcarriers l , as illustrated in annotated Figure 3, below. Ex-1008, p. 2.



245. In particular, Tang explains that, following decoding, the received replicated data symbols, $\tilde{d}_1(l)$ and $\tilde{d}_2(l)$, “are regarded as *extra ‘pilot symbols’* and can be used to compute the channel frequency response at the sub-carriers l and $l + 1$ ” using the following formula:

Updated Channel Matrix Estimate  $\tilde{\mathbf{H}}_s = \left(\tilde{\mathbf{d}}_s^H \tilde{\mathbf{d}}_s \right)^{-1} \tilde{\mathbf{d}}_s^H \mathbf{r},$ (18)

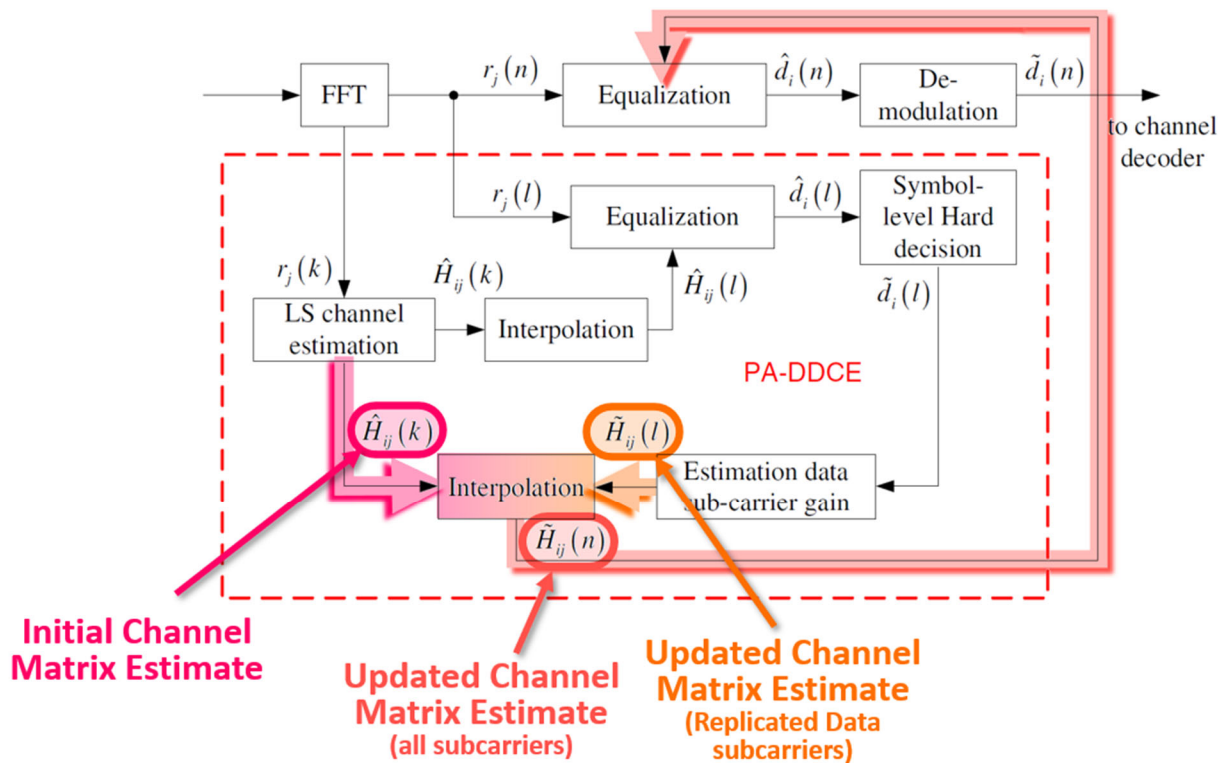
where

$$\tilde{\mathbf{H}}_s = \begin{bmatrix} \tilde{H}_{11}(l) & \tilde{H}_{21}(l) \\ \tilde{H}_{12}(l) & \tilde{H}_{22}(l) \end{bmatrix}, \quad (19)$$

and

$$\tilde{\mathbf{d}}_s = \begin{bmatrix} \tilde{d}_1(l) & \tilde{d}_2(l+1) \\ \underbrace{-\tilde{d}_2^*(l) \quad \tilde{d}_1^*(l+1)}_{\text{Decoded Replicated Data Symbols}} \end{bmatrix}. \quad (20)$$

Ex-1008, p.4. The final updated estimated channel frequency response $\tilde{H}_{ij}(n)$, at all subcarriers n , can then be obtained through interpolation between the initial estimate $\hat{H}_{ij}(k)$, at pilot subcarriers k , and the updated estimate $\tilde{H}_{ij}(l)$, at the replicated data subcarriers l , as illustrated in annotated Figure 3 below. Ex-1008, p.4.

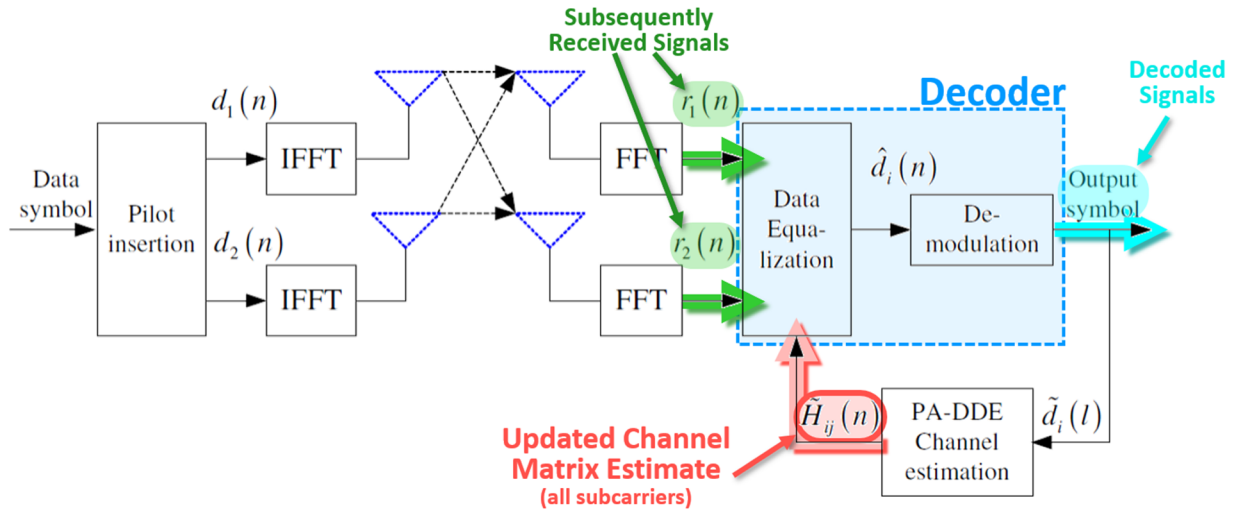


246. Thus, Tang teaches or suggests generating an updated estimate of the channel matrix (Tang’s final estimated channel frequency response $\tilde{H}_{ij}(n)$) based, at least in part, on the replicated data.

- g. Element 1[f]: decoding subsequently received signals over the communications channel using the updated estimate of the channel matrix.**

247. Tang teaches or suggests Element 1[f].

248. As illustrated in annotated Figure 1 below, Tang’s final estimated channel frequency response $\tilde{H}_{ij}(n)$ (“the updated estimate of the channel matrix”) is used by the “data equalization” block of Tang’s receiver, as part of decoding received signals $r_j(n)$.



