

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

**PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 8,565,331**

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LIST OF EXHIBITS¹

Ex. No.	Description
Ex-1001	U.S. Patent No. 8,565,331 (“the ’331 Patent”)
Ex-1002	Declaration of Dr. Matthew C. Valenti
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Ex-1004	Prosecution History of the ’331 Patent (Application No. 12/999,029)
Ex-1005	European Patent Application Publication No. EP 2114029 (“Haustein”)
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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”)
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Ex-1013	INTENTIONALLY LEFT BLANK
Ex-1014	INTENTIONALLY LEFT BLANK
Ex-1015	INTENTIONALLY LEFT BLANK

¹ 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.

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Ex-1016	INTENTIONALLY LEFT BLANK
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Ex-1018	INTENTIONALLY LEFT BLANK
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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”)
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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. No.	Description
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)

I. INTRODUCTION

Samsung Electronics Co., Ltd. and Samsung Electronics America, Inc. (collectively, “Petitioner”) request *inter partes* review (“IPR”) 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”).

II. MANDATORY NOTICES UNDER 37 C.F.R. §42.8

Real Parties-in-Interest: Petitioner identifies the following real parties-in-interest: Samsung Electronics Co., Ltd. and Samsung Electronics America, Inc.

Related Matters: PO has asserted the ’331 Patent against Samsung Electronics Co., Ltd. and Samsung Electronics America, Inc. in *Empire Technology Development LLC v. Samsung Electronics Co., Ltd., et al.*, Case No. 2-23-cv-00427 (E.D. Tex.).

Lead and Backup Counsel:

- Lead Counsel:

William M. Fink (Reg. No. 72,332)
O’Melveny & Myers LLP
1625 Eye Street, NW
Washington, DC 20006
Telephone: (202) 383-5300
Fax: (202) 383-5414
E-Mail: tfink@omm.com

- Backup Counsel:

Brian Cook (Reg. No. 59,356)
O’Melveny & Myers LLP

400 South Hope Street, 18th Floor
Los Angeles, CA 90071
Telephone: (213) 430-6000
Fax: (213) 430-6407
E-Mail: bcook@omm.com

Nicholas Whilt (Reg. No. 72,081)
O'Melveny & Myers LLP
400 South Hope Street, 18th Floor
Los Angeles, CA 90071
Telephone: (213) 430-6000
Fax: (213) 430-6407
Email: nwhilt@omm.com

Benjamin M. Haber (Reg. No. 67,129)
O'Melveny & Myers LLP
400 South Hope Street, 18th Floor
Los Angeles, CA 90071
Telephone: (213) 430-6000
Fax: (213) 430-6407
Email: bhaber@omm.com

Service Information: Petitioner consents to electronic service by email to the following addresses:

- tfink@omm.com
- bcook@omm.com
- nwhilt@omm.com
- bhaber@omm.com

III. FEE AUTHORIZATION

The PTO is authorized to charge any fees due during this proceeding to Deposit Account No. LA50-0639.

IV. GROUNDS FOR STANDING

Petitioner certifies that the '331 Patent is available for review, and Petitioner is not barred or estopped from requesting review.

V. PRECISE RELIEF REQUESTED

Petitioner requests review and cancellation of Claims 1-8 as unpatentable based on the following grounds, supported by a declaration from Dr. Matthew C. Valenti. Ex-1002; Ex-1003.

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)

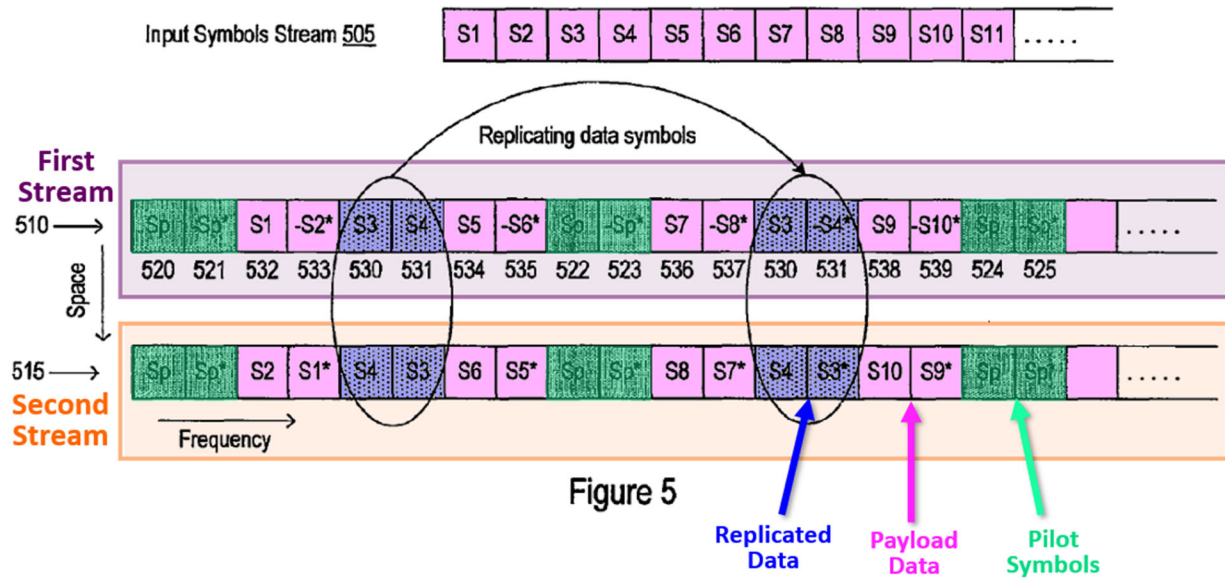
VI. THE CHALLENGED PATENT

The '331 Patent describes the “use of replicated data as a pilot symbol in a communications system.” Ex-1001, 4:3-5. It 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.

The '331 Patent states decoding transmissions in prior art wireless communication systems requires “knowledge of properties of the communications channel over which the transmission is received.” Ex-1001, 1:37-63. Obtaining such knowledge 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, 2:1-6. However, “[t]he need to insert pilot symbols into the transmitted data streams” adversely affects data rate because the pilot symbols increase overhead. Ex-1001, 2:4-6.

Accordingly, the '331 Patent uses copied, or replicated, payload data to serve as pilot symbols such that the effective data rate is increased. *Id.*, 2:61-3:2. 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.² Ex-1001, 1:52-58, 8:1-9.



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.

² 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. Ex-1002 ¶43, n.3.

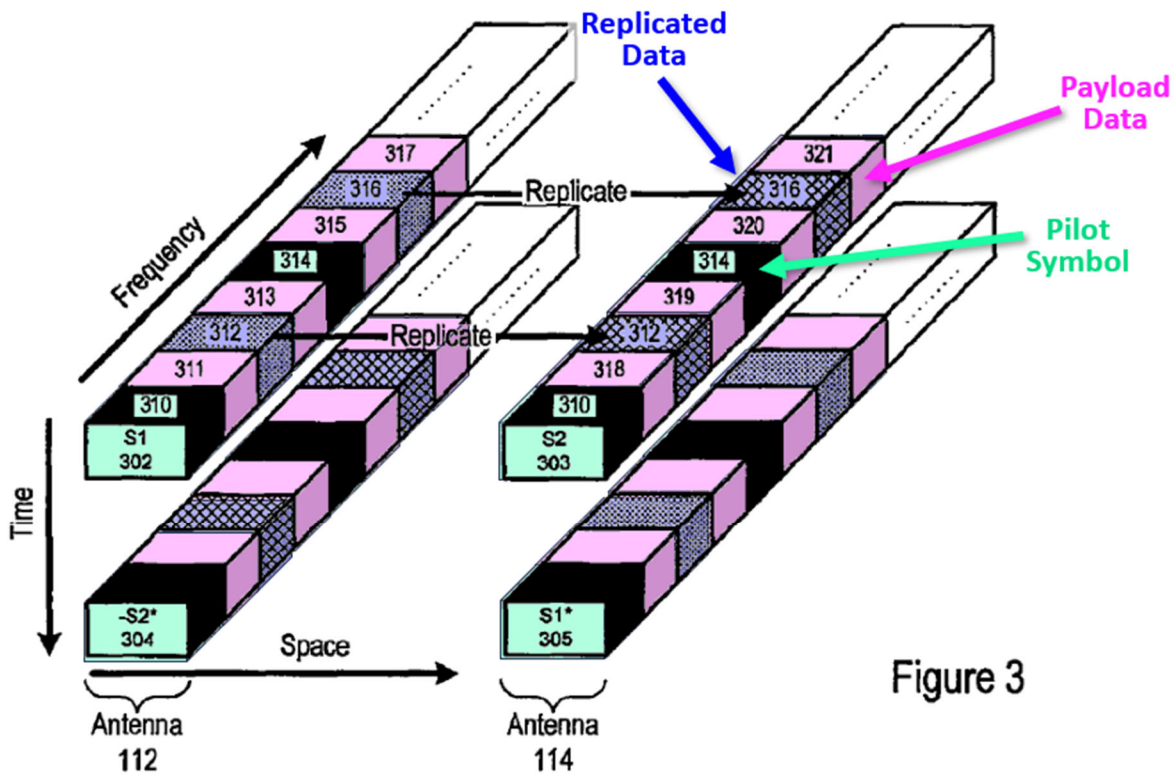
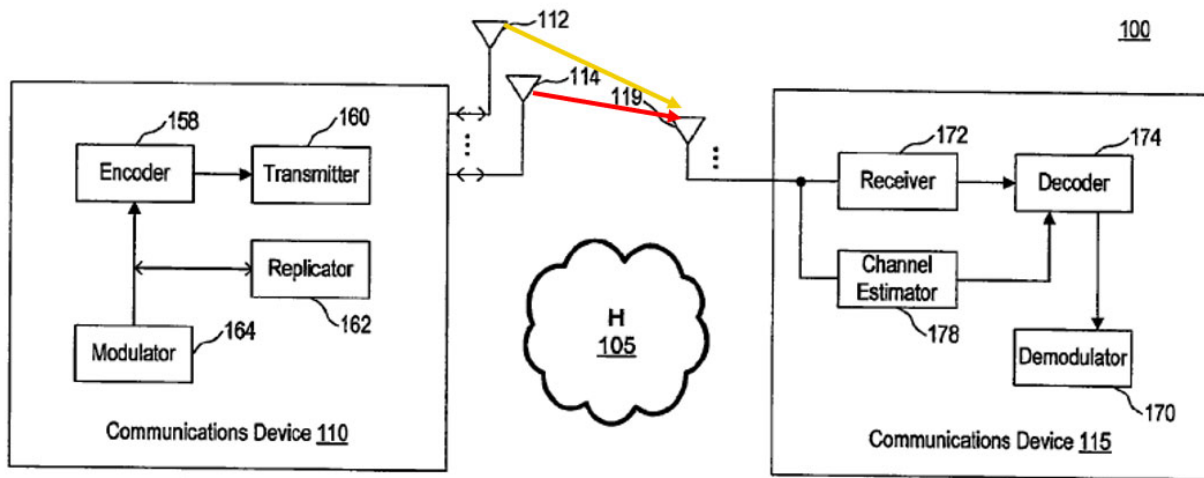


Figure 3

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. Ex-1001, 1:42-55. For example, annotated Figure 1, below, shows a first stream (yellow) and second stream (red) transmitted through antennas 112 and 114. *Id.*, 4:59-67.



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. And “[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.” Ex-1001, 5:50-57; Ex-1002 ¶¶41-46.

VII. PROSECUTION HISTORY OF THE '331 PATENT

The '331 Patent was filed August 20, 2010 as international patent application PCT/US2010/046106. 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.

This Petition presents new arguments and prior art not considered during prosecution, and nothing precludes considering them in the first instance under 35 U.S.C. §325(d). All claims are invalid as obvious. Ex-1002 ¶¶47-49.

VIII. LEVEL OF ORDINARY SKILL IN THE ART

A person of ordinary skill in the art at the relevant time (“POSITA”) would have had a bachelor’s degree in electrical engineering, computer science, computer engineering, or a related field, and two-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. Ex-1002 ¶¶35-36.

IX. PRIORITY DATE

The ’331 Patent is entitled to a priority date no earlier than August 20, 2010 (the filing date of PCT Application No. PCT/US2010/046106). PO has asserted in the pending district court litigation between the parties that the challenged claims were “conceived as of July 1, 2008,” “reduced to practice with reasonable diligence,” and are “entitled to a priority date of at least July 1, 2008.” Ex-1021, 25. Petitioner disputes this priority date, at least because PO has failed to produce any evidence of diligent reduction to practice. Regardless, the references relied upon in Grounds 2 and 3 of this petition are prior art even if this earlier date is assumed.

X. CLAIM CONSTRUCTION

Petitioner interprets the claims according to *Phillips*. 37 C.F.R. §42.100(b). To resolve this Petition, Petitioner does not believe that any term requires express construction.³ CTPG, 44; Ex-1002 ¶¶85-86.

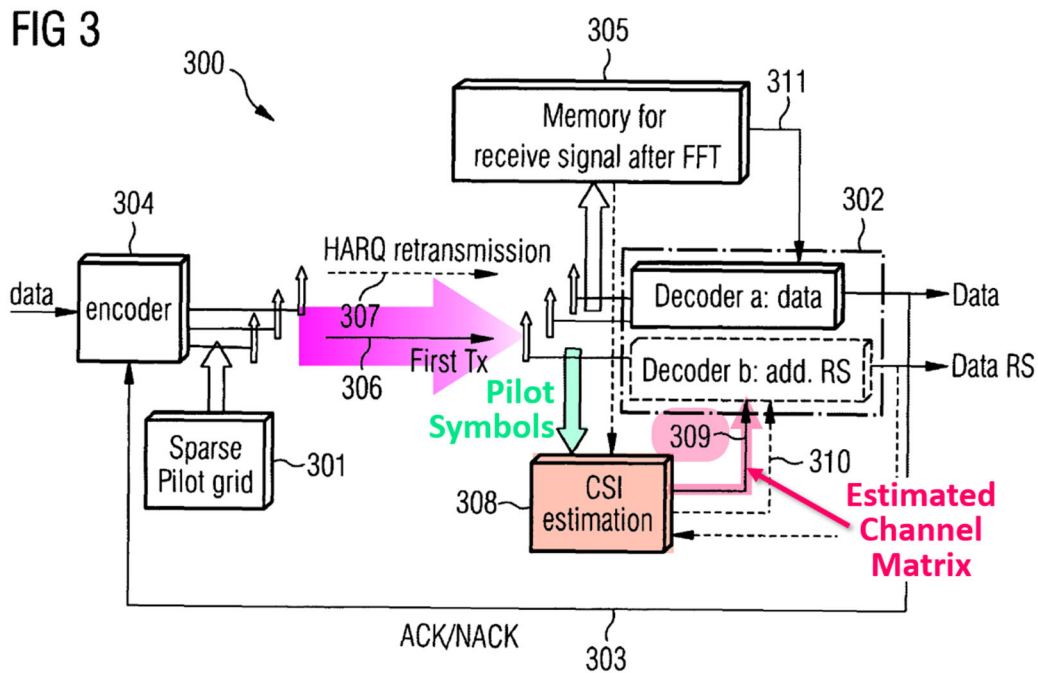
XI. BRIEF DESCRIPTION OF THE APPLIED PRIOR ART

A. Haustein (Ex-1005)

Haustein (European Patent App. Pub. No. EP2114029) was published November 4, 2009 and is prior art under pre-AIA 35 U.S.C. §102(a).

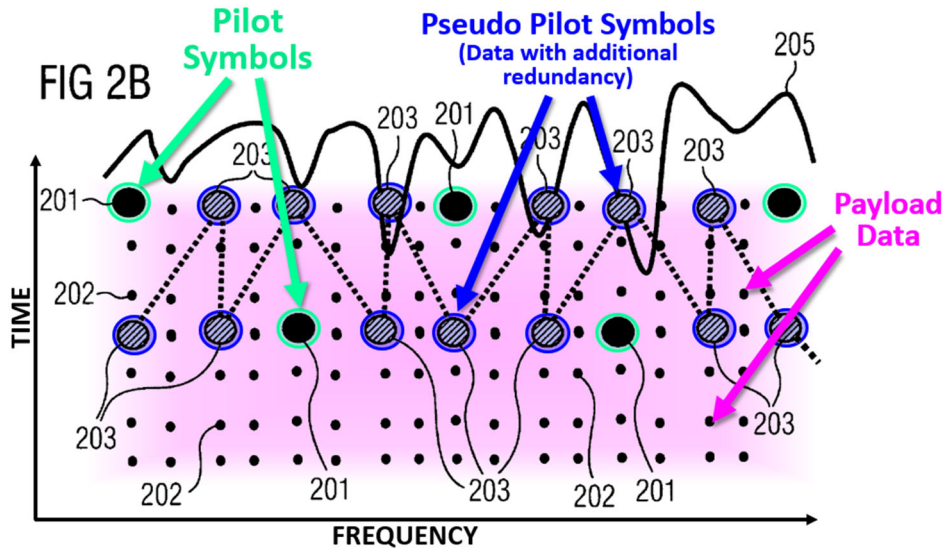
Haustein teaches a method for “improved channel estimation” in an LTE (cellular phone) communication system that uses multiple antennas to transmit data. Ex-1005 ¶¶1, 8 (“MIMO”), 51. Haustein’s system is shown in Figure 1, annotated to show first data transmission 306 (pink):

³ District court claim construction procedures have not yet begun. Petitioner respectfully reserves all rights to raise claim construction and other arguments in district court. Additionally, Petitioner will request leave to submit the district court’s claim construction as soon as it becomes available. Moreover, should Patent Owner raise implied claim construction arguments in its Preliminary Response, Petitioner will respectfully seek a Preliminary Reply to respond. CTPG, 44-45 (permitting petitioner to respond to claim construction raised by patent owner).



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.

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.



The additional redundancy of redundant payload data 203 may be achieved through repetition, and a POSITA would have understood repetition is a common way to add redundancy. Ex-1002 ¶72. The replicated data is then sent over two separate streams using Alamouti block coding, just as in the '331 Patent. Ex-1005 ¶¶38, 48.

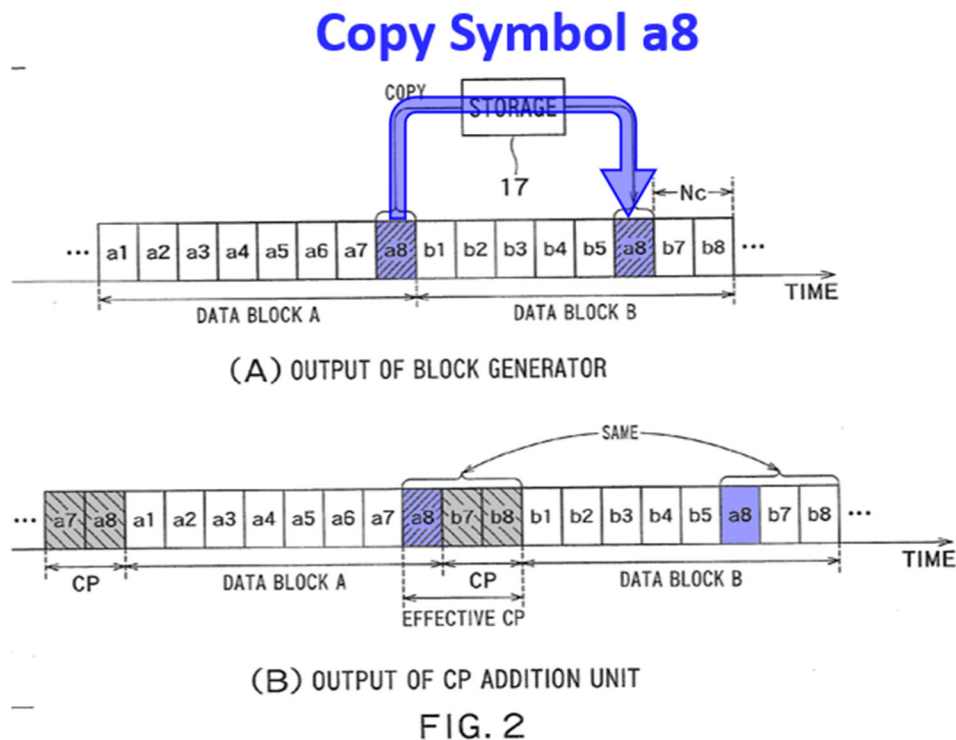
If all first transmission data was not decoded correctly, Haustein teaches retransmission. However, because certain payload data 203 was already sent with higher redundancy to help ensure that it, at least, can be decoded, that data 203 is now assumed to be “known data,” which means it can be used as “pseudo pilot” data when the first data transmission is sent again in a retransmission. *Id.* ¶¶50, 52.

In retransmission, 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. Ex-1005 ¶¶3, 50.

B. Ban (Ex-1006)

Ban (U.S. Patent App. Pub. No. 2008/0222482) was published September 11, 2008 and is prior art under pre-AIA 35 U.S.C. §102(b).

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 a 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.



While Figure 2 illustrates an example in which a data symbol (a8) is copied from a block of data symbols (block A) into another block of data symbols (block B), 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. 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 (Ex-1007)

Wang (U.S. Patent App. Pub. No. 2002/0003774) was published January 10, 2002 and is prior art under pre-AIA U.S.C. §102(b).

Wang discloses channel estimation in “a wireless orthogonal frequency division multiplex (OFDM) communication system with space time transmit diversity.” Ex-1007 ¶1. Because the transmission quality between a transmitting device and a receiving device “is often deteriorated by fading effects and the like,” (*id.* ¶2), improvements can be made 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.”⁴ *Id.* ¶23.

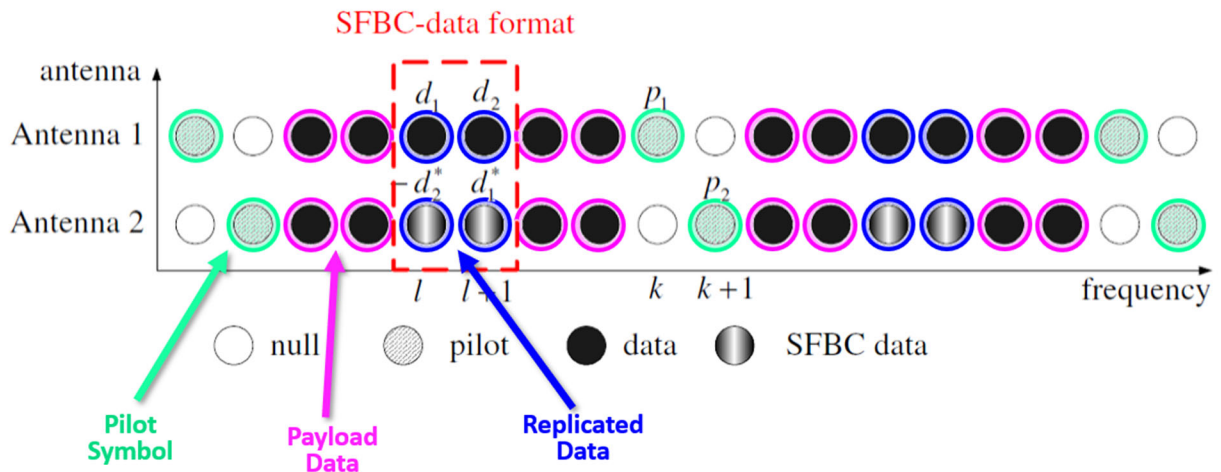
⁴ All annotations and emphases are added herein unless otherwise noted.

D. Tang (Ex-1008)

Tang 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). Tang is prior art under pre-AIA U.S.C. §102(b).

Tang teaches a “joint pilot-aided and blind decision-directed channel estimation (PA-DDCE) scheme” (Ex-1008, Abstract) 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 inserts “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.*, Abstract), generating an “enhanced” channel estimate (*id.*, p.3).

Tang’s data format is a “space frequency block code (SFBC)-data [] format.” *Id.*, p.1. Figure 5 shows 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.*



XII. DETAILED EXPLANATION OF THE UNPATENTABILITY GROUNDS

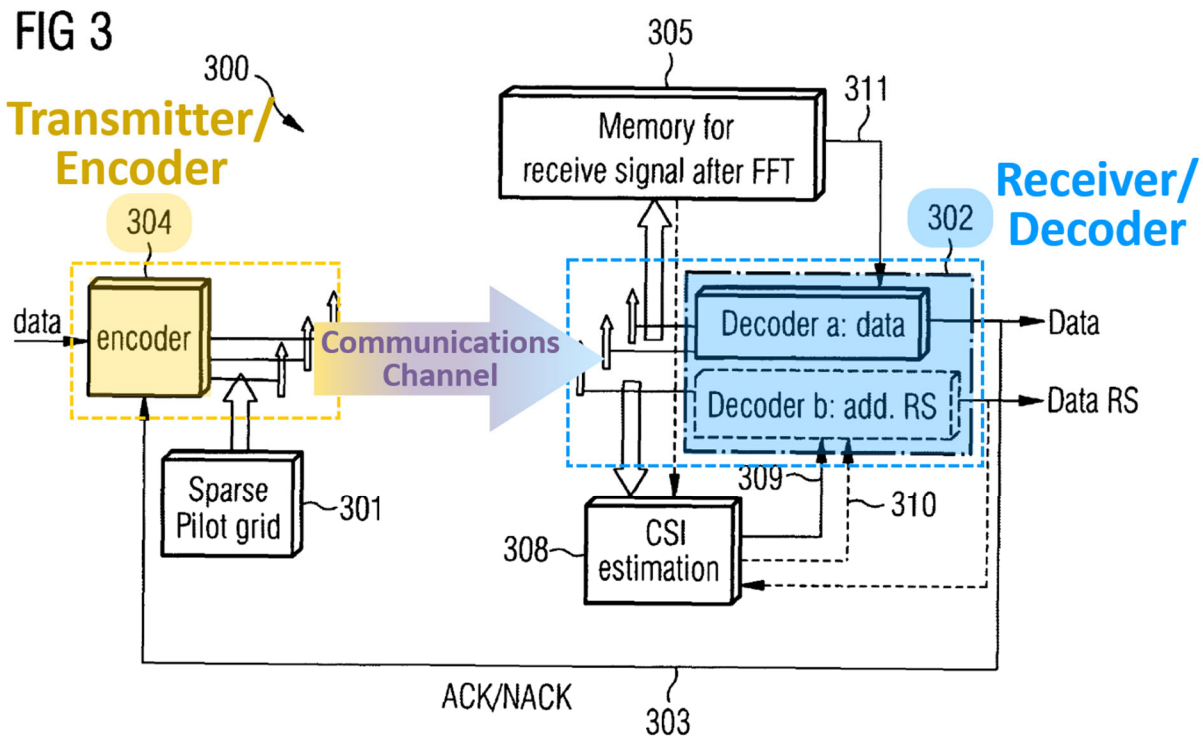
A. Ground 1: Claims 1-8 Are Obvious over Haustein

1. Independent Claim 1

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

Haustein teaches or suggests the preamble, to the extent it is limiting. Ex-1002 ¶¶87-89.

