

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

LG ELECTRONICS, INC.,
Petitioner,

v.

CONSTELLATION DESIGNS, LLC,
Patent Owner.

Case No. IPR2023-00319
U.S. Patent No. 10,693,700

**DECLARATION OF GIUSEPPE CAIRE REGARDING PATENT
OWNER'S PRELIMINARY RESPONSE FOR *INTER PARTES* REVIEW OF
U.S. PATENT NO. 10,693,700**

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I, Dr. Giuseppe Caire, hereby declare as follows:

I. Introduction

1. My name is Giuseppe Caire. I have been retained in the above-referenced *inter partes* review proceeding by Constellation Designs, LLC, to evaluate United States Patent No. 10693,700 (the “700 patent”) against certain references that are presented by the Petitioner. As detailed in this report, it is my opinion that the Petition does not establish that of the challenged claims are anticipated or rendered obvious by the references presented by the Petitioner. If requested by the Patent Trial and Appeal Board, I am prepared to testify at trial about my opinions expressed herein.

II. Qualifications

2. I have over thirty years of experience in the field of electrical engineering. For the past nine years I have held a Full Professorship and faculty position as the Chair of Communications and Information Theory at Technische Universität Berlin. In my work and research, I have researched and written about Information Theory, Communication Theory and Coding Theory, Wireless Communication Systems, Signal Processing and Statistics.

3. Prior to my appointment at the Technische Universität, Berlin I was a tenured Full Professor at the University of Southern California, Los Angeles from

2005-2016. Although I am currently at the Technische Universität Berlin, I have retained the title of Adjunct Research Professor at the University of Southern California, Los Angeles since 2016. Prior to my tenure at the University of Southern California, Los Angeles, I spent seven years as a Professor at Eurecom Institute, and held various Assistant Professorships from 1995-1998.

4. I studied Electrical Engineering and received my Ph.D. in 1994 from the Politecnico di Torino, my Master's Degree in 1992 from Princeton University, and my Bachelor of Science Degree in 1990 from the Politecnico di Torino. In addition to my studies at undergraduate and graduate levels and academic qualifications, I have held industrial research positions such as my current role as the Director of the Huawei-TU Berlin Joint Innovation Center, which has a focus on fundamental research in wireless technology.

5. I have authored or co-authored over four hundred publications in the areas of computer networks, and telecommunications. My publication and patents are listed on my curriculum vitae, which is attached hereto as EX2012.

6. In 2021, I was awarded the Leibniz Price, which is awarded to "exceptional scientists and academics for their outstanding achievements in the field of research" and known as the most important research award in Germany. In 2022, I was elected a Member of the Berlin Brandenburg Akademie der Wissenschaften

(BBAW). Further, I served as President of the Institute of Electrical and Electronics Engineers (IEEE) Information Theory Society in 2011.

7. As a result of my background in information and communication theory, I have extensive knowledge regarding the state of the technical art in this area at the time of filing of the '700 patent.

8. One of my papers was cited and relied upon by Petitioner. Specifically, I am co-author of EX1018 an article titled "Bit-Interleaved Coded Modulation" which was published in IEEE Transactions on Information Theory, Vol. 44, No. 3, May 1998 at pp. 927-946. This paper has been cited in other publications over thirty two hundred (3200) times (Google Scholar).

III. Materials Considered

9. In preparing this declaration, I have reviewed the specification and claims of U.S. Patent No. 10,693,700 ("700 Patent" (EX1001)) and the file history of the '700 patent (EX1002). I understand the '700 patent was issued on June 23, 2020 from U.S. Patent Application No. 16/726,037, which forms part of a chain of continuations including application Ser. No. 12/156,989 filed Jun. 5, 2008 and issued on Jul. 12, 2011 as U.S. Pat. No. 7,978,777, which claimed priority to U.S. Provisional Application 60/933,319 filed Jun. 5, 2007. (EX1010).

10. I have also reviewed the Petition and all publications and exhibits cited in the Petition.

11. I have also reviewed relevant parts of the publications and exhibits cited in this declaration, including the following publications:

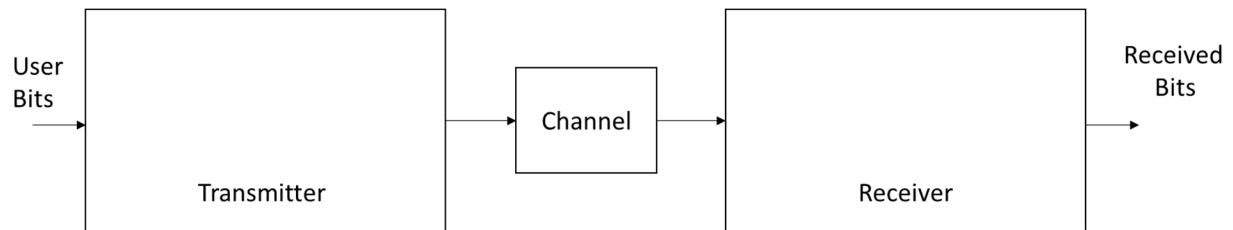
- U. Madhow, *Fundamentals of Digital Communiaton*, Cambridge University Press 2008 (“Madhow” (EX2003)); and
- R.G. Gallager, *Principles of Digital Communication*, Cambridge University Press 2008 (“Gallager” (EX2004)).

IV. Using “Constellations” In Digital Communications

12. The challenged patent concerns an improved method and system for using “constellations” in a digital communication system. A digital communication system is used to transmit digital bits (sequences of 0s and 1s) from one device (a transmitter) to another (a receiver). As explained below in more detail, a “constellation” point is a carrier signal value (such as amplitude and/or phase) that can be used to represent a longer sequence of bits. Transmitting information using an appropriate constellation point signal value can make a data communication system faster and more efficient.

A. Overview of a Digital Communication System

13. A digital communication system typically includes a transmitter that sends information to a receiver over a wireless or wired channel. (EX2003 at 2-4; EX2004 at 1-5, 95, 181-183, 208-209).

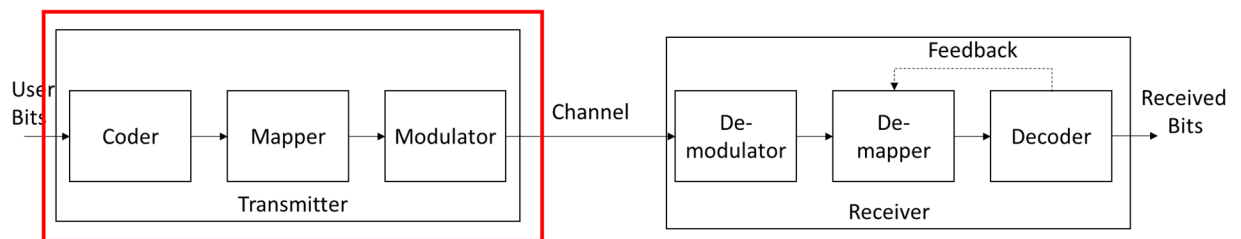


14. As illustrated in the above overview, information in the form of user bits (sequences of 0s and 1s) is input to the transmitter, which first converts those bits into an electromagnetic signal and then transmits that electromagnetic signal over the channel to the receiver. (EX2003 at 2-4; EX2004 at 1-5, 95, 181-183, 208-209). As the electromagnetic signal passes through the channel, bits and data can be lost or corrupted; in this manner, the channel introduces “noise” (signal loss) to the transmission. (EX2003 at 2-4; EX2004 at 1-5, 95, 181-183, 208-209). The receiver receives the electromagnetic signal (along with any noise introduced by its passage through the channel) and converts the received signal back into bits. (EX2003 at 2-4; EX2004 at 1-5, 95, 181-183, 208-209).

15. Each digital communication system has a measurable “capacity,” which is the maximum amount of information that the system can reliably send over the channel. (EX2003 at 252; EX2004 at 253-254, 311-312).

1. The Transmitter

16. In a digital communication system, the transmitter typically includes three main components: a coder, a mapper, and a modulator. (EX2003 at 2-4; EX2004 at 1-5, 95, 181-183, 208-209).



17. The **coder** is used to transform the input user bits into a longer sequence of output bits according to error-correcting codes to enable later error correction by the receiver. (EX2003 at 2-3; EX2004 at 11, 298). For example, the coder may add additional redundant bits to the input user bits that would later enable the receiver’s decoder to use error-correcting codes (such as turbo codes or Low Density Parity Check (LDPC) codes) to help detect or recover user bits lost to noise during transmission. (EX2003 at 2-3; EX2004 at 11, 298).

18. The amount of expansion in the number of bits from the input user bits to the longer sequence of output bits is referred to as the code rate. The code rate is a ratio of the relative length of the input user bits to the length of the output bits. For example, a code rate of $1/2$ indicates that for every bit in the sequence of input user bits, there are 2 bits in the sequence of output bits. Similarly, a code rate of $3/5$ indicates that for every 3 bits in the sequence of input user bits, there are 5 bits in the sequence of output bits.

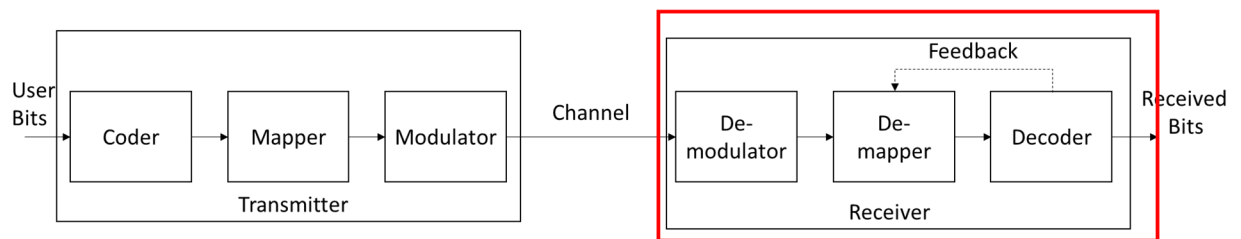
19. The resulting new bit sequence is input to the **mapper**, which maps this new sequence to constellation points, which are one or more carrier signal values (such as amplitude and/or phase) that can be used to represent a longer sequence of bits. (EX2003 at 7; EX2004 at 181-209). Such mapping and constellations are a focal point of the challenged claims and are discussed in more detail in the following “Constellation Mapping and Demapping” section.