249. As explained in above (Element 1[f] for Ground 1 based on Haustein), a POSITA would have understood that, following receipt of the pilot symbols and replicated data symbols that are used to generate the final estimated channel frequency response $\tilde{H}_{ij}(n)$, Tang's receiver would use $\tilde{H}_{ij}(n)$ to decode subsequently received signals $r_j(n)$ over a coherence time over which the channel is assumed not to be varying (i.e., the time over which $\tilde{H}_{ij}(n)$ is assumed not to change), until a new set of pilot symbols and replicated data symbols are received. In particular, a POSITA would have understood that, by waiting a coherence time interval between pilot signal transmissions, during which time interval received signals are decoded using the latest estimate of the channel matrix, "pilot overhead," which Tang teaches "diminishes the system spectrum efficiency," may be reduced.

Ex-1008, p.2.

250. Thus, the updated estimate of the channel matrix would be used to decode subsequently received signals over the communication channel during the coherence time until the next pilot block is transmitted. Thus, Tang renders claim 1 obvious.

2. Dependent Claim 2: The method of claim 1, wherein said decoding the replicated data comprises using a joint detection technique.

251. Tang teaches or suggests Claim 2. Tang's decoding process, through which received replicated data symbols $r_j(l)$ are transformed into decoded replicated data $\tilde{d}_i(l)$, uses "four-branch MRRC [*maximal-ratio receiver combining*]" (Ex-1008, p.3), which the '331 Patent specifically identifies as an example of a "joint detection technique" (Ex-1001, 10:28-30). In particular, the '331 Patent states that "a joint detection technique is used to decode the replicated data, *such as max-ratio combining.*" *Id.*

3. Dependent Claim 4: The method of claim 1, wherein said decoding the replicated data comprises using a space-frequency block decoding technique.

252. Tang teaches or suggests Claim 4. Tang teaches generating replicated data by encoding data symbols d_1 and d_2 using a space frequency block code (SFBC). Ex-1008, pp.1, 3. Decoding such space-frequency-block-encoded data at the receiver thus employs a space-frequency block decoding technique.

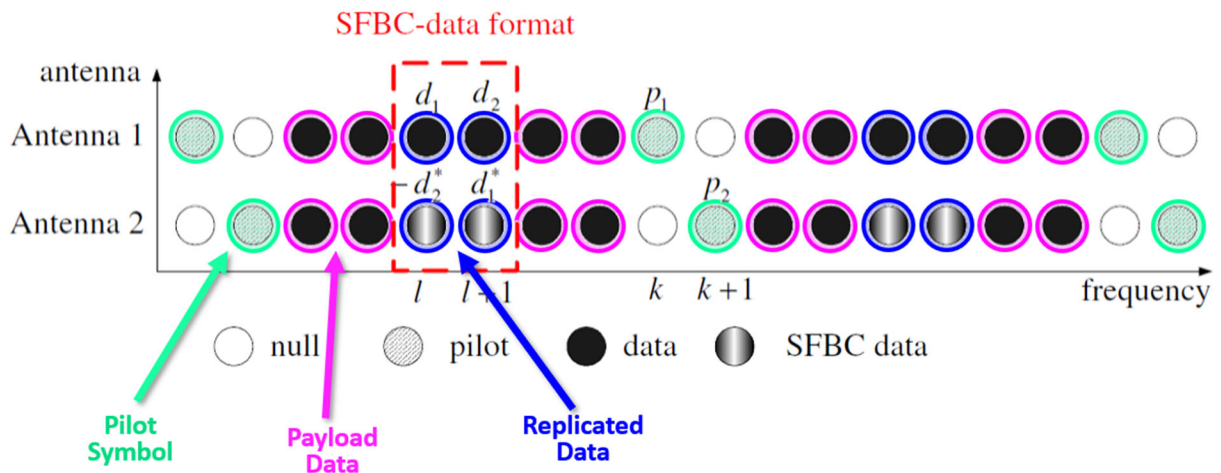
4. Dependent Claim 3: The method of claim 1, wherein said decoding the replicated data comprises using a space-time block decoding technique.

253. Tang teaches or suggests Claim 3. As explained for Claim 4, Tang teaches space-frequency block decoding through Tang's use of the space-frequency block code data-format. A POSITA would have recognized that data symbols d_1 and d_2 could also be encoded/decoded using a space-time block code, similarly providing spatial diversity, and enabling their use as "extra' pilot symbols" (Ex-1008, p.4). In particular, Alamouti's paper describes both "space-time coding," where "the encoding is done in space and time," as well as "space-frequency coding," where "two adjacent carriers may be used." Ex-1023, 0002-0003.

5. Dependent Claim 5: The method of claim 1, wherein the replicated data includes same data symbols in multiple data streams.

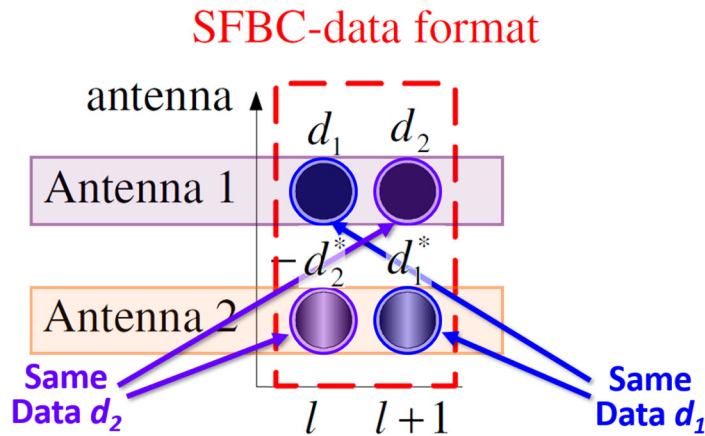
254. Tang teaches or suggests Claim 5.

255. As explained for Element 1[c] and illustrated in annotated Figure 5 below, Tang teaches replicating data symbols (d_1 and d_2) from a data stream transmitted by one antenna into a data stream transmitted by another antenna.



256. While Figure 5 (excerpted/annotated below) illustrates that complex conjugates of data symbols d_1 and d_2 are transmitted by the second antenna to achieve orthogonality, a POSITA would have understood that each data symbol d_i and its complex conjugate, d_i^* , correspond to the same underlying data symbol. See, e.g., Ex-1025, 0539-0540 (describing block coding techniques, such as Alamouti encoding, and explaining that in such techniques, redundancy may be introduced in a system with multiple transmit antennas “by sending from each transmit antenna a differently encoded (and fully redundant) version of *the same signal*”). For example, Wang explains that its “space time coding” scheme (corresponding to the Alamouti space-time coding scheme) generates “[a] second data stream [that] contains *the identical data content* as the first data stream, but in a different arrangement,” and a POSITA would have understood that the same would be true of Tang’s SFBC-data format (which is equivalent to Alamouti’s space-frequency coding scheme). Ex-

1007, ¶23; Ex-1023, 0003-0004. Further, the '331 Patent also contemplates that d_i and its complex conjugate, d_i^* , correspond to two representations of the same underlying data symbol. *See, e.g.*, Ex-1001, Fig. 5 (equating s_3 and s_3^*). Moreover, certain modulation schemes, e.g., BPSK, use real symbols for which $s_1 = s_1^*$.¹¹