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:



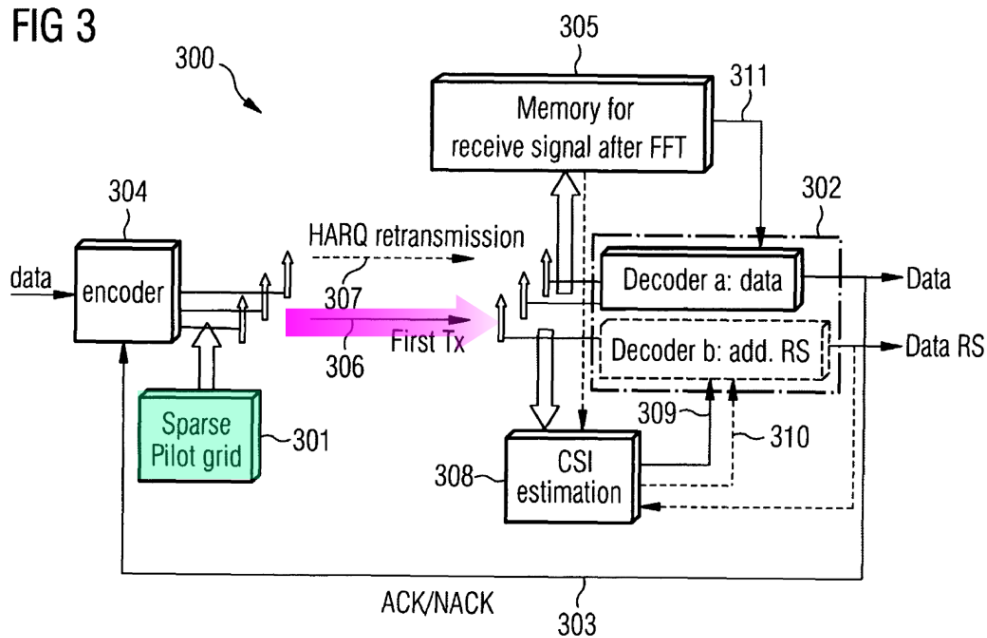
Properties of the communications channel are determined from known pilot symbols, and the rest of the data is then decoded based on the estimated channel properties: “the pilot signals are used for an estimation of a Channel State Information (CSI) 308. The estimated channel state is then used in the 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;

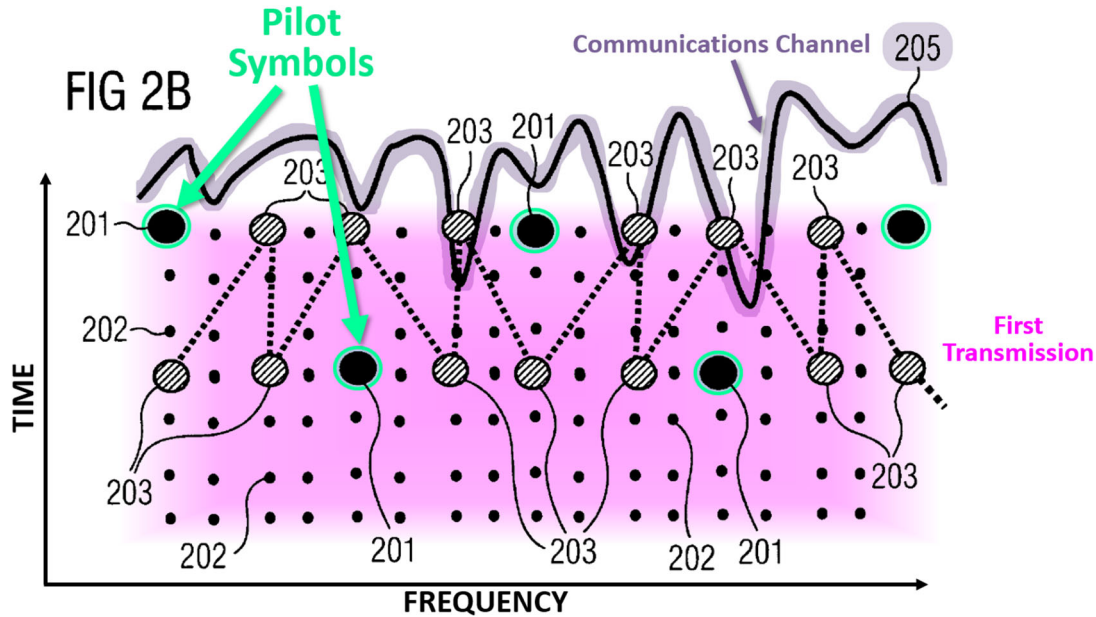
Haustein teaches or suggests Element 1[a]. Ex-1002 ¶¶90-92.

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:



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”). 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.”).

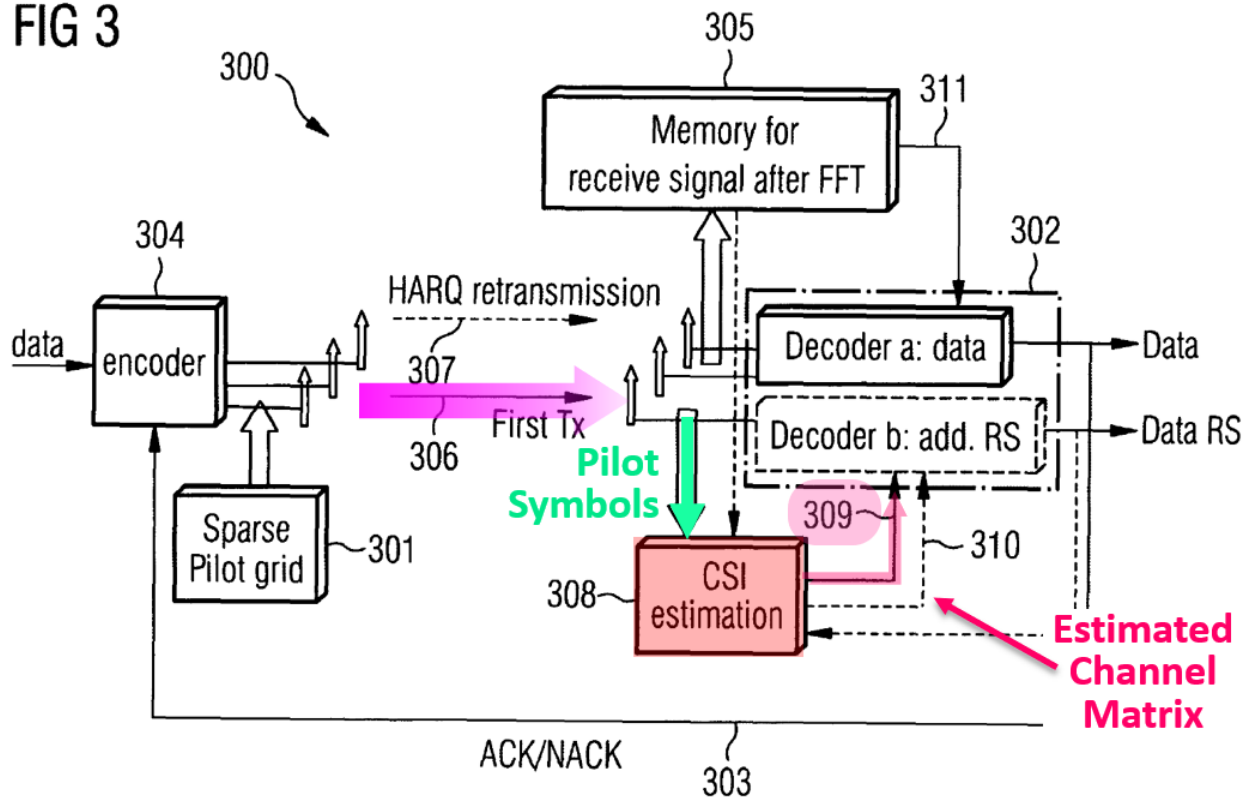


- c. **Element 1[b]: estimating a channel matrix of the communications channel based, at least in part, on the pilot symbol;**

Haustein teaches or suggests Element 1[b]. Ex-1002 ¶¶93-95.

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



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. Ex-1002 ¶95. In the case of multiple antennas, such as the two-antenna 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, $\begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}$, where h_{ij} represents the channel between the i -th transmit and the j -th receive antenna. Ex-1002 ¶¶53-55, 95.

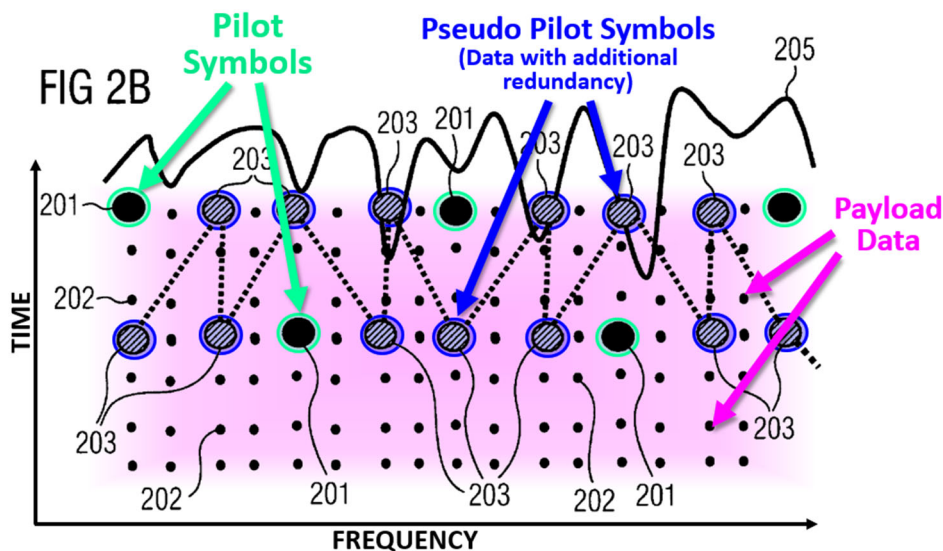
- d. **Element 1[c]: receiving replicated data from multiple data streams transmitted over the communications channel;**

Haustein teaches or suggests Element 1[c]. Ex-1002 ¶¶96-104.

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

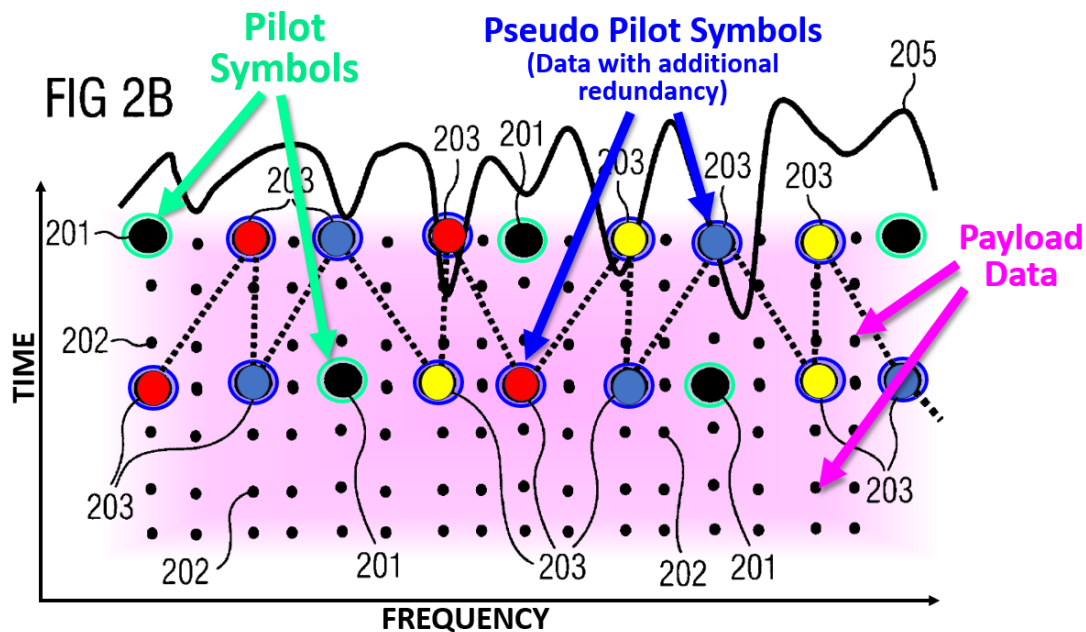
Haustein’s first transmission is depicted in Figure 2B, annotated below.



It includes pilot symbols 201 (green) and payload data 202 and replicated data 203 (blue). Ex-1005 ¶48. Payload data 202 are “normal payload data” (*id.*, ¶47), 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.*, ¶48. To ensure 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.*; *id.*, Claim 6 (“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.”).

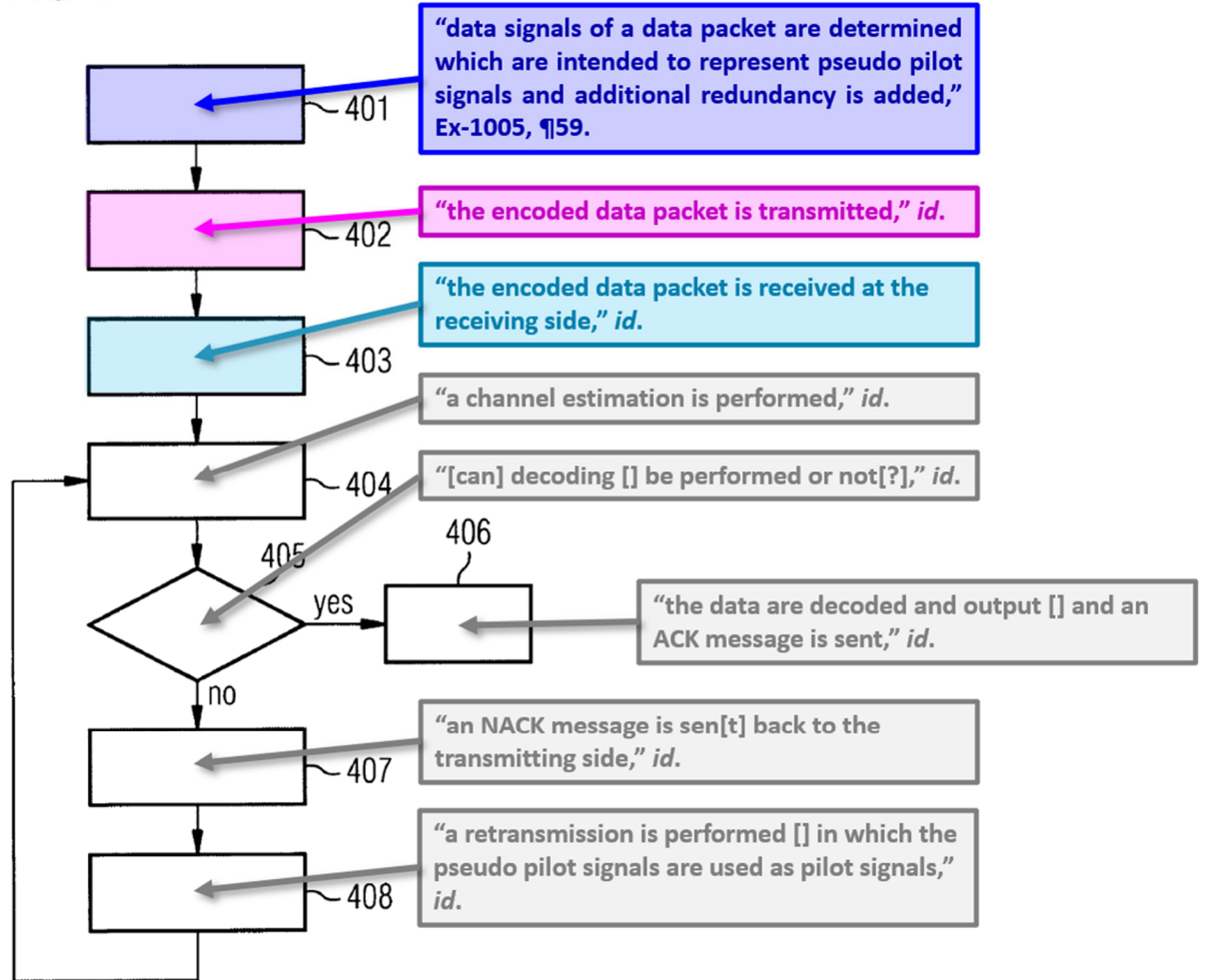
The “‘normal data,’ [202] i.e.,[.] the payload data not intended for improvement of the channel estimation,” is transmitted such that “the additional amount of redundancy will be small or zero to minimize the overhead.” Ex-1005 ¶51. But the redundant payload data 203 is sent with “additional redundancy” 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.

As Dr. Valenti illustrates below, redundancy in redundant payload data/pseudo-pilot data 203 can be achieved by repeating certain data symbols in frequency and/or in time. Ex-1002 ¶101. 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 and blue data 203 similarly indicate different repeated data. The additional redundancy ensures they are accurately decoded even if other payload data is not. *See* Ex-1005 ¶¶22, 48, 51; Ex-1002 ¶101.



Step 401 of Haustein's Figure 4, below, shows "data signals of a data packet are determined which are intended to represent pseudo pilot signals *and additional redundancy is added*," prior to transmission. Ex-1005 ¶59, Fig. 4, Cl. 6.

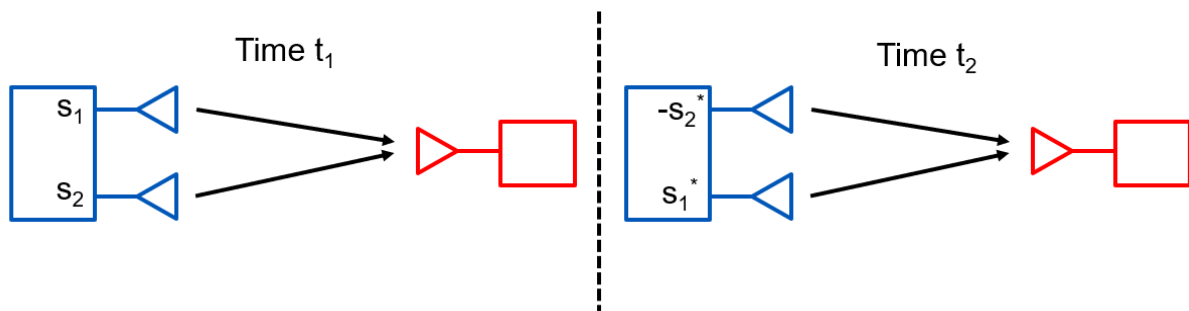
FIG 4



(2) Transmission Over Two Streams

The redundant data discussed above is transmitted over the communication channel in multiple data streams. *Ex-1002 ¶103*. 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. Ex-1002 ¶103. Dr. Valenti's drawing, 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.⁵ 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. Ex-1002 ¶103.



Accordingly, Haustein teaches both adding redundant data into a data packet transmitted by a first antenna of transmitter/encoder 304 (a first data 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, as Element 1[c] requires. See Ex-1005 ¶38, Fig.3; Ex-1002 ¶104.

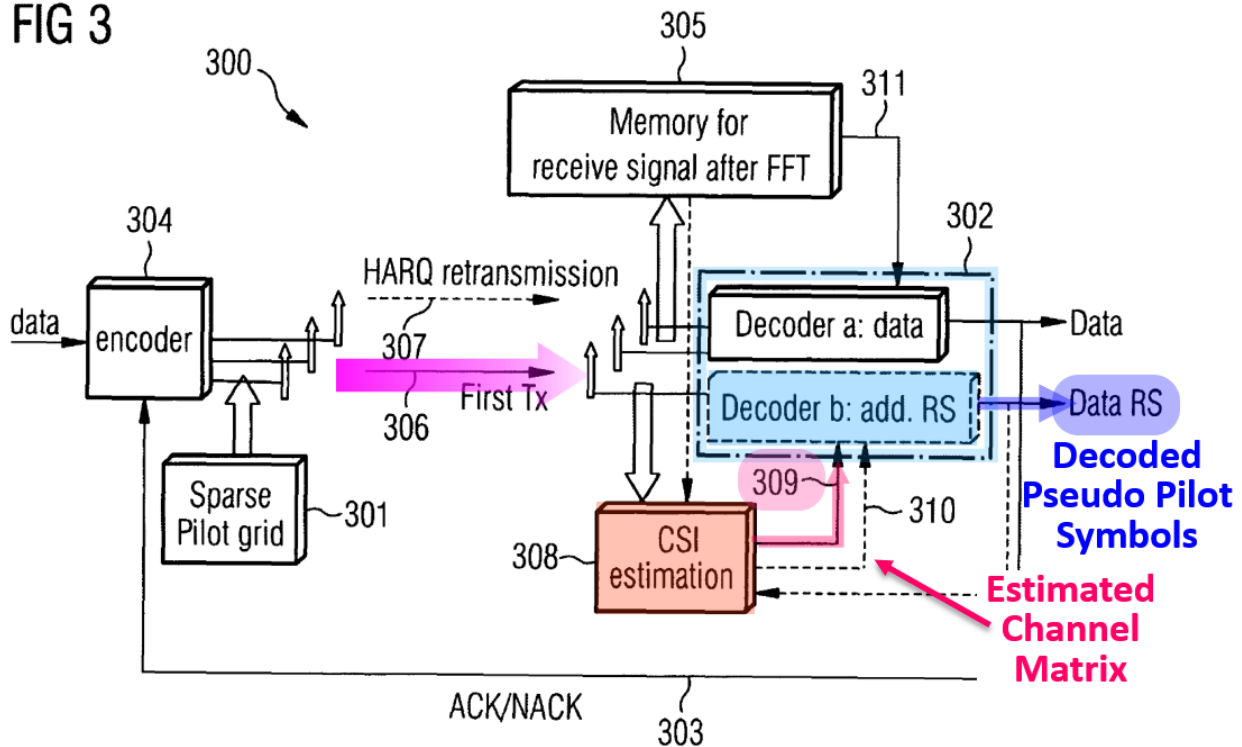
⁵ Note that a receiver (red) with two antennas could also be used. Ex-1002 ¶103, n.4. Alamouti space-time block coding is described in the '331 patent as "known in the art." Ex-1001, 1:42-49.

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

Haustein teaches or suggests Element 1[d]. Ex-1002 ¶¶105-107.

As explained for Element 1[b], pilot signals received in first transmission 306 “are used for an estimation of a Channel State Information (CSI) 308” or estimated channel matrix. Ex-1005 ¶50. The “estimated channel state is then used in the decoding which is indicated by the arrows 309 and 310,” as illustrated below. *Id.* 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 transmitted over two antennas using Alamouti block coding.

FIG 3



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

Haustein teaches or suggests Element 1[e]. Ex-1002 ¶¶108-114.

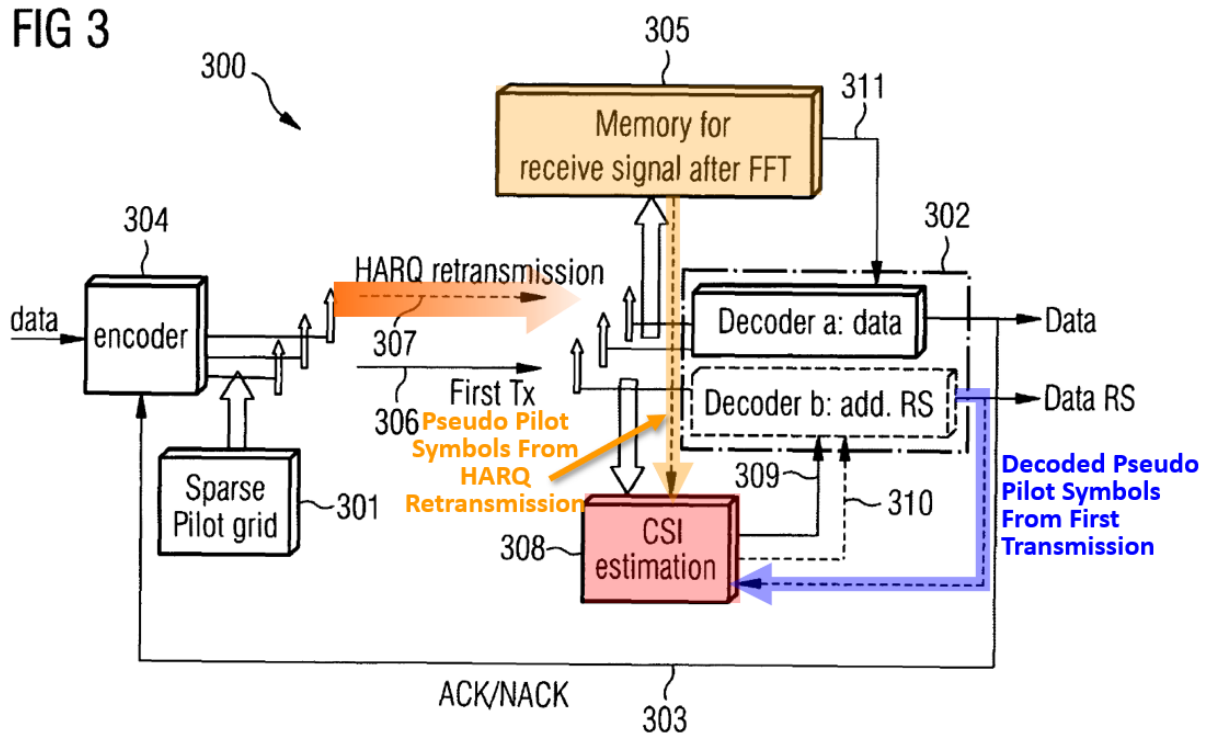
In case the first transmission cannot be fully decoded, “the data block is retransmitted using additional pilot signals which are formed by payload data of the

original transmission.” Ex-1005 ¶22. This retransmission occurs when a “CRC,” or “Cyclic Redundancy Check”⁶ on the received data fails, indicating the presence of errors. Ex-1005 ¶49. A POSITA would have understood Haustein’s statement that “decoding cannot be performed,” to mean that error(s) were present such that *some* of the received data was not properly decoded. Ex-1002 ¶109 (describing CRC). However, the additional redundancy provided to redundant payload data/pseudo-pilot data 203 in first transmission 306 ensures 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 assumed as correctly decoded and is available for channel estimation as pseudo pilot symbols. Ex-1002 ¶¶110-111. Adding redundancy is one of several methods Haustein discloses to ensure that pseudo-pilot data 203 of first transmission 306 is properly decoded. Ex-1002 ¶112.

Upon CRC failure, the first transmission is retransmitted. Retransmission 307 includes the same pilot 201 and data 202/203 symbols as the first transmission 306 and 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

⁶ A CRC is used to detect errors in a transmission. See https://en.wikipedia.org/wiki/Cyclic_redundancy_check.

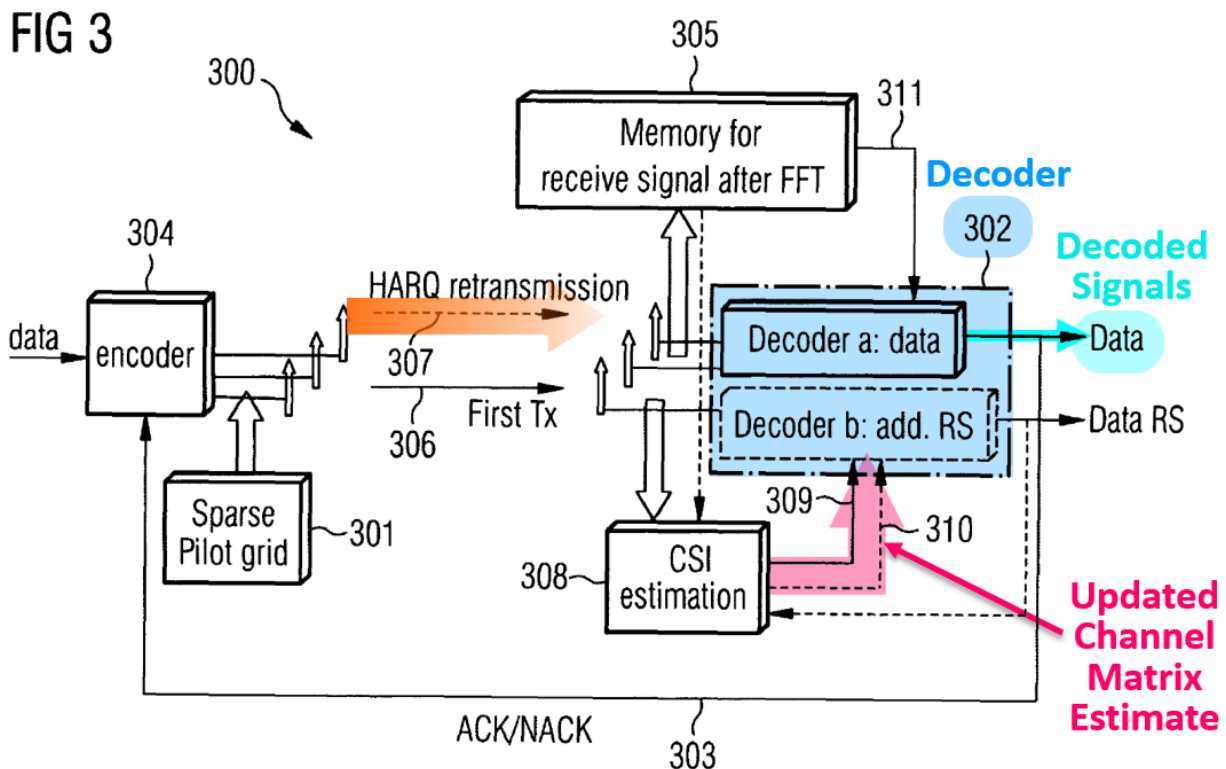
updated channel estimate (“updated estimate of the channel matrix”) to decode retransmission 307, as shown in Figure 3. Ex-1005 ¶50 (“in the case of the retransmission the pilots of the original sparse pilot grid [201] and the pseudo pilot signals [203] are used in the CS[I] estimation and thus for the decoding.”), ¶¶51-52.