20. Next, the mapper provides these constellation values to the **modulator**, which creates a signal to be modulated to reflect the constellation values provide by the mapper and then be sent through the channel. (EX2003 at 2-3; EX2004 at 181-209). There are numerous different ways for a modulator to apply such information to a carrier signal. (EX2003 at 2-3; EX2004 at 181-209). For example, in a Pulse Amplitude Modulation (PAM), the modulator can modify (modulate) the amplitude

of the carrier signal so that the signal's different amplitudes will represent different bit sequences. (EX2003 at 45; EX2004 at 184-196).

2. The Receiver

21. In a digital communication system, the receiver typically mirrors the transmitter and includes: a de-modulator, a demapper, and a decoder. (EX2003 at 2-4; EX2004 at 1-5, 11, 95, 181-183, 208-209).



22. The extracted signal values are then input to the **demapper**, which is used to help identify which bit sequence corresponds to the extracted constellation signal values. (EX2003 at 3-4; EX2004 at 181-209). Such demapping is discussed in more detail in the following “Constellation Mapping and Demapping” section.

23. Next, the **decoder** uses information from the demapper and the structure of the error-correcting code to try to identify the appropriate bit sequence and recover any of the user bits lost or corrupted due to noise during transmission. (EX2003 at 3-4, EX2004 at 11).

B. Constellation Mapping and Demapping

1. Constellation Point Locations and Labels

24. As discussed above, the transmitter's coder provides sequences of bits (comprising the original user bits plus error correcting bits) to the mapper. The mapper then maps each sequence to constellation points.

25. A constellation point has at least two characteristics: (1) it is a value associated with a variable characteristic of the signal transmitted over the channel; and (2) it represents a unique bit sequence. As explained below, the former is a constellation point's "location," and the latter is its "label."

26. Signal characteristics that may be used as constellation point locations include amplitude, phase, and frequency. (EX2003 at 2-3, 45; EX2004 at 181-209). The particular signal characteristic (or characteristics) used as constellation point locations can depend on the type of modulation performed by the modulator. (EX2003 at 2-3, 45; EX2004 at 181-209). For example, recall that if a modulator uses pulse amplitude modulation (PAM) to apply information to the carrier signal, the resulting signal's different amplitudes are used to represent different bit sequences. (EX2003 at 45; EX2004 at 184-196). In such a system, the signal's different amplitudes may serve as constellation point locations.

27. To illustrate, if the transmitter can send a high frequency signal having pulses of any amplitude between 0 and 1.0 volts, then any amplitude between 0 and 1.0 volts can be chosen and used as a constellation point. For example, if four constellation points are needed, each of 0, .33, .66, and 1.0 volts could be used as an individual constellation point. Where a particular constellation point falls on the spectrum of available values is called its “location.”

28. To continue this simplified illustration, if each sequence of bits to be communicated from the transmitter to the receiver comprises a series of shorter 2-bit sequences (00, 01, 10, and 11), then each of those 2-bit sequences can be assigned to a corresponding constellation point. For example, using the constellation points identified above, the 01 sequence could be assigned any one of the 0, .33, .66, and 1.0 volt constellation points. The sequence to which a constellation point is assigned is its “label.”

29. To continue this simplified illustration, if each sequence of bits to be communicated from the transmitter to the receiver comprises a series of shorter 2-bit sequences (00, 01, 10, and 11), then each of those 2-bit sequences can be assigned to a corresponding constellation point. For example, using the constellation points identified above, the 01 sequence could be assigned any one

of the 0, .33, .66, and 1.0 volt constellation points. The sequence to which a constellation point is assigned is its “label.”

30. To complete this simplified example, the following depicts the location and labels for four constellation points. The first constellation point is located at 0.0 volts and is labeled to “00,” the second is located at .33 volts and is labeled to the “01,” and so on.

Constellation Label	Constellation Location
“00”	0
“01”	.33
“10”	.66
“11”	1.0

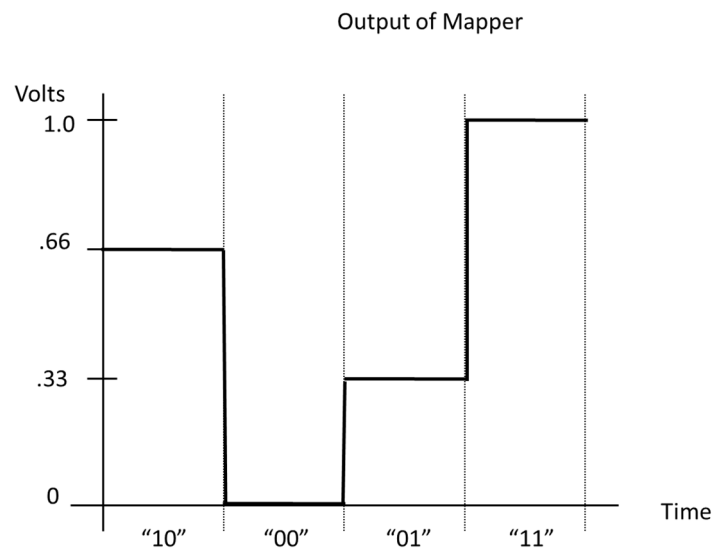
2. The Mapper

31. The transmitter’s mapper uses these constellation labels and locations to map a bit sequence to a corresponding sequence of constellation points. (EX2003 at 7; EX2004 at 181-209). For example, to send sequence “10000111”, the mapper would take each 2-bit sequence, and map it to its corresponding constellation point. Applying the locations and labels from the below table using the PAM example, the sequence “10000111” would be broken into its composite bit sequences 10, 00, 01, and 11, which would be mapped to the voltages .66, 0.0, .33, and 1.0 respectively.

Constellation Label	Constellation Location
---------------------	------------------------

"00"	0
"01"	.33
"10"	.66
"11"	1.0

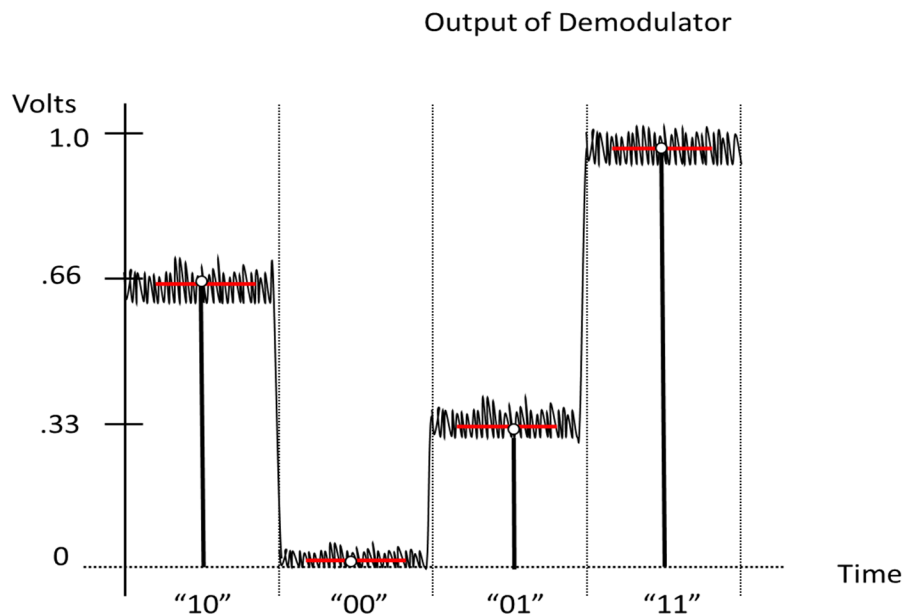
32. The resulting output of the example mapper is the sequence 0.66, 0.0, 0.33, and 1.0 shown in the following figure, in which the y-axis represents voltage and the x-axis represents time. For reference, the transmitted bit sequence is shown for each time slot below the figure.



3. The Demapper

33. On the receiver side, the demodulator receives and demodulates the received signal, which is a noisy version of the transmitted signal, in an attempt to extract the transmitted constellation point signal values. (EX2003 at 3-4; EX2004 at 181-209). But because noise results from the transmission, the demodulated

signal may not be identical to the constellation points output from the mapper (as shown above) but might include errors. (EX2003 at 3-4; EX2004 at 181-209). An example output of the demodulator is shown below, in which a time-dependent continuous waveform is shown in black including noise, the average of the time-dependent continuous waveform is shown in red, the output of the demodulator is shown as discrete time values in black, and the figure is again annotated with the corresponding bit sequence:



34. This demodulated signal is then sent to the demapper so that the demapper can convert the demodulated signal values back to bits based on the constellation points. (EX2003 at 3-4; EX2004 at 181-209). But because of the noise introduced during transmission, the signal characteristic (e.g., amplitude, phase,

frequency) values of received pulses may not exactly match the assigned constellation point locations. (EX2003 at 3-4; EX2004 at 181-209). Accordingly, in some implementations, the demapper uses a predetermined set of signal characteristic (e.g., amplitude, phase, frequency) ranges to attempt to determine the corresponding bit sequence¹. (EX2003 at 127).

35. Continuing the ongoing example, the demapper could use the following amplitude ranges to map the received signal to a corresponding bit sequence:

Output of Demodulator (y)	Bit Sequence
$y \leq .25$	"00"
$.25 < y \leq .5$	"01"
$.5 < y \leq .75$	"10"
$.75 \leq y$	"11"

Applying this demapping scheme:

- if the output of the demodulator is less than or equal to .25 volts, then the bit sequence is "00";

¹ For the purpose of illustrating the basic operation of a demapper, the described example illustrates a demapper that performs "hard" decisions, that is, outputs actual decisions on which bit sequence corresponds to the input signal. In many implementations, the demapper performs "soft" decisions, that is, outputs probabilities on which bit sequence corresponds to the input signal.