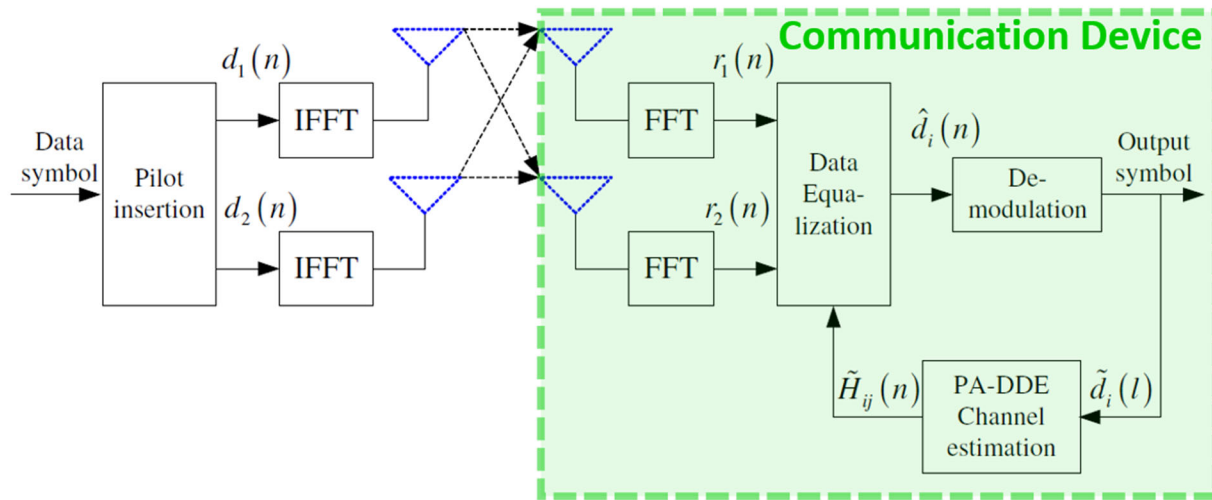
6. Independent Claim 6:

a. Element 6[pre]: A communication device comprising:

257. Tang teaches or suggests the preamble, to the extent it is limiting.

258. Tang's receiver, illustrated below, is a communication device, because it includes "two receive antennas" to receive signals, $r_j(n)$ (where j corresponds to the j th receive antenna), transmitted by "two transmit antennas." Ex-1008, p.2.

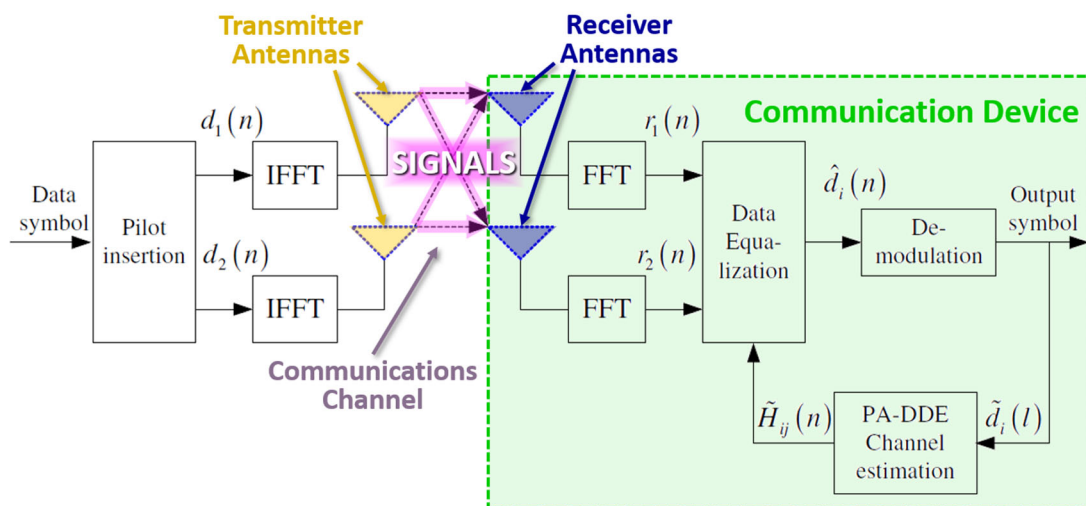
¹¹ *See, e.g.*, https://en.wikipedia.org/wiki/Phase-shift_keying



b. Element 6[a]: a receiver configured to receive signals over a communications channel,

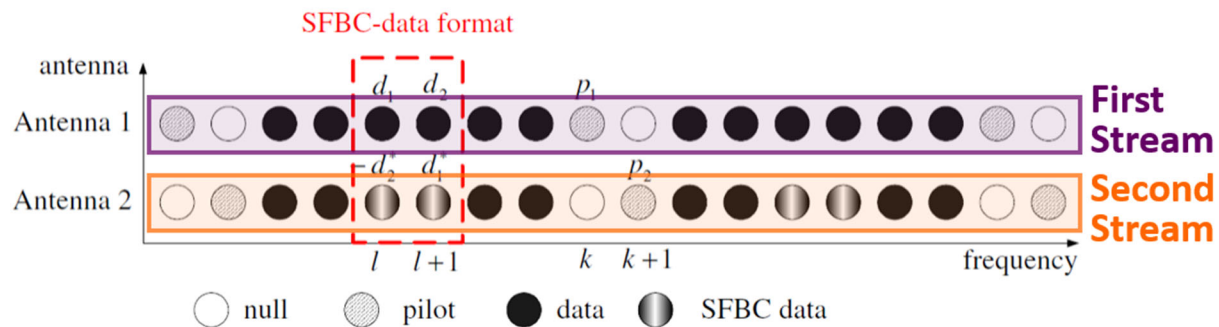
259. Tang teaches or suggests Element 6[a].

260. Figure 1, below, illustrates the claimed “receiver” coupled to Tang’s “two receive antennas” that receive signals, $r_j(n)$, transmitted over a communication channel between the two transmit antennas and the two receive antennas. Ex-1008, p.2.

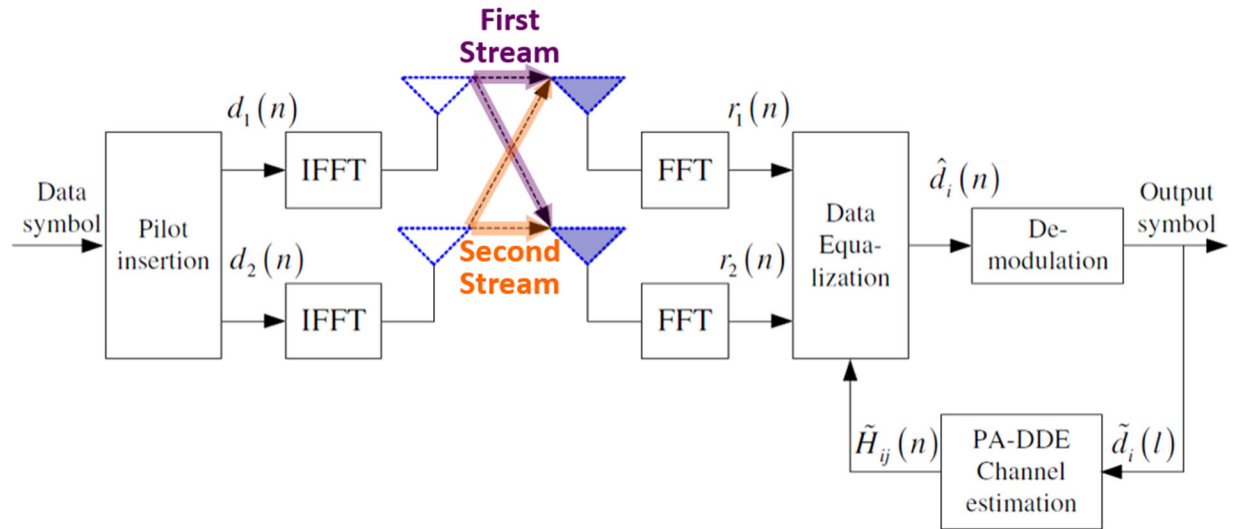


- c. **Element 6[a][i]: wherein the signals are based at least in part on first and second data streams transmitted over a communications channel,**

261. Tang teaches or suggests Element 6[a][i]. As explained for Element 1[c], Tang teaches that each of its transmit antennas transmits a stream of data symbols. Ex-1008, p.2. Thus, transmit antenna 1 transmits a “first” data stream, and transmit antenna 2 transmits a “second” data stream, as illustrated in annotated Figure 5 below.