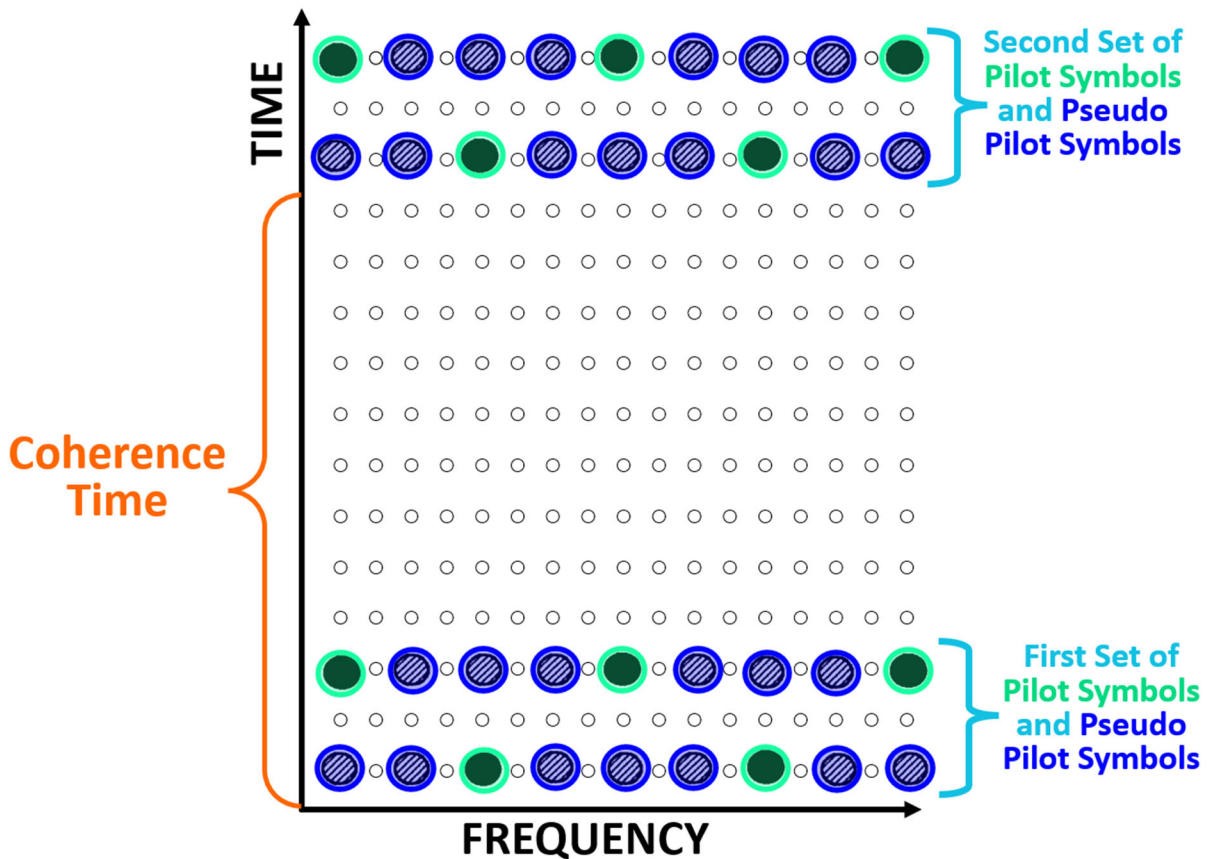
Thus, an updated estimate of the channel matrix is based, at least in part, on the redundant payload data 203 received in the first transmission 306. Ex-1002 ¶¶113-114.

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

Haustein teaches or suggests Element 1[f]. Ex-1002 ¶¶115-118. Figure 3, below, shows CSI estimation block 308 provides the updated estimate of the channel matrix to decoder 302, which uses it to decode retransmission 307. *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].



Although not required by the claim, Haustein also teaches or suggests using the updated channel estimate to decode additional subsequently received signals. Haustein pilot grid is inserted into the data packet “with certain spacing in time.” Ex-1005 ¶3. The time spacing between sets of pilot signals depends on the channel “coherence time” (*id.*), which a POSITA would have understood as the time during which the channel does not vary, such that a single channel estimate may be used to decode the data. Dr. Valenti explains this with reference to his drawing below. Ex-1002 ¶115.



A first set of pilot/pseudo-pilot symbols at the bottom is followed by several sets of data and then a second set of pilot/pseudo-pilot symbols. The two sets of pilots are separated by Haustein's "certain spacing in time," which corresponds to the estimated channel coherence time. 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 the duration of the coherence time, until the next set of pilot symbols is received. Ex-1002 ¶116. Accordingly, a POSITA would have recognized that 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 during the coherence time. Ex-1002 ¶117.

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

Haustein teaches or suggests Claim 2. Ex-1002 ¶¶119-121. As explained for Elements 1[c]-[d], Haustein's redundant payload data 203 corresponds to "replicated data." 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. Ex-1002 ¶120 (citing Ex-1024, 8:4-24 (providing examples of "joint detection method[s]" including decoding using Alamouti block decoding)).

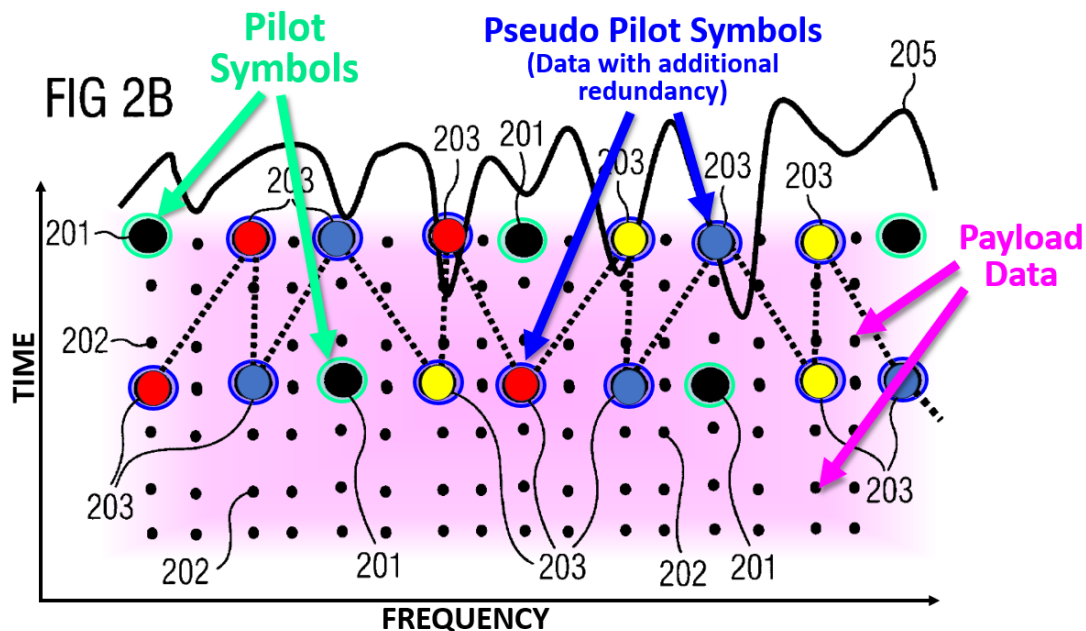
3. Dependent Claim 3/4: The method of claim 1, wherein said decoding the replicated data comprises using a [space-time/space-frequency] block decoding technique.

Haustein teaches or suggests Claims 3-4. Ex-1002 ¶¶122-123. 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, Ex-1002 ¶122 (citing Ex-1023, 0002-0003 (describing “space-time coding” done in space and time and “space-frequency coding” where “two adjacent carriers may be used”)). At the receiver, Alamouti block decoding must be performed to combine the redundant copies, ensuring that the “pseudo reference signals” are decoded “with high accuracy.” Ex-1005, ¶51; Ex-1002 ¶123 (citing Ex-1023, 0004).

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

Haustein teaches or suggests Claim 5. Ex-1002 ¶¶124-127. 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 uses 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-1002 ¶124; Ex-1001, 1:42-49 (“known in the art”). Referring to annotated Figure 2B, if Haustein’s symbol grid below were sent using Alamouti space-time block coding using two antennas, the red data 203, for example, would be transmitted on both the first antenna and on the second antenna because odd rows would be transmitted by the first antenna and even rows by the second antenna. Ex-1002 ¶125. Thus, red, blue, and yellow data is sent at least once in each data stream by each antenna. *Id.*



Accordingly, Haustein teaches or suggests sending first transmission 306, which includes redundant payload 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.

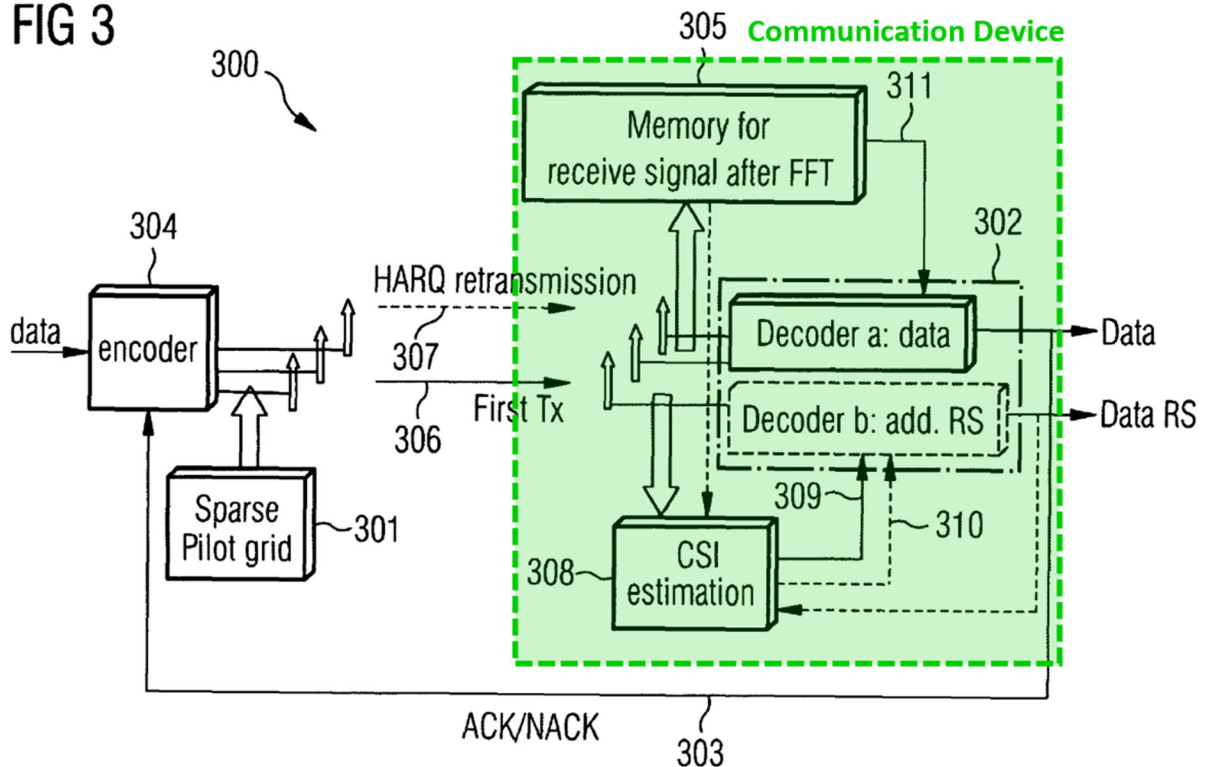
5. Independent Claim 6:

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

Haustein teaches or suggests the preamble, to the extent it is limiting. Ex-1002 ¶¶128-129.

Haustein's "receiving device [] adapted to receive a data packet" transmitted by a "sending device" (Ex-1005, Cl. 13) is a "communication device."

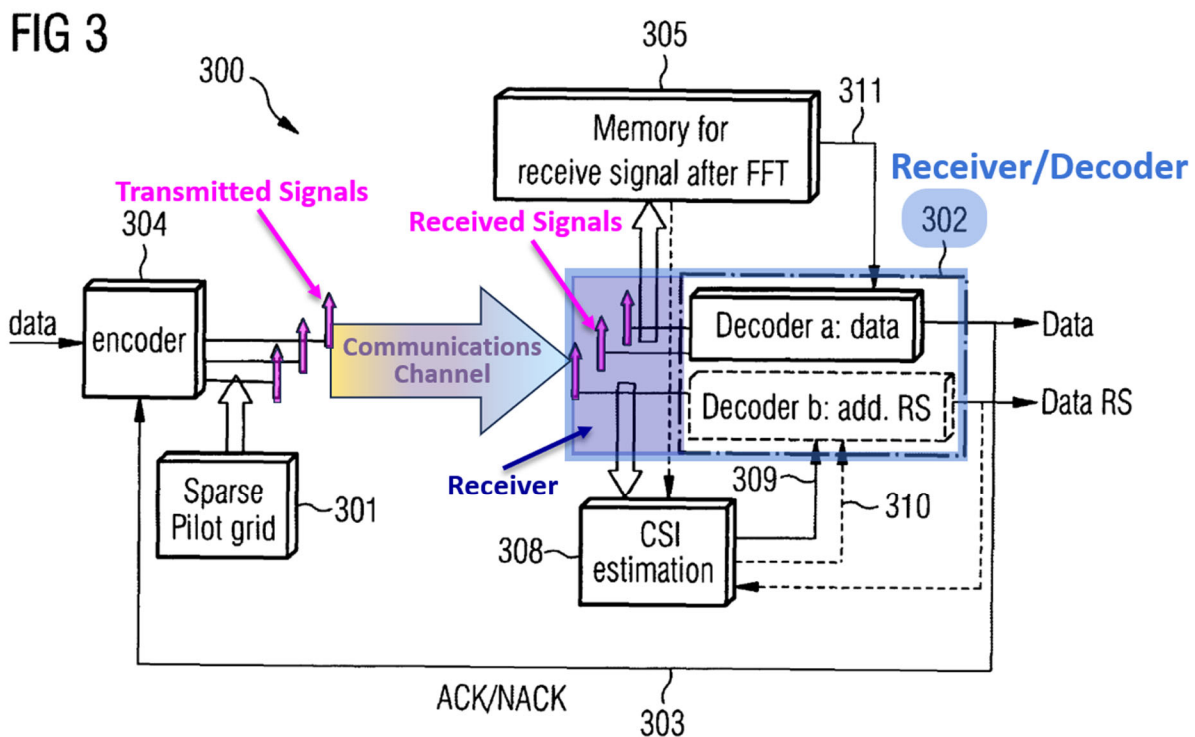
FIG 3



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

Haustein teaches or suggests Element 6[a]. Ex-1002 ¶¶130-131. The pilot symbols 201, data 202, and redundant payload data 203 of first transmission 306 correspond to the claimed “receive[d] signals.” Ex-1005 ¶49 (receiver/decoder 302), Fig. 3; Ex-1002 ¶130.

As explained for Element 1[pre]/1[c], Haustein discloses a receiver/decoder 302 configured to receive signals transmitted by transmitter/encoder 304 over a “communications channel,” 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,**

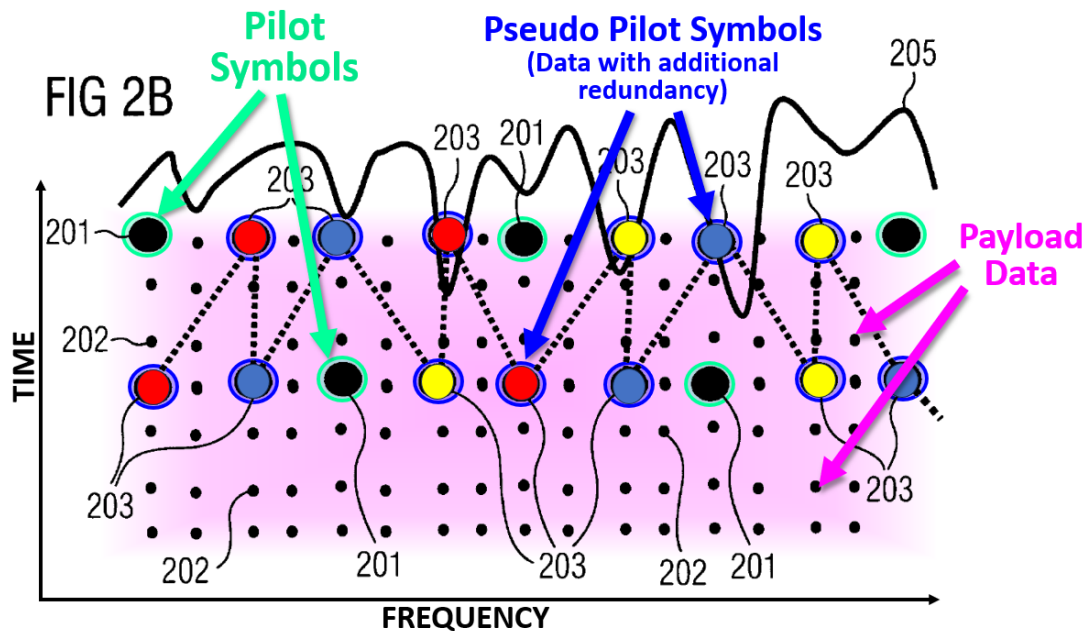
Haustein teaches or suggests Element 6[a][i]. Ex-1002 ¶132. As explained for Element 1[c], Haustein's transmitter/encoder 304 uses two transmit antennas to transmit two data streams to receiver/decoder 302, by using "Alamouti processing ... to insert extra diversity ... e.g.,] on a second subcarrier 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;**

Haustein teaches or suggests Element 6[a][ii]. Ex-1002 ¶¶133-136. Haustein's redundant payload data/pseudo-pilot data 203 in transmission 306 corresponds to the claimed at least one data symbol. Ex-1002 ¶133.

As explained for Element 1[c], first transmission 306 includes "pseudo pilot signals" 203 corresponding to replicated data pre-designated to be used as known pilot symbols in a potential subsequent retransmission. Ex-1005 ¶¶50-51; Ex-1002 ¶134. As explained for Element 6[a][i] (and Claim 4), 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."); Ex-1002 ¶134.

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.

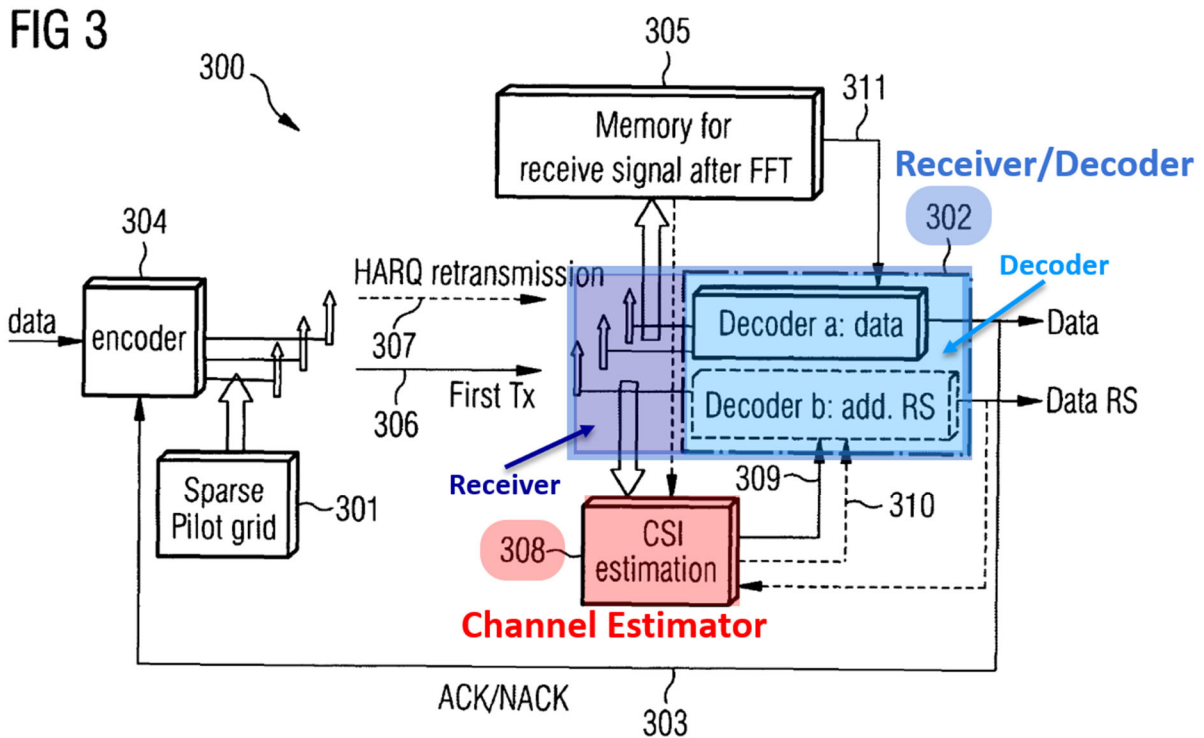


Thus, the second data stream includes at least one data symbol replicated from the first data stream, either as its complex conjugate (using Alamouti space-frequency block coding) or as a direct copy (in the case of Alamouti space-time block coding). Ex-1002 ¶¶135-136.

- 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;**

Haustein teaches or suggests Element 6[b]. Ex-1002 ¶¶137-139.

Haustein's Figure 3 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. The decoding is performed using channel estimation 309/310 from CSI estimation 308, demonstrating coupling between the decoder and the channel estimator. Ex-1005 ¶50; Ex-1002 ¶138.



As explained in for Elements 6[a]-6[a][ii], 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("This allows the

receiver to decode the data bins intended as ‘pseudo reference [or pilot] symbols’ (RS) with high accuracy.”); Ex-1002 ¶139.

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

Haustein teaches or suggests Element 6[c]. Ex-1002 ¶140. 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), and uses them to generate estimated channel state 309/310, as explained for Elements 1[b] and 1[e]. *See also* Ex-1005 ¶50.

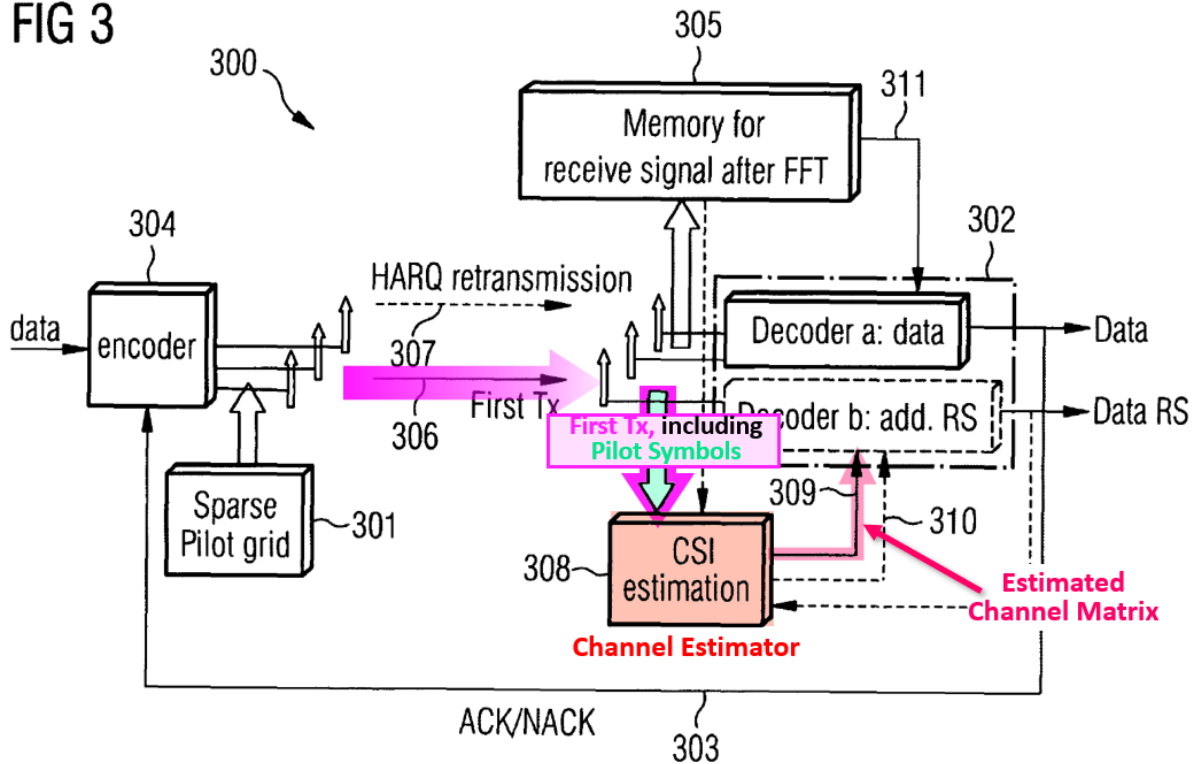
g. Element 6[c][i]: wherein the channel estimator is configured to receive the received signals and the decoded at least one data symbol,

Haustein teaches or suggests Element 6[c][i]. Ex-1002 ¶¶141-144.

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.”

Haustein’s CSI estimation block 308 in Figure 3 receives first transmission 306 and uses pilot symbols 201 to generate a channel matrix estimate, as explained for Element 1[b]. *See also* Ex-1005 ¶50; Ex-1002 ¶143.

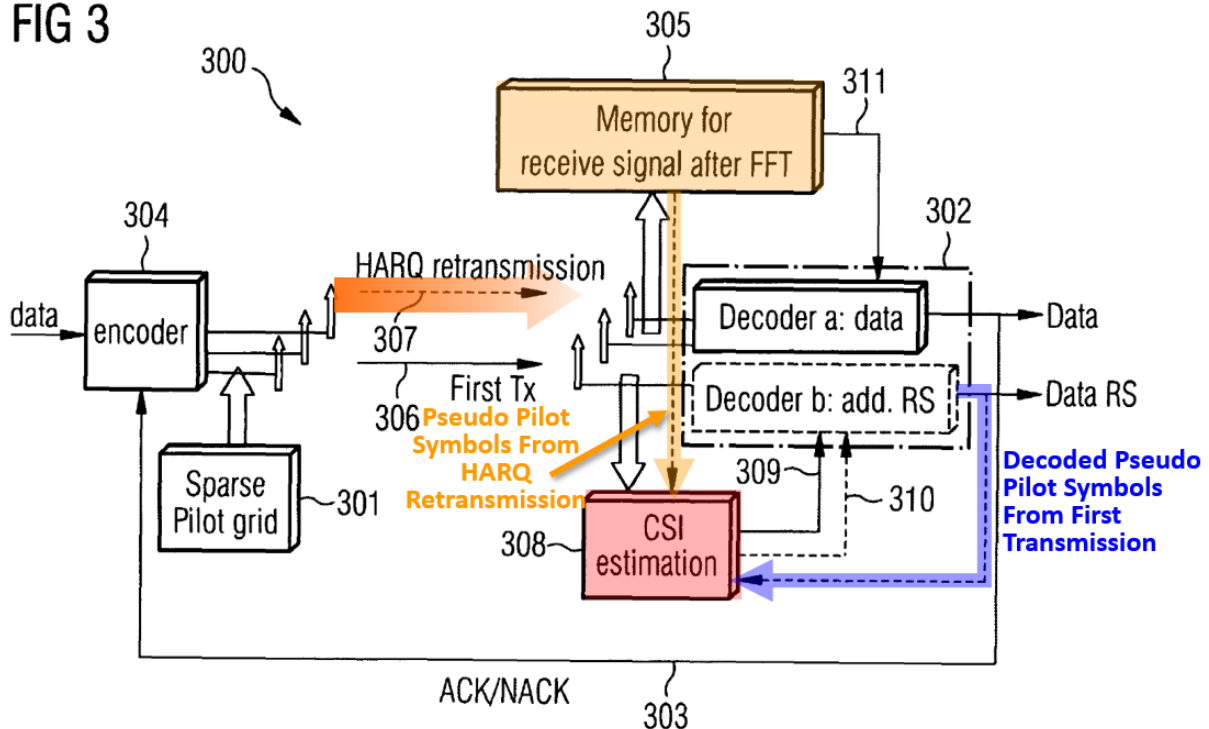
FIG 3



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.” Ex-1001 3:42. 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. 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]. Ex-1002 ¶144.

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**

Haustein teaches or suggests Element 6[c][ii]. Ex-1002 ¶¶145-146. 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 (the “channel matrix”) for use by decoder 302 in decoding retransmission 307, as described for Element 1[f]. Ex-1002 ¶145.

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 the decoding cannot be performed ... a retransmission is performed 408 in which the pseudo pilot signals are used as pilot signals.” Ex-1005 ¶59. For the reasons explained in addressing Element 1[d], 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; Ex-1002 ¶146.

- 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.**

Haustein teaches or suggests Element 6[d], as explained previously for Element 1[f]. Element 6[b] recites “the decoder is configured to receive the received signals,” which is met when the decoder receives first transmission 306. Ex-1001, Cl. 6. 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. *Id.*

This estimate of the channel matrix is also used to decode additional subsequently received signals that arrive during the coherence time period, as discussed with reference to Element 1[f], above. Ex-1002 ¶¶147-149.

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.

Haustein teaches or suggests Claim 7. Ex-1002 ¶150. As explained for Element 6[c][ii], Haustein's redundant payload data/pseudo-pilot data 203 corresponds to 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 have understood that Alamouti block decoding is a type of joint detection technique. Ex-1002 ¶150 (citing Ex-1024, 8:4-24; Ex-1023, 0002-0003).

