

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. IPR2023-00229
U.S. Patent No. 11,019,509

**PATENT OWNER'S PRELIMINARY RESPONSE
PURSUANT TO 37 C.F.R. § 42.107(a)**

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TABLE OF AUTHORITIES

35 U.S.C. § 103.....33

TABLE OF EXHIBITS

Exhibit	Description
2001	Declaration of Dr. Giuseppe Caire
2002	Declaration of Dr. Gerhard Bauch
2003	U. Madhow, <i>Fundamentals of Digital Communication</i> , Cambridge University Press 2008
2004	R.G. Gallager, <i>Principles of Digital Communication</i> , Cambridge University Press 2008
2005	Eroz et al., <i>New DVB-S2X constellations for improved performance on the satellite channel</i> , Int. J. Satell. Commun. Network 2016; 34:351–360, Published online 14 September 2015 in Wiley Online Library (wileyonlinelibrary.com)
2006	RESERVED
2007	N.S. Login et al., <i>Non-Uniform Constellations for ATSC 3.0</i> , IEEE Transactions on Broadcasting, Vol. 62, No. 1, March 2016
2008	P. Gill, W. Murry, M. Wright, <i>Practical Optimization</i> , Emerald Group Publishing Limited (1982)
2010	RESERVED
2011	RESERVED
2012	Curriculum Vitae and Publication List of Dr. Giuseppe Caire
2013	Curriculum Vitae of Dr. Gerhard Bauch
2014	RESERVED
2015	Giuseppe Caire, Giorgio Taricco, and Ezio Biglieri, <i>Bit-Interleaved Coded Modulation</i> , IEEE Transactions of Information Theory, vol. 44, no. 3, May 1998 (“Caire”)
2016	Alexander Schretz, and Chris Weck, <i>Hierarchical modulation – the transmission of two independent DVB-T multiplexes on a single frequency</i> , European Broadcasting Union Technical Review, April 2003, pages 1-13.
2017	Gerhard Bauch, Frank Schreckenbach, Christoph Hausl, and Tetsushi Abe, <i>Turbo modulation and coding: Design and evaluation of iterative bit-interleaved coded modulation methods</i> , European Transactions on Telecommunications, Published online on April 12, 2007 in Wiley InterScience (www.interscience.wiley.com)

I. Introduction

The challenged claims and subject matter are not merely patentable over the prior art, they are revolutionary. For over 60 years prior to the '509 Patent's inventions, experts strove to design digital communication systems that could perform near the ultimate limit for reliable transmission of information, known as the Shannon channel capacity limit. They all failed.

But where others failed for 60 years, the '509 Patent inventors succeeded, developing a system and approach that did the unthinkable and finally achieved capacity near or equal to the Shannon limit. They did so by going against all conventional wisdom in digital communications design. Instead of trying to improve error-correcting methods used to transmit constellations, they tried to improve the constellations themselves. Instead of keeping constellation points uniformly spaced, they experimented with changing both the locations and labels of the constellations.

The result was revolutionary. The inventors of the '509 Patent developed a technique for optimizing signal constellations for capacity. The resulting communication systems were astronomical improvements over the prior art, providing never before seen levels of performance that finally achieved the holy grail sought for 60 years, the Shannon channel capacity limit.

And Petitioner LG took notice. It previously marveled that the inventive constellations yielded performance gains “well above the famous [Shannon] shaping gain limit of 1.53 dB.” (EX2007 at 202). Petitioner LG also previously conceded that the inventors were the first to describe the use of optimizing a constellation for capacity. (EX2007 at 197).

But now that LG is accused of infringing these acknowledged inventions, it is singing a different tune. The Board should deny institution, however, because LG’s Petition fails to establish the required reasonable likelihood of success under any of the asserted grounds for at least the following independent reasons:

- *Bauch*’s constellation with non-unique mappings cannot be used with LDPC codes but instead requires the constellation be precisely matched with a weaker code, such as a convolutional code; and
- A person of ordinary skill in the art would not want to make the proposed combination because the modification would not provide an improvement to *Eroz*, would require substantial and unexplained functional changes to *Eroz*, and many of the advantages relied upon by the Petition would not be achieved.

Indeed, although each Ground relies solely on combining *Bauch*’s constellation having non-unique mappings with *Eroz*’s LDPC decoder in order to allegedly render obvious a system having a LDPC decoder and a constellation with

at least two points having the same location, as required by every claim, **the author of *Bauch* has submitted a declaration confirming that his constellation cannot be effectively used with a LDPC decoder.** For example, author Dr.

Gerhard Bauch has confirmed:

- “My co-authors and I did not develop and did not describe using turbo codes with the constellations described in the *Bauch* publication. In that publication, we refer only to turbo iterations or turbo detections, which are synonymous with iterative decoding and demapping, and refers to the feeding back of information from the decoder to the demapper. Instead, our disclosed approach required the use of a weak code such as a convolutional code. And that is what we disclosed. Indeed, a stronger code such as a turbo code or LDPC code would not have reasonably worked with the disclosed constellations.” (EX2002 at 13).
- “One should not use the constellations with non-unique mappings that I disclose in my publications with a stronger code such as a turbo code or LDPC code. This is because my constellations require the code to be precisely matched with the constellation in order to achieve error free decoding. Such matching could not be achieved by a stronger turbo code or LDPC code because they do not have the characteristics