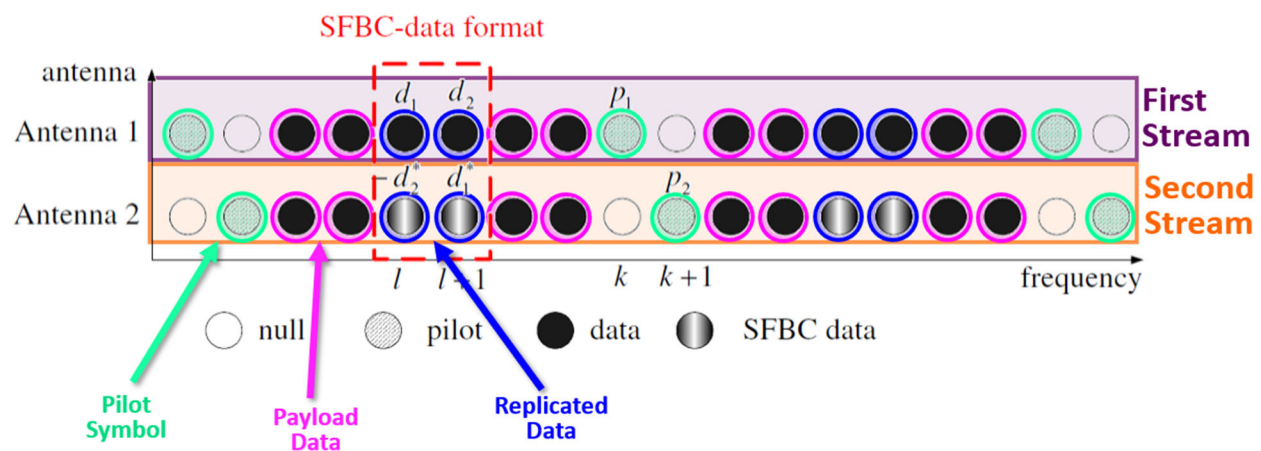
262. As illustrated in annotated Figure 1 below, each of Tang’s receive antennas receives both a copy of the first data stream transmitted by transmit antenna 1 and a copy of the second data stream transmitted by transmit antenna 2.



- d. **Element 6[a][ii]: wherein the second data stream includes at least one data symbol replicated from the first data stream;**

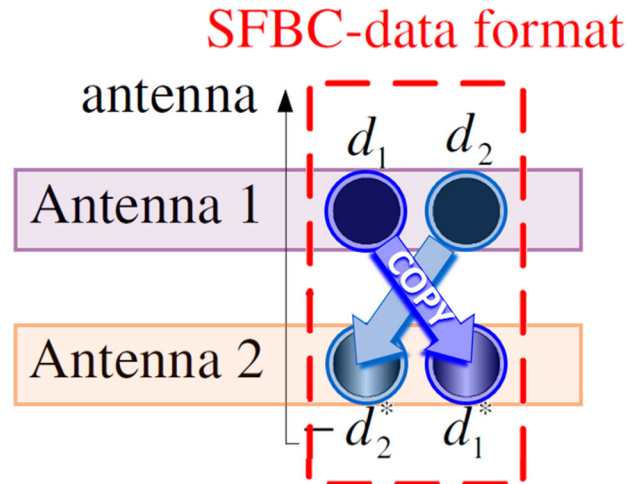
263. Tang teaches or suggests Element 6[a][ii].

264. As explained for Element 1[c], Tang discloses inserting a “space frequency block code (SFBC)-data [] format” in the middle of any two adjacent pilot sub-carriers,” as illustrated in annotated Figure 5 below. Ex-1008, pp.1-2.



265. In the SFBC data format, data symbol d_1 , to be transmitted in sub-carrier l by antenna 1, is copied into sub-carrier $l + 1$ of the data stream to be transmitted by antenna 2. And, data symbol d_2 is copied from sub-carrier $l + 1$ of antenna 1's data stream into sub-carrier l of antenna 2's data stream. Ex-1008, p. 3. Here, while complex conjugates of d_1 and d_2 are transmitted by the second antenna (to achieve orthogonality), a POSITA would have understood that d_i and its complex conjugate, d_i^* , correspond to the same underlying data symbol. *See, e.g.*, Ex-1025, 0539-0540 (describing block coding techniques, such as Alamouti encoding, and explaining that in such techniques, redundancy may be introduced in a system with multiple transmit antennas “by sending from each transmit antenna a differently encoded (and fully redundant) version of *the same signal*”). For example, Wang explains that its “space time coding” scheme (corresponding to the Alamouti space-time coding scheme) generates “[a] second data stream [that] contains *the identical data content* as the first data stream, but in a different arrangement,” and a POSITA would have understood that the same would be true of Tang's SFBC-data format (which is equivalent to Alamouti's space-frequency coding scheme). Ex-1007, ¶23; Ex-1023, 0003-0004. Further, the '331 Patent also contemplates that d_i and its complex conjugate, d_i^* , correspond to two representations of the same

underlying data symbol. *See, e.g.*, Ex-1001, Fig. 5 (equating s_3 and s_3^*). Moreover, certain modulation schemes, e.g., BPSK, use real symbols for which $s_1 = s_1^*$.¹²



266. Thus, Tang teaches or suggests that the second data stream (transmitted by transmit antenna 2) includes at least one data symbol (d_1 and d_2) replicated from the first data stream (transmitted by transmit antenna 1).

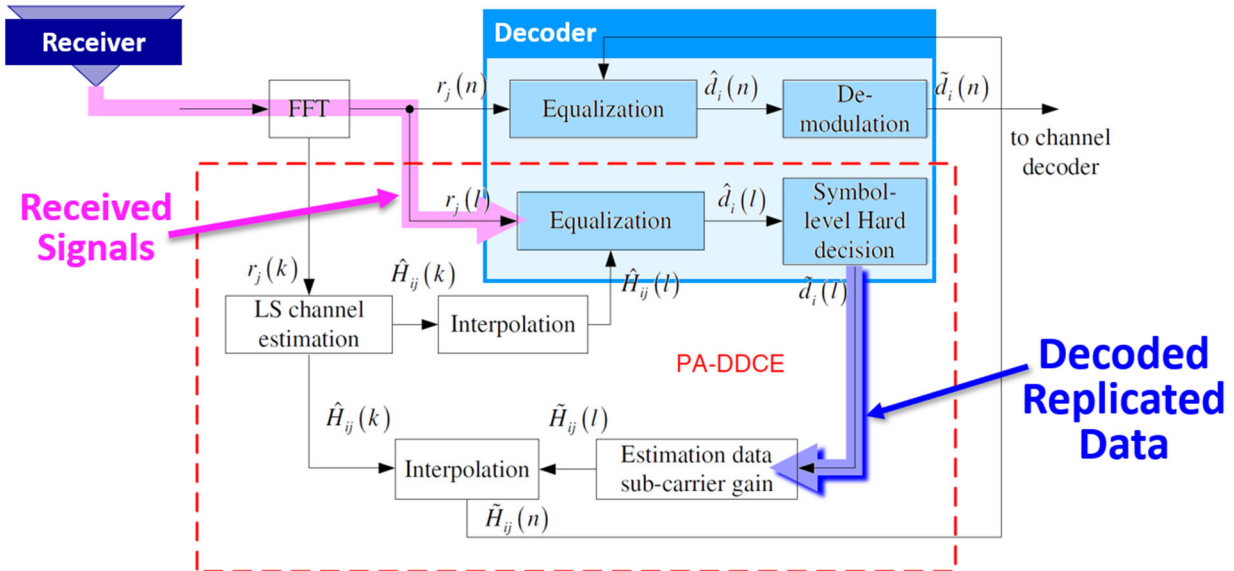
- e. **Element 6[b]: a decoder coupled to the receiver and the channel estimator, wherein the decoder is configured to receive the received signals and decode the at least one data symbol replicated from the first data stream;**