- if the output of the demodulator is greater than .25 but less than or equal to .5, then the bit sequence is “01”;
- if the output of the demodulator is greater than .25 but less than .75, then the bit sequence is “10”; and
- if the output of the demodulator is greater than .75, then the bit sequence is “11”.

36. Using this mapping, the example output from the demodulator (shown in the figure above) would be demapped to “10” for the first pulse, demapped to “00” for the second pulse, demapped to “01” for the third pulse, and demapped to “11” for the fourth pulse. Put together, these component bits result in the sequence “10000111.”²

V. Prior Art Approaches

37. Digital communications systems and constellations as described above were generally known in the art. A primary—and wholly unrealized—goal in designing such systems was to design systems able to perform very close to the ultimate limit for reliable transmission of information, which is established by

² To simplify the illustrative example, it does not include any error correction coding.

Shannon channel coding theorem and is known as the Shannon channel capacity limit.

38. In designing these prior art systems, conventional wisdom dictated that constellation locations must be equally spaced apart so that that each constellation point is as far as possible from its neighboring points. But this and all other prior art approaches fell far short of their “holy grail,” the Shannon limit.

A. Channel Capacity Measures

39. Each digital communication system has a measurable “capacity,” which is the maximum amount of information that the system can reliably send over the channel. (EX2003 at 252; EX2004 at 253-254, 311-312). As detailed in the challenged ’700 Patent, two different ways of measuring capacity are “joint capacity” and “parallel decode capacity.” (EX1001 at 5:6-8; 6:42-7:30).

40. In general, letting X denote the channel input signal (sent by the transmitter) and Y the channel output signal (obtained at the receiver), Shannon channel coding theorem proves that the capacity C is equal to the maximum of the mutual information $I(X;Y)$ where the maximization is over all possible statistical distributions of the input X , subject to physical constraints imposed on the channel (e.g., average transmit power). As a consequence, in order to determine the channel capacity it is essential to define what the channel input X and the channel output Y

are. In particular, when the channel input is any possible (unquantized) signal value, subject to the average power constraint, and the channel output Y is the (unquantized) signal sampled at the receiver, and the channel introduces additive Gaussian noise, we have the well-known Shannon capacity formula measured in bit/second given as $C = B \log(1 + \text{SNR})$ where B is the channel bandwidth (in Hz) and SNR is the Signal to Noise Ratio, i.e., the ratio between the signal power and the noise power at the receiver. When the input X is constrained to be a point of a discrete constellation (i.e., a finite set of values defined by the corresponding amplitude and phase of the transmitted signal), and the output Y is defined as before, as the unquantized signal value at the receiver, the corresponding capacity is generally less than the above Shannon limit and depends on the constellation X .

41. A non-trivial design problem consists of finding constellations X approaching the above limit in a certain range of SNR, while maintaining some simplicity in the actual modulator design. This type of constellation-dependent capacity is referred to in the literature as “coded-modulation” (CM) capacity, or also “joint decoding capacity” in some works, since it assumes that the receiver treats the received signal as a whole, without any form of simplifying (and suboptimal) preprocessing.

42. A simplified and “pragmatic” approach to system design was proposed under the name of “pragmatic coded modulation” in Zehavi, Zehavi, E., 1992. 8-PSK trellis codes for a Rayleigh channel. IEEE Transactions on Communications, 40(5), pp.873-884, and popularized by Caire et al. as Bit-Interleaved Coded Modulation in EX1018 (G. Caire, G. Taricco, and E. Biglieri, “Bit-interleaved coded modulation,” IEEE Transactions on Information Theory, vol. 44, no. 3, pp. 927–946, 1998).

43. This approach considers that, at the transmitter, a sequence of binary coded information bits (output by a binary encoder) is interleaved (i.e., the order of the sequence is scrambled according to a specific permutation pattern). The interleaved sequence is partitioned into small blocks called “labels”, and each label is mapped onto signal constellation points via a mapping referred to as “binary labeling” of the constellation points. At the receiver, a particular processing referred to as “demapper” produces soft values that represent the “likelihood” of each bit in the labels. The sequence of likelihoods is then treated as the output of a virtual channel. As such, the appropriate capacity metric for such a method is different, and was found through an explicit formula in Caire et al. (EX2015). This is known as BICM capacity, or also “parallel decoding capacity” since it is as if the label bits were input to individual bit-wise parallel

channels, and then decoded in parallel at the receiver. Generally speaking, while the joint decoding capacity is a function of only the constellation X , the parallel decoding capacity is a function of both X and the binary labeling, i.e., for the same constellation X the parallel decoding capacity is different for different binary labelings of the points.

44. In general, for a given constellation X , the joint decoding capacity is an upper bound to the parallel decoding capacity for any possible binary labeling. It should also be said that, more recently, some authors have proposed an iterative decoder/demapper scheme for which some soft likelihood values are fed back from the decoder to the demapper, and the demapper is recalculated on the basis of this feedback information. This reprocessing can be performed multiple times in an iterative fashion. It has been shown that this iterative processing of BICM (so-called BICM-ID, that stands for BICM with Iterative Demapping) can significantly reduce the gap between the BICM (parallel decoding) capacity and the CM (joint decoding) capacity. This however comes at a non-trivial increase in the decoder/demapper complexity.

B. The Shannon Channel Capacity Limit

45. Regardless of which measure is used, each communication channel's capacity is constrained by the Shannon channel capacity limit, which represents the

theoretically best capacity a channel could possibly achieve in light of physically unsurmountable limits on error correction methods. (EX2003 at 252-255, 263-264; EX2004 at 1,184-187, 253). Just as nothing can move faster than the speed of light, no channel's capacity can exceed the Shannon capacity limit. (EX2003 at 252-255, 263-264; EX2004 at 1).

46. Shannon calculated at this capacity limit by determining the maximum possible efficiency of error correcting methods. (EX2003 at 252-255, 263-264; EX2004 at 1,184-187, 253). This maximum amount of error correction is then compared to the levels of noise and data corruption to determine the Shannon limit, which is the maximum amount of data that can reliably transmitted over a given communication channel using error correcting methods of the maximum possible efficiency. (EX2003 at 252-255, 263-264; EX2004 at 1,184-187, 253).

C. Prior Art Approaches Failed To Achieve the Shannon Limit

47. Claude Shannon first published the Shannon channel capacity limit in 1948. (EX2004 at 1). But although Shannon's limit formed a critical foundation to information theory, he did not describe any practical method for achieving this capacity limit. (EX2004 at 1). Thus, for the next 60 years, achieving a channel capacity near or equaling this limit became the ultimate goal for communication systems designers. (EX2004 at 1).

1. Constellation Point Locations That Are Equally Spaced

48. The '700 Patent's Background explains that the most prevalent (by far) approach at the time of the invention was to locate constellation points with equal spacing between points to maximize the distance between neighboring constellation points. (EX1001 at 1:46-50).

49. As already discussed and illustrated above, noise is introduced when constellation points are sent from the transmitter to the receiver. (EX2003 at 2-4; EX2004 at 1-5, 95, 181-183, 208-209).

50. The prevailing wisdom was that if constellation points were located close together (for example, if one constellation point at 0.7 volts and another at 0.6), then there was a greater chance that noise would cause the demapper to mistake one transmit signal value for another, resulting in the wrong bit sequence being selected and output. Thus, to minimize the chances of noise resulting in the demapper erroneously selecting the wrong bits, it was well accepted that constellation points should be spaced equally apart, to maximize the distance between any two neighboring locations. (EX1001 at 1:44-52).

51. Accordingly, most viable systems spread constellation locations evenly over the range of values that the locations could take, putting as much distance between any two points as the range of values allowed, and resulting in equal spacing

between constellation points. (EX1001 at 1:44-52; 2:6-17; 7:61-63). At the time of the invention, such “equally spaced” locations were well accepted as the best approach with no drawbacks to be improved upon. (EX1001 at 1:44-52, 2:6-17; 7:61-63).

VI. The Challenged '700 Patented Inventions

A. The Patent's Improved Approach to Implementing Non-Uniform Constellations

1. Optimizing Constellation Locations and Labels

52. The '700 Patent discloses that one way to freely assigning constellation point locations and labels is to optimize those locations and labels. (EX1001 at 2:30-34, 2:51-53, 3:7-10, 3:15-17, 3:22-24).

53. In general, optimization requires choosing an objective function (such as a system's capacity) and then repeatedly (iteratively) changing variables (such as constellation locations and labels) until an optimized solution for the objective function is achieved. (EX2008 at 20).

54. In the optimization approach disclosed in the '700 Patent, the objective function to be optimized can be the system's capacity, such as its parallel decode capacity. (EX1001 at 6:42-63). In addition, the independent variables that may be iteratively changed until an optimized capacity is achieved

to include the constellation locations and labels. (E.g., EX1001 at 3:4-12; 7:10-19).

55. The patent also identifies numerous different ways for defining the “optimized” solution. For example, in one optimization embodiment, achieving the optimized solution requires varying constellation points until a maximized capacity is achieved. (E.g., EX1001 at 3:4-12). In another embodiment, the optimized solution is reached when constellation points provide “a given capacity at a reduced signal-to-noise ratio compared to” an equally spaced constellation. (E.g., EX1001 at 2:51-55). In other examples, the optimized solution is achieved when the constellation results in a “predetermined improvement” over an equally spaced constellation. (E.g., EX1001 at 2:7-11). In another example, an optimized solution is reached when a performance of each iteration of an optimization process have converged; in other words, when additional iterations of the process does not result in a meaningful performance improvement.