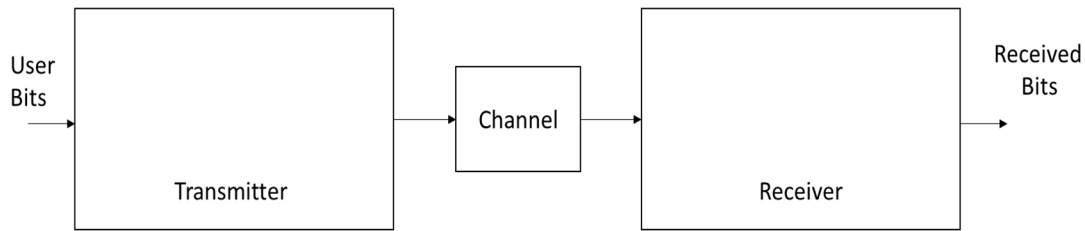
necessary to allow iterative decoding and demapping to provide the appropriate amount of extrinsic information to pass between the decoder and the demapper at each iteration. As a result, and as I have published previously, use of the constellations with non-unique mappings with a powerful FEC code such as a turbo code or LDPC code will not be effective. Further, the constellations should be used with a weak code, such as a convolutional code.” (EX2002 at 17).

II. Using “Constellations” In Digital Communications

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 Communications System

A digital communication system typically includes a transmitter that sends information to a receiver over a wireless or wired channel. (EX2001 at 13; EX2003 at 2-4; EX2004 at 1-5, 95, 181-183, 208-209).

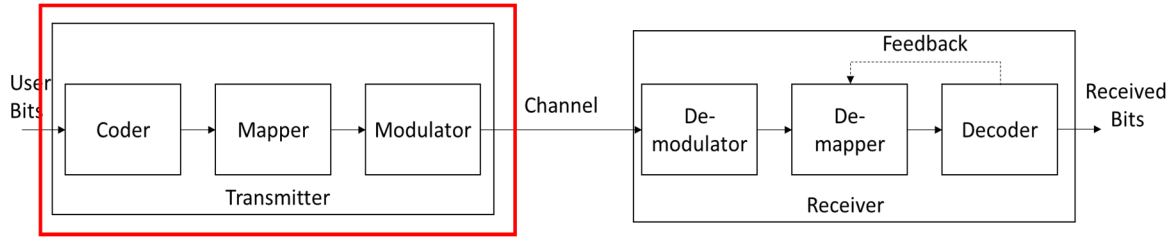


As illustrated in the above overview, information in the form of user bits (sequences of 0s and 1s) is input to the transmitter, which first converts those bits into an electromagnetic signal and then transmits that electromagnetic signal over the channel to the receiver. (EX2001 at 8; EX2003 at 2-4; 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. (EX2001 at 8; 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. (EX2001 at 8; EX2003 at 2-4; EX2004 at 1-5, 95, 181-183, 208-209).

Each digital communication system has a measurable “capacity,” which is the maximum amount of information that the system can reliably send over the channel. (EX2001 at 9; EX2003 at 252; EX2004 at 253-254, 311-312).

1. The Transmitter

In a digital communication system, the transmitter typically includes three main components: a coder, a mapper, and a modulator. (EX2001 at 9; EX2003 at 2-4; EX2004 at 1-5, 95, 181-183, 208-209).



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. (EX2001 at 9; 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 convolutional codes, turbo codes, or Low Density Parity Check (LDPC) codes) to help detect or recover user bits lost to noise during transmission. (EX2001 at 9; EX2003 at 2-3; EX2004 at 11, 298).

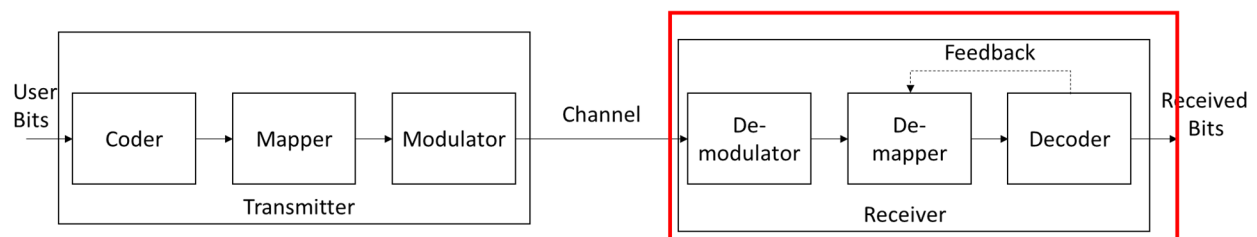
The resulting new bit sequence is input to the **mapper**, which maps this new sequence to constellation points, which are one or more carrier signal values (such as amplitude and/or phase) that can be used to represent a longer sequence of bits. (EX2001 at 9-10; EX2003 at 7; EX2004 at 181-209). Such 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. (EX2001 at 10).

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. (EX2001 at 10; EX2003 at 2-3; EX2004 at 181-209). There are numerous different ways for a modulator to apply such information to a carrier signal. (EX2001 at 10; 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. (EX2001 at 10; EX2003 at 45; EX2004 at 184-196).

2. The Receiver

In a digital communication system, the receiver typically mirrors the transmitter and includes: a de-modulator, a demapper, and a decoder. (EX2001 at 10; EX2003 at 2-4; EX2004 at 1-5, 11, 95, 181-183, 208-209).



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. (EX2001 at 11; EX2003 at 3-4; EX2004 at 181-209). Such demapping is discussed in more detail in the following “Constellation Mapping and Demapping” section.

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. (EX2001 at 11; EX2003 at 3-4, EX2004 at 11).

B. Constellation Mapping and Demapping

1. Constellation Point Locations and Labels

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

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. (EX2001 at 11). As explained below, the former is a constellation point’s “location,” and the latter is its “label.”