267. Tang teaches or suggests Element 6[b].

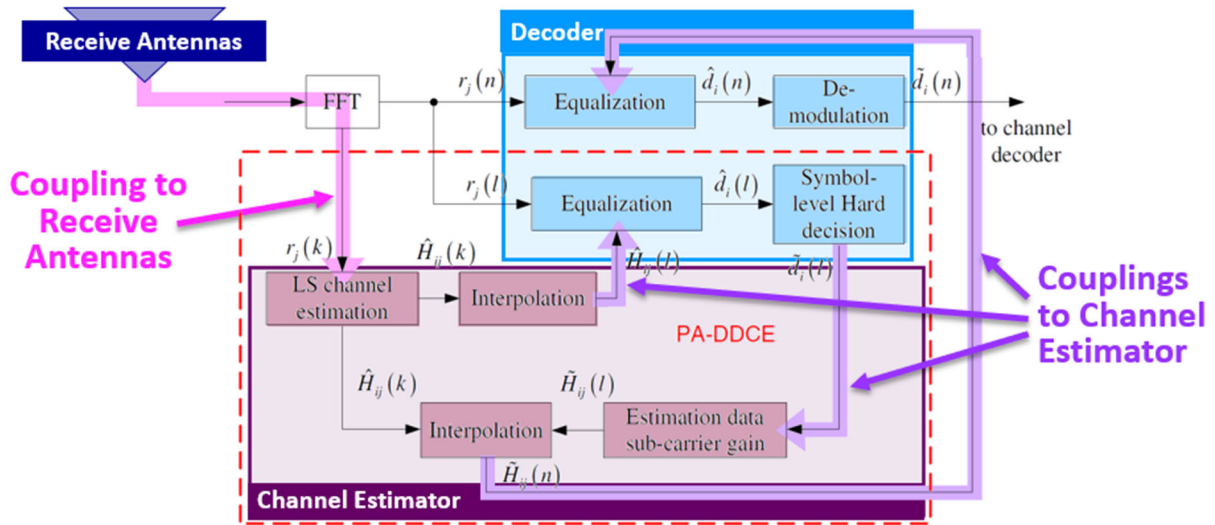
268. Together, Tang’s “data equalization” and “symbol-level hard decision” blocks, illustrated in annotated Figure 3 below, correspond to the claimed “decoder,” because they are configured to use an estimated channel matrix ($\hat{H}_{ij}(l)$) to perform

¹² *See, e.g.*, https://en.wikipedia.org/wiki/Phase-shift_keying

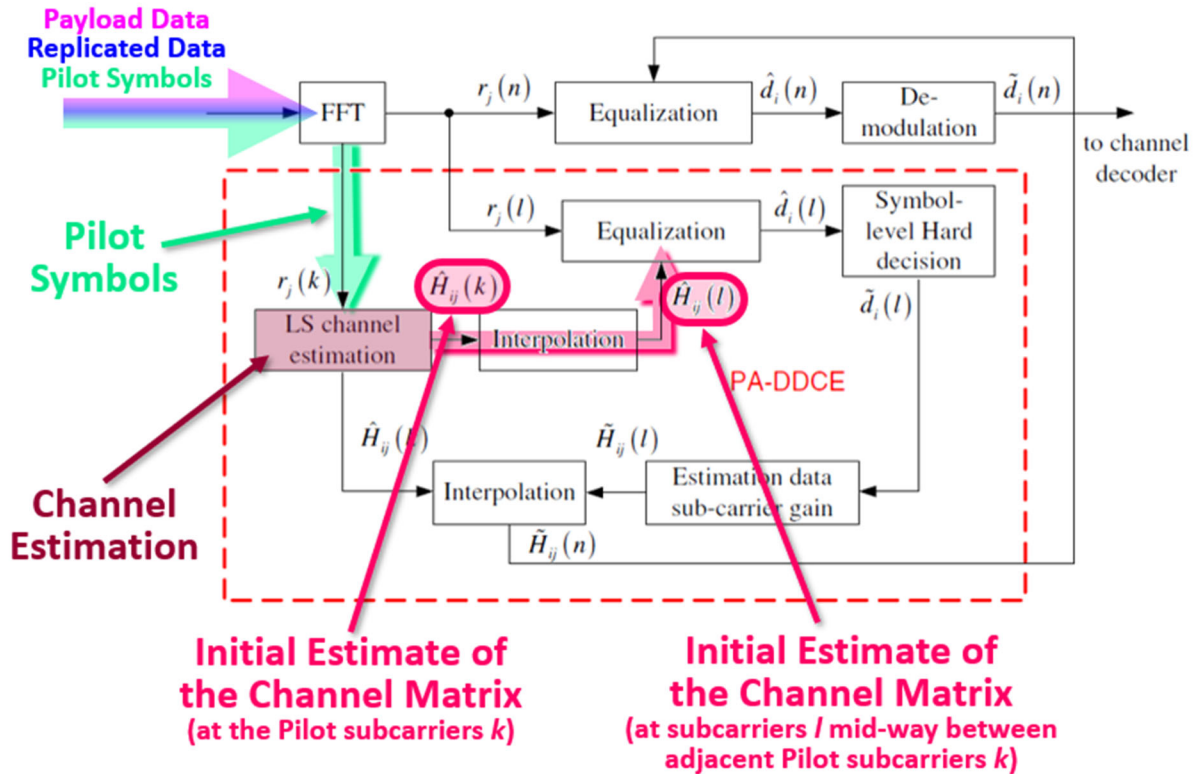
“equalization” and “symbol-level hard decision” decoding on received signals $r_j(l)$, as explained for Element 1[d]. Ex-1008, pp.2, 4.



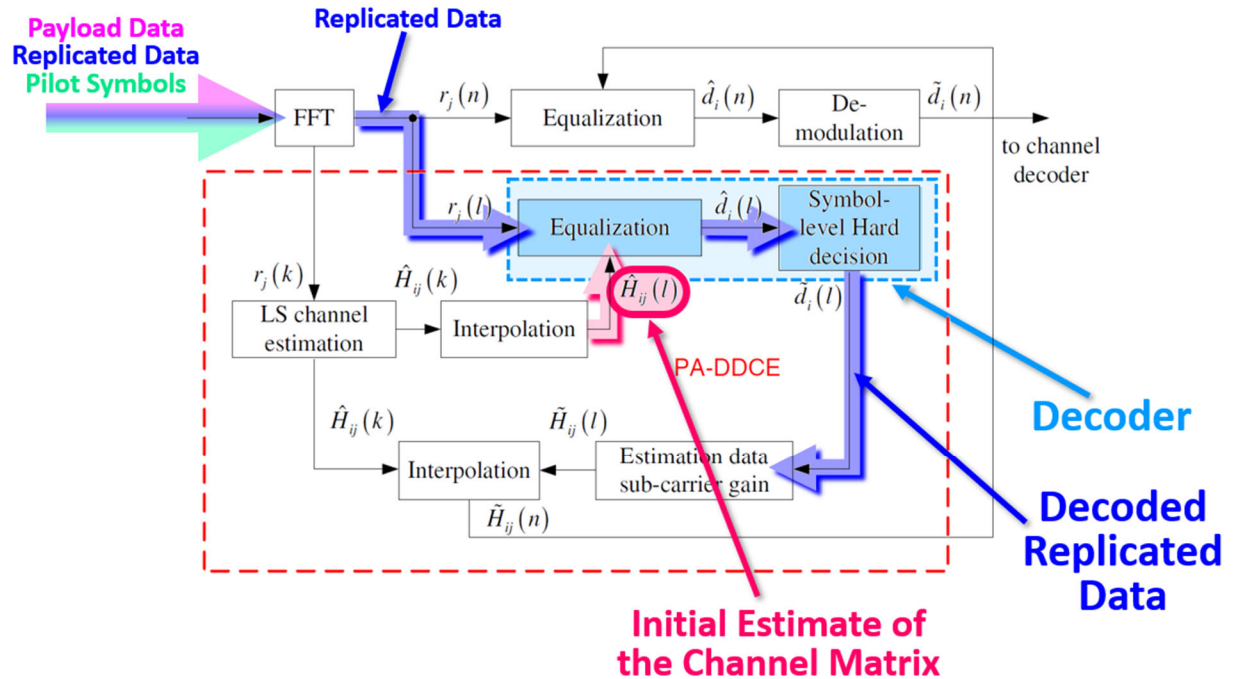
269. As illustrated in annotated Figure 3, below, this decoder is coupled to the PA-DDCE channel estimator (corresponding to “LS channel estimation,” “Interpolation,” and “Estimation data sub-carrier gain” blocks), and to Tang’s receive antennas through the “FFT” block, from which it receives signals $r_j(l)$.