2. The '700 Patent Describes Optimizing Single-Dimension and Multi-Dimension Constellations

56. The '700 patent teaches that both single dimension constellations (such as PAM) and multi-dimension constellations (such as QAM) can be optimized. (EX1001 at 10:8-13). One approach disclosed by the '700 patent for optimizing a multidimensional QAM constellation is to directly optimize over each degree of

freedom. (EX1001 at 13:2-11). Another disclosed approach to optimizing a multidimensional QAM constellation is to first optimize a PAM constellation, then apply that PAM constellation to both of the in-phase and quadrature components. The '700 Patent describes this approach as orthogonalizing the PAM constellation into a second dimension to form the QAM constellation. (EX1001 at 3:25-34; 12:42-67). This results in a constellation that has a number of points that is equal to the square of the number of PAM points, for example a PAM-8 is orthogonalized to a QAM-64 (8×8). (EX1001 at 3:25-34; 12:42-67). Further, the QAM-64 includes the same PAM-8 spacing among points in both dimensions, that is, in the in-phase dimension and the quadrature dimension.

57. The '700 illustrates an example of this orthogonalizing approach in Figure 21, showing that a PAM-8 constellation optimized for capacity at a user bit rate per dimension of 1.5 bits per second can be used to construct a QAM-64 constellation. As shown below in annotated Figures 13b and 21, orthogonalizing a capacity optimized PAM-8 includes replicating a full PAM-8 constellation 8 times. (EX1001 at 3:25-34; 12:42-67).

PAM-8 constellations optimized for parallel decoding capacity at different

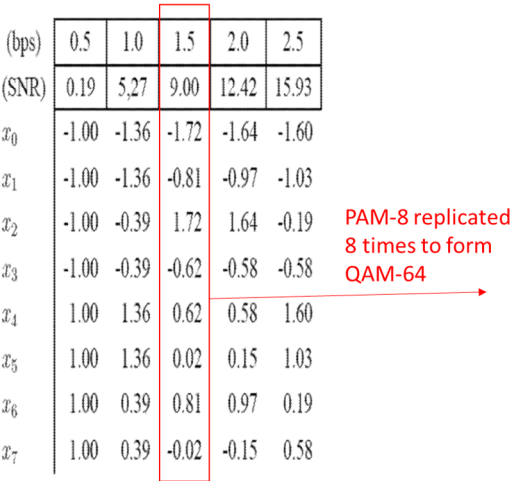


FIG. 13b

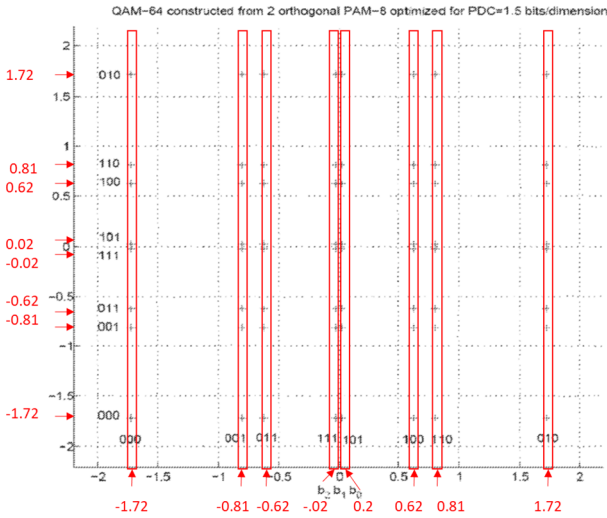


FIG. 21

58. The resulting combination is similarly spaced in both dimensions (i.e., the in-phase and quadrature). That is, the spacing of points in both the x and y-axis of Figure 21 are distributed according to the PAM-8 optimized locations. The distribution of the x-axis is highlighted in the above annotated figure 21. The distribution of the y-axis is highlighted in the below annotated figure 21.

PAM-8 constellations optimized for parallel decoding capacity at different

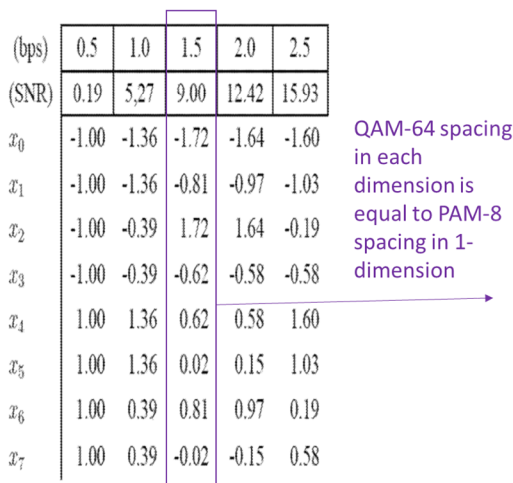


FIG. 13b

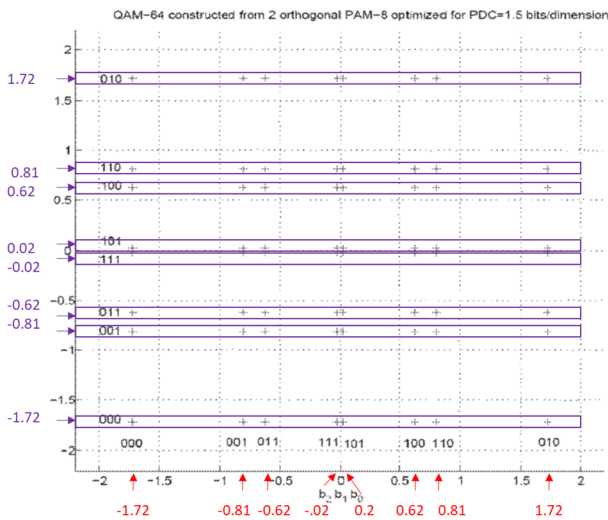


FIG. 21

59. This approach uses the same 8 point PAM locations, which were optimized for capacity, to produce 64 point QAM locations that have been optimized for capacity.

3. Non-Uniform Constellations Optimized For Particular Code Rates

60. The '700 Patent discloses that optimization of constellation points can yield different constellations depending on the signal to noise ratio (SNR) and code rate for which they are optimized. (EX1001 at 5:11-16). For example, the '700 Patent teaches that in many instances, a constellation optimized for one code rate can achieve gains that cannot be achieved at another code rate. (EX1001 at 5:16-21). Put another way, a given non-uniform constellation will not enable the best possible

performance across all code rates. (EX1001 at 5:16-21). As an example, a constellation optimized for a code rate of 1/2 provides gains when with a code rate of 1/2, but may not provide the same gains at other code rates, such as 2/3 code rate. Instead, when using a code rate of 2/3, a different constellation may be used – a constellation optimized for use at 2/3 code rate.

61. As a result, the inventors disclosed a number of example different constellations, each of which is optimized at different operating conditions, including a respective coding rate and SNR. For example, the '700 Patent discloses a number of tables identifying a plurality of different symbol constellations that are capable of providing a greater capacity at a specific code rate and SNR than the other symbol constellations for the same code rate. For example, Figs. 11b, 13b, 15b and 17b all disclose constellations that are optimized for parallel decode capacity for use at a specific SNR and code rate. FIG. 11b is illustrated below. The table provides the constellation locations (x_0, x_1, x_2, x_3), the corresponding SNR, and the user bit rate. As acknowledged by the Petition, the code rate can be easily determined from the user bit rate. (Petition at 6). The code rate can be determined from a well-known equation relating the number of user bits per dimension to the code rate and which is described in the '319 Application. (EX1010 at 2). The equation is given by:

$$\eta = \frac{R(\log_2(M))}{N_{dim}}$$

62. where η is the number of user bits per dimension, R is the code rate, M is the number of constellation points, and N_{dim} is the number of signal dimensions. (EX1010 at 2). Rearranging this equation one can compute the code rate (R) as a function of the user bits per dimension as follows:

$$R = \frac{\eta(N_{dim})}{\log_2(M)}$$

63. As an example, in order to compute the equivalent code rate for a QAM-16 for the user bits per dimension (η) listed in figure 11b, we would take the number of dimension (N_{dim}) to be 2, the number of constellation points (M) to be 16, and the user bits per dimension (η), which is listed in figure 11c, as [0.50, 0.75, 1.00, 1.25, 1.50]. The resulting code rates can easily be computed as [2/8, 3/8, 4/8, 5/8, 6/8]. Note that similar calculations can be performed for each constellation size (e.g., QAM-64 (from PAM-8), QAM-256 (from PAM-16), QAM-1024 (from PAM-32), etc.).

64. The below figure has been annotated with these code rates for a corresponding QAM-16 built by orthogonalizing the PAM-4 optimized constellations. Each column of the table provides a different, unique constellation.

PAM-4 constellations optimized for parallel decoding capacity at different

(CR_{QAM16})	$\frac{2}{8}$	$\frac{3}{8}$	$\frac{4}{8}$	$\frac{5}{8}$	$\frac{6}{8}$
(bps)	0.50	0.75	1.00	1.25	1.50
(SNR)	0.19	3.11	5.26	7.22	9.25
x_0	-1.00	-1.30	-1.36	-1.37	-1.36
x_1	-1.00	-0.56	-0.39	-0.33	-0.39
x_2	1.00	1.30	1.36	0.33	1.36
x_3	1.00	0.56	0.39	1.37	0.39

FIG. 11b

65. Similarly, the '700 Patent discloses a number of locus plots showing the optimized constellations over a broad range of code rates. These locus plots include figures 10c, 12c, 14c, and 16c. In these locus plots, the y-axis represents the constellation point location and the x-axis represents the target data rate in bits per second, from which the code rate can be determined. Thus each vertical “slice” of a locus plot represents a different optimized constellation. An annotated Figure 10c and 11b are shown below illustrating that each vertical slice of the locus plot (figure 10c) is a different optimized constellation.