Signal characteristics that may be used as constellation point locations include amplitude, phase, and frequency. (EX2001 at 11; 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. (EX2001 at 11-12; 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. (EX2001 at 12; EX2003 at 45; EX2004 at 184-196). In such a system, the signal's different amplitudes may serve as constellation point locations.

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. (EX2001 at 12). 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. (EX2001 at 12). Where a particular constellation point falls on the spectrum of available values is called its "location." (EX2001 at 12).

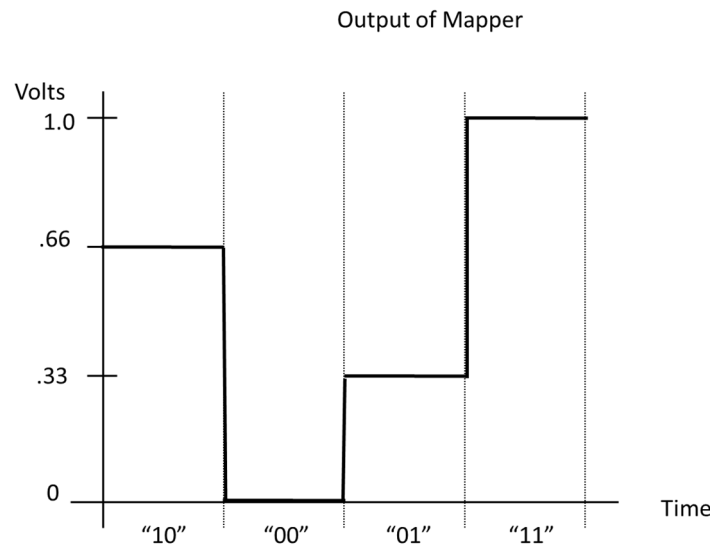
To continue this simplified illustration, if each sequence of bits to be communicated from the transmitter to the receiver comprises a series of shorter 2-bit sequences (00, 01, 10, and 11), then each of those 2-bit sequences can be assigned to a corresponding constellation point. (EX2001 at 12). For 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. (EX2001 at 12). The sequence to which a constellation point is assigned is its "label." (EX2001 at 12).

2. The Mapper

The transmitter's mapper uses these constellation labels and locations to map a bit sequence to a corresponding sequence of constellation points. (EX2001 at 13; 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. (EX2001 at 13). 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. (EX2001 at 13).

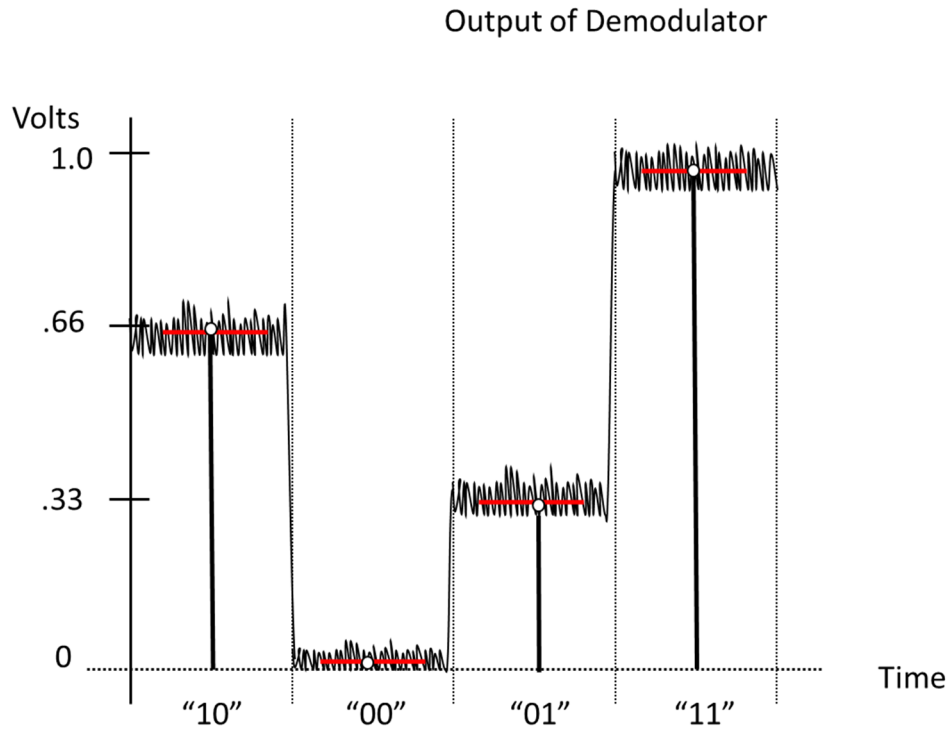
Constellation Label	Constellation Location
"00"	0
"01"	.33
"10"	.66
"11"	1.0

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. (EX2001 at 13). For reference, the transmitted bit sequence is shown for each time slot below the figure.



3. The Demapper

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. (EX2001 at 14; 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. (EX2001 at 14; 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:



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. (EX2001 at 15; 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. (EX2001 at 15; 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. (EX2001 at 15; EX2003 at 127).

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”;
- 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 .5 but less than .75, then the bit sequence is “10”; and

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. (EX2001 at 33). In many implementations, the demapper performs “soft” decisions, that is, outputs probabilities on which bit sequence corresponds to the input signal. (EX2001 at 33).

- if the output of the demodulator is greater than .75, then the bit sequence is “11”. (EX2001 at 16).

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. (EX2001 at 16-17). Put together, these component bits result in the sequence “10000111.”² (EX2001 at 17).