270. As explained for Element 1[d] and illustrated in annotated Figure 3 below, in Steps 1 and 2 of Tang's disclosed method, received pilot symbols are used to generate channel estimates at the pilot subcarriers k , from which channel estimates at the replicated data subcarriers l , $\hat{H}_{ij}(l)$, are obtained through interpolation. Ex-1008, p.2.



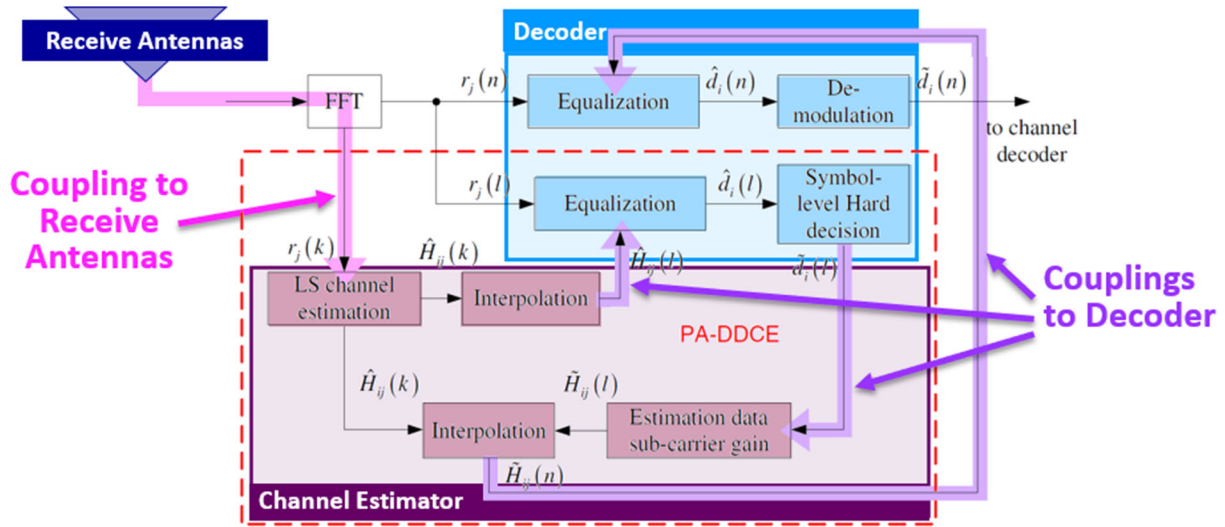
271. Then, in Steps 3 and 4 of Tang’s method, the estimated channel frequency response $\hat{H}_{ij}(l)$ (interpolated to the replicated data subcarriers l) is used to decode the received replicated data symbols $r_j(l)$, through “equalization” and “symbol-level Hard decision” decoding, as illustrated in annotated Figure 3 below, resulting in decoded replicated data $\tilde{d}_i(l)$. Ex-1008, p.2.



f. **Element 6[c]: a channel estimator coupled to the decoder and the receiver,**

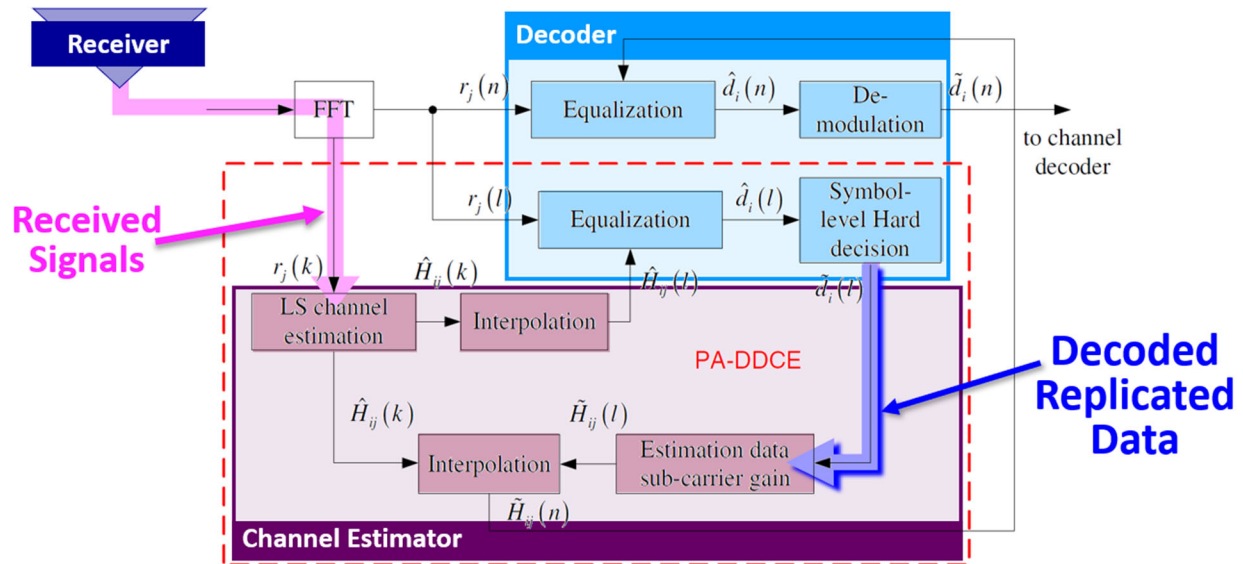
272. Tang teaches or suggests Element 6[c].

273. As illustrated below, Tang's channel estimator (including "LS channel estimation," "Interpolation," and "Estimation data sub-carrier gain" blocks) is coupled both to Tang's receive antennas ("receiver") and to "equalization" and "symbol-level Hard decision" blocks (forming part of the claimed "decoder," as explained for Element 6[b]).



- g. **Element 6[c][i]:** wherein the channel estimator is configured to receive the received signals and the decoded at least one data symbol, / **Element 6[c][ii]:** wherein the channel estimator is configured to estimate a channel matrix of the communications channel based, at least in part, on the decoded at least one data symbol; and