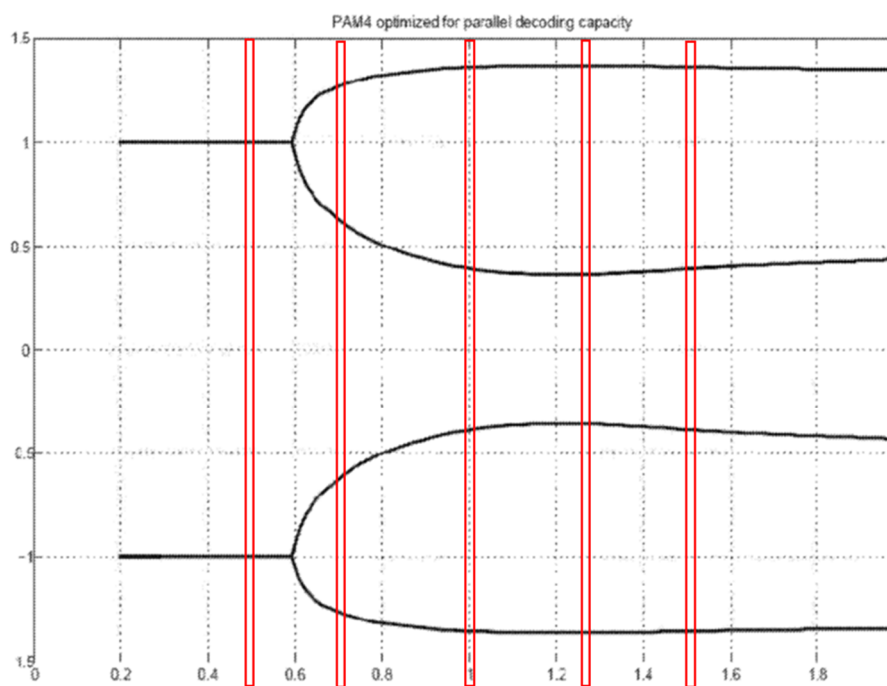


FIG. 10c

(bps)	0.50	0.75	1.00	1.25	1.50
(SNR)	0.19	3.11	5.26	7.22	9.25
x_0	-1.00	-1.30	-1.36	-1.37	-1.36
x_1	-1.00	-0.56	-0.39	-0.33	-0.39
x_2	1.00	1.30	1.36	0.33	1.36
x_3	1.00	0.56	0.39	1.37	0.39

FIG. 11b

66. Thus, the '700 patent discloses not only a number of discrete examples of optimized constellations in the tables of figures 11b, 13b, 15b, and 17b, but the '700 patent discloses optimized constellations over a broad range of code rates in the locus plots of figures 10c, 12c, 14c, and 16c.

4. Using Multiple Optimized Constellations For a System Having Multiple Code Rate and SNR Operating Points

67. In light of the inventors' recognition that optimization results in different non-uniform constellations for a given code rate and/or SNR, the '700 Patent discloses communication systems that can "adapt location of points in a constellation in response to changes in channel conditions, changes in code rate, or changes in the target user data rate." (EX1001 at 4:62-5:11). As an example, the '700 Patent describes a communication system that can select an information rate that meets the end user rate goal, and then use a capacity-optimized constellation that provides gains for the selected rate that meets the end user rate goal. (EX1001 at 11:51-12:10). The optimized constellation can be selected from a set of code rate and constellation pairs, where each constellation has been optimized for capacity at its respective code rate. (EX1001 at 10:48-51).

68. To illustrate this concept, an annotated Figure 10c is provided below. The x-axis has been annotated to show the code rates for a QAM-16 built by orthogonalizing the PAM-4 constellations shown in Figure 10c. As an example, a system utilizing multiple optimized constellations for different code rates can initialize at an operating code rate of $4/10$, at which point the communication system can utilize the constellation point locations indicated in the locus plot at the $4/10$ code rate. In the example, if the system then changes to a code rate operating point

of 6/10, the system can utilize the constellation point locations indicated in the locus plot at the 6/10 code rate. Using this technique, the '700 patent teaches that a system can adapt to any desired code rate (e.g., based on changing channel conditions, target user rate) and utilize the disclosed optimized constellation according to its respective code rate.

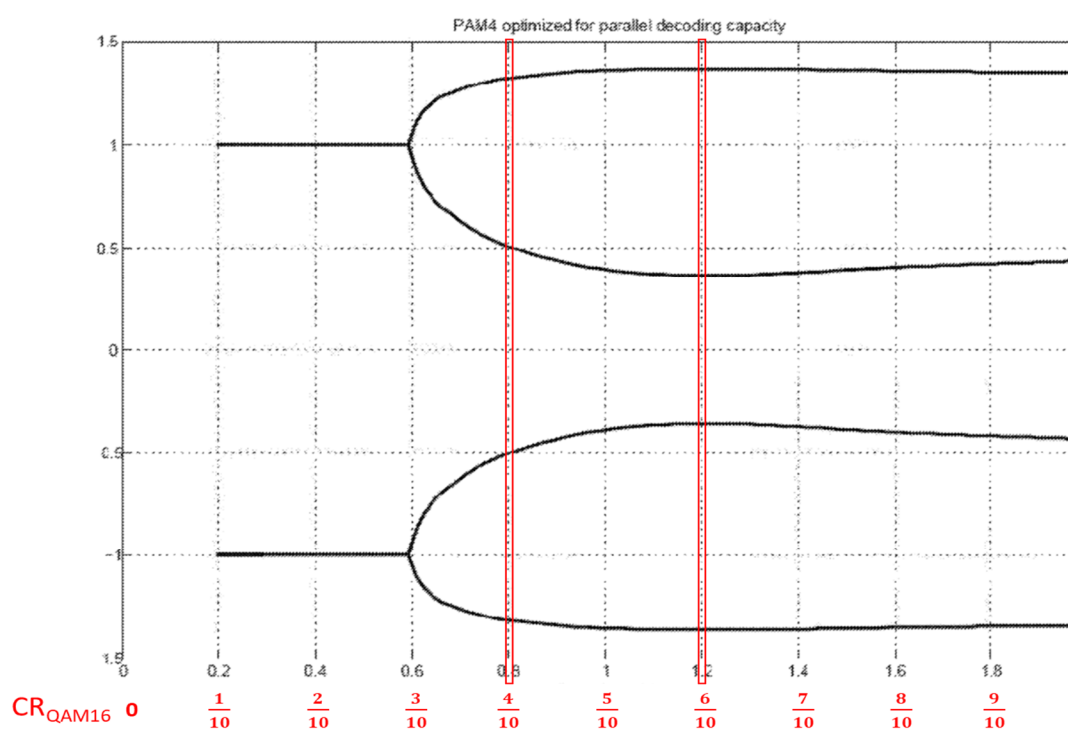


FIG. 10c

B. The Challenged Claims

69. The foregoing innovative approaches are embodied in the challenged claims, each of which requires a plurality of multidimensional constellations having constellation points non-uniformly spaced in each degree of freedom, and

where the receiver is capable of selecting a code rate and constellation pair from a plurality of predetermined code rate and constellation pairs.

70. For example, each of these limitations is present and highlighted in the following exemplary claim 1:

1. A communication system, comprising:

a receiver capable of receiving signals via a communication channel having a channel signal-to-noise ratio (SNR), wherein the receiver comprises:

a demodulator capable of demodulating a received signal into a demodulated signal;

a demapper, coupled to the demodulator, capable of determining likelihoods using the demodulated signal and a multidimensional symbol constellation selected from a plurality of multidimensional symbol constellations; and

a decoder, coupled to the demapper, capable of using the likelihoods determined by the demapper to provide a sequence of received bits based upon a low density parity check (LDPC) code;

wherein the plurality of multidimensional symbol constellations comprises a plurality of different non-uniform multidimensional symbol constellations having the same number of constellation points, where *the*

constellation points are non-uniformly spaced in each degree of freedom available to the multidimensional symbol constellations;

wherein the receiver is capable of selecting an LDPC code rate and multidimensional symbol constellation pair from a plurality of predetermined LDPC code rate and multidimensional symbol constellation pairs, where each of the plurality of different non-uniform multidimensional symbol constellations is only included in one of the plurality of predetermined LDPC code rate and multidimensional symbol constellation pairs.

VII. The Petition

71. I understand LG's Petition asserts the following Grounds:

Ground	References	Basis	Challenged Claims
1A	'777 Patent and ATSC322	§ 103	2-3, 12-13, 22-23
1B	'777 Patent and ATSC327	§ 103	5, 15, 25

72. I understand that each and every ground is premised on LG's assertion that the challenged claims are not entitled to the priority date of US Provisional application No. 60/933,319 ("319 Provisional" or EX1010) nor the priority date of US Patent 7,978,777 ("777 Patent" or EX1015). But as explained below, at least the '777 Patent provides sufficient written description support for the challenged

claims such that the challenged claims are entitled to at least a priority date of the '777 Patent filing date.

VIII. The Challenged Claims Are Entitled to Priority of at Least the '777 Patent Because the '777 Patent Has Sufficient Written Description to Show the Inventors Possessed The Claimed Invention At the Time of the '777 Patent Application's Filing

73. The '777 Patent provides targeted examples of constellations across code rate ranges that directly correspond to the claimed ranges in the '700 Patent. (See EX1015, 10:25-11:13, Figs. 10a-17b).

74. The '777 Patent specification provides targeted examples of constellations across code rate ranges that directly correspond to the claimed ranges in the '700 Patent. Focusing on the challenged limitations, they cover *code rate ranges* for a plurality of **QAM** symbol constellations and those code rate ranges provide operating points under which non-uniform constellations provide a benefit. See, e.g., EX1001, Claim 2 (claiming a plurality of QAM-16 constellations, where each constellation is paired with a code rate that falls within the range of equal to or greater than $3/8$ and less than or equal to $6/8$). The specification clearly emphasizes and discloses these elements and their relationship with each other.

75. For example, the '777 patent highlights QAM constellations and explains that they are “attractive in many applications because they have low-complexity demappers.” EX1015, 12:11-16 (under heading “Geometrically Shaped

QAM Constellations”). The specification further explains that a QAM constellation for a given bit rate can be constructed from a PAM constellation at that bit rate by “orthogonalizing” the PAM constellation. *See id.* at 12:11-37 (constructing a QAM-64 constellation by orthogonalizing a PAM-8 constellation and noting “Due to the orthogonality of the in-phase and quadrature components the capacity characteristics [(e.g., bit rate)] of the resulting QAM-64 constellation are identical to that of the PAM-8 constellation on a per-dimension basis.”). As explained above, orthogonalizing a PAM constellation into a QAM constellation would have been well within the knowledge and abilities of a POSITA.