C. Forward Error Correcting Coding and Decoding

As noted above, the coder may add additional redundant information to the input user bits that later enables the receiver’s decoder to use error-correcting codes to help detect or recover bits lost to noise during transmission. (EX2001 at 17; EX2003 at 2-3; EX2004 at 11, 298). Example error correcting codes include convolutional codes and more powerful codes such as Turbo and LDPC codes. (EX2001 at 17).

A convolutional code is a type of error correcting code that operates by convolving a binary information sequence through a filter, or “code generator”. (EX2001 at 17; EX2003 at 294-295; EX2004 at 312-314). Convolutional codes are important because they are deployed in many practical systems but are generally

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

considered weaker than more powerful codes (such as turbo or LDPC codes) because they provide a higher bit error rate for a given code rate. (EX2001 at 17; EX2003 at 294-295).

Turbo codes are more powerful error correcting methods than convolutional codes and can utilize multiple convolutional decoders that exchange information in order to achieve a lower bit error rate, as compared to a convolutional code. (EX2001 at 17-18; EX2003 at 325).

LDPC codes are similar to Turbo codes in that they are both powerful error correcting codes and involve iterations within the decoder in order to perform the error correcting function. (EX2001 at 18; EX2003 at 342-343).

D. Hierarchical Communications

The digital communication systems and techniques discussed so far have all related to typical non-hierarchical systems in which the communication system transmits a single stream of bits. (EX2001 at 18). However, one class of communication systems multiplex multiple data streams into a single channel, effectively creating two separate data streams. (EX2001 at 18; EX2016 at 2-3). The modulation scheme can take those two separate data streams into consideration in both location of constellation points and mapping of bits to constellation points. (EX2001 at 18). Such an approach is referred to as hierarchical modulation and finds applicability in digital television broadcast where television broadcasters can

provide a lower-quality fallback signal in the case of weak signals. (EX2001 at 18; EX2016 at 2-3). This allows for a graceful degradation instead of a complete signal loss. (EX2001 at 18; EX2016 at 2-3).

Hierarchical modulation also allows for varying levels of quality of service. (EX2001 at 18; EX2016 at 2-4). For example, a smaller coverage area closer to the transmitter can provide higher data rates (e.g., higher resolution video, additional channels), while a larger coverage area can still provide for basic service. (EX2001 at 18-19; EX2016 at 2-4).

In hierarchical modulation, different bits are provided with varying levels of reliability. (EX2001 at 19; EX2016 at 2-4). This can include creating a high priority data stream, which is more robust, and a low priority data stream, which is less robust. (EX2001 at 19; EX2016 at 2-4). Fundamental to hierarchical systems is that in order to provide the increased robustness for the high priority data stream, the robustness of the lower priority data stream must be decreased. (EX2001 at 19; EX2016 at 2-4). That is to say, that a hierarchical system does not provide for more reliable communication for all bits being transmitted, rather, hierarchical systems increase the robustness of some data at the cost of reducing the robustness of other data, as compared to an equivalent non-hierarchical system. (EX2001 at 19; EX2016 at 2-4).

Hierarchical modulation also does not increase the overall data transmission rate of a communication system. (EX2001 at 19). To the contrary, the net data rate of the low priority and the high priority data streams will actually be less than an equivalent non-hierarchical system due to the overhead required in implementing the hierarchical communications. (EX2001 at 19; EX2016 at 3).

III. Prior Art Approaches

Digital communications systems and constellations as described above were generally known in the art. (EX2001 at 19). 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 Shannon channel coding theorem and is known as the Shannon channel capacity limit. (EX2001 at 19-20).

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. (EX2001 at 20). But this and all other prior art approaches fell far short of their “holy grail,” the Shannon limit. (EX2001 at 20).

A. The Shannon Channel Capacity Limit

Each digital communication system has a measurable “capacity,” which is the maximum amount of information that the system can reliably send over the

channel. (EX2001 at 20; EX2003 at 252; EX2004 at 253-254, 311-312). As detailed in the challenged '509 Patent, two different ways of measuring capacity are “joint capacity” and “parallel decode capacity.” (EX1001 at 6:42-7:30).

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. (EX2001 at 23; 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. (EX2001 at 24; EX2003 at 252-255, 263-264; EX2004 at 1).

Shannon calculated at this capacity limit by determining the maximum possible efficiency of error correcting methods. (EX2001 at 24; 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. (EX2001 at 24; EX2003 at 252-255, 263-264; EX2004 at 1,184-187, 253).

B. Prior Art Approaches Failed To Achieve the Shannon Limit

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). But until the invention disclosed and claimed in the '509 Patent, no designers were able to even come close.

Nearly every prior approach had at least two things in common: (1) equally spaced constellations; and (2) a focus on improving joint capacity.

1. Constellation Point Locations That Are Equally Spaced

The '509 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 1:44-50).

As already discussed and illustrated above, noise is introduced when constellation points are sent from the transmitter to the receiver. (EX2001 at 25; EX2003 at 2-4; EX2004 at 1-5, 95, 181-183, 208-209).

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. (EX2001 at 25). 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; EX2001 at 25).

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; EX2001 at 25). 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, 2:4-16; EX2001 at 25).

After 60 years of this approach, however, there still existed a tremendous gap between the achieved capacities and the Shannon limit. Specifically, even after the development of LDPC codes in the 1990s, a large and seemingly insurmountable “Shannon gap” of at least 1.53 dB remained.