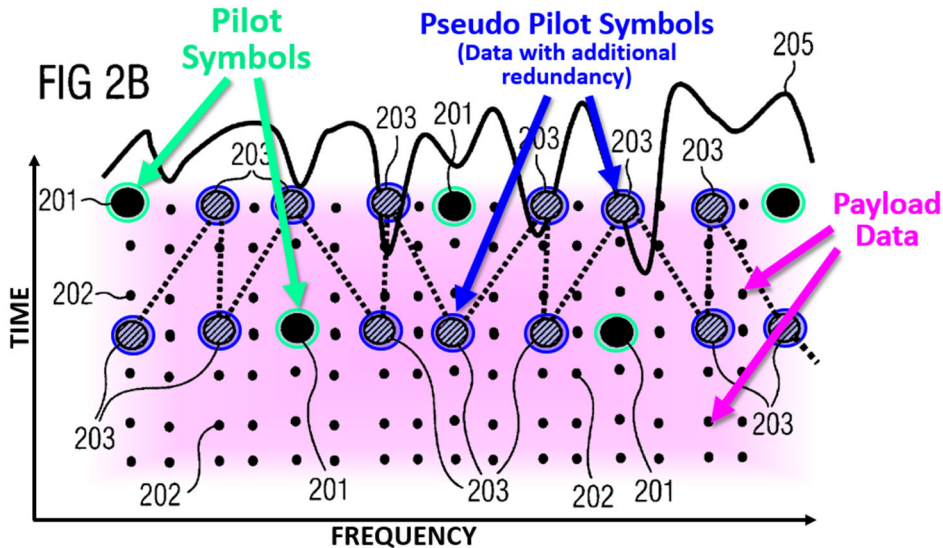
7. Dependent Claim 8

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

Haustein teaches or suggests Element 8[a]. Ex-1002 ¶¶151-152.

As explained for Element 6[a][i], first transmission 306 comprises first and second streams (via Alamouti block coding). Each stream of first transmission 306

includes at least one pilot symbol 201, as explained for Element 1[e]. 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. Ex-1002 ¶152.



- 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.**

Haustein teaches or suggests Element 8[b]. Ex-1002 ¶153. 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.” Ex-1002 ¶153.

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

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 transmitting OFDM symbols (Ex-1006 ¶81; Ex-1007 ¶1), and using pilot symbols for channel estimation (Ex-1006 ¶134; Ex-1007 ¶1). Ex-1002 ¶¶154-159.

Ban extends the cyclic prefix in 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-1002 ¶155. A POSITA seeking to implement Ban’s system to increase decoding reliability would have been motivated to search for additional techniques to further improve decoding reliability. *Id.* Wang discloses one such well-known method.⁷

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

⁷ The method described in Wang is applicant admitted prior art (“Alamouti coding”) (Ex-1001, 1:42-49), but Wang provides a complete description of the method.

transmission quality.” Ex-1007 ¶2. Wang notes that “transmission quality ... 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 adds 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.*

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. Ex-1002 ¶157. 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 coding⁸), to transmit the same data over two orthogonal data streams.

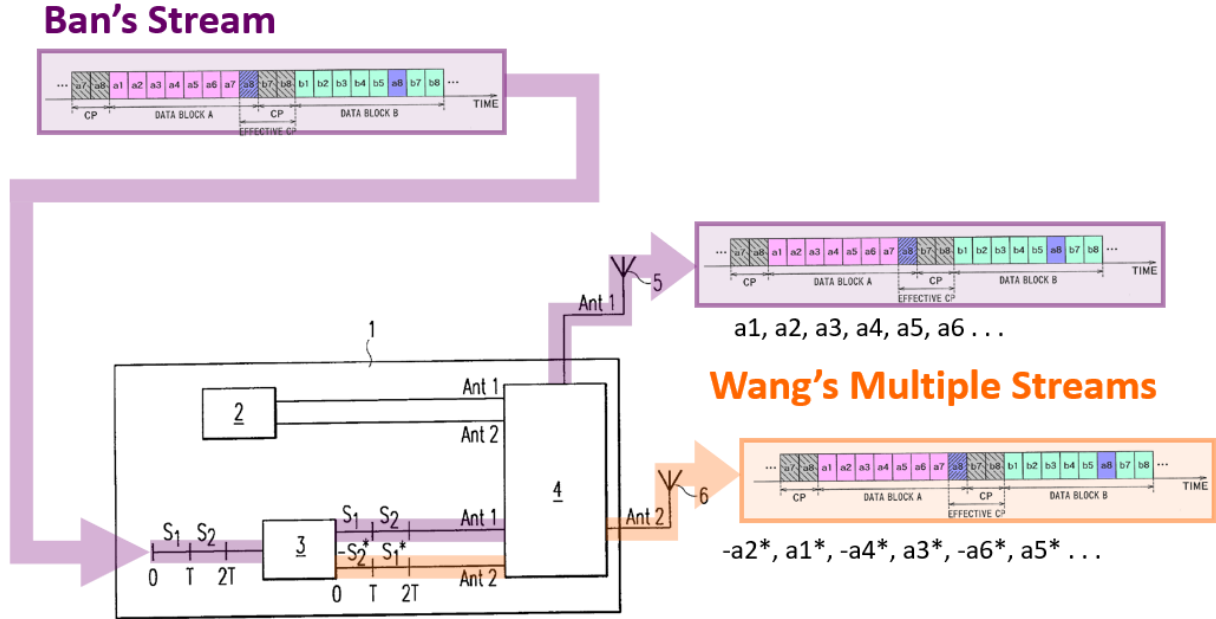
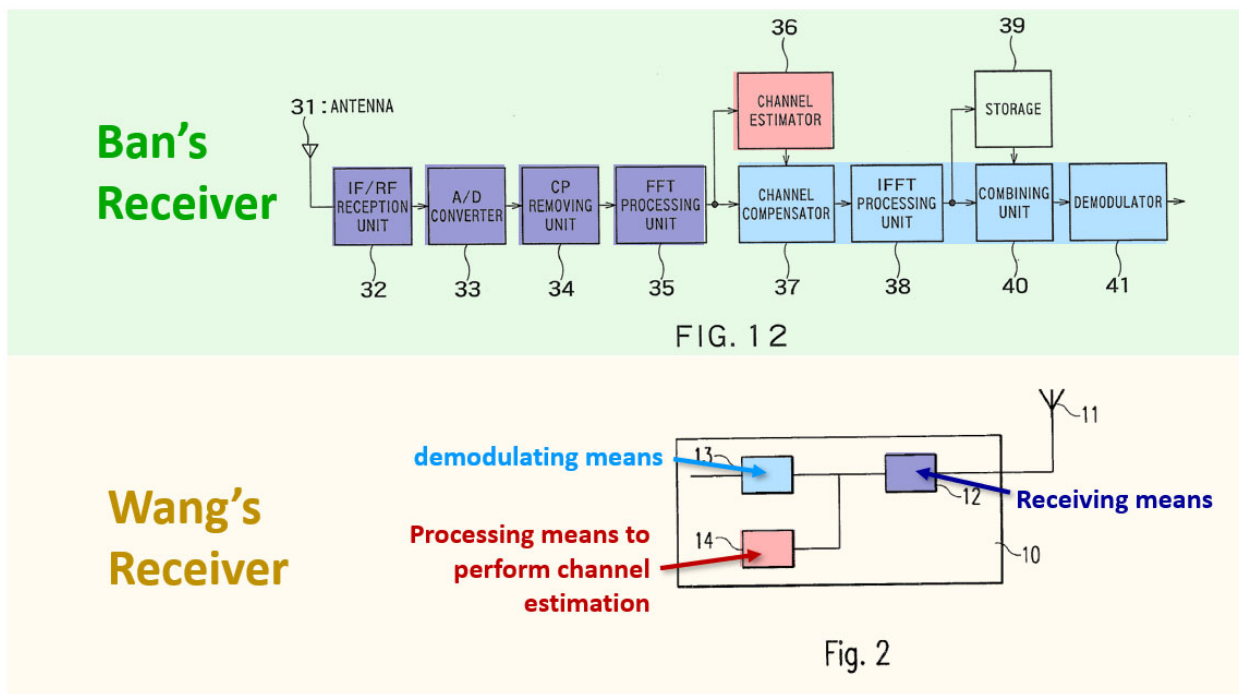


Fig. 1

In Ban-Wang, Ban's receiver would also have been modified to receive the pilots and data over two spatial streams, as 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 second antenna 6. On the basis of this channel estimation result, both the STTD encoded

⁸ Although not referred to by name, the well-known Alamouti block code $\begin{bmatrix} S1 & S2 \\ -S2^* & S1^* \end{bmatrix}$ is depicted after element 3 in Figure 1 and in the description of paragraph 27 of Wang. Ex-1002 ¶157, n.6.

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; Ex-1002 ¶¶158. 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; Ex-1002 ¶¶158.



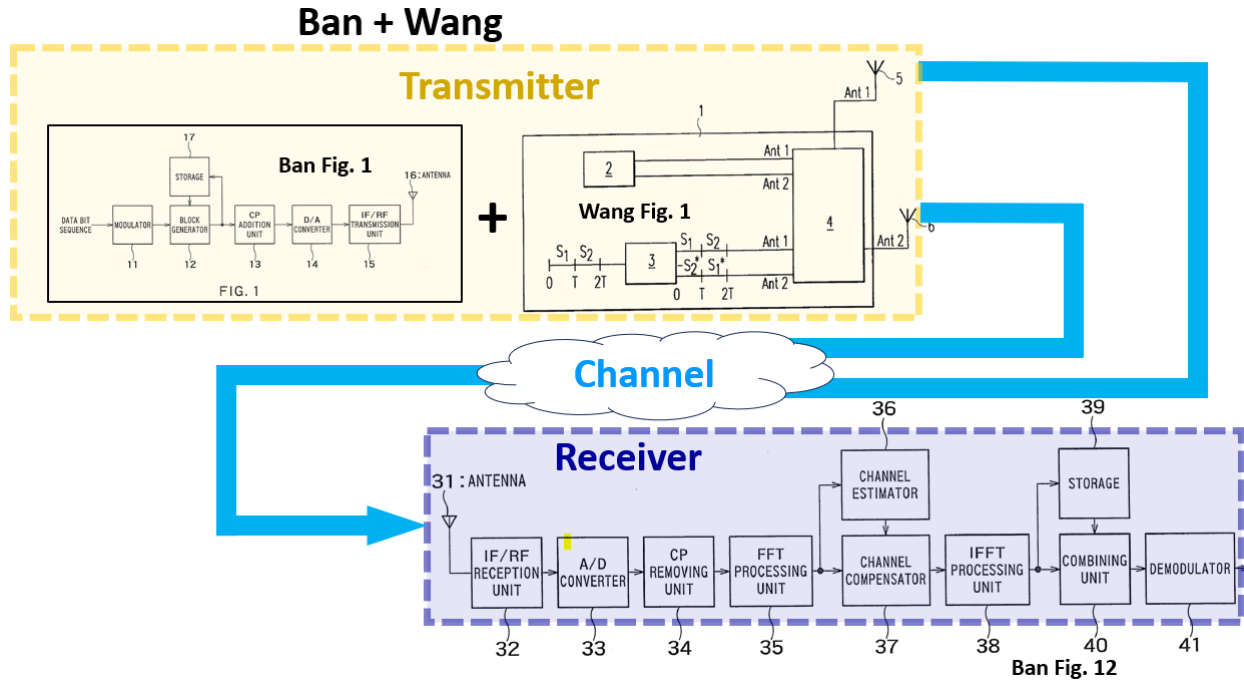
A POSITA would have expected such a combination to be successful because adding spatial diversity to a transmission, such as by using Alamouti coding, as described in Wang, was a well-known technique for increasing reliability of data transmission through a noisy or fading channel. Ex-1002 ¶159; Ex-1023; *see also* Ex-1001, 1:45-58 (describing Alamouti coding 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. Ex-1002 ¶159.

2. Independent Claim 1

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

Ban-Wang teaches or suggests the preamble, to the extent it is limiting. Ex-1002 ¶¶160-163.

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'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); Ex-1002 ¶162. In the Ban-Wang system, the transmitter is modified to add Wang's Space-Time Transmit Diversity coding, and the receiver is modified to decode the two streams received from the two transmit antennas. Ex-1002 ¶162.

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). Ex-1002 ¶163.

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

Ban-Wang teaches or suggests Element 1[a]. Ex-1002 ¶164. 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;

Ban-Wang teaches or suggests Element 1[b]. Ex-1002 ¶¶165-166. Ban’s receiver includes “channel estimator 36,” as illustrated in annotated Figure 12, below.

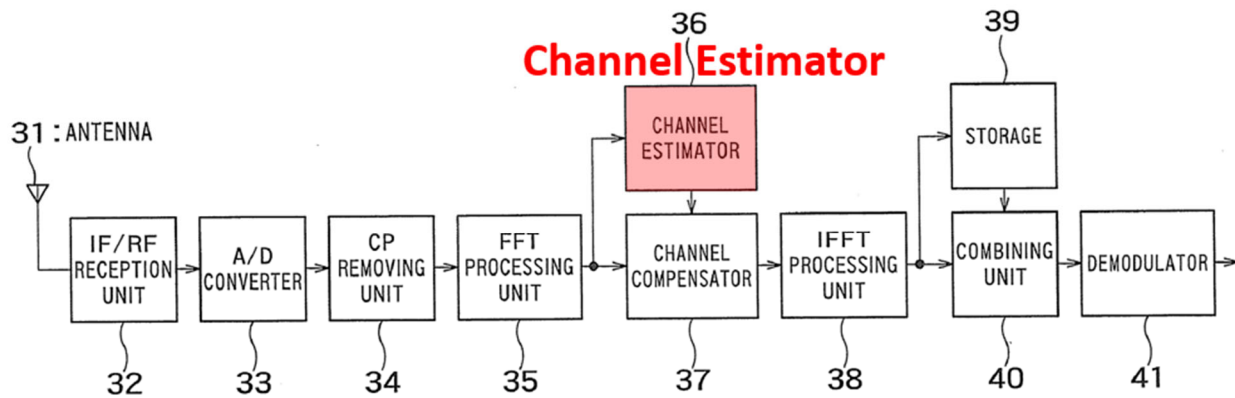


FIG. 12

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, $[h_{11} \ h_{12}]$ given the two antenna transmission to one antenna reception in the Ban-Wang combination. Ex-1002 ¶166.

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

Ban-Wang teaches or suggests Element 1[c]. Ex-1002 ¶¶167-178.

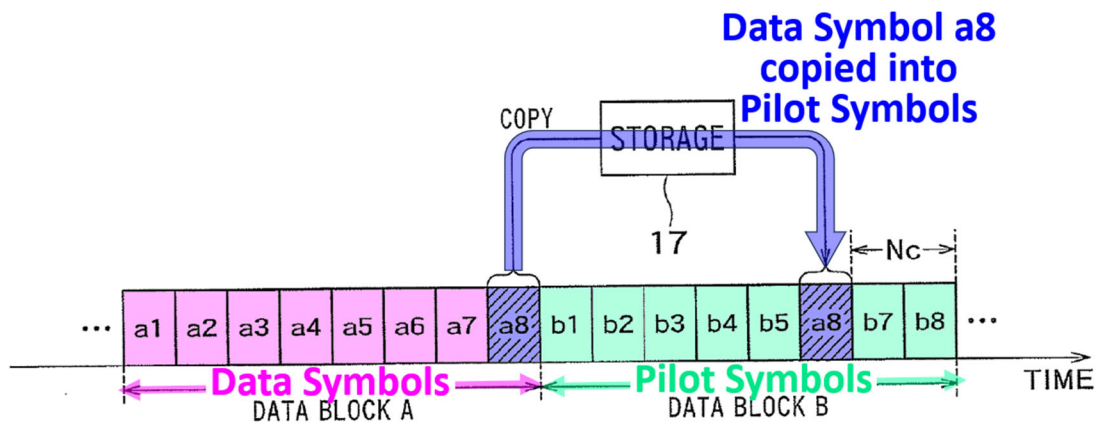
Ban-Wang teaches or suggests the claimed “replicated data” by copying data within a data stream (Ex-1006 ¶90) as part of Ban’s method for effectively extending the cyclic prefix length (Ex-1006 ¶81). Ban-Wang then teaches applying Alamouti

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

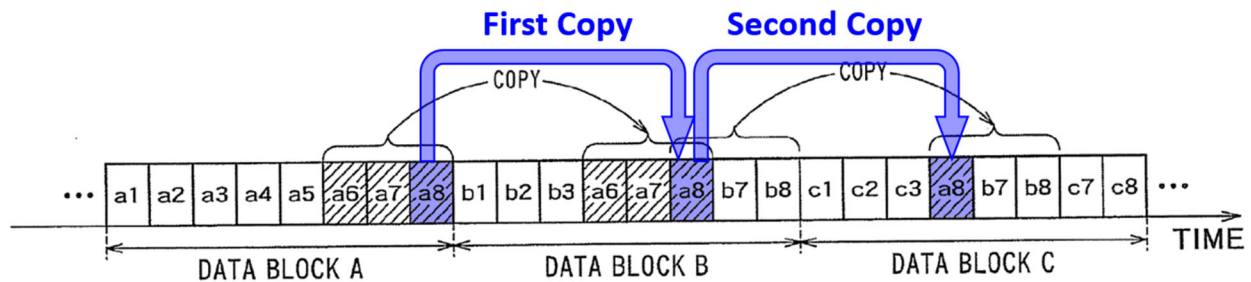
As explained for Element 1[pre], Ban extends the cyclic prefix of data block B (Ex-1006 ¶81), by copying (i.e., replicating) data from the preceding data block A into block B, before generating the cyclic prefix for block B, as shown in Figure 2A. Ex-1006 ¶90. Ban teaches that this same copying process may also be used to extend the cyclic prefix 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:⁹

⁹ 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.

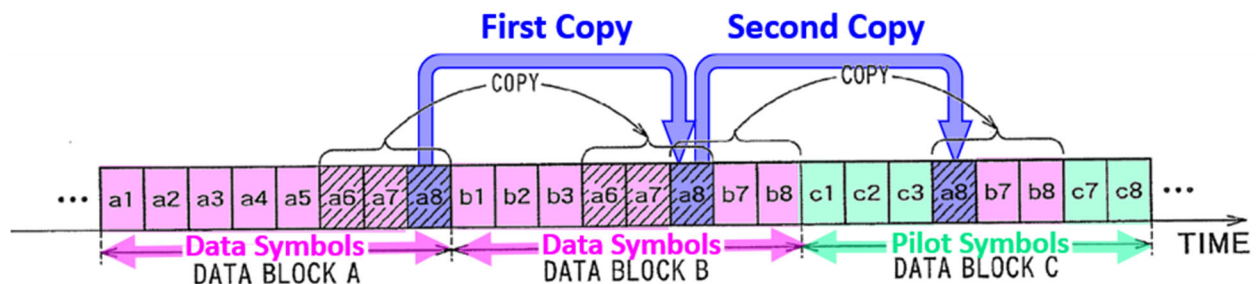


(A) OUTPUT OF BLOCK GENERATOR

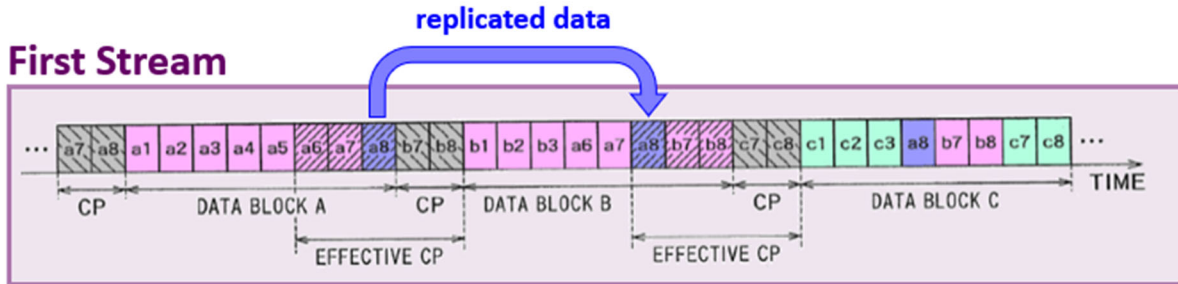
Such copying may happen multiple times. Annotated Figure 3A shows data symbol a_8 copied two times, from block A into both blocks B and C. Ex-1006 ¶97.



Because data may be copied to a pilot block (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, as annotated below:



Ex-1002 ¶171. 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

Ban-Wang teaches or suggests that the copied data symbols are transmitted over the communication channel in multiple data streams. Ex-1002 ¶¶173-177. As discussed above, Wang uses “space time transmit diversity (STTD)” (Ex-1007 ¶1), specifically Alamouti coding, in which “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.

As explained in Section XII.B.1 (motivation to combine), 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. Ex-1002 ¶174.

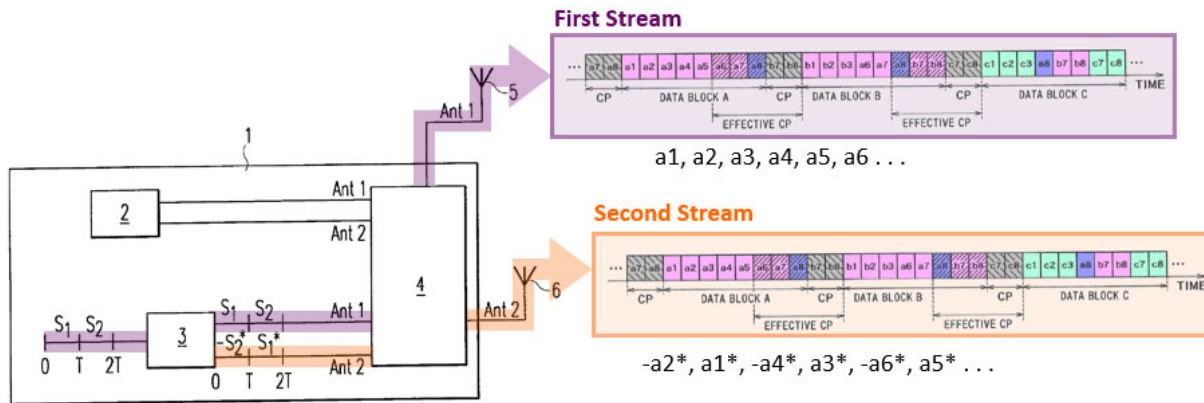
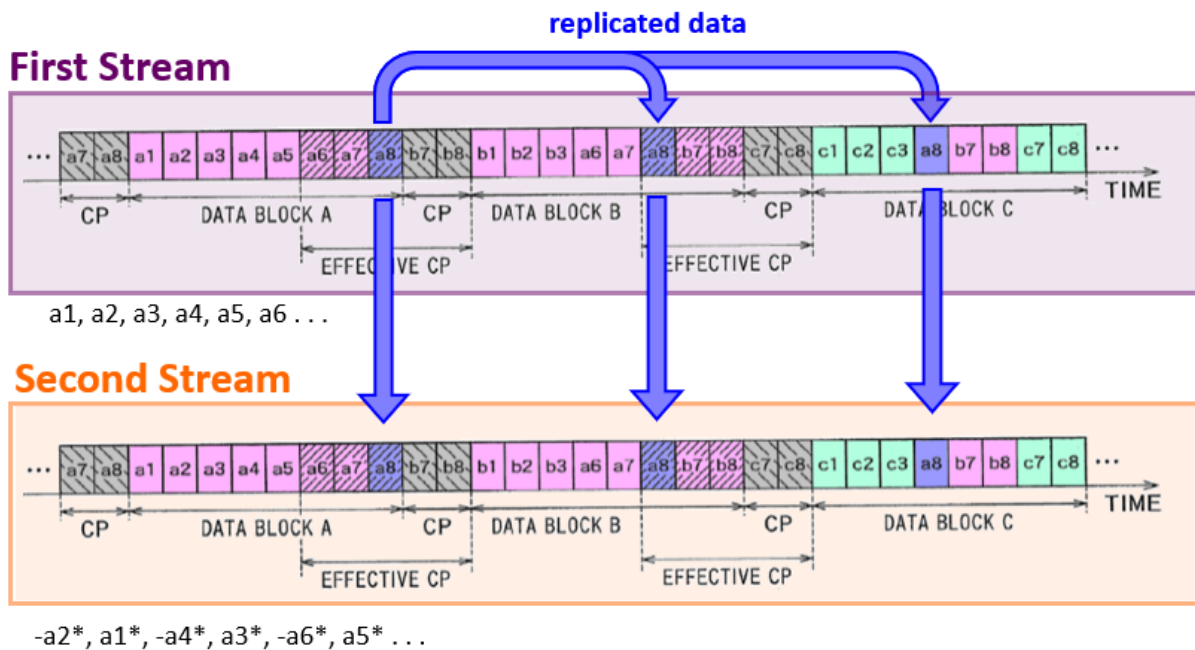


Fig. 1

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 in Section XII.B.1, 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; Ex-1002 ¶175.

Accordingly, in Ban-Wang, data symbols replicated within Ban's first data stream are transmitted over both a first data stream and a second data stream using Wang's STTD, as illustrated below:



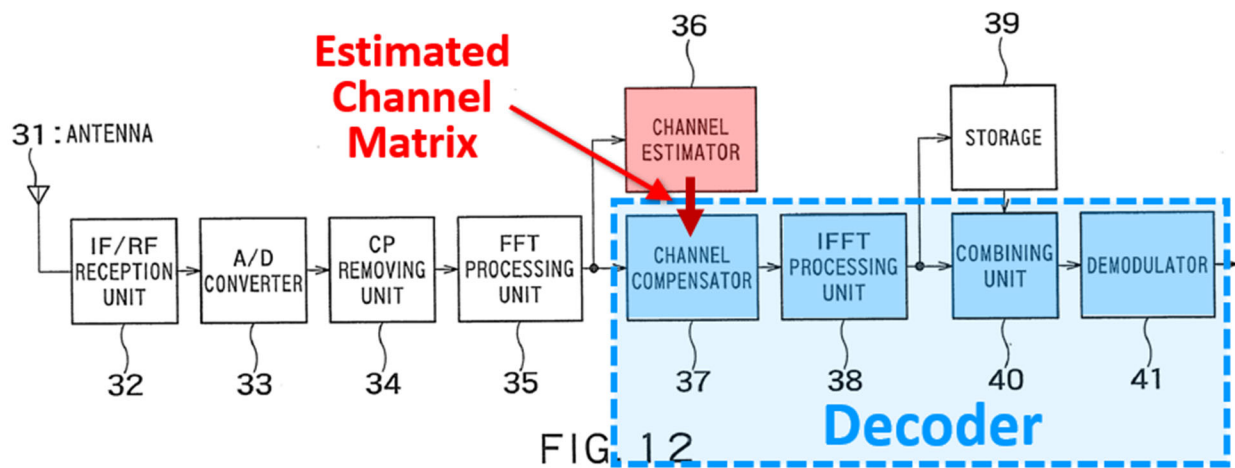
The second stream will “contain[] the identical data content as the first data stream, but in a different arrangement” (Ex-1007 ¶23), which is represented in the above figure by the notations indicating that symbols a1, a2, etc.... are sent as -a2*, a1*, etc.... in the second stream and received by Ban-Wang’s receive antenna. Ex-1002 ¶177.

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

Ban-Wang teaches or suggests Element 1[d]. Ex-1002 ¶¶179-182.

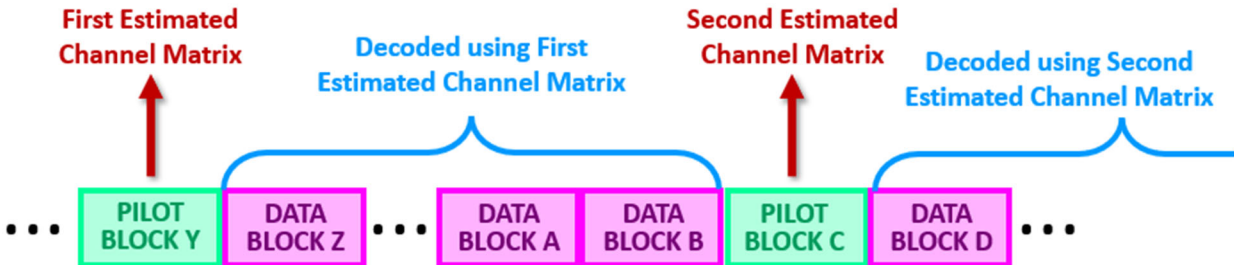
As explained for Elements 1[a] and 1[b], both Ban and Wang teach receiving “pilot symbols” and using those pilot symbols to estimate the channel matrix. Ex-1006 ¶134; Ex-1007 ¶27. Ban explains that “channel compensator 37” uses the

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. Ex-1002 ¶180.