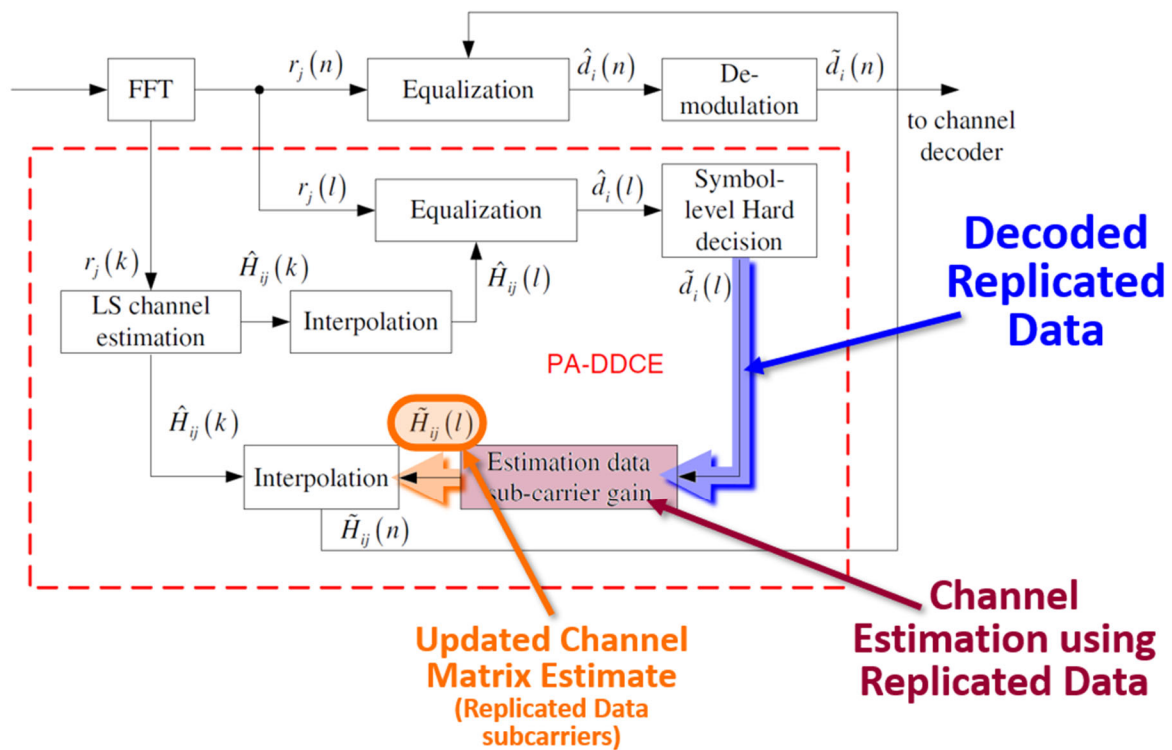
274. Tang teaches or suggests Elements 6[c][i] and 6[c][ii]. As illustrated in annotated Figure 3, below, Tang's PA-DDCE channel estimator is configured to receive the signals transmitted by Tang's transmit antennas 1 and 2 as first and second streams ("received signals"):



275. As explained for Elements 1[a] and 1[b], received pilot symbols p_1 and p_2 are processed using Least Square (LS) channel estimation to calculate “the estimated channel frequency response $\hat{H}_{ij}(k)$ on the pilot sub-carriers $[(k)]$.” Ex-1008, p.2. A POSITA would have understood that Tang’s channel estimator (of which “LS channel estimation block” is a part) would be configured to receive the data streams transmitted by Tang’s transmit antennas (“receive the received signals”), and to identify and extract, from those streams, the pilot symbols on which the channel estimator operates. In particular, a POSITA would have recognized that, because Tang’s Figure 3 does not separately illustrate logic to identify and extract pilot symbols from the received data streams, such logic would have been included within the LS channel estimation block.

276. Tang also teaches that the “estimation data sub-carrier gain” block (part of Tang’s “channel estimator,” as explained for Element 6[c]) receives the decoded

at least one data symbol ($\tilde{d}_i(l)$), as illustrated in annotated Figure 3, above. As explained for Element 1[e], Step 5 of Tang’s disclosed channel estimation method involves using the decoded replicated data symbols $\tilde{d}_i(l)$ to calculate a “new data subcarrier channel frequency response $\tilde{H}_{ij}(l)$ ” at the replicated data subcarriers l , as illustrated in annotated Figure 3, below. Ex-1008, p. 2.



277. In particular, Tang explains that, following decoding, the received replicated data symbols, $\tilde{d}_1(l)$ and $\tilde{d}_2(l)$, “are regarded as *extra ‘pilot symbols’* and can be used to compute the channel frequency response at the sub-carriers l and $l + 1$ ” using the following formula:

Updated Channel Matrix Estimate  $\tilde{\mathbf{H}}_s = \left(\tilde{\mathbf{d}}_s^H \tilde{\mathbf{d}}_s \right)^{-1} \tilde{\mathbf{d}}_s^H \mathbf{r},$ (18)

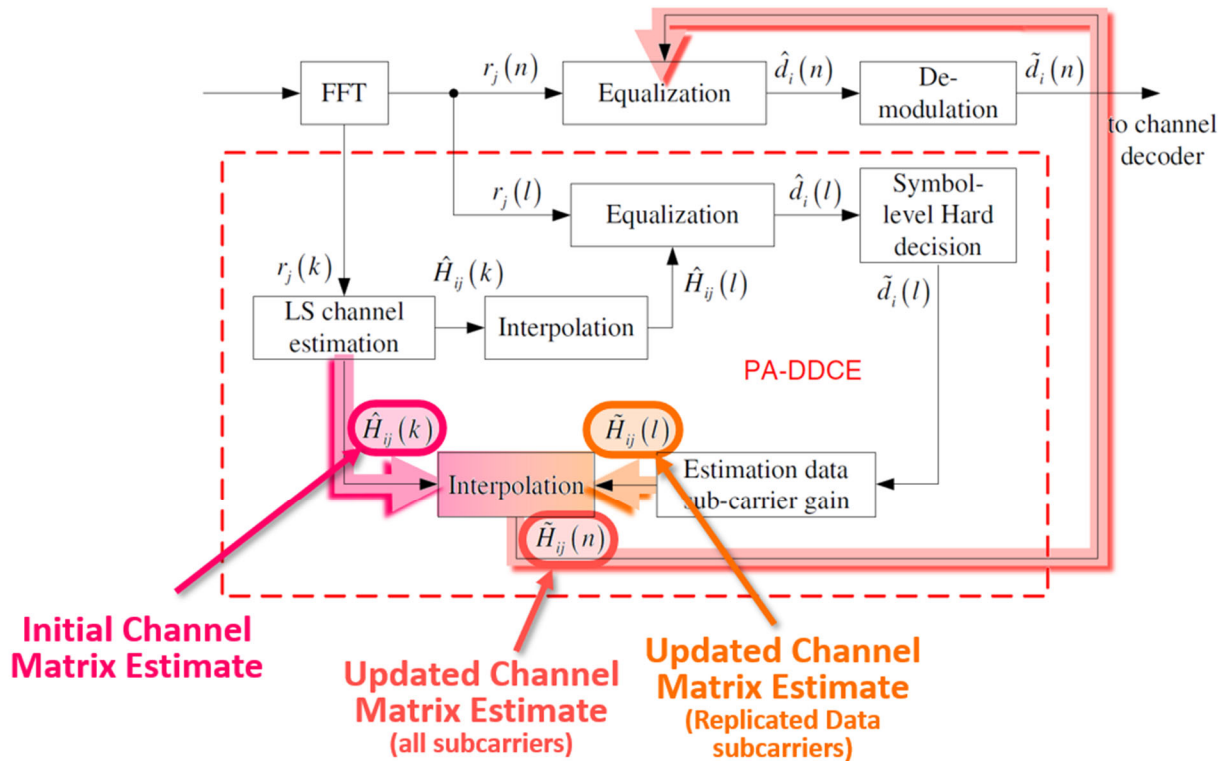
where

$$\tilde{\mathbf{H}}_s = \begin{bmatrix} \tilde{H}_{11}(l) & \tilde{H}_{21}(l) \\ \tilde{H}_{12}(l) & \tilde{H}_{22}(l) \end{bmatrix}, \quad (19)$$

and

$$\tilde{\mathbf{d}}_s = \begin{bmatrix} \tilde{d}_1(l) & \tilde{d}_2(l+1) \\ \underbrace{-\tilde{d}_2^*(l) \quad \tilde{d}_1^*(l+1)}_{\text{Decoded Replicated Data Symbols}} \end{bmatrix}. \quad (20)$$

Ex-1008, p.4. The final estimated channel frequency response $\tilde{H}_{ij}(n)$, at all subcarriers n , can then be obtained through interpolation between the initial estimate $\hat{H}_{ij}(k)$, at pilot subcarriers k , and the updated estimate $\tilde{H}_{ij}(l)$, at the replicated data subcarriers l , as illustrated in annotated Figure 3 below. Ex-1008, p.4.