IV. The Challenged '509 Patented Inventions

But after others tried and failed for 60 years, the '509 Patent inventors succeeded, developing a system and approach that finally closed the gap and achieved capacity approaching the Shannon limit. They did so by going against the conventional wisdom. Instead of trying to improve error-correcting methods used to transmit constellations, they tried to improve the constellations themselves. Instead of keeping constellation points uniformly spaced, they experimented with changing both the locations and labels of the constellations.

The result was revolutionary. The '509 Patent inventors developed a technique for optimizing constellation points, varying their locations and labels to arrive at a non-uniformly spaced set of constellations that optimized capacity. The resulting communication systems were astronomical improvements over the prior art, providing never before seen levels of performance that finally achieved the holy grail sought for 60 years, the Shannon channel capacity limit.

The inventors recognized that when optimizing a constellation with a fixed number of points, at certain code rates and SNRs, a lower number of unique locations may provide an improvement. As a result, the inventors disclosed constellations having overlapping locations, effectively providing optimized constellation at all code rates, even where the optimized constellation had a fewer number of unique locations.

The inventors further recognized that while optimizing constellations could be applied broadly, any given optimized constellation provided gains over an operating range, such as at or near a particular code rate and/or SNR. As a result, the inventors further recognized and described techniques for using different constellations at different code rates, where each constellation was optimized for use at its respective code rate. By selecting the appropriate constellation for a code rate, the inventors described systems that can utilize multiple constellations, each optimized for use with a particular code rate.

A. The Development of the Inventive Technology

The inventions described in the '509 patent were made with the support of the U.S. government and NASA, and co-inventor Dr. Christopher Jones worked at NASA for over five years as a renowned expert in the development of the type of error correcting codes deemed so important to improving joint capacity. (EX1001 at 1:32-34). A focus of Dr. Jones's NASA work was developing communications systems and error-correction methods used for deep space robotic probes to Mars, including the Mars Reconnaissance Orbiter, Mars Science Lander, Mars Volatile Evolution Explorer, and the Mars Perseverance Rover.

As of 2006, Dr. Jones's NASA experiences led him to conclude that real world limitations on error-correcting methods were preventing him from achieving the desired capacity gains. He also concluded that attempts to cure these

limitations by further improving error-correcting methods would be prohibitively complex.

Accordingly, Dr. Jones joined with co-inventor Maged Barsoum, and together they took a very different tack. Rather than focusing on improving error-correcting methods, the inventors instead moved their focus to improving the constellation. And to do so, they took an even more unconventional approach: rather than following the convention of maximizing the distance between constellation points, they experimented with freely varying those locations and labels.

Counter-intuitively, they discovered that unequally spaced constellation points with appropriately assigned labels could achieve superior performance to equally spaced constellations. Based on this discovery, they developed innovative approaches for freely assigning the locations and labels of constellation points using optimization, allowing them to choose constellations that, among other things, optimized a system's capacity.

B. The Patent's Revolutionary Approach To Implementing Non-Uniform Constellations

Thus, the '509 Patent inventors bucked prevailing wisdom to develop revolutionary methods for freely assigning constellation point locations and labels, including optimizing those locations and labels in order to optimize capacity. The

resulting innovations and combinations of innovations disclosed in the '509 Patent specification include:

- Instead of predetermining constellation locations, the inventors optimized those locations, varying them in all dimensions to find the combination of locations that resulted in an optimized solution;
- In addition to optimizing using constellation point locations, the inventors also optimized the constellation labels, varying which locations were associated with which bit sequences to find the best combinations of locations and labels that resulted in an optimized solution;
- The inventors recognized that different systems and capacity measurements would require different optimized constellation point locations and labels, and taught tailoring each set of constellation points to a specific system and capacity, including freely assigning locations and labels in order to optimize capacity; and
- The inventors developed an approach of optimizing for different operating conditions (such as signal to noise ratio, error correcting codes) that allow for reducing the gap to the Shannon limit across a wide variety of conditions.

The results exceeded all expectations. Systems utilizing their inventions not only overcame the real-world limitations of error-correcting methods, they achieved never before seen levels of capacity.

C. The Patent's Improved Approach to Selecting Constellation Points

1. Optimizing Constellation Locations and Labels

The '509 Patent discloses that one way to freely assigning constellation point locations and labels is to optimize those locations and labels. (EX1001 at 2:31-35, 2:51-53, 3:7-10, 3:15-17, 3:22-24; EX2001 at 26).

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. (EX2001 at 26; EX2008 at 20).

In the optimization approach disclosed in the '509 Patent, the objective function to be optimized can be the system's capacity, such as its parallel decode capacity. (EX1001 at 8:61-62; EX2001 at 26). In addition, the independent variables that may be iteratively changed until an optimized capacity is achieved include the constellation locations and labels. (E.g., EX1001 at 7:10-19; EX2001 at 26).

The patent also identifies numerous different ways for defining the "optimized" solution. (EX2001 at 26). For example, in one optimization embodiment, achieving the optimized solution requires varying constellation points

until a maximized capacity is achieved. (E.g., EX1001 at 3:5-8; (EX2001 at 26).

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 2:53-55; EX2001 at 26-27). 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 2:56-63; 3:7-11; EX2001 at 27). 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. (E.g., EX1001 at 7:60-8:2; EX2001 at 27).