76. The calculation of the code rate for a multidimensional QAM is straight forward and well within the ability of a person of ordinary skill in the art. Therefore, the ‘777 patent teaches that QAM constellations are desirable and straightforward to construct using PAM constellations.

77. To further understand the scope of the disclosed QAM constellations, a POSITA would look to the specification’s examples of PAM constellations. (EX1015, 10:25-11:13 (under heading “Capacity Optimized Pam Constellations”)). In that section, the ‘777 patent discloses locus plots and corresponding design tables for PAM constellations across a **range** of **bit rates** and SNR values. (*Id.*; *see also id.* at Figs. 10a-17b). Further, this section explains that the disclosed **bit rates** are

easily converted to **code rates** and provides examples of that conversion. (*Id.* at 10:51-62 (converting bit rates to code rates for PAM constellations and providing formulae for those conversions)). As explained above, this bit rate to code rate conversion was routine. Thus, a POSITA would understand that the specification discloses code rate data for four types of PAM constellations: PAM-4,8,16,32. *See id.* at 10:25-11:13. Importantly, these four PAM constellations orthogonalize to the four types of claimed QAM constellations (QAM-16,64,256,1024 correspond to PAM-4xPAM-4, PAM-8xPAM-8, PAM-16xPAM-16, PAM-32xPAM-32). *See id.* at 12:11-37, Claims 2-3, 12-13, 22-23.

78. So, for each type of claimed QAM constellation, a POSITA would simply reference the relevant PAM data to understand the scope of the disclosure of code rates. For example, a POSITA would look to Figures 14a-d and 15a-b, the design tables and locus plots for PAM-16, to understand the scope of the disclosure of code rates for a plurality of QAM-256 constellations. The design tables list PAM-16 constellation designs for code rates of $3/8$, $4/8$, $5/8$, $6/8$, $7/8$. (*See* EX1015 at Fig. 15b). Notably, the highest and lowest code rate values in the design tables correspond exactly to the end points of the claimed code rate range for QAM-256 constellations, $3/8$ and $7/8$. (*See* EX1001 at Claims 3, 13, 23). Turning to the corresponding locus plots, those figures show constellation point locations across a

continuous range of code rates that encompasses the code rate values from the design tables. (See EX1015 at Fig. 14c).

79. This disclosure of a range of code rates is squarely in line with the specification's disclosure of "Adaptive Rate Design" embodiments. That section discloses a system capable of switching to alternate constellation and code rate pairs. (EX1001 at 12:29-40). In other words, "[i]n a number of embodiments, the communication systems can adapt location of points in a constellation in response to channel conditions, changes in code rate and/or to change the target user data rate"—the communication systems are able to operate across a range of code rates to provide a specific constellation optimized for each code rate in that range. (EX1015 at 5:7-11). Accordingly, the '777 Patent provides support for each and every value within the range and specifically highlights the values at the end-points of the claimed ranges.

80. Further, the '777 Patent is replete with disclosures that the code rate is a key aspect of the invention. *See, e.g.*, EX1015 at 5:4-11 ("Processes for selecting capacity optimized constellations to achieve increased coding gains based upon a specific **coding rate** in accordance with embodiments of the invention are described below. In a number of embodiments, the communication systems can adapt location

of points in a constellation in response to channel conditions, changes in **code rate** and/or to change the target user data rate.”) (emphasis added).

81. The challenged limitation of claims 2, 12, and 22 of the '700 Patent is a plurality of QAM-16 constellations and code rate pairs where the code rate “is equal to or greater than $3/8$ and less than or equal to $6/8$.” (Petition at 4). The '777 patent provides support for this range: it describes optimized PAM-4 non-uniform constellations for code rates ranging from $3/8$ to $6/8$, and PAM-4 orthogonalizes to QAM-16. Figure 11b below shows the disclosed PAM-4 constellations and has been annotated to show the code rates for a QAM-16, which is easily determined from the bit rate. This figure has been further annotated to identify the explicit disclosure of the two end points of the range, $3/8$ and $6/8$.

PAM-4 constellations optimized for parallel decoding capacity at different

(CR_{QAM16})	$\frac{2}{8}$	$\frac{3}{8}$	$\frac{4}{8}$	$\frac{5}{8}$	$\frac{6}{8}$
(bps)	0.50	0.75	1.00	1.25	1.50
(SNR)	0.19	3.11	5.26	7.22	9.25
x_0	-1.00	-1.30	-1.36	-1.37	-1.36
x_1	-1.00	-0.56	-0.39	-0.33	-0.39
x_2	1.00	1.30	1.36	0.33	1.36
x_3	1.00	0.56	0.39	1.37	0.39

FIG. 11b

82. In addition to the disclosure of the two end points (and two intervening values) in Figure 11b, Figure 10c below is a locus plot for the PAM-4 constellations. Figure 10c has been annotated to show the code rates for a QAM-16 constellation and to demonstrate the claimed range. Figure 10c thus discloses constellations for every code rate between the two disclosed end points.

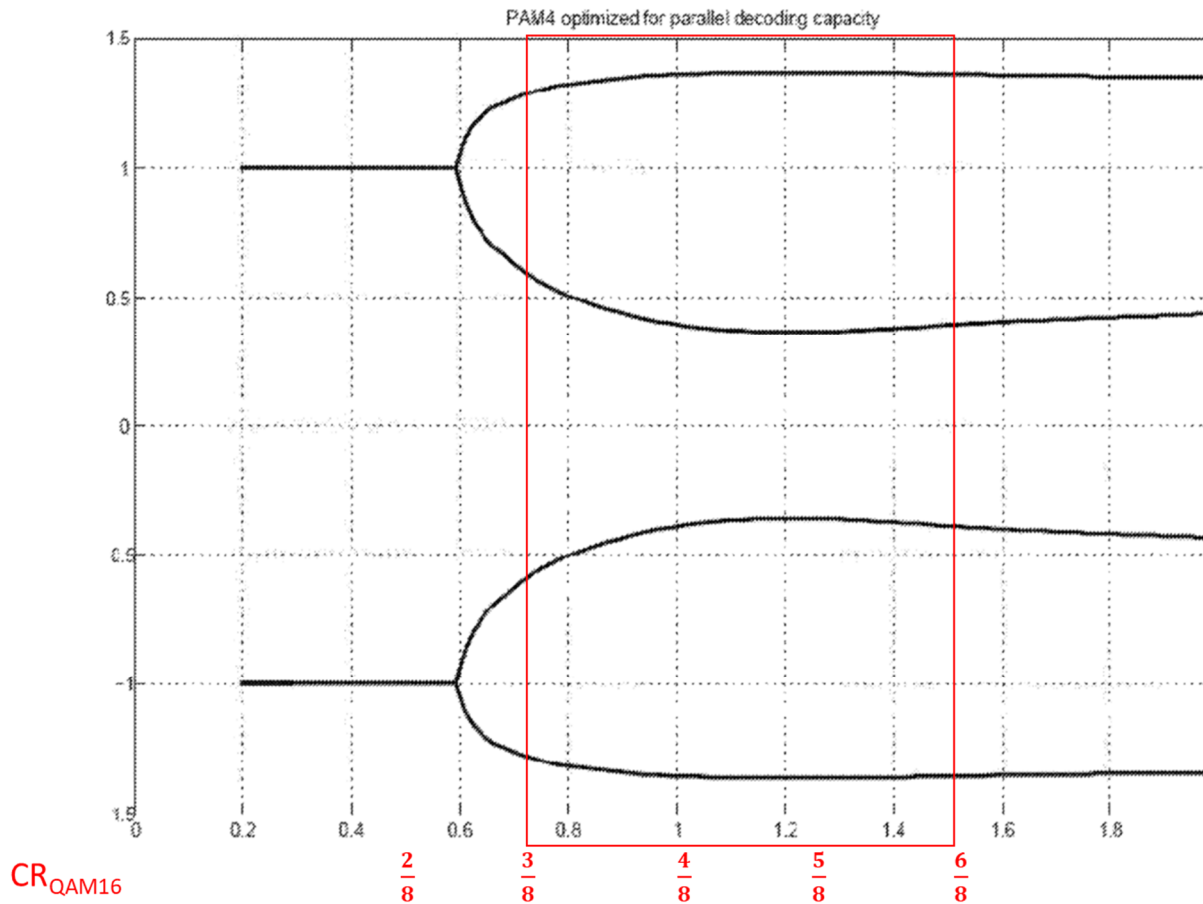


FIG. 10c

83. The first challenged limitation of claims 3, 13, and 23 of the '700 Patent is a plurality of QAM-64 constellations and code rate pairs where the code rate "is equal to or greater than 2/6 and less than or equal to 5/6." (Petition at 5). The '777 patent provides support for this range: it describes optimized PAM-8 non-uniform constellations for code rates ranging from 2/6 to 5/6, and PAM-8 orthogonalizes to QAM-64. Figure 13b below shows the disclosed PAM-8 constellations and has been annotated to show the code rates for a QAM-64, which is easily determined from