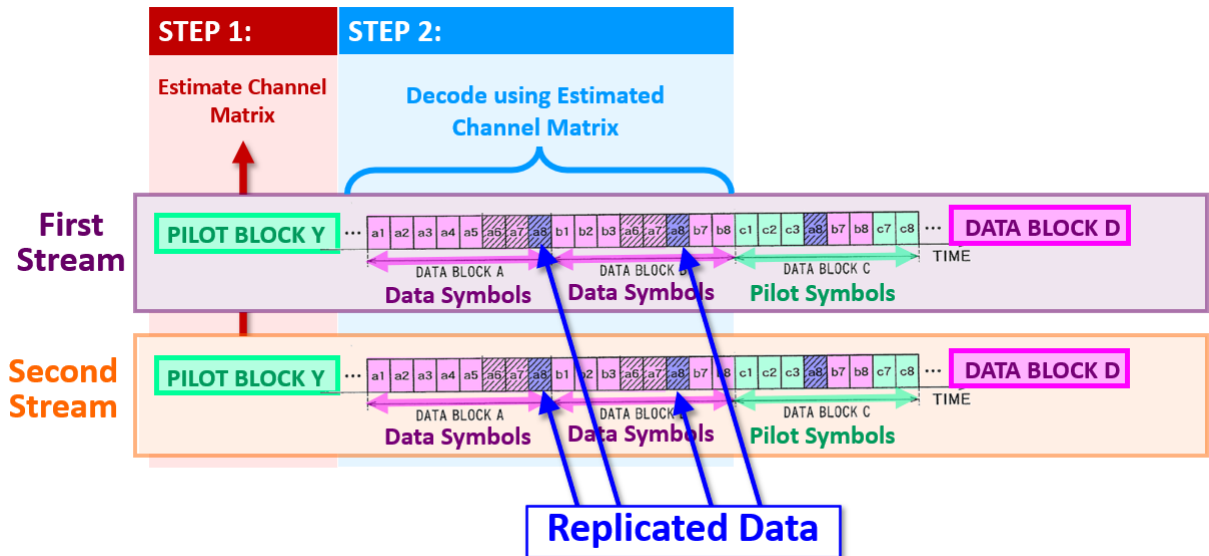


A POSITA would have understood that the channel estimate from a first set of pilot symbols may be used to decode several data blocks. Ex-1002 ¶181. For example, after receiving a first block of pilot symbols (Pilot Block Y, below) and using those pilot symbols to generate a first estimated channel matrix, 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. *Id.* Dr. Valenti illustrates this process below:



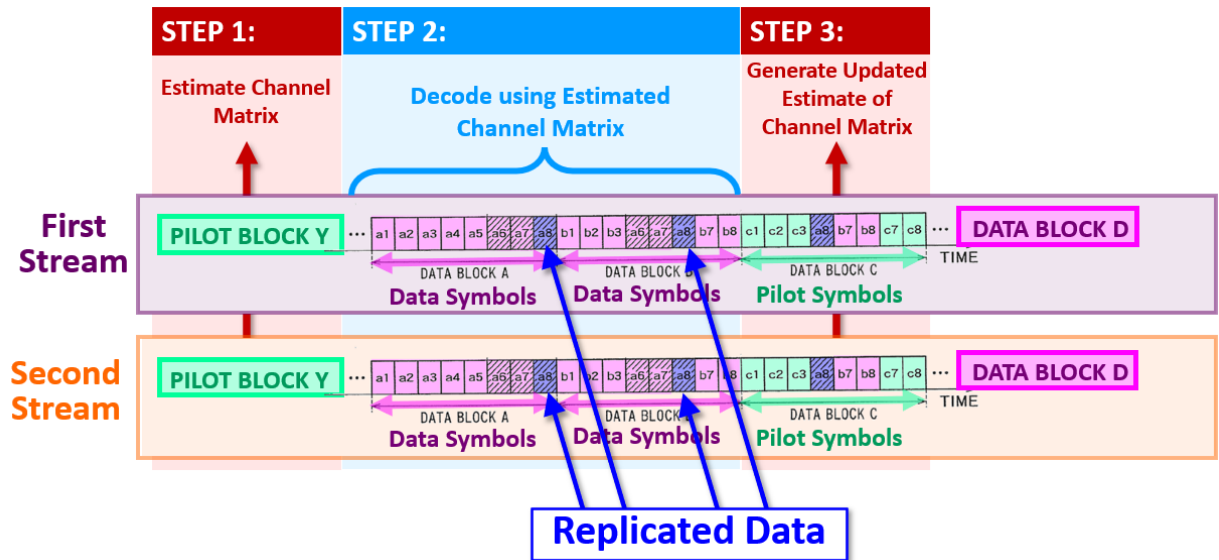
Thus, prior to receiving data blocks A and B (including replicated data symbol a8), Ban-Wang’s receiver would receive pilot symbols of block Y. *See* Ex-1006 ¶134; Ex-1007, Cl. 13 (“transmitting ... pilot symbols via said first and said second antenna means” and “receiving said pilot symbols in a single 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). Ex-1002 ¶182. Thus, the replicated data is decoded using the estimated channel matrix.



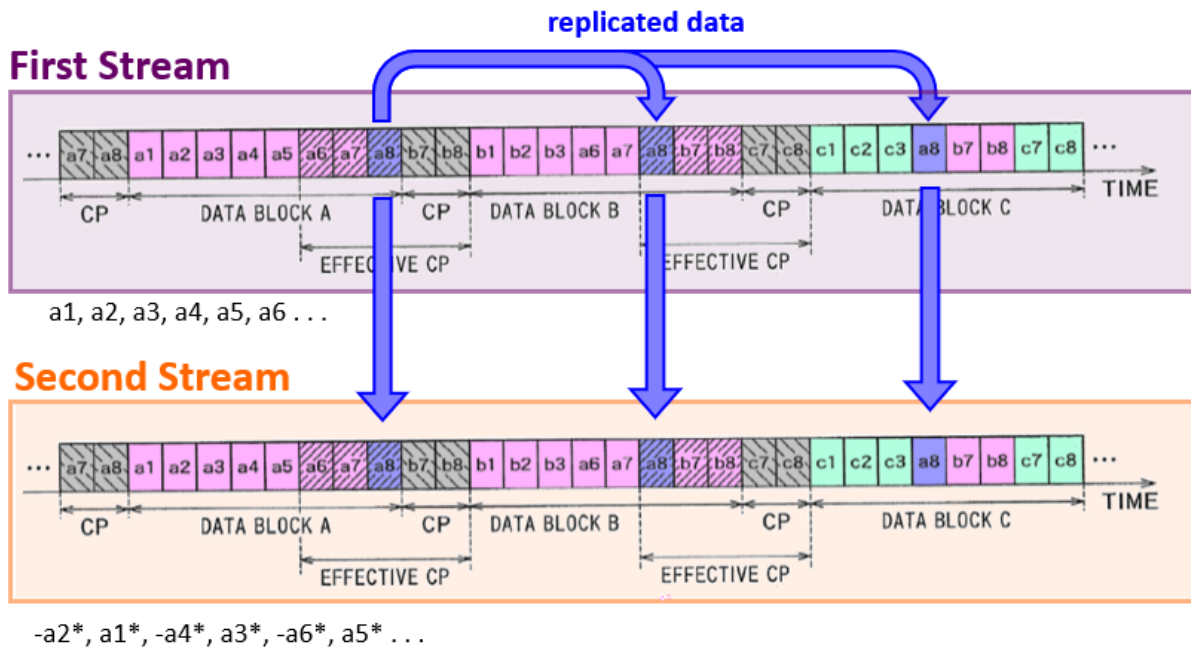
- f. **Element 1[e]: generating an updated estimate of the channel matrix based, at least in part, on the replicated data; and**

Ban-Wang teaches or suggests Element 1[e]. Ex-1002 ¶¶183-185.

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"):



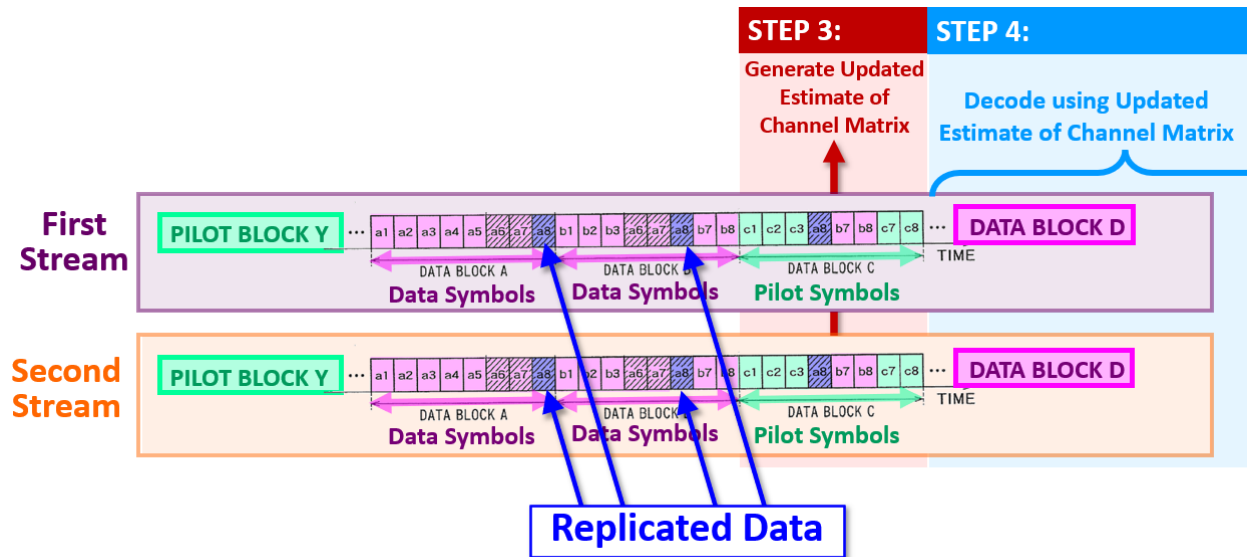
Ban teaches using the data symbols received in block C, in addition to the pilot symbols within that block, to perform a new channel estimation (“generat[e] an updated estimate of the channel matrix,” step 3, above), by treating those data symbols as known data (i.e., in the same manner as pilot symbols), 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. Ex-1002 ¶185.



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

Ban-Wang teaches or suggests Element 1[f]. Ex-1002 ¶¶186-188.

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 (step 4, below) to decode subsequently received blocks of data symbols (e.g., data block D, below), until the next block of pilot symbols are received and used to generate a new estimate of the channel matrix. Ex-1002 ¶187.



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

Ban-Wang teaches or suggests Claim 2. Ex-1002 ¶¶189-191.

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. The '331 Patent explains "a joint detection technique is used to decode the replicated data, *such as max-ratio combining*." Ex-1001, 10:28-30.

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 in §XII.A.2, is another type of joint detection technique.

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

Ban-Wang teaches or suggests Claim 3. Ex-1002 ¶¶192-193.

As explained for Element 1[e], Ban-Wang decodes the replicated 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. Ex-1002 ¶193 (citing Ex-1023, 0003).

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

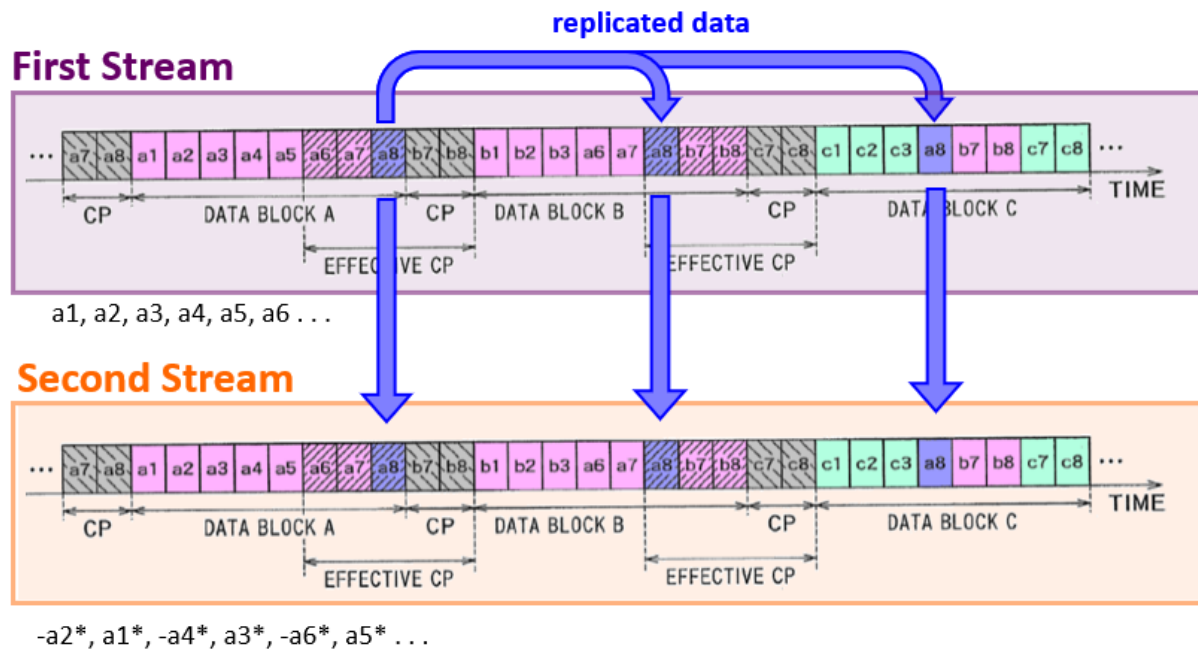
Ban-Wang teaches or suggests Claim 4. Ex-1002 ¶¶194-195.

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. Ex-1002 ¶195 (citing 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.

Ban-Wang teaches or suggests Claim 5. Ex-1002 ¶¶196-198.

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.



Wang's STTD ensures "[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."¹⁰ Ex-1007 ¶23.

¹⁰ 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^*). Moreover, certain modulation schemes, e.g., BPSK, use real symbols for which $s_1 = s_1^*$. Ex-1002 ¶198, n.8.

Thus, Ban-Wang teaches or suggests that the replicated data includes the same data symbols in multiple data streams.

7. Independent Claim 6:

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

Ban-Wang teaches or suggests the preamble, to the extent it is limiting. Ex-1002 ¶¶199-200.

Ban's receiver, illustrated below, is a communication device, because it includes "a reception unit configured to sequentially receive data blocks" (Ex-1006 ¶32) transmitted by a transmitter (Ex-1006 ¶29).

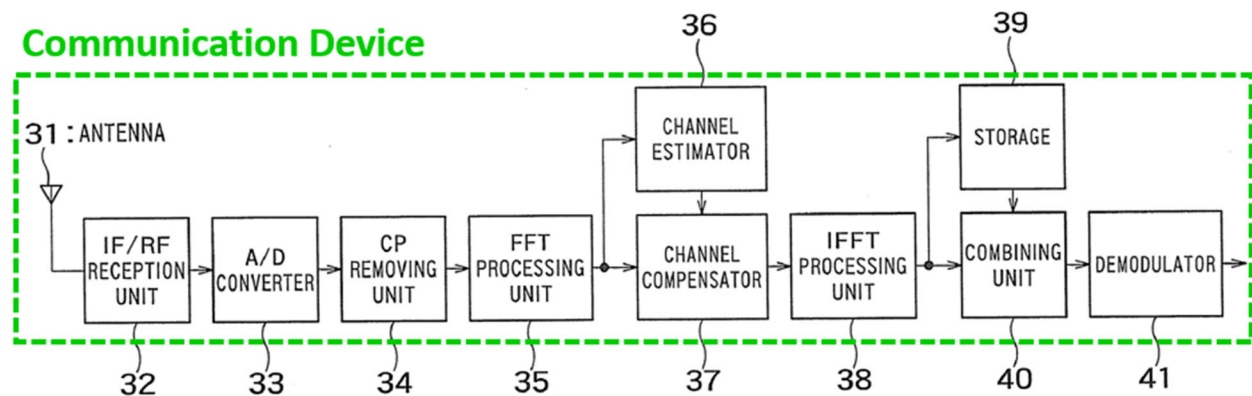


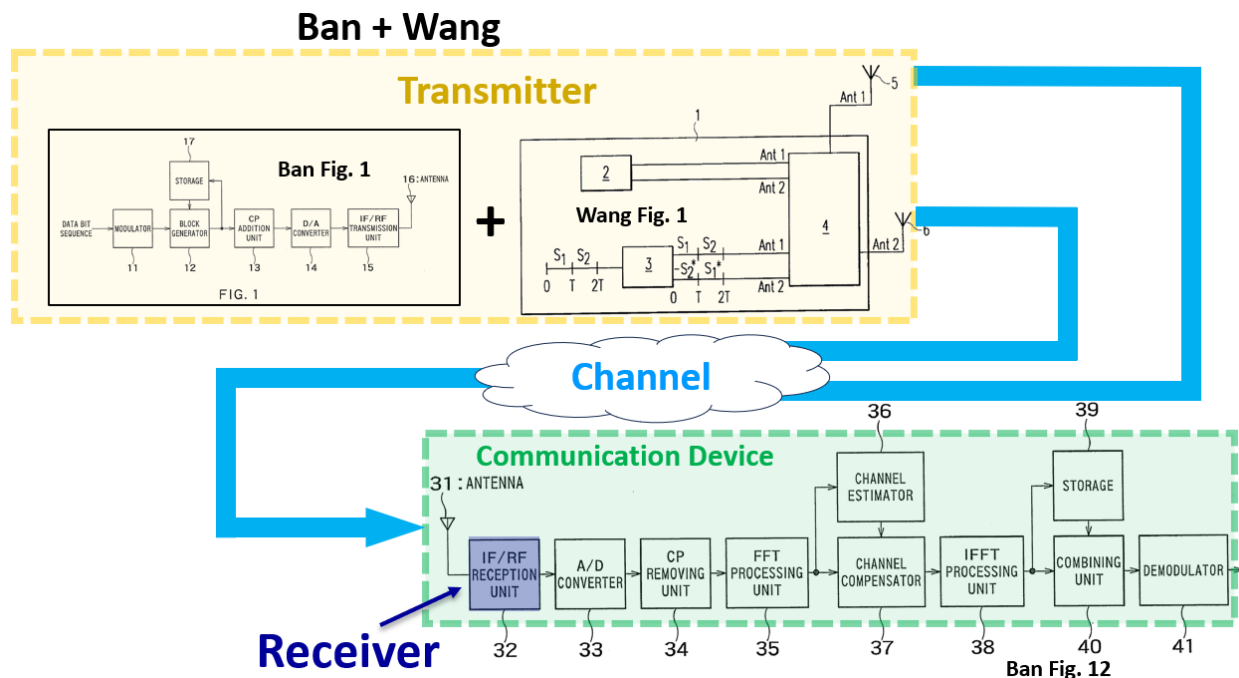
FIG. 12

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

Ban-Wang teaches or suggests Element 6[a]. Ex-1002 ¶¶201-202.

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. Ban states “[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.” Ex-1006 ¶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).



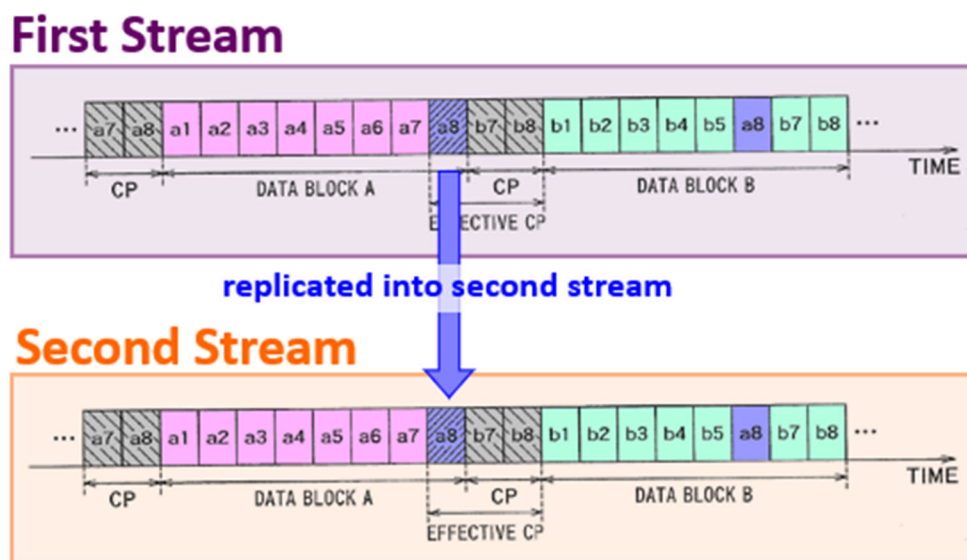
- c. **Element 6[a][i]: wherein the signals are based at least in part on first and second data streams transmitted over a communications channel,**

Ban-Wang teaches or suggests Element 6[a][i]. Ex-1002 ¶203. As explained for Element 1[c], Ban-Wang’s receiver receives signals transmitted as first and second data streams. In Wang’s STTD system (specifically, Alamouti coding), 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. 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;**

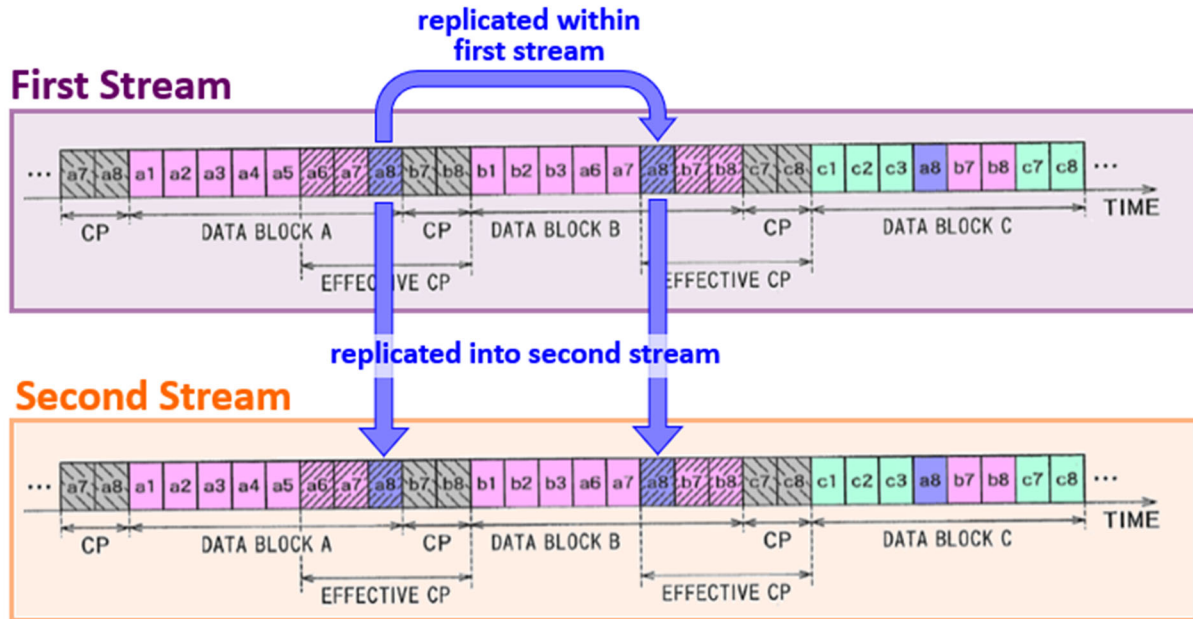
Ban-Wang teaches or suggests Element 6[a][ii]. Ex-1002 ¶¶204-205. As explained for Element 1[c], Ban-Wang replicates data symbols from the first data stream into the second data stream through STTD. Ex-1007 ¶¶1, 3, 23. As illustrated below, data symbol a8 is replicated from block A of the first data 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.”); Ex-1002 ¶204. Applying an Alamouti code generates copies of symbols in the second

data stream that are complex conjugated or negative but are nonetheless replicated symbols.¹¹ *Id.*



The “at least one data symbol replicated from the first data stream” into the second data stream may also have been replicated withing the first data stream, as illustrated below:

¹¹ Furthermore, for certain modulations such as BPSK, the symbols have real values and the complex conjugate is the same as the original symbol. Ex-1002 ¶204, n.9.

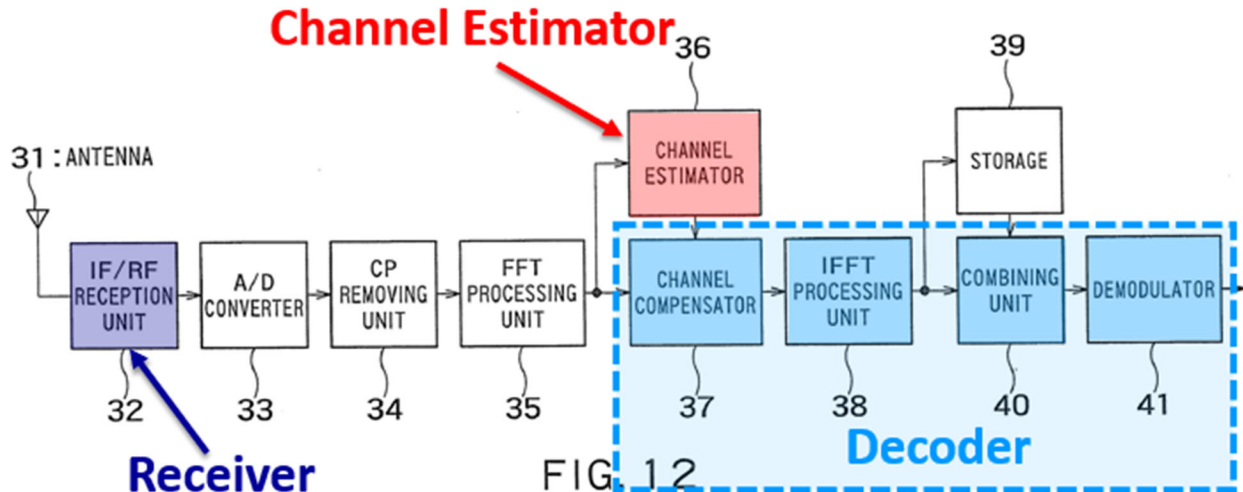


- e. **Element 6[b]: a decoder coupled to the receiver and the channel estimator, wherein the decoder is configured to receive the received signals and decode the at least one data symbol replicated from the first data stream;**

Ban-Wang teaches or suggests Element 6[b]. Ex-1002 ¶¶206-208.

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]. Ex-1002 ¶207. 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. Ex-1002 ¶207.

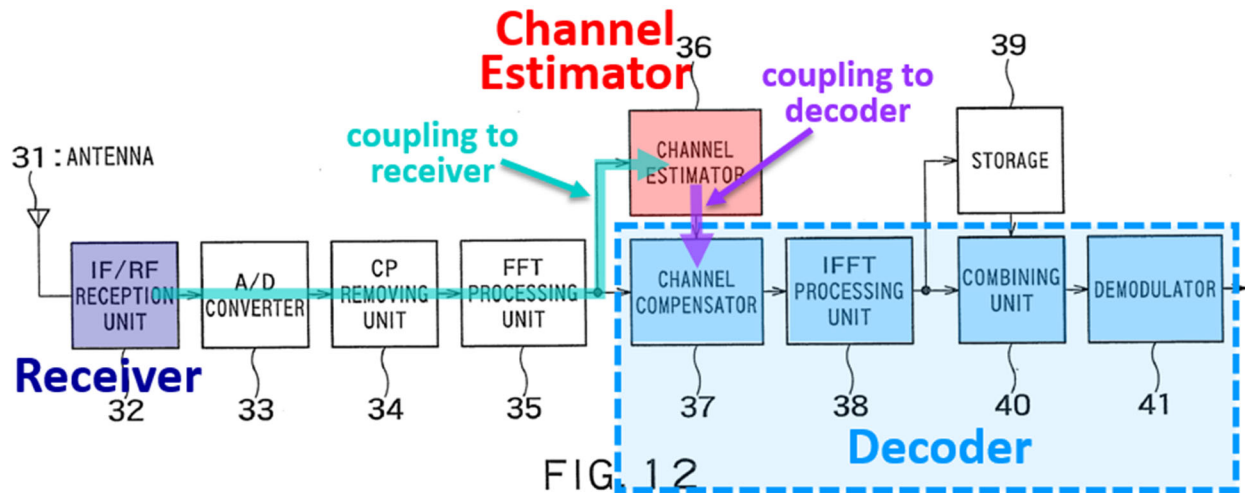


As explained for Element 1[e], in the combined Ban-Wang system, data symbols transmitted in multiple streams are received and passed to Ban’s decoder, which is configured to perform equalization processing (Ex-1006 ¶135) and decoding of the data. Ex-1006 ¶136; Ex-1002 ¶208. The signals received from the two streams (including data symbol a8, “replicated from the first data stream”) are subsequently demodulated (“decode[d]”) by demodulator 41. Ex-1006 ¶137; Ex-1002 ¶208.