2. Optimized Constellations That Have Overlapping Points

The ‘509 Patent inventors disclose that when optimizing constellations at different SNR and code rates, if a constellation having fewer locations would provide greater capacity, then the optimization will place points on top of one another. (EX1001 at Figures 13b, 14c; EX2001 at 27). For example, if optimizing an 8-point PAM, for a given SNR and code rate, a PAM with 4 unique locations or a PAM with 2 unique locations may have better performance. (EX2001 at 27). In this instance, rather than using a 4-point PAM or a 2-point PAM, the ‘509 Patent Inventors describe placing points on top of one another. (EX2001 at 27). An example

of such an approach is given in figure 13b. (EX2001 at 27). Figure 13b provides a table showing different constellation locations that are optimized at different code rates. (EX2001 at 27). Each column represents a different constellation. (EX2001 at 27). In the first column of the table of figure 13b, the PAM-8 constellation includes 8 points with a first set of four overlapping points (x_0, x_1, x_2, x_3) and a second set of four overlapping points (x_4, x_5, x_6, x_7). (EX2001 at 27-28). In other words, there are only two unique locations. In the second column of the table of figure 13b, the PAM-8 constellation includes 8 points with four sets of two overlapping points ($(x_0, x_1), (x_2, x_3), (x_4, x_5), (x_6, x_7)$). (EX2001 at 28).

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

Overlapping points are also illustrated in figure 12c. (EX2001 at 28). The locus plot shows that the optimized constellations at target user rate (x-axis) below approximately 0.6 bits per symbol (bps) have only two unique locations (resulting in two sets of four overlapping points), and the optimized constellations between 0.6 bits per symbol (bps) and approximately 1.3 bits per symbol (bps) have only four unique locations (resulting in four sets of two overlapping points). (EX2001 at 28).

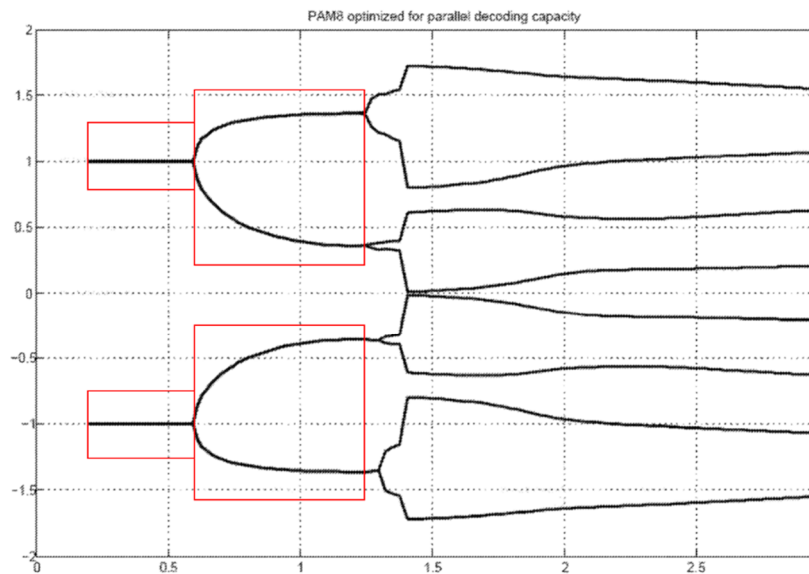


FIG. 12c

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

In light of the inventors' recognition that optimization results in different non-uniform constellations for a given code rate and/or SNR, the '509 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 5:25-28; EX2001 at 29). As an example, the ‘509 Patent describes a communication system 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 11:45-12:22; EX2001 at 29). 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 5:22-25; EX2001 at 29-30).

To illustrate this concept, an annotated figure 10c is provided below. (EX2001 at 30). 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. (EX2001 at 30). 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 (0.8 bps, indicated by the first vertical “slice”). (EX2001 at 30). 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 (1.2 bps, indicated by the second vertical “slice”). (EX2001 at 30). Using this technique, the ‘509 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. (EX2001 at 30).