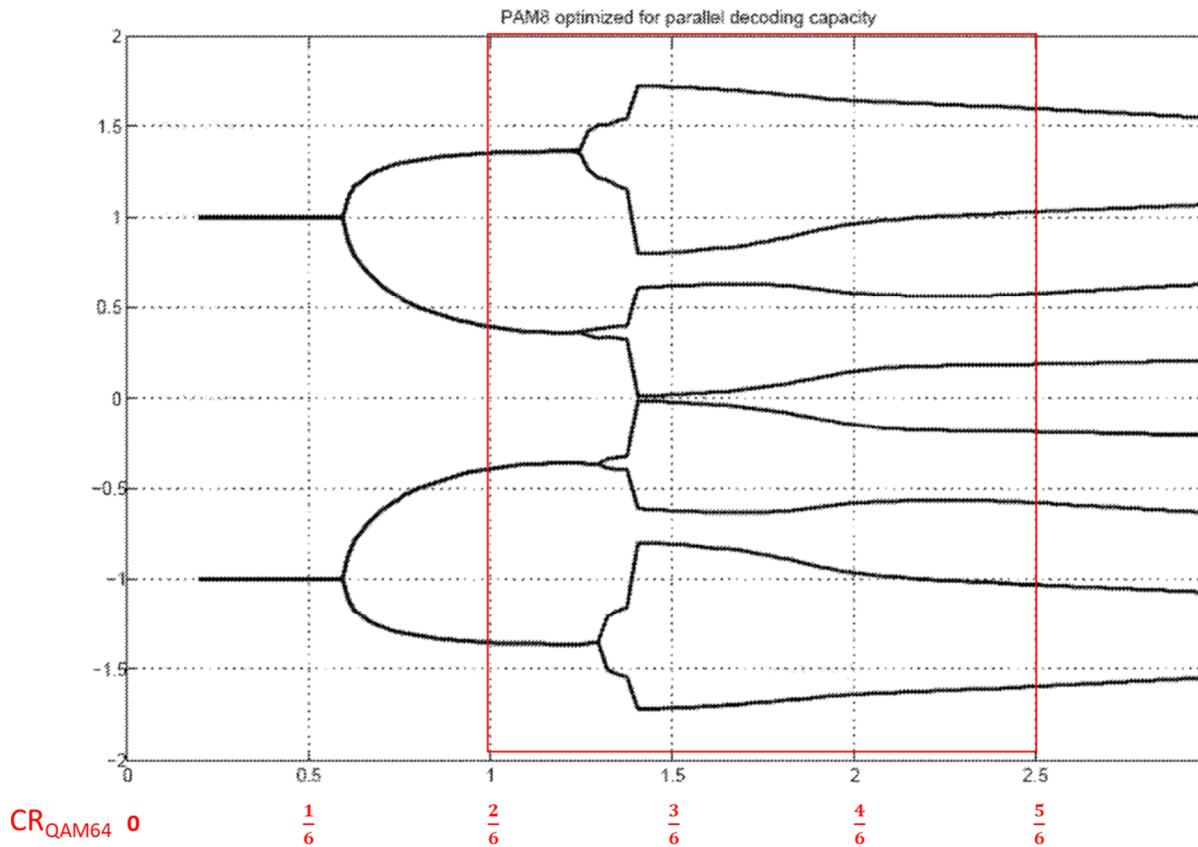
the bit rate. This figure has been further annotated to identify the explicit disclosure of the two end points of the range, 2/6 and 5/6.

PAM-8 constellations optimized for parallel decoding capacity at different

(CR_{QAM64})	$\frac{1}{6}$	$\frac{2}{6}$	$\frac{3}{6}$	$\frac{4}{6}$	$\frac{5}{6}$
(bps)	0.5	1.0	1.5	2.0	2.5
(SNR)	0.19	5.27	9.00	12.42	15.93
x_0	-1.00	-1.36	-1.72	-1.64	-1.60
x_1	-1.00	-1.36	-0.81	-0.97	-1.03
x_2	-1.00	-0.39	1.72	1.64	-0.19
x_3	-1.00	-0.39	-0.62	-0.58	-0.58
x_4	1.00	1.36	0.62	0.58	1.60
x_5	1.00	1.36	0.02	0.15	1.03
x_6	1.00	0.39	0.81	0.97	0.19
x_7	1.00	0.39	-0.02	-0.15	0.58

FIG. 13b

84. In addition to the disclosure of the two end points (and two intervening values) in Figure 13b, Figure 12c below is a locus plot for the PAM-8 constellations. Figure 12c has been annotated to show the code rates for a QAM-64 constellation and to demonstrate the claimed range. Figure 10c thus discloses constellations for every code rate between the two disclosed end points.



85. The second challenged limitation of claims 3, 13, and 23 of the '700 Patent is a plurality of QAM-256 constellations and code rate pairs where the code rate “is equal to or greater than 3/8 and less than or equal to 7/8.” (Petition at 5).

The '777 patent provides support for this range: it describes optimized PAM-16 non-uniform constellations for code rates ranging from 3/8 to 7/8, and PAM-16 orthogonalizes to QAM-256. Figure 15b below shows the disclosed PAM-16 constellations and has been annotated to show the code rates for a QAM-256, which is easily determined from the bit rate. This figure has been further annotated to identify the explicit disclosure of the two end points of the range, 3/8 and 7/8.

PAM-16 constellations optimized for parallel decoding capacity at different

(CR _{QAM256})	$\frac{3}{8}$	$\frac{4}{8}$	$\frac{5}{8}$	$\frac{6}{8}$	$\frac{7}{8}$
(bps)	1.5	2.0	2.5	3.0	3.5
(SNR)	9.00	12.25	15.42	18.72	22.13
x_0	-1.72	-1.98	-1.89	-1.84	-1.75
x_1	-1.72	-1.29	-1.36	-1.42	-1.42
x_2	-0.81	1.94	1.89	1.84	1.75
x_3	-0.81	-1.17	-1.14	-1.11	-1.15
x_4	1.72	-0.38	-0.35	-0.40	-0.47
x_5	1.72	-0.65	-0.70	-0.65	-0.68
x_6	-0.62	-0.38	-0.34	-0.29	-0.28
x_7	-0.62	-0.68	-0.76	-0.83	-0.90
x_8	0.62	1.09	1.13	1.11	1.15
x_9	0.62	0.76	0.76	0.84	0.90
x_{10}	0.02	1.26	1.35	1.42	1.42
x_{11}	0.02	0.76	0.70	0.65	0.68
x_{12}	0.81	0.06	0.00	0.05	0.09
x_{13}	0.81	0.29	0.34	0.29	0.28
x_{14}	-0.02	0.06	0.00	-0.05	-0.09
x_{15}	-0.02	0.29	0.35	0.40	0.47

FIG. 15b

86. Notably, the claimed range is entirely coextensive with the values in Figure 15b—the end points of the claimed range are the same as the high and low

code rates disclosed in the design table. In addition to the disclosure of the two end points (and three intervening values) in Figure 15b, Figure 14c below is a locus plot for the PAM-16 constellations. Figure 14c has been annotated to show the code rates for a QAM-256 constellation and to demonstrate the claimed range. Figure 14c thus discloses constellations for every code rate between the two disclosed end points.

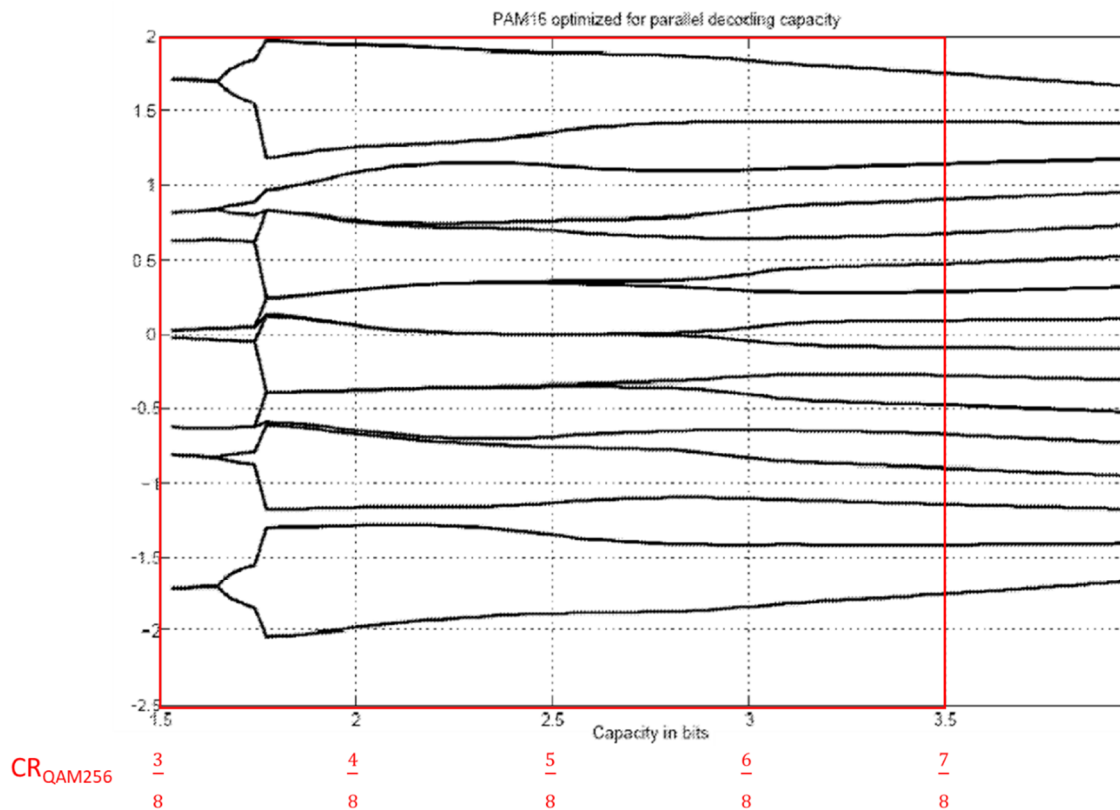


FIG. 14c

87. The third challenged limitation of claims 3, 13, and 23 of the '700 Patent is a plurality of QAM-1024 constellations and code rate pairs where the code rate "is equal to or greater than 4/10 and less than or equal to 9/10." (Petition at 5).

The '777 patent provides support for this range: it describes optimized PAM-32 non-uniform constellations for code rates ranging from 4/10 to 9/10, and PAM-32 orthogonalizes to QAM-1024. Figure 17b below shows the disclosed PAM-32 constellations and has been annotated to show the code rates for a QAM-1024, which is easily determined from the bit rate. This figure has been further annotated to identify the explicit disclosure of the two end points of the range, 4/10 and 9/10.