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

Ban-Wang teaches or suggests Element 6[c]. Ex-1002 ¶¶209-210.

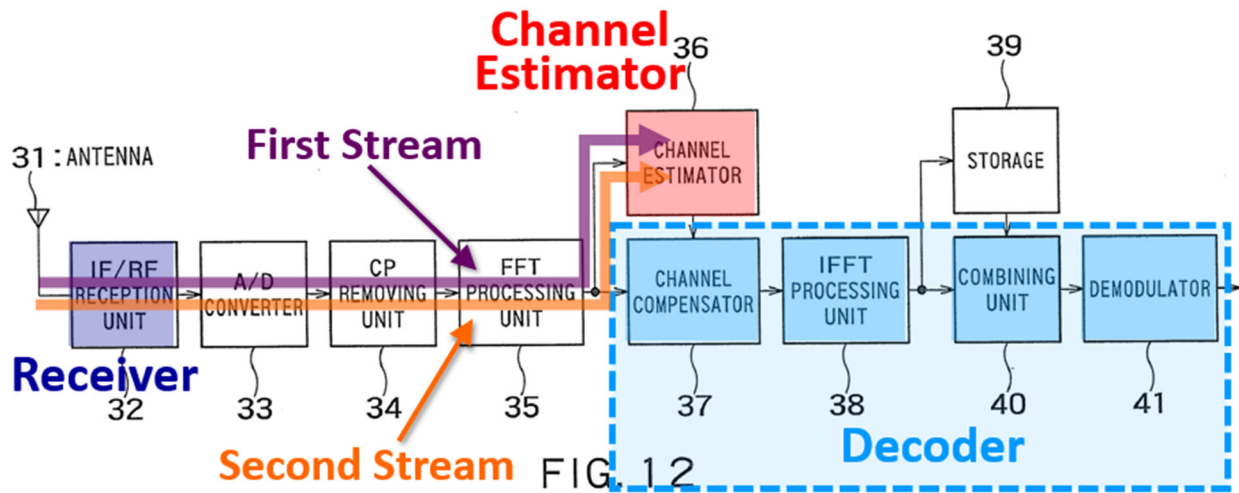
As illustrated below, Ban's channel estimator 36 is coupled both to reception unit 32 ("receiver") and to channel compensator 37 (forming part of the claimed "decoder," as explained for Element 6[b]). Ex-1006 ¶135; Ex-1002 ¶210.



- 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

Ban-Wang teaches or suggests Elements 6[c][i] and 6[c][ii]. Ex-1002 ¶¶211-216.

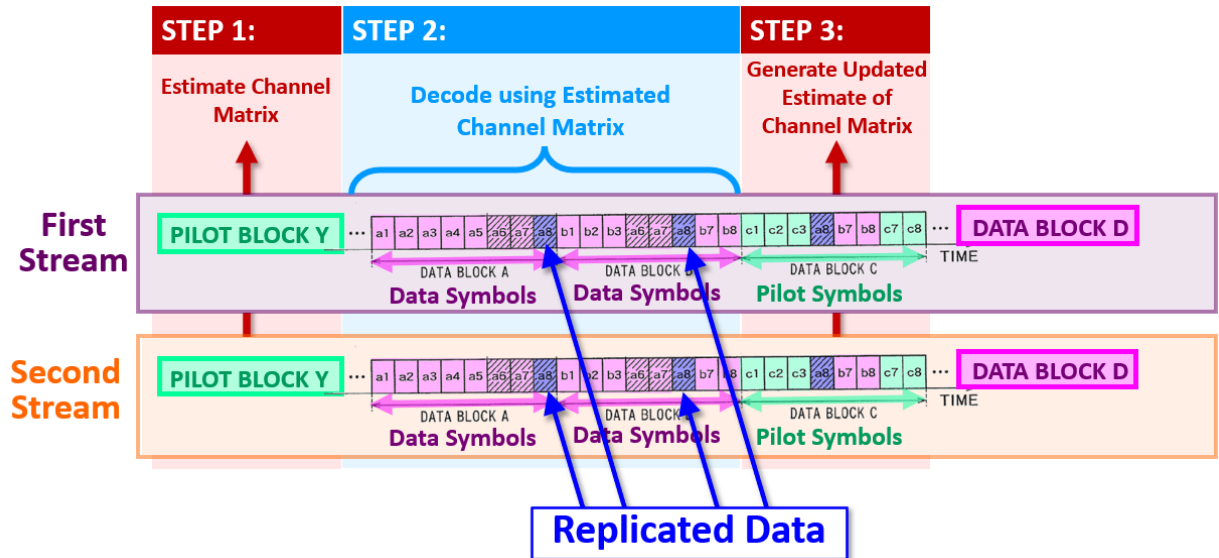
As illustrated in annotated Figure 12, below, in the combined Ban-Wang system, channel estimator 36 is configured to receive the signals transmitted in the first and second streams ("received signal"):



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. Ex-1002 ¶213. 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. *Id.*

Ban also teaches 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

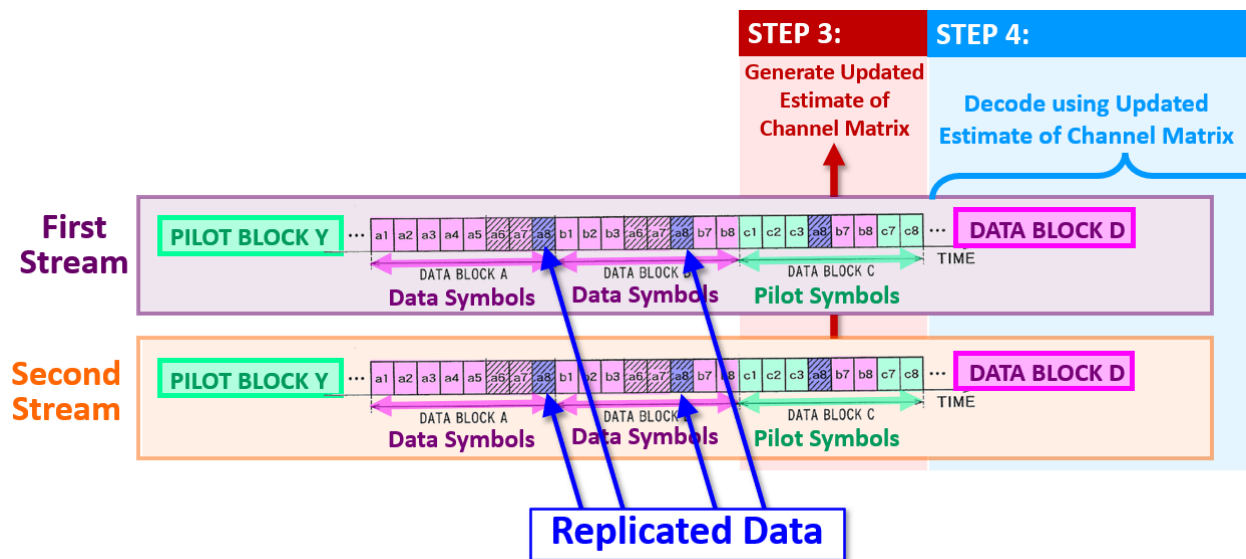
and B, as illustrated below. *Id.* (“some of [the] pilot symbols in the data block are replaced with data symbols of the preceding data block”):



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 since copies of those data symbols that were received and decoded 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.”); Ex-1002 ¶215.

- 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.**

Ban-Wang teaches or suggests Element 6[d]. Ex-1002 ¶¶217-218. 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 (step 4, below), 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. Ex-1002 ¶217.



- 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.**

Ban-Wang teaches or suggests Claim 7. Ex-1002 ¶¶219-221.

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).

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

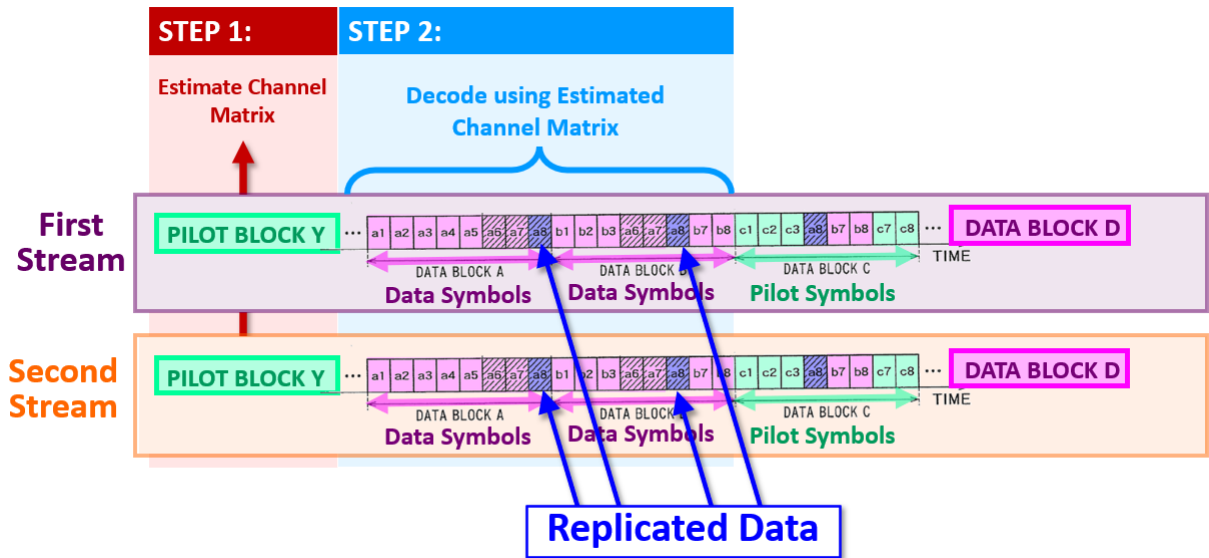
- a. Element 8[a]: The communication device of claim 6 wherein the first and second data streams each further include at least one pilot symbol, and**

Ban-Wang teaches or suggests Element 8[a]. Ex-1002 ¶¶222-223.

As explained for Element 1[a], Ban receives 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. Ex-1002 ¶223.

- 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.**

Ban-Wang teaches or suggests Element 8[b]. Ex-1002 ¶¶224-225. 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]. Ex-1002 ¶224.



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:**

Tang teaches or suggests the preamble, to the extent it is limiting. Ex-1002 ¶¶226-229.

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

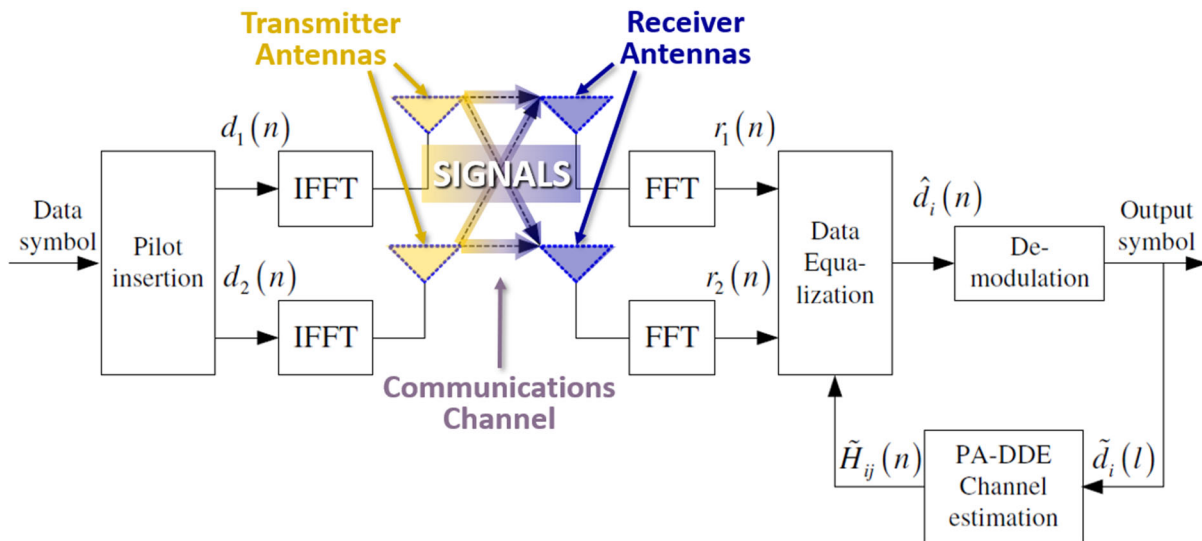
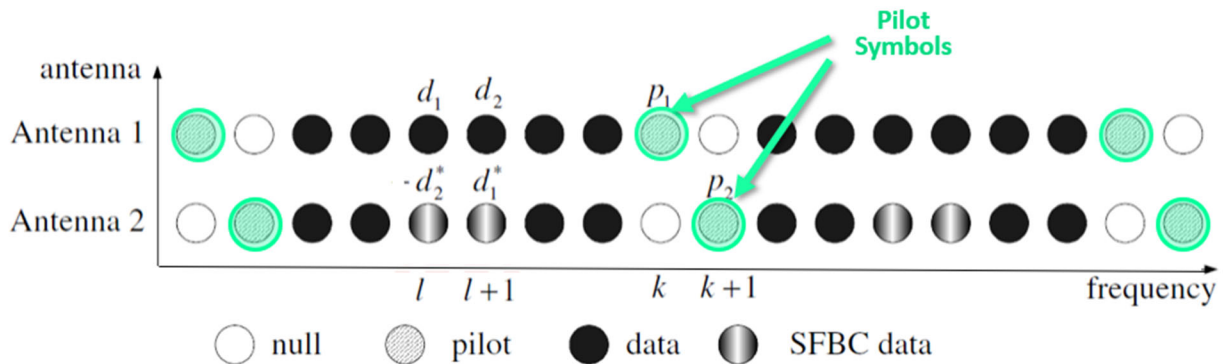


Figure 1 shows that Tang’s transmitter and receiver include multiple processing blocks that take a “data symbol” through “pilot insertion” and “modulat[ion] by inverse fast Fourier transform (IFFT)” before transmission through “two transmit antennas,” and then, following reception via “two receive antennas,” through multiple steps for decoding (including channel estimation, equalization, and demodulation) to recover the “output symbol” at the receiver. Ex-1008, pp.2-3; Ex-1002 ¶228.

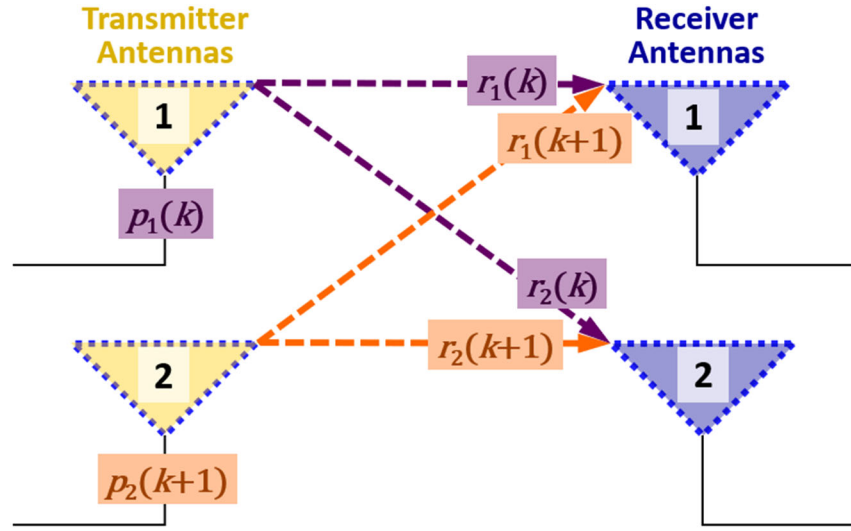
To enhance decoding, by “guarantee[ing] the accuracy of the channel estimation,” while nevertheless “achiev[ing] a good tradeoff between the pilots overhead and the system performance,” Tang teaches a “joint point-aided and blind decision-directed channel estimation (PA-DDCE) scheme.” Ex-1008, p.1.

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

Tang teaches or suggests Element 1[a]. Ex-1002 ¶¶230-231. 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.



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. Ex-1002 ¶231.



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

Tang teaches or suggests Element 1[b]. Ex-1002 ¶¶232-235. Tang first uses 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. Ex-1002 ¶232.

First, 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. The components of the estimated channel matrix are calculated using these received pilot symbols, as follows:

The diagram illustrates the calculation of channel frequency response estimates for two adjacent subcarriers, k and $k+1$. The equations are as follows:

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

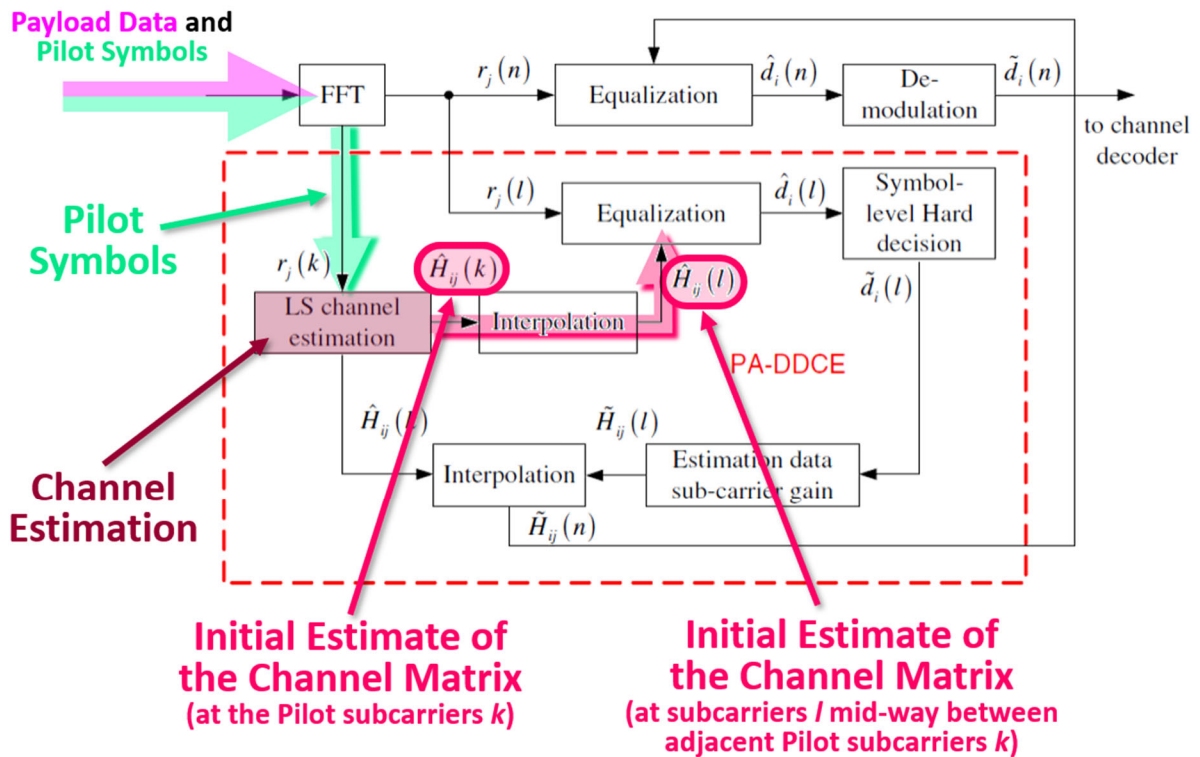
Annotations and arrows indicate the source of the symbols:

- Pilot Symbols Received at Subcarrier k** : Points to the received symbols $r_1(k)$ and $r_2(k)$ in the equations for subcarrier k .
- Pilot Symbol Transmitted at Subcarrier k** : Points to the transmitted symbol $p_1(k)$ in the equations for subcarrier k .
- Pilot Symbols Received at Subcarrier $k+1$** : Points to the received symbols $r_1(k+1)$ and $r_2(k+1)$ in the equations for subcarrier $k+1$.
- Pilot Symbol Transmitted at Subcarrier $k+1$** : Points to the transmitted symbol $p_2(k+1)$ in the equations for subcarrier $k+1$.

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

Next, “[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. Ex-1002 ¶234.

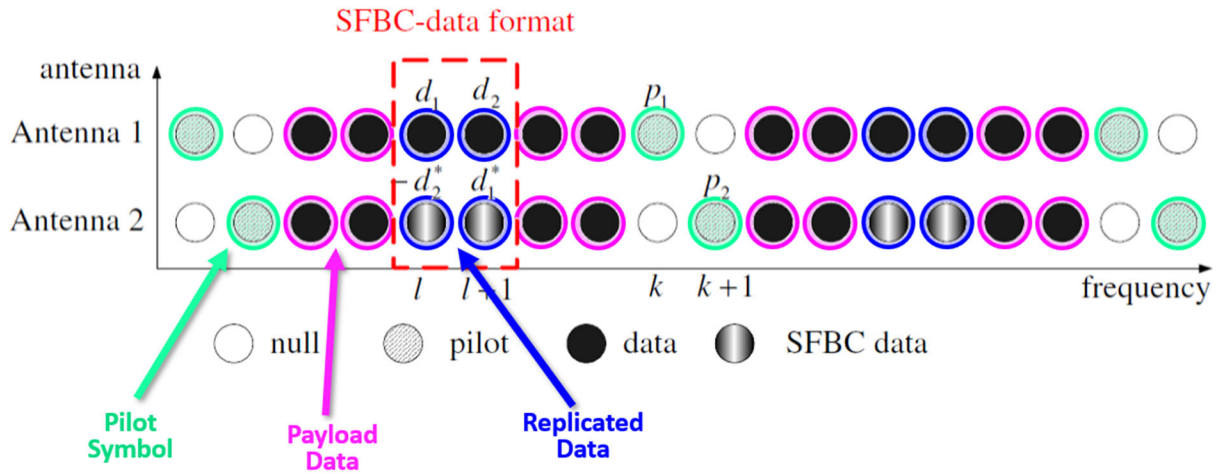


Thus, Tang teaches or suggests estimating a channel matrix $\mathbf{H}$ of the communications channel ($\hat{H}_{ij}(l)$) based, at least in part, on the received pilot symbols $r_j(k)$ and $r_j(k + 1)$.

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

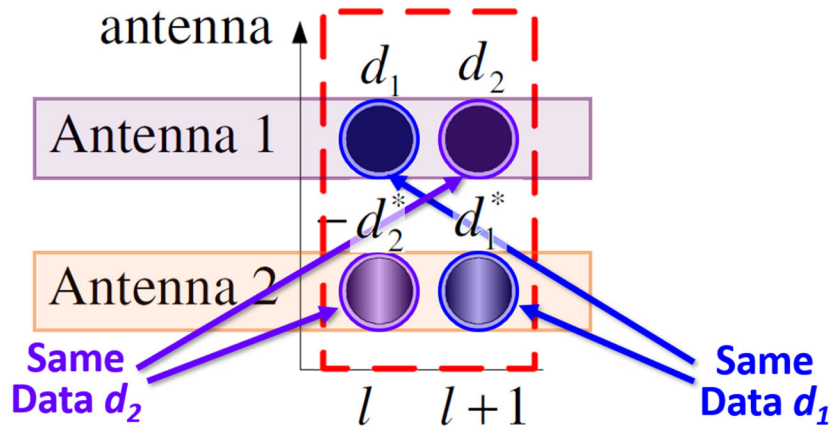
Tang teaches or suggests Element 1[c]. Ex-1002 ¶¶236-238.

Tang inserts “data symbols ... in the middle of any two adjacent pilot subcarriers,” so they can be used for improved channel estimation. Ex-1008, p.1. For example, Tang presents a “space frequency block code (SFBC)-data [] format,” as illustrated in annotated Figure 5, below. *Id.*

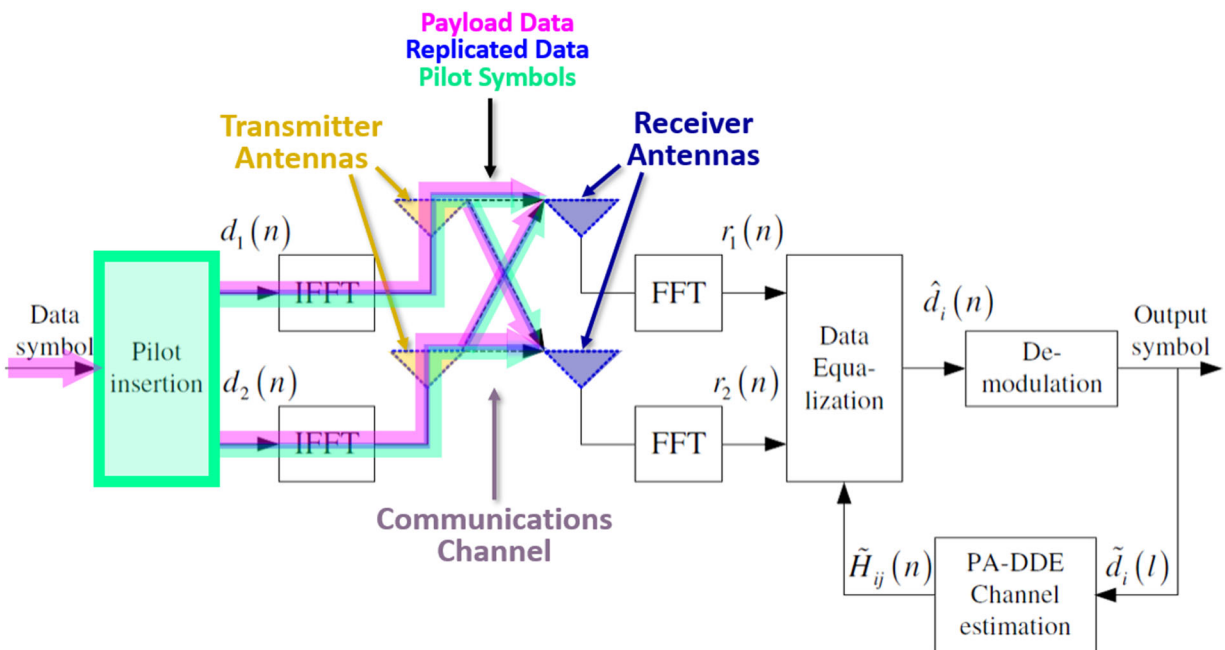


Using the SFBC-data format, data symbol d_1 , to be transmitted in sub-carrier l by antenna 1, is copied into sub-carrier $l + 1$ of the data stream to be transmitted by antenna 2. Similarly, data symbol d_2 is copied from sub-carrier $l + 1$ of antenna 1's data stream into sub-carrier l of antenna 2's data stream. Ex-1008, p.3; Ex-1002 ¶237. 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. Ex-1002 ¶237.

SFBC-data format



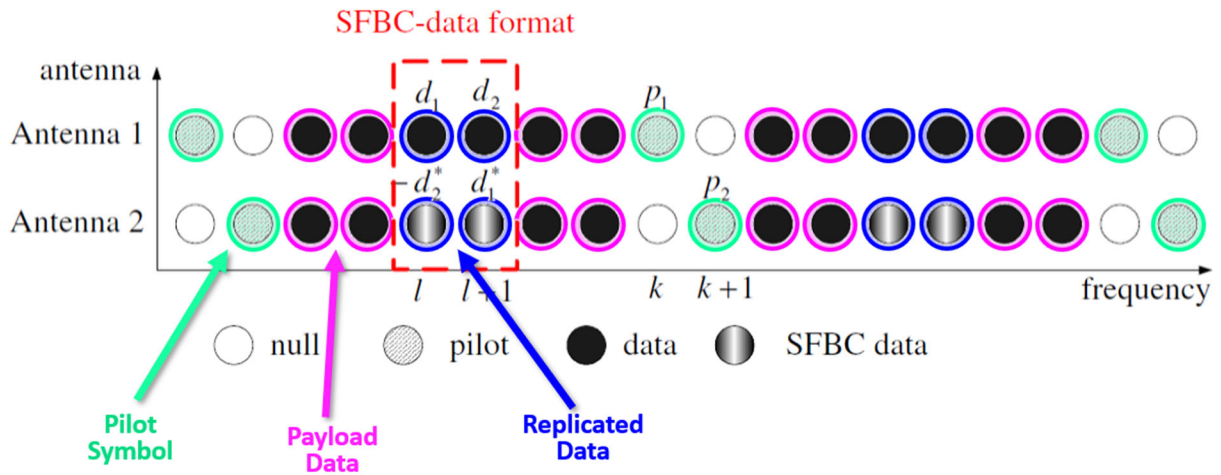
These replicated data symbols are received by each receive antenna j , as received data symbols $r_j(l)$. Ex-1008, p.2. Thus, Tang teaches or suggests receiving replicated data from multiple data streams transmitted over the communications channel, as illustrated in annotated Figure 3, below.