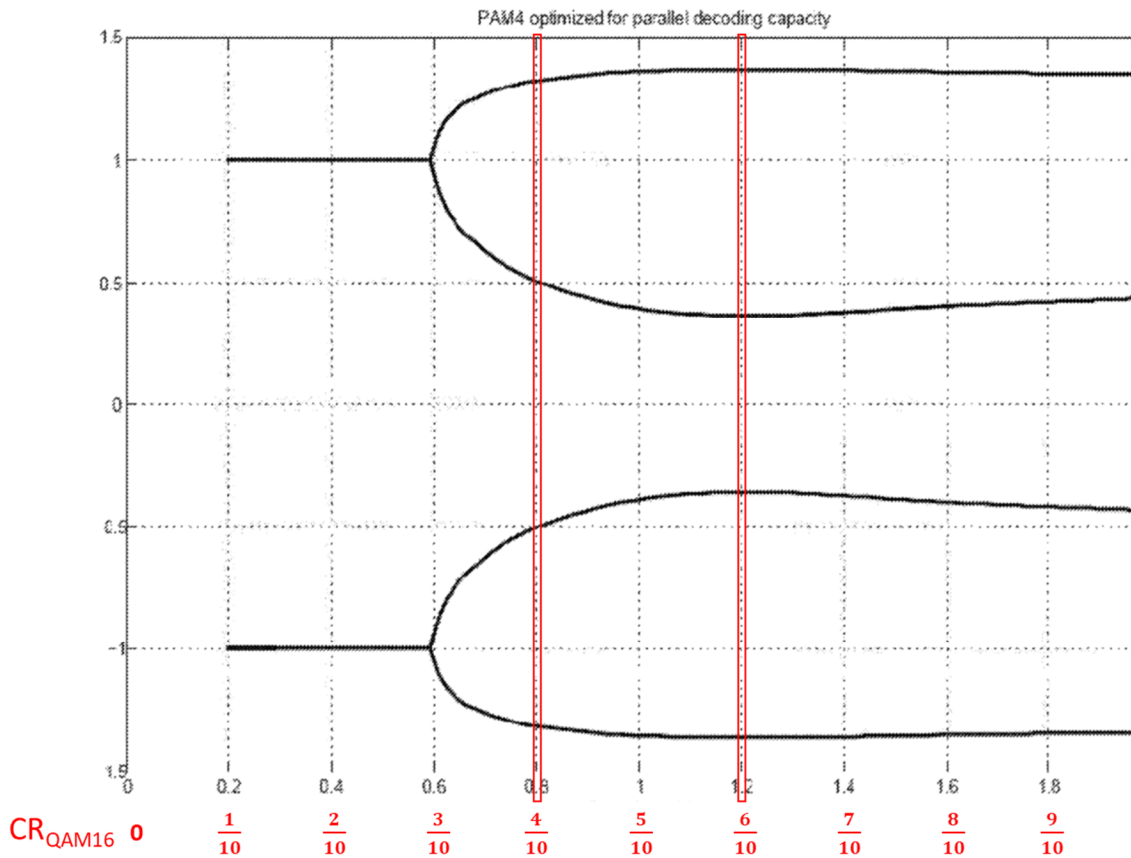


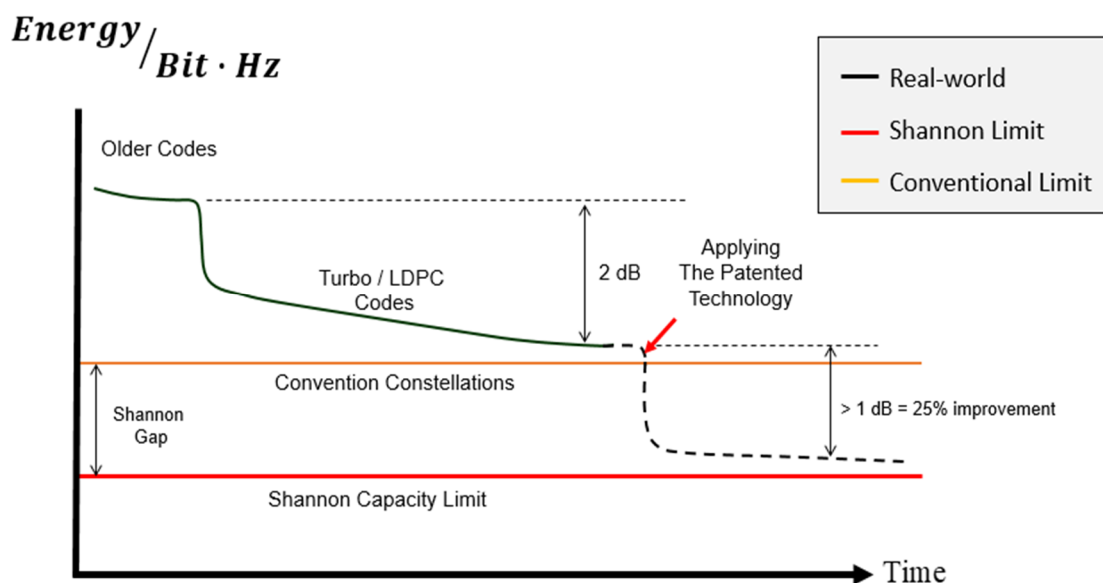
FIG. 10c

D. The Revolutionary Results

The inventor's unusual approach of freely assigning labels and locations in order to optimize capacity produced spectacular results. And when freely assigning locations and labels specifically to optimize parallel decode capacity, the

results were even more spectacular—capacity increased so much that the holy grail, the Shannon capacity limit, was approached. (EX1001 at 2:21-25).

As reported in the '509 Patent, despite all of the years and resources applied to improving conventional approaches and the error-correcting codes used therein, capacity had plateaued and remained over 1 dB away from the Shannon capacity limit. (EX1001 at 2:25-27). But as shown in '509 Patent Figure 8a, when the '509 Patent techniques were applied to freely assign constellation locations and labels to maximize parallel decode capacity, an improvement of 1.5 dB over existing systems was achieved, effectively closing the gap and effectively achieving the Shannon capacity limit after 60 years of trying. (EX1001 at 2:27-28, 10:5-33). As illustrated below, this improvement represented a 25% improvement over conventional approaches and constellations.



Thus, when inventors Jones and Barsoum presented their techniques and results in 2007, the communications world took notice. The techniques were replicated and validated by others and eventually incorporated into a new standard for satellite digital broadcasting, known as DVB-S2X. A leading commentator Mustafa Eroç – the same author of *Eroç* – described that in this new improved standard, “NUCs [Non Uniform Constellations] have been optimized, which aim at maximizing the [parallel decode] capacity of the AWGN channel,” resulting in improvements that are “extraordinarily large.” (EX2005 at 353-534).

E. The Challenged Claims

The foregoing innovative approaches are embodied in the challenged claims, each of which require a LDPC code and a constellation having constellation points at a plurality of unique locations that are unequally spaced and the locations of at least two of the constellation points are the same. (EX2001 at 31).