PAM-32 constellations optimized for parallel decoding capacity at different

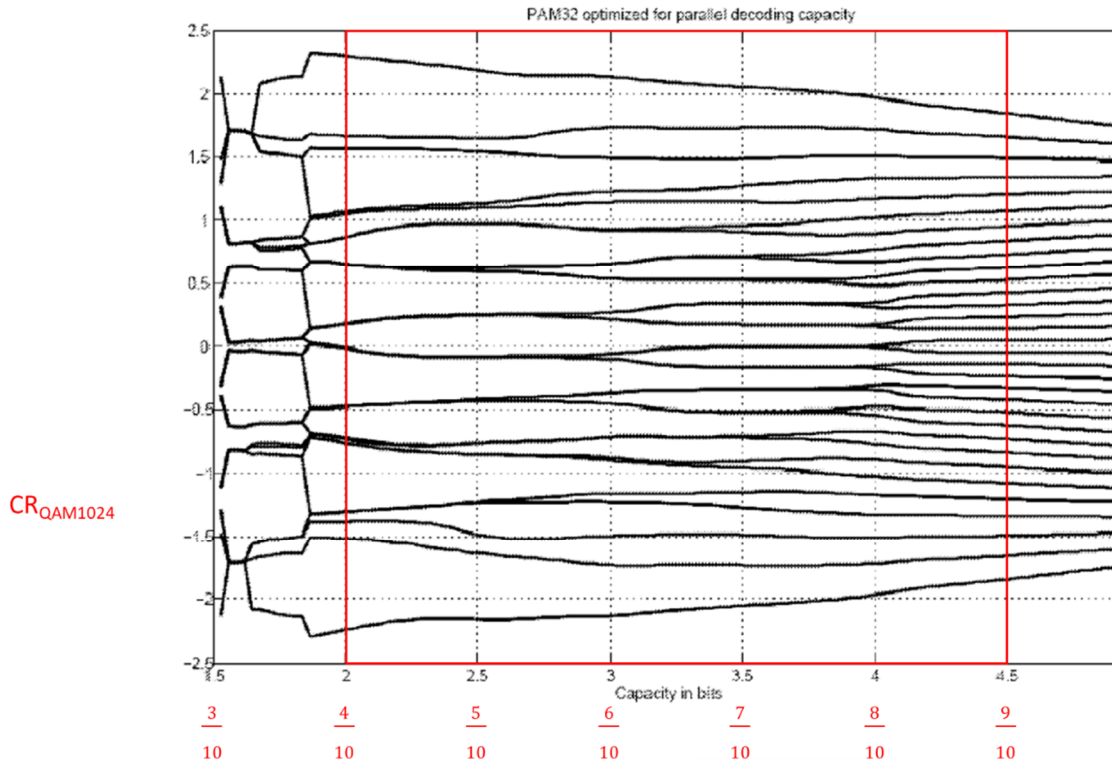
	$\frac{4}{10}$	$\frac{5}{10}$	$\frac{6}{10}$	$\frac{7}{10}$	$\frac{8}{10}$	$\frac{9}{10}$
($CR_{QAM1024}$)	2.0	2.5	3.0	3.5	4.0	4.5
(bps)	12.21	15.27	18.42	21.52	24.79	28.20
(SNR)						
x_0	-2.25	-2.16	-2.14	-2.05	-1.97	-1.85
x_1	-1.52	-1.64	-1.75	-1.74	-1.72	-1.66
x_2	2.30	2.19	-1.31	2.05	1.97	-1.35
x_3	-1.39	-1.48	-1.43	-1.49	-1.51	-1.49
x_4	1.56	1.54	2.14	-0.96	-1.03	1.85
x_5	-1.31	-1.23	1.75	-1.15	-1.17	1.66
x_6	1.67	1.65	-1.07	-0.91	-0.90	-1.21
x_7	-1.31	-1.24	-1.04	-1.28	-1.33	-1.08
x_8	-0.48	-0.43	-0.36	-0.17	-0.17	-0.42
x_9	-0.72	-0.76	-0.36	-0.34	-0.31	-0.52
x_{10}	-0.48	-0.43	-0.62	-0.17	-0.15	-0.73
x_{11}	-0.73	-0.76	-0.62	-0.34	-0.35	-0.62
x_{12}	-0.48	-0.42	-0.29	-0.71	-0.67	-0.33
x_{13}	-0.76	-0.86	-0.29	-0.52	-0.55	-0.23
x_{14}	-0.48	-0.42	-0.77	-0.72	-0.77	-0.84
x_{15}	-0.76	-0.86	-0.77	-0.52	-0.48	-0.96
x_{16}	0.87	0.98	1.07	1.49	1.51	1.21
x_{17}	0.66	0.63	1.04	1.28	1.33	1.08
x_{18}	0.87	0.98	0.77	1.74	1.72	0.84
x_{19}	0.66	0.63	0.77	1.15	1.17	0.96
x_{20}	1.07	1.13	1.31	0.72	0.77	1.35
x_{21}	0.66	0.59	1.43	0.91	0.90	1.49
x_{22}	1.05	1.10	0.62	0.71	0.67	0.73
x_{23}	0.66	0.60	0.62	0.96	1.03	0.62
x_{24}	-0.01	-0.08	0.02	0.00	0.01	0.05
x_{25}	0.17	0.25	0.02	0.17	0.15	0.14
x_{26}	-0.01	-0.08	0.29	0.00	-0.01	0.33
x_{27}	0.17	0.25	0.29	0.17	0.17	0.23
x_{28}	-0.01	-0.08	-0.02	0.52	0.48	-0.05
x_{29}	0.17	0.25	-0.02	0.34	0.35	-0.14
x_{30}	-0.01	-0.08	0.36	0.52	0.55	0.42
x_{31}	0.17	0.25	0.36	0.34	0.31	0.52

FIG. 17b

88. Notably, the claimed range is entirely coextensive with the values in Figure 17b—the end points of the claimed range are the same as the high and low code rates disclosed in the design table. In addition to the disclosure of the two end points (and four intervening values) in Figure 17b, Figure 16c below is a locus plot for the PAM-32 constellations. Figure 16c has been annotated to show the

code rates for a QAM-1024 constellation and to demonstrate the claimed range.

Figure 16c thus discloses constellations for every code rate between the two disclosed end points.



89. The '777 Patent describes determining optimized constellations for each operating SNR:

As is discussed further below, direct optimization of the constellation points of a communication system utilizing a capacity approaching channel code, can yield different constellations *depending on the SNR for which they are optimized*. Therefore, the *same constellation is unlikely to achieve the same coding gains applied across all code rates; that is, the same constellation will not enable the best possible performance across all rates*. In many instances, a constellation

at one code rate can achieve gains that cannot be achieved at another code rate.”

EX1015 at 4:62-5:11 (emphasis added).

Optimizing a constellation for a specified capacity often involves an iterative process, because ***the optimal constellation depends upon the SNR*** at which the communication system operates.

Id. at 7:26-29 (emphasis added).

The optimization process typically finds the constellation that gives the ***largest PD capacity or joint capacity at a given SNR***. The optimization process itself often involves an iterative numerical process that among other things considers several constellations and ***selects the constellation that gives the highest capacity at a given SNR***.

Id. at 8:47-56.

90. Therefore, for each operating SNR, an unequally spaced constellation performs best at that operating SNR compared to the other unequally spaced constellations that may be used but may not provide the same gains as those other constellations at different operating SNR. (See EX1015 at 4:62-5:11, 6:15-22, 7:26-29, 8:47-56). Accordingly, the constellation optimized at a given SNR performs better than the other constellations optimized at different SNRs for that given SNR. Conversely, all other constellations, which are optimized for different operating SNR, perform worse at the given SNR.

91. In addition, the specification includes a number of tables identifying a plurality of different non-uniform multidimensional symbol constellations that are

capable of providing a greater parallel decoding capacity at a specific SNR than the other symbol constellations in the plurality of multidimensional symbol constellations at the same SNR. For example, Figs. 11b, 13b, 15b and 17b all disclose constellations that are capable of providing the greatest parallel decoding capacity at a specific SNR. Figures 11b and 13b are shown below.

PAM-4 constellations optimized for parallel decoding capacity at different

(bps)	0.50	0.75	1.00	1.25	1.50
(SNR)	0.19	3.11	5.26	7.22	9.25
x_0	-1.00	-1.30	-1.36	-1.37	-1.36
x_1	-1.00	-0.56	-0.39	-0.33	-0.39
x_2	1.00	1.30	1.36	0.33	1.36
x_3	1.00	0.56	0.39	1.37	0.39

FIG. 11b

PAM-8 constellations optimized for parallel decoding capacity at different

(bps)	0.5	1.0	1.5	2.0	2.5
(SNR)	0.19	5.27	9.00	12.42	15.93
x_0	-1.00	-1.36	-1.72	-1.64	-1.60
x_1	-1.00	-1.36	-0.81	-0.97	-1.03
x_2	-1.00	-0.39	1.72	1.64	-0.19
x_3	-1.00	-0.39	-0.62	-0.58	-0.58
x_4	1.00	1.36	0.62	0.58	1.60
x_5	1.00	1.36	0.02	0.15	1.03
x_6	1.00	0.39	0.81	0.97	0.19
x_7	1.00	0.39	-0.02	-0.15	0.58

FIG. 13b

92. Thus, a system using a PAM-8 (or orthogonalized to QAM-64) operated at an SNR of 5.27 dB would utilize a constellation having points located at the positions indicated in the second column of figure 13b, and this constellation would provide greater capacity than all other PAM-8 (or QAM-64) constellations

at that operating SNR of 5.27 dB. If the system switches to an operating SNR of 9.00 dB, then the system would utilize a constellation having points located at the positions indicated in the third column of figure 13b, and this constellation would provide greater capacity than all other PAM-8 (or QAM-64) constellations at that operating SNR of 9.00 dB, including the constellation defined by the locations indicated in the second column of figure 13b (*i.e.*, the optimal constellation for an operating SNR of 5.27 dB).

93. Accordingly, the '777 Patent discloses a plurality of different non-uniform multidimensional symbol constellations that are capable of providing a greater parallel decoding capacity at a specific SNR than the other symbol constellations in the plurality of multidimensional symbol constellations at the same SNR.

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

Dated: April 17, 2023



Dr. Giuseppe Caire