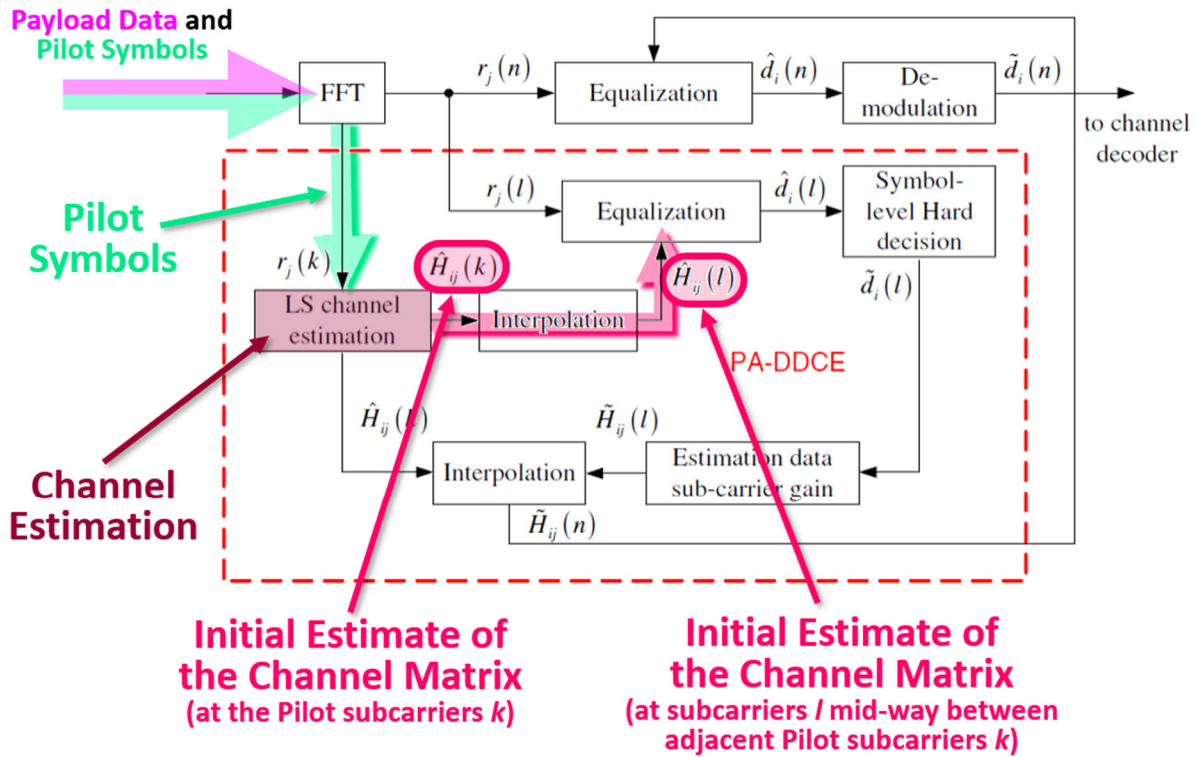
e. Element 1[d]: decoding the replicated data using the estimated channel matrix;

Tang teaches or suggests Element 1[d]. Ex-1002 ¶¶239-242.

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 $l+1$:

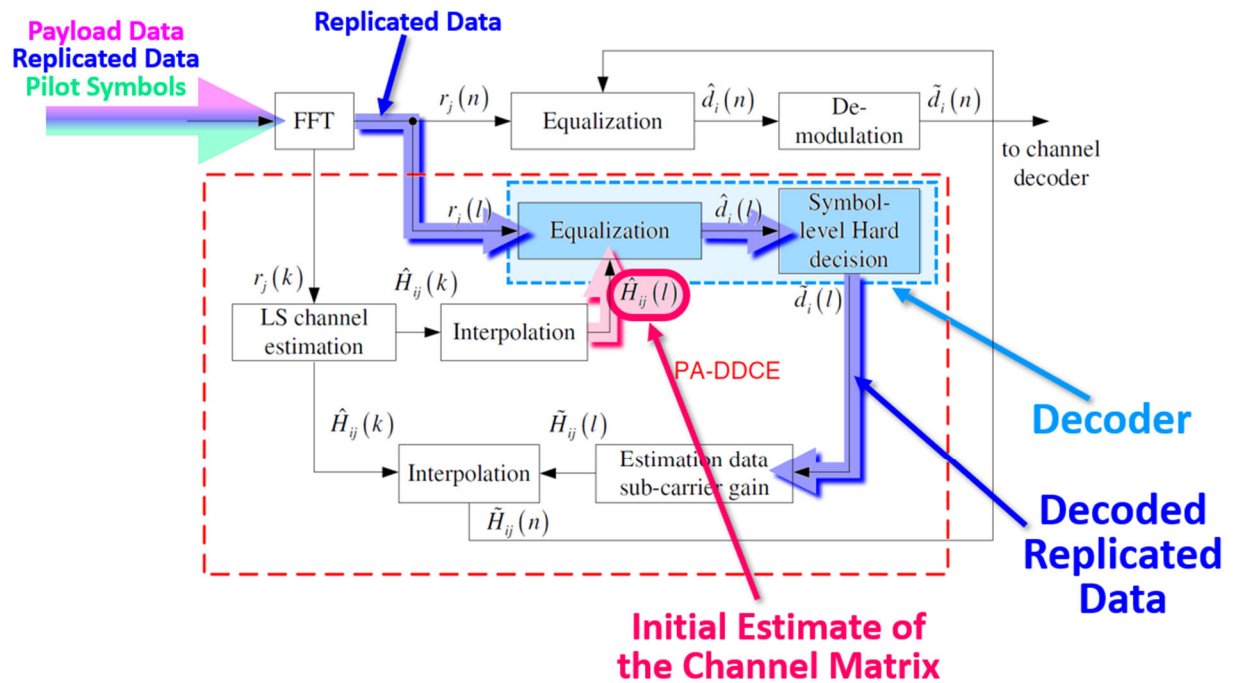


As explained for Element 1[b] and illustrated in annotated Figure 3 below, the received pilot symbols are used to generate channel estimates at the pilot subcarriers k , from which channel estimates at the replicated data subcarriers l , $\hat{H}_{ij}(l)$, are obtained through interpolation:



Next, 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 $\tilde{d}_i(l)$.

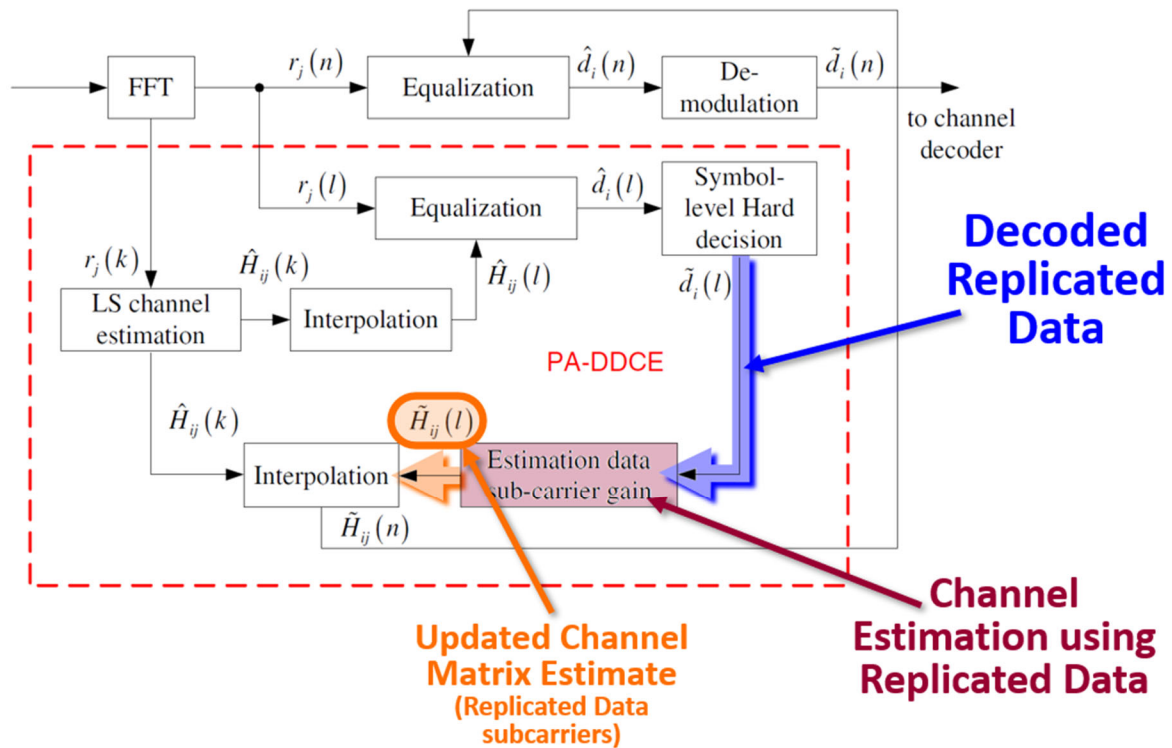
Ex-1008, p.2.



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

Tang teaches or suggests Element 1[e]. Ex-1002 ¶¶243-246.

The replicated data symbols $\tilde{d}_i(l)$ are then used 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.



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 $\rightarrow \tilde{\mathbf{H}}_s = \left(\tilde{\mathbf{d}}_s^H \tilde{\mathbf{d}}_s \right)^{-1} \tilde{\mathbf{d}}_s^H \mathbf{r}, \quad (18)$

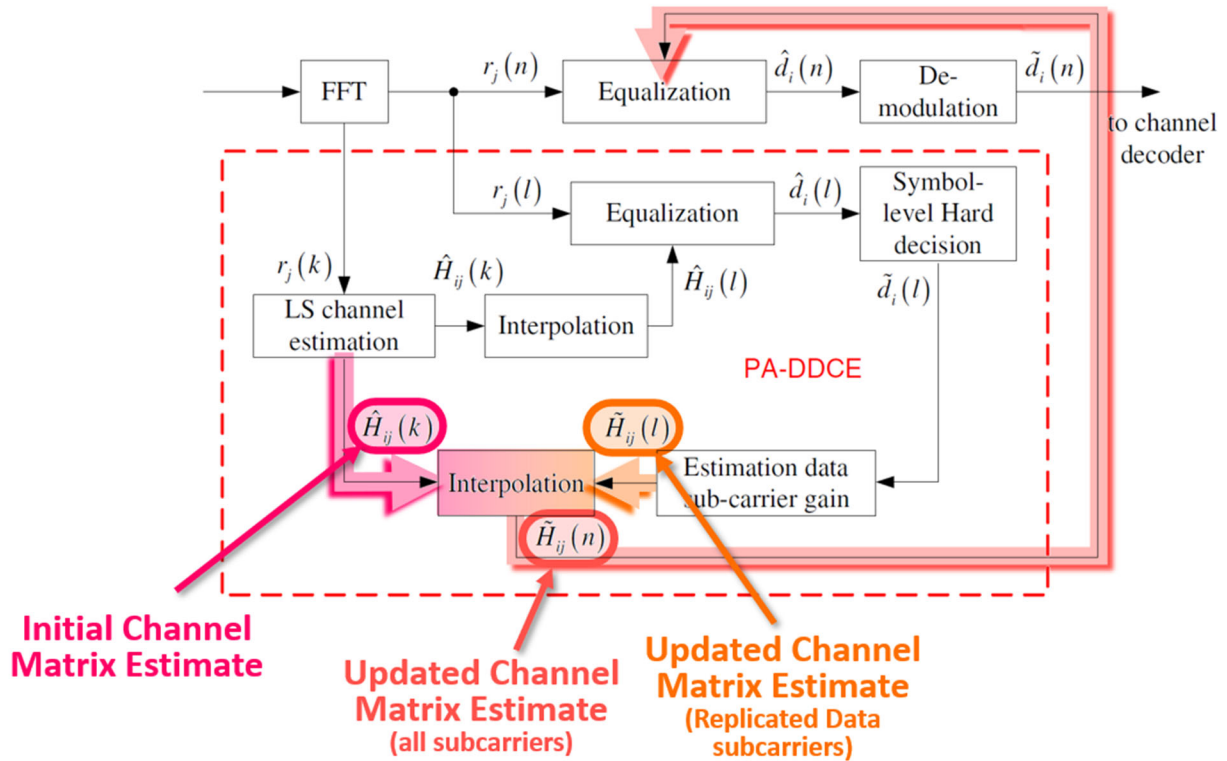
where

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

and

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

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.

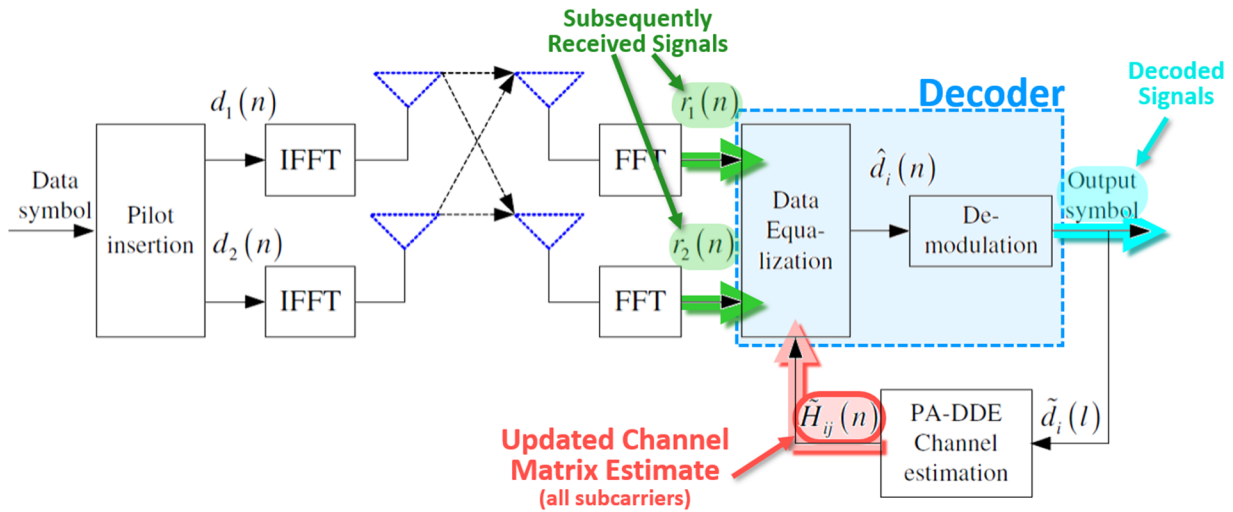


Thus, Tang teaches or suggests generating an updated estimate of the channel matrix (Tang's final estimated channel frequency response $\tilde{H}_{ij}(n)$) based, at least in part, on the replicated data.

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

Tang teaches or suggests Element 1[f]. Ex-1002 ¶¶247-250.

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 $r_j(n)$. Ex-1002 ¶248.



As explained in Section XII.A.1.g (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. Ex-1002 ¶249. 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, pp.1-2; Ex-1002 ¶249.

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.

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

Tang teaches or suggests Claim 2. Ex-1002 ¶251. 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 identifies as an example of a “joint detection technique” (Ex-1001, 10:28-30).

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

Tang teaches or suggests Claim 4. Ex-1002 ¶252. 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. Ex-1002 ¶252.

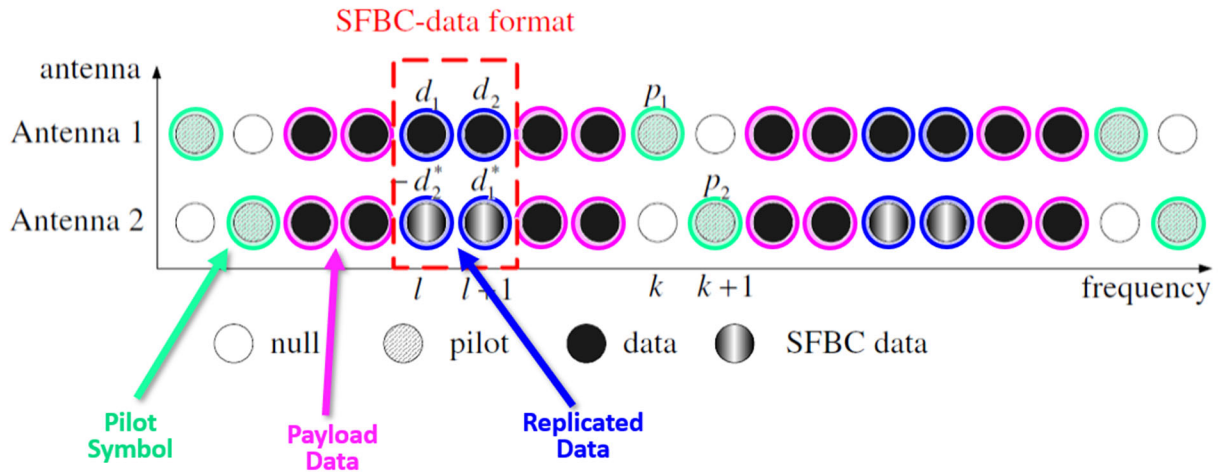
4. Dependent Claim 3: The method of claim 1, wherein said decoding the replicated data comprises using a space-time block decoding technique.

Tang teaches or suggests Claim 3. Ex-1002 ¶253. As explained for Claim 4, Tang teaches space-frequency block decoding. 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. Ex-1008, p.4; Ex-1002 ¶253 (citing Ex-1023, 0002-0003).

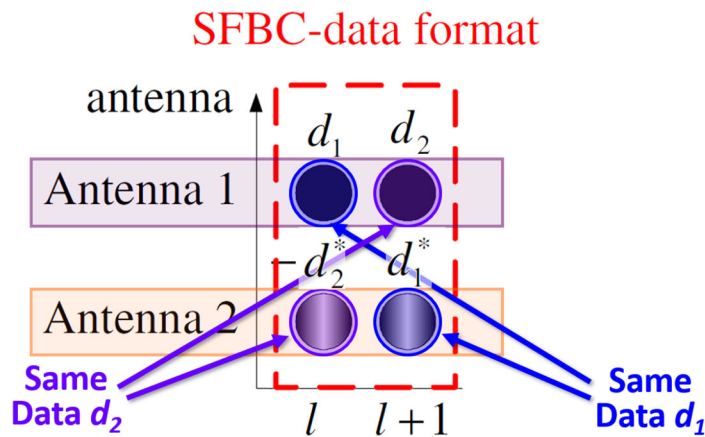
5. Dependent Claim 5: The method of claim 1, wherein the replicated data includes same data symbols in multiple data streams.

Tang teaches or suggests Claim 5. Ex-1002 ¶¶254-256.

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.



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. Ex-1002 ¶256.

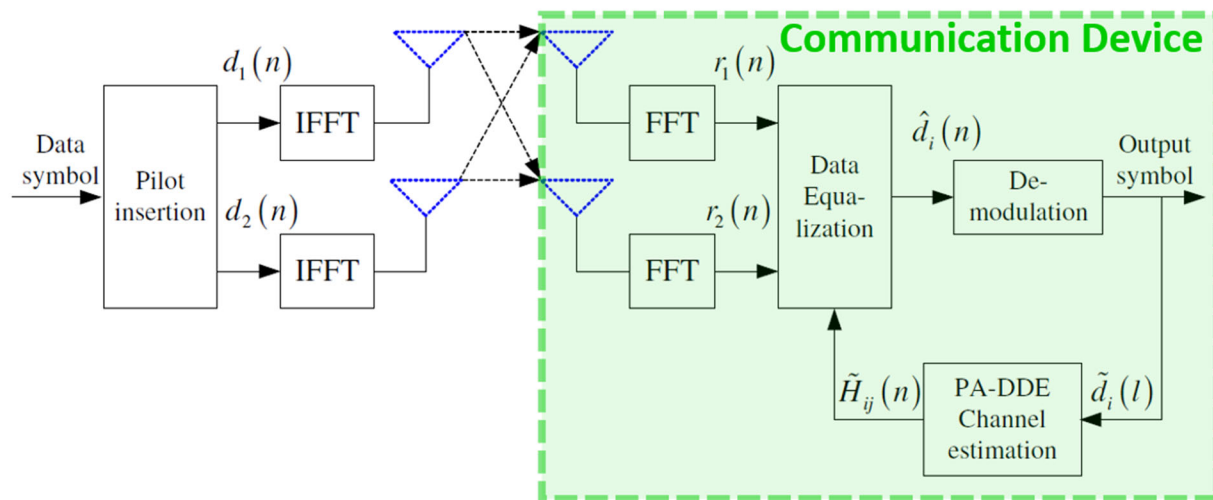


6. Independent Claim 6:

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

Tang teaches or suggests the preamble, to the extent it is limiting. Ex-1002 ¶¶257-258.

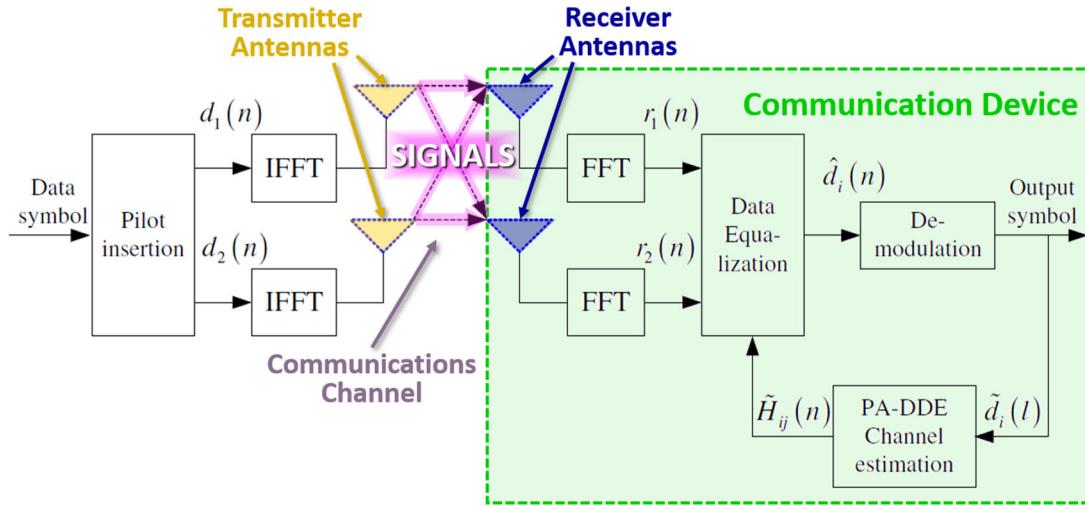
Tang's receiver, illustrated below, is a communication device, because it includes "two receive antennas" to receive signals, $r_j(n)$ (where j corresponds to the j th receive antenna), transmitted by "two transmit antennas." Ex-1008, p.2.



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

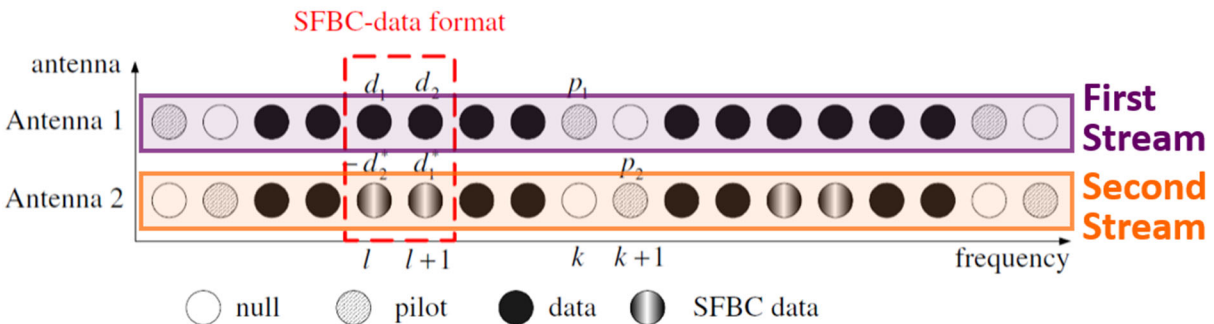
Tang teaches or suggests Element 6[a]. Ex-1002 ¶¶259-260.

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.

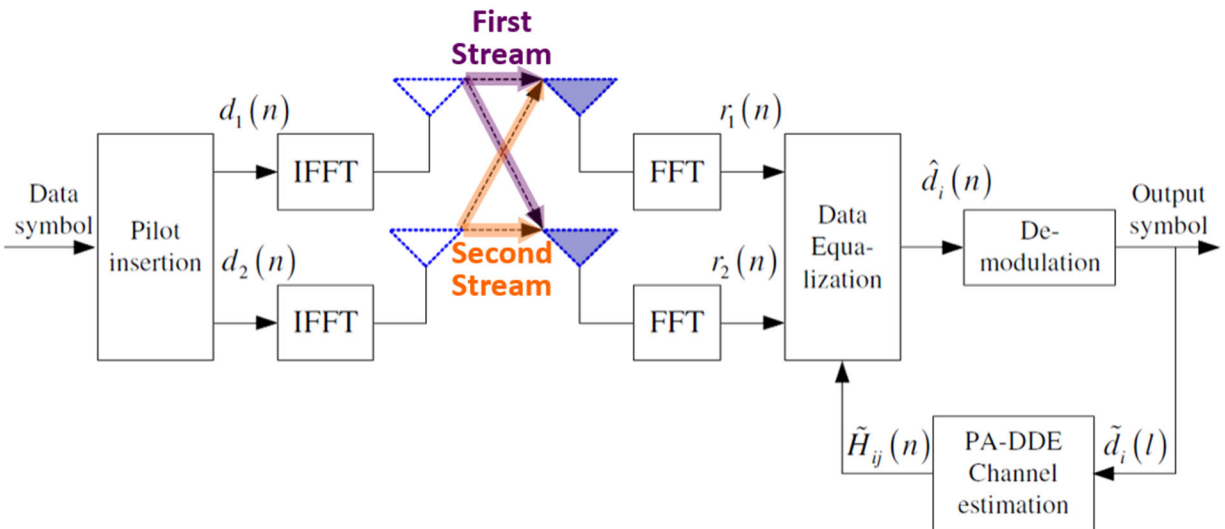


- c. **Element 6[a][i]: wherein the signals are based at least in part on first and second data streams transmitted over a communications channel,**

Tang teaches or suggests Element 6[a][i]. Ex-1002 ¶¶261-262. 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.



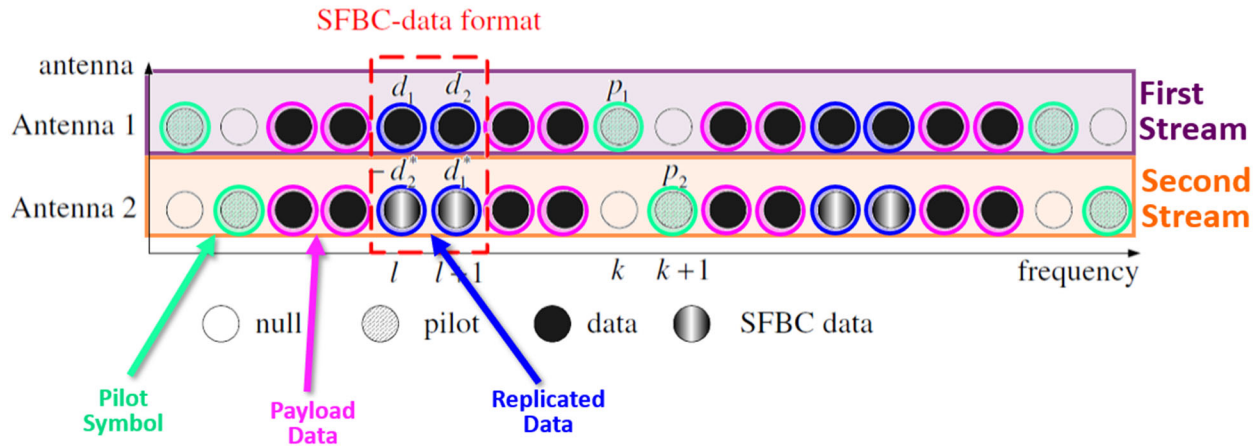
As illustrated in annotated Figure 1 below, each of Tang's receive antennas receives both a copy of the first data stream transmitted by transmit antenna 1 and a copy of the second data stream transmitted by transmit antenna 2. Ex-1002 ¶262.