278. Thus, Tang teaches or suggests that the PA-DDCE channel estimator is configured to estimate a channel matrix of the communications channel (Tang's final estimated channel frequency response $\tilde{H}_{ij}(n)$) based, at least in part, on the decoded at least one data symbol (the decoded received replicated data symbols, $\tilde{d}_1(l)$ and $\tilde{d}_2(l)$).

- h. Element 6[d]: wherein the decoder is further configured to decode subsequent received signals based, at least in part, on the estimate of the channel matrix.**

279. Tang teaches or suggests Element 6[d]. As explained for Element 1[f], a POSITA would have understood that, following receipt of the pilot symbols and replicated data symbols that are used to generate the final estimated channel

frequency response $\tilde{H}_{ij}(n)$ (“the estimate of the channel matrix”), Tang’s receiver would use $\tilde{H}_{ij}(n)$ to decode subsequently received signals $r_j(n)$ over a coherence time over which the channel is assumed not to be varying (i.e., the time over which $\tilde{H}_{ij}(n)$ is assumed not to change), until a new set of pilot symbols and replicated data symbols are received.

280. Thus, Tang renders claim 6 obvious.

7. Dependent Claim 7: The communication device of claim 6 wherein the decoder is configured to decode the at least one data symbol using a joint detection technique.

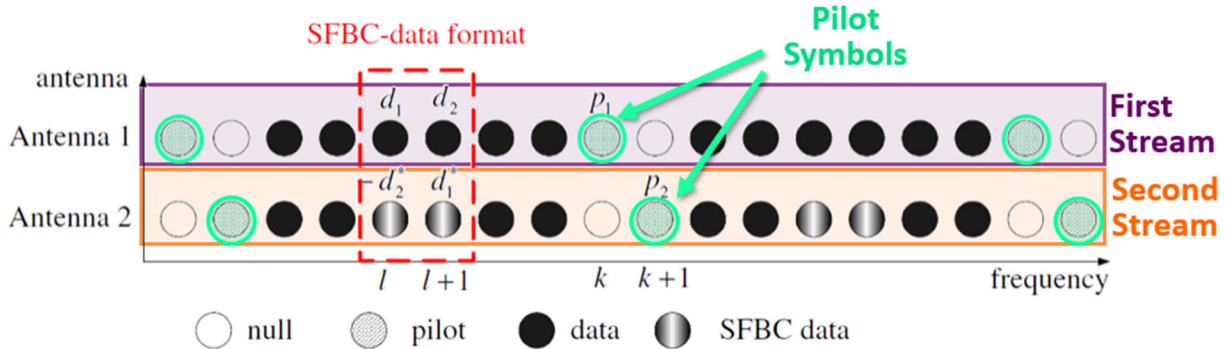
281. Tang teaches or suggests Claim 7. Tang’s decoding process, through which received replicated data symbols $r_j(l)$ (“the at least one data symbol”) are transformed into decoded replicated data $\tilde{d}_i(l)$, uses four-branch maximal-ratio receiver combining (Ex-1008, p.3), which the ’331 Patent identifies as an example of a “joint detection technique” (Ex-1001, 10:28-30).

8. Dependent Claim 8

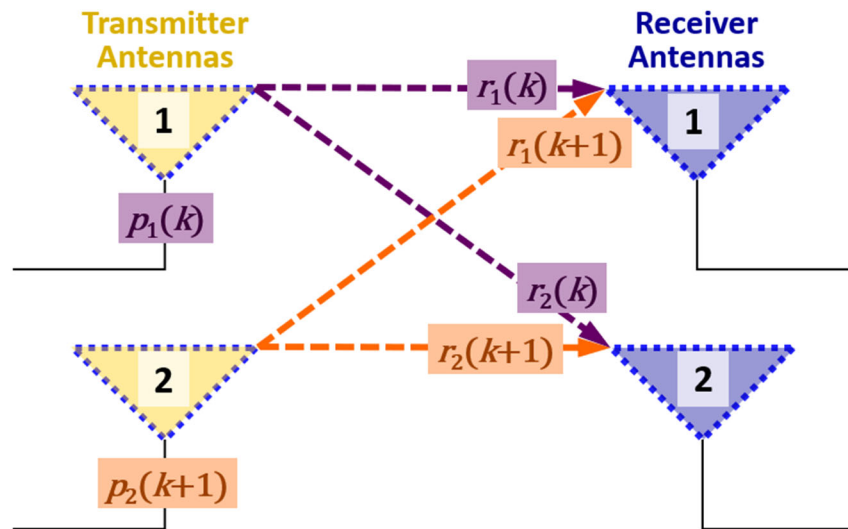
a. Element 8[a]: The communication device of claim 6 wherein the first and second data streams each further include at least one pilot symbol, and

282. Tang teaches or suggests Element 8[a]. As explained for Element 1[a], Tang teaches transmitting pilot symbol p_1 using the first transmit antenna (i.e., within the “first” data stream) and transmitting pilot symbol p_2 using the second

transmit antenna (i.e., within the “second” data stream), as illustrated in annotated Figure 2 below. Ex-1008, p.2.



283. These pilot symbols are received by each of Tang’s receive antennas $j = 1, 2$, as signals $r_j(k)$ and $r_j(k + 1)$, as illustrated in the image below:



- b. **Element 8[b]:** wherein the channel estimator is configured to receive the at least one pilot symbol and generate an initial estimate of the channel matrix based, at least in part on the at least one pilot symbol.

284. Tang teaches or suggests Element 8[b]. As explained for Element 1[b], Tang uses LS channel estimation to calculate “the estimated channel frequency

response $\hat{H}_{ij}(k)$ on the pilot sub-carriers $[(k)]$ ” (“an initial estimate of the channel matrix”), using signals $r_j(k)$ and $r_j(k + 1)$, received at the j th receive antenna and corresponding to transmitted pilot symbols $p_1(k)$ and $p_2(k + 1)$, respectively. Ex-1008, p.2. In particular, for a MIMO-OFDM system with two transmit antennas and two receive antennas, Tang provides the following equations for the components of the estimated channel matrix, which depend on the received pilot symbols:

The diagram shows four equations for the estimated channel matrix components. Annotations with arrows point to specific parts of the equations:

- Pilot Symbols Received at Subcarrier k** (green arrow pointing to $r_1(k)$ and $r_2(k)$)
- Pilot Symbol Transmitted at Subcarrier k** (green arrow pointing to $p_1(k)$)
- Pilot Symbols Received at Subcarrier $k + 1$** (cyan arrow pointing to $r_1(k + 1)$ and $r_2(k + 1)$)
- Pilot Symbol Transmitted at Subcarrier $k + 1$** (cyan arrow pointing to $p_2(k + 1)$)

$$\begin{aligned}\hat{H}_{11}(k) &= r_1(k)/p_1(k) \\ \hat{H}_{12}(k) &= r_2(k)/p_1(k) \\ \hat{H}_{21}(k+1) &= r_1(k+1)/p_2(k+1) \\ \hat{H}_{22}(k+1) &= r_2(k+1)/p_2(k+1).\end{aligned}$$

Ex-1008, p.2, equation 2 (annotated).

IX. CONCLUSION

285. For the reasons set forth above, I believe that Claims 1-8 of the '331 Patent are unpatentable in view of the prior art.

286. In signing this declaration, I recognize that it 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 in 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.

287. I reserve the right to supplement my opinions in the future to respond to any arguments that the Patent Owner raises and to take into account new information as it becomes available to me.

288. I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Respectfully Submitted,

Matthew C. Valenti

Date: June 7, 2024