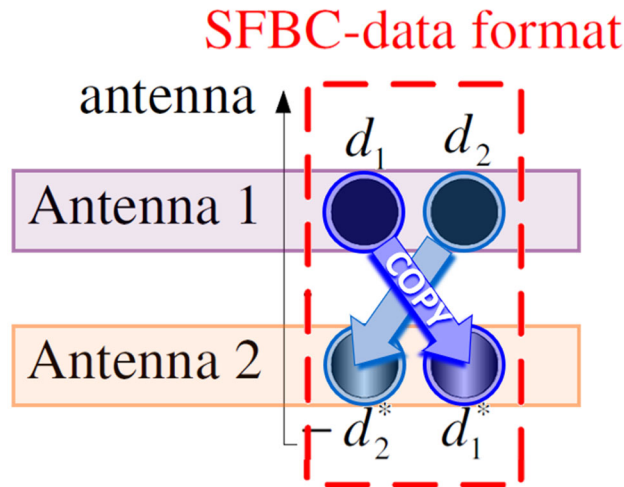
- d. **Element 6[a][ii]: wherein the second data stream includes at least one data symbol replicated from the first data stream;**

Tang teaches or suggests Element 6[a][ii]. Ex-1002 ¶¶263-266.

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.



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. Ex-1002 ¶265. 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. Ex-1002 ¶265.



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;**

Tang teaches or suggests Element 6[b]. Ex-1002 ¶¶267-271.

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 “equalization” and “symbol-level hard decision” decoding on received signals $r_j(l)$, as explained for Element 1[d]. Ex-1008, pp.2, 4; Ex-1002 ¶268.

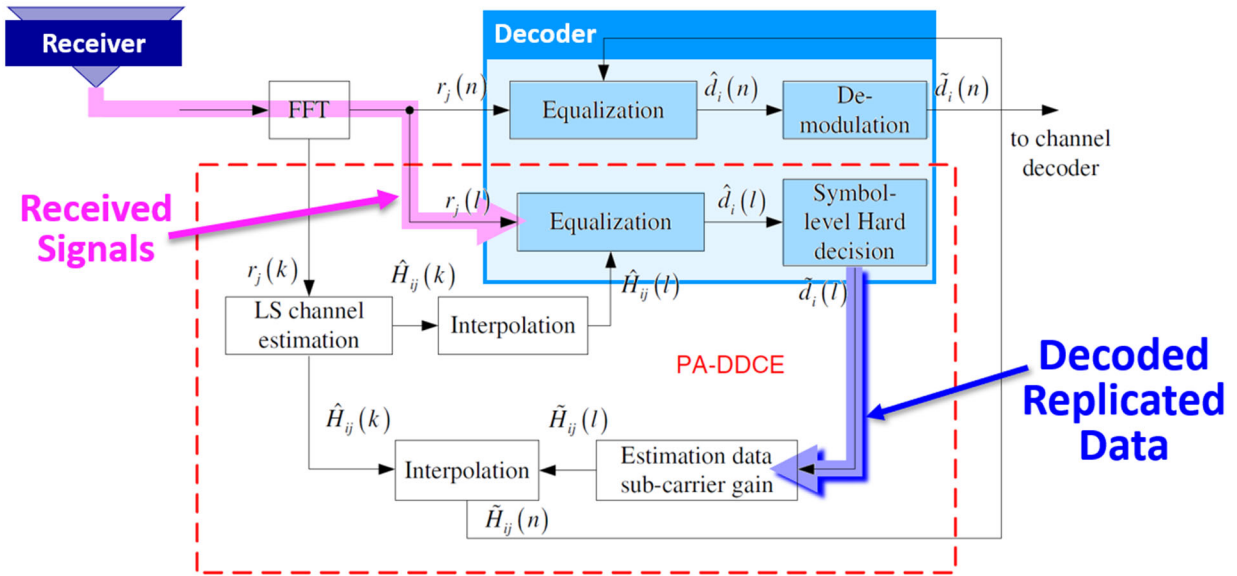
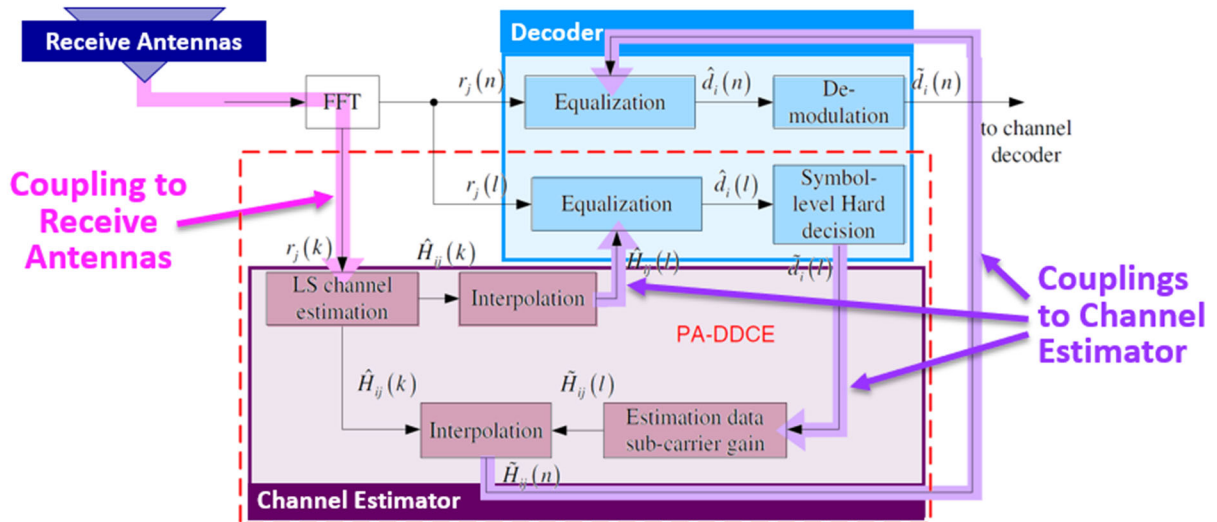
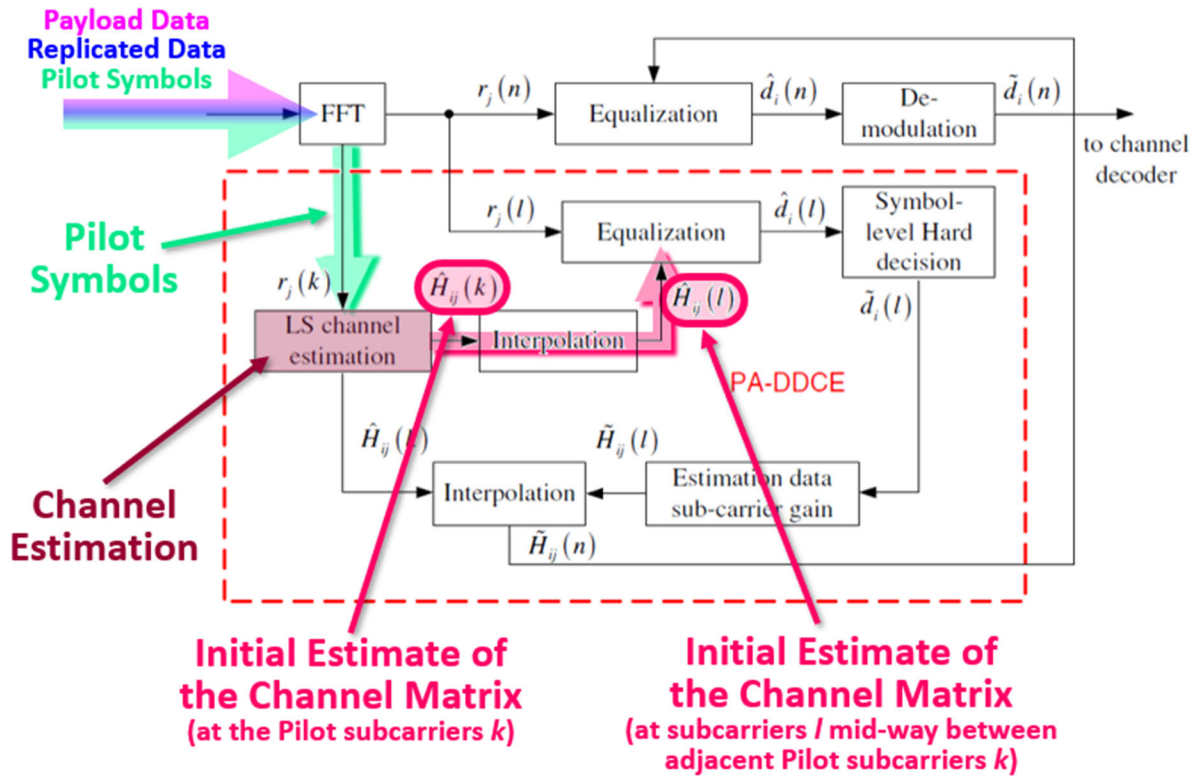


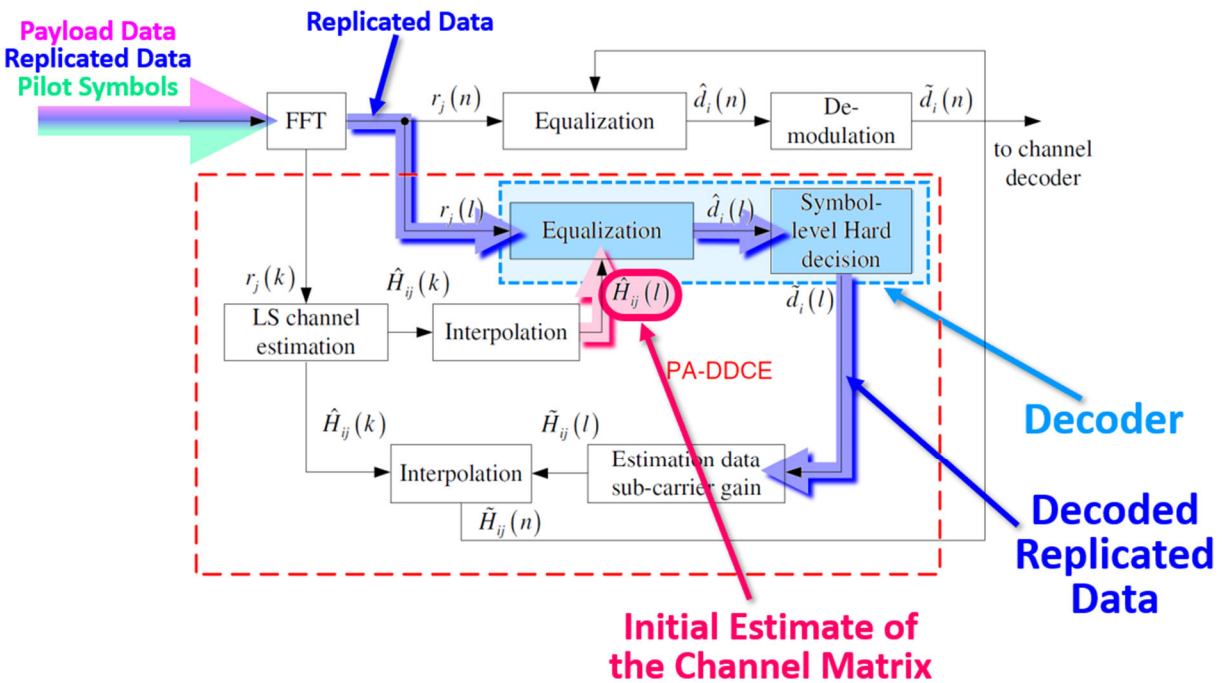
Figure 3 shows the decoder is coupled to the PA-DDCE channel estimator (corresponding to “LS channel estimation,” “Interpolation,” and “Estimation data sub-carrier gain” blocks), and to Tang’s receive antennas through the “FFT” block, from which it receives signals $r_j(l)$. Ex-1002 ¶269.



As explained for Element 1[d], 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.



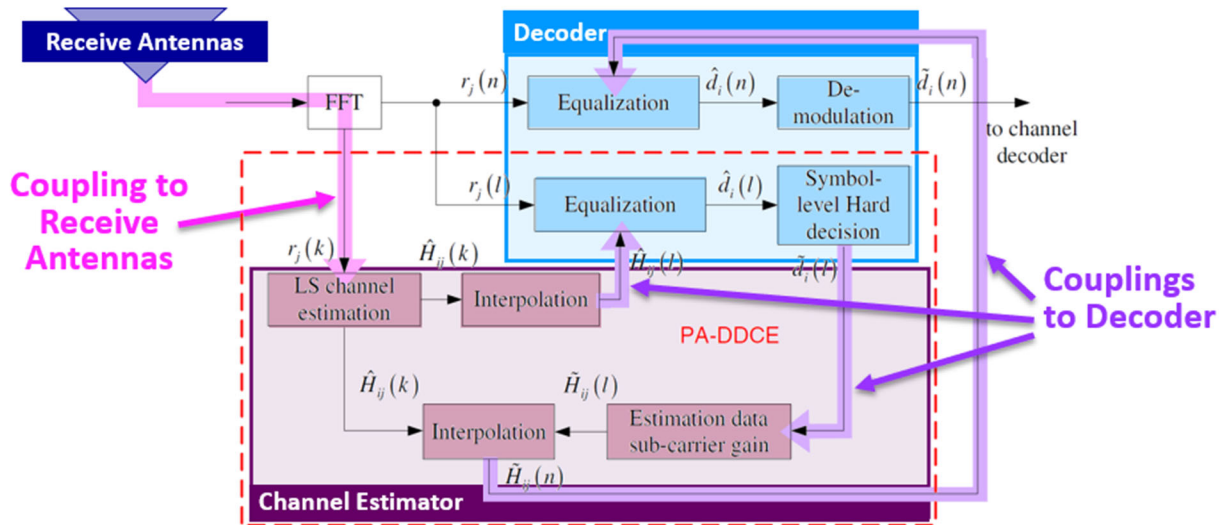
Next, the estimated channel frequency response $\hat{H}_{ij}(l)$ (interpolated to the replicated data subcarriers l) is used to decode the received replicated data symbols $r_j(l)$, through “equalization” and “symbol-level Hard decision” decoding, as illustrated in annotated Figure 3 below, resulting 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,**

Tang teaches or suggests Element 6[c]. Ex-1002 ¶¶272-273.

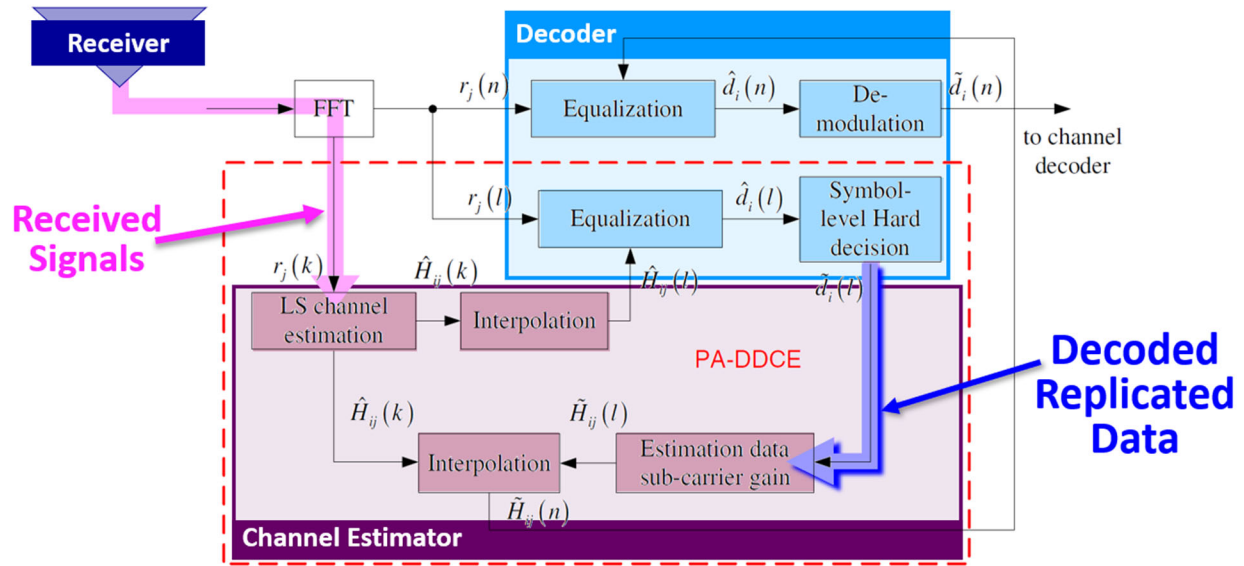
As illustrated below, Tang’s channel estimator (including “LS channel estimation,” “Interpolation,” and “Estimation data sub-carrier gain” blocks) is coupled both to Tang’s receive antennas (“receiver”) and to “equalization” and “symbol-level Hard decision” blocks (forming part of the claimed “decoder,” as explained for Element 6[b]). Ex-1002 ¶273.



- a. **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

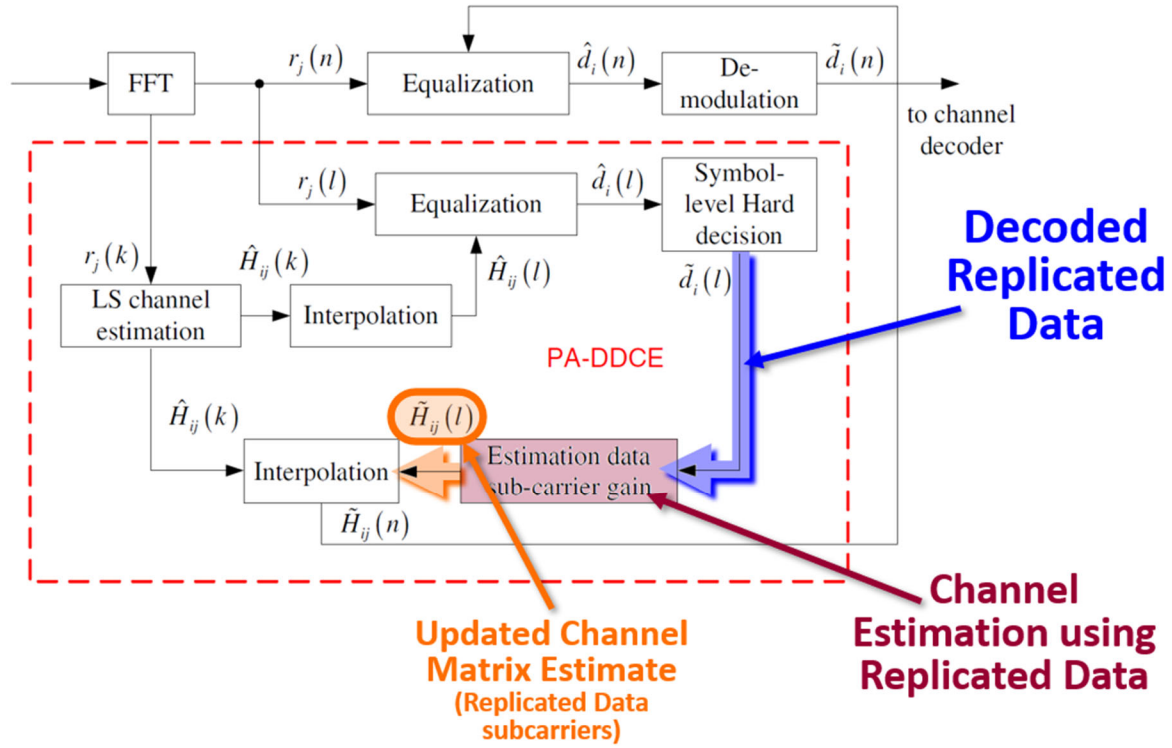
Tang teaches or suggests Elements 6[c][i] and 6[c][ii]. Ex-1002 ¶¶274-278.

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"):



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.

In addition, 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. Ex-1002 ¶276. As explained for Element 1[e], Tang uses 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.



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

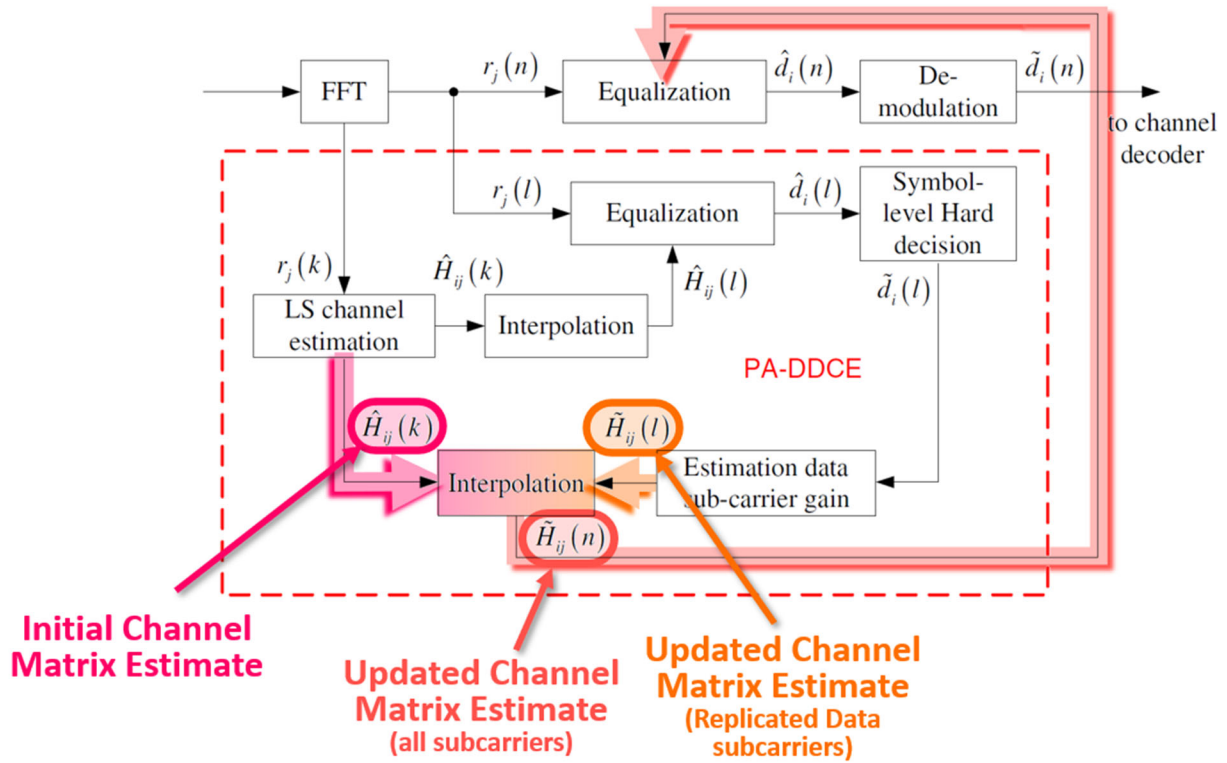
where

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

and

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



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 $\tilde{d}_2(l)$).

- b. 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.**

Tang teaches or suggests Element 6[d]. Ex-1002 ¶¶279-280. 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. Ex-1002 ¶279.

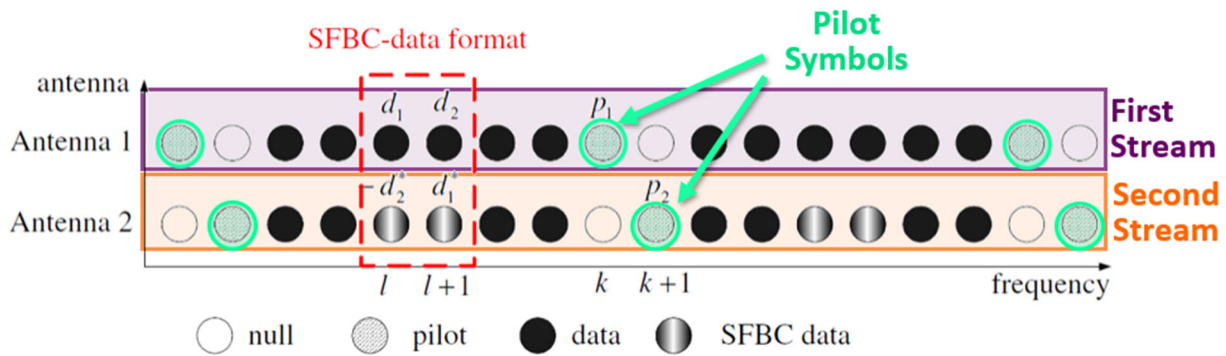
- 7. Dependent Claim 7: The communication device of claim 6 wherein the decoder is configured to decode the at least one data symbol using a joint detection technique.**

Tang teaches or suggests Claim 7. Ex-1002 ¶281. 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).

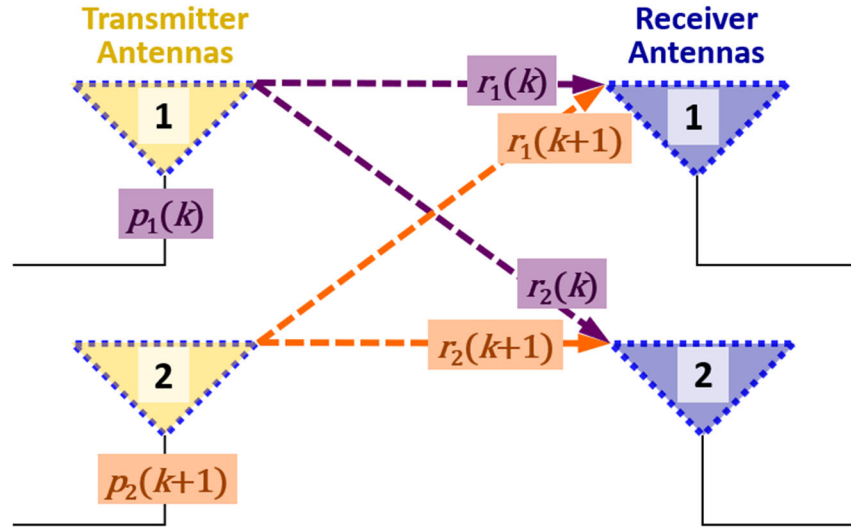
8. Dependent Claim 8

- 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**

Tang teaches or suggests Element 8[a]. Ex-1002 ¶¶282-283. As explained for Element 1[a], pilot symbols p_1 and p_2 are transmitted using the first transmit antenna (“first” data stream) and second transmit antenna (“second” data stream), respectively, as illustrated in annotated Figure 2 below. Ex-1008, p.2.



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:



Ex-1002 ¶283.

- 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.**

Tang teaches or suggests Element 8[b]. Ex-1002 ¶284. 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. Tang provides the following equations for the components of the estimated channel matrix, which depend on the received pilot symbols:

The diagram shows equation 2 from Ex-1008, p.2, with annotations. The equation is:

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

Annotations include:

- Green arrows pointing to $r_1(k)$ and $r_2(k)$ from a box labeled "Pilot Symbols Received at Subcarrier k ".
- A green box labeled "Pilot Symbol Transmitted at Subcarrier k " with an arrow pointing to $p_1(k)$.
- Cyan arrows pointing to $r_1(k+1)$ and $r_2(k+1)$ from a box labeled "Pilot Symbols Received at Subcarrier $k+1$ ".
- A cyan box labeled "Pilot Symbol Transmitted at Subcarrier $k+1$ " with an arrow pointing to $p_2(k+1)$.

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

XIII. DENIAL UNDER *FINTIV* IS NOT APPROPRIATE

Should Patent Owner argue against institution under *Fintiv*, Petitioner may serve a prior art stipulation and/or respectfully request leave for a Preliminary Reply to respond.

XIV. CONCLUSION

Petitioner requests institution of IPR for Claims 1-8 of the '331 Patent based on each of the grounds in this Petition.

Respectfully Submitted,

/s/ William M. Fink

CERTIFICATE OF WORD COUNT

Pursuant to 37 C.F.R. §42.24(d), Petitioner certifies that this petition includes 13,974 words, as measured by Microsoft Word, exclusive of the table of contents, mandatory notices under §42.8, certificates of service, word count, and exhibits.

CERTIFICATE OF SERVICE (37 C.F.R. § 42.6(e)(1))

The undersigned hereby certifies that the above document was served on June 7, 2024, by filing this document through the Patent Trial and Appeal Board P-TACTS System, as well as delivering a copy via express mail upon the following attorneys of record for the Patent Owner and Petitioner:

IP Spring
161 N. Clark St.
Suite 1700
Chicago, IL 60601

A courtesy copy was sent to the below counsel via electronic mail:

Nathaniel Browand
Milbank LLP
55 Hudson Yards
New York, NY 10001
Email: nbrowand@milbank.com

Elizabeth L. DeRieux
Capshaw Derieux, LLP
114 East Commerce Avenue
Gladewater, Texas 75647
Email: ederieux@capshawlaw.com

Dated: June 7, 2024

Respectfully submitted,

/s/ William M. Fink

William M. Fink (Reg. No. 72,332)
O'Melveny & Myers LLP
1625 Eye Street, NW
Washington, DC 20006
Telephone: (202) 383-5300
Fax: (202) 383-5414
Email: tfink@omm.com
Attorney for Petitioner