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 symbol constellation that includes constellation points at a plurality of unique point locations,*** where:

the plurality of unique point locations are unequally spaced;

the constellation points each have a location and a different label; and

the locations of at least two of the constellation points are the same; 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.***

V. The Petition Relies on A Combination of *Eroz* and *Bauch* for All Grounds

LG's Petition asserts the following Grounds:

Ground	References	Basis	Challenged Claims
1	<i>Eroz</i> and <i>Bauch</i>	§ 103	1, 9, 11, 19, 21, 22
2	<i>Eroz</i> , <i>Bauch</i> , and <i>DVB-T</i>	§ 103	10, 20, 30
3	<i>Eroz</i> , <i>Bauch</i> , <i>DVB-T</i> , and <i>DeGaudenzi</i>	§ 103	2, 8, 12, 18, 23, 29

Each and every ground relies solely on the combination of *Eroz* and *Bauch*. But *Eroz* and *Bauch* do not render any of the challenged claims obvious. Indeed, the Petition fails to show how or why a person of ordinary skill would combine these references. And all evidence shows that not only can *Eroz* and *Bauch* **not be combined**, there is **no reason to do so**.

A. *Eroz*

As noted above, at the time of the '509 filing, most communication systems utilized constellations with equally spaced locations, and this was well accepted as the best approach. *Eroz* is no different. (EX2001 at 33).

Eroz describes an elementary non-hierarchical digital communications system in which a transmitter utilizes a traditional equally spaced constellation coupled with LDPC codes. (EX1004, at [0033], [0069]; EX2001 at 33). *Eroz* teaches a point-to-point (*i.e.*, one-to-one) digital communication system, in which a single transmitter communicates to a single receiver. (EX1004 at [0030], [0033]; EX2001 at 33). *Eroz*'s one-to-one system is shown in Figure 1, which is reproduced below. (EX1004 at [0030], [0033]; EX2001 at 33).

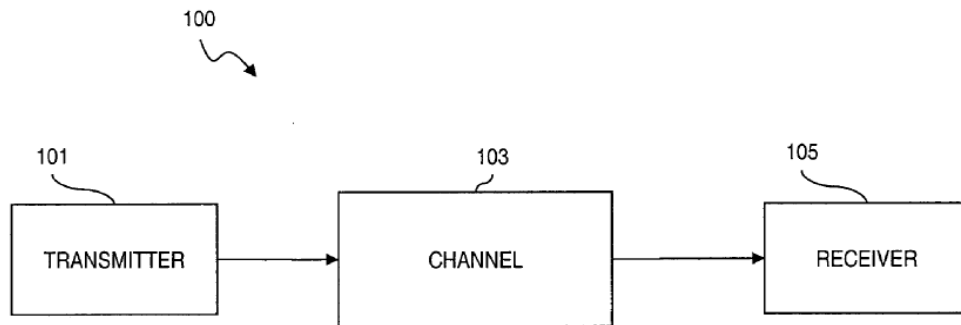


FIG. 1

Eroz's receiver, shown in figure 3 (reproduced below), includes a demodulator 301, a bit metric generator 307 (which performs demapping), and a LDPC decoder 305. (EX2001 at 34). Attempting to improve system performance, *Eroz's* technique utilizes specific LDPC arrangements in the LDPC Decoder that simplifies the encoding with limited performance loss (*e.g.*, enables a lowering of encoding scheme complexity while simultaneously improving data transmission rates). (EX1004 at [0006] and [0007]; EX2001 at 34). Moreover, *Eroz's* approach is non-hierarchical, that is, there is a single data stream and all bits have the same level of error protection. (EX2001 at 34).

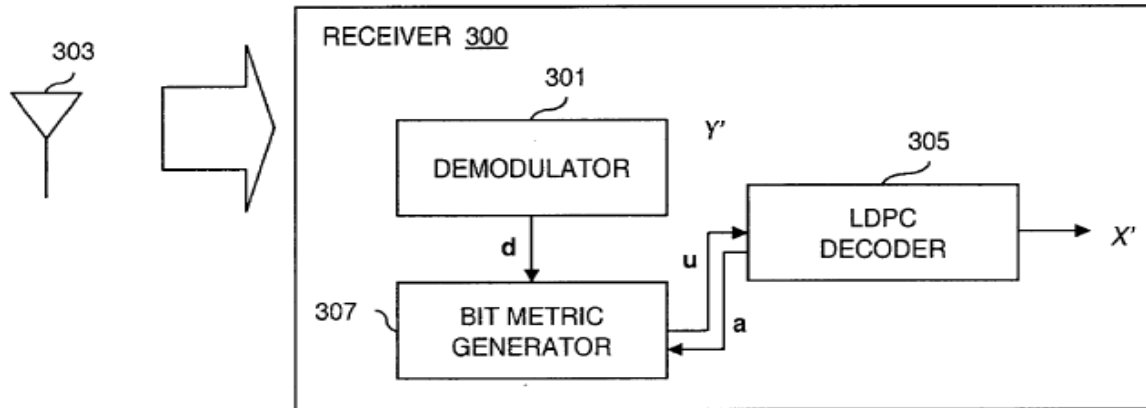


FIG. 3

In order to achieve this lower complexity encoding, *Eroz* employs a coding scheme that does not require the performance of iterations between the decoder and demapper. (EX1004 at [0070]; EX2001 at 35). Note that while a LDPC decoder will perform iterations as part of the LDPC process, ***iterative detection*** refers to the passing of information from the decoder to the demapper (bit metric generator 307 in *Eroz*). (EX2001 at 35). Iterative detection is sometimes referred to as iterative demapping or iterative decoding and demapping. *Eroz* explains that advantageously “there is *no need to iterate* between the LDPC decoder 305 and the bit metric generator 307.” (EX1004 at [0070]; EX2001 at 35).

B. *Bauch*

Rather than trying to improve system performance, *Bauch* intentionally sacrifices performance to create a hierarchical system in which some bits are more

reliable and some bits are less reliable. (EX1004 at 13:17-34; 14:19-25; 14:32-38; 15:5-7; 15:14-36; EX2001 at 35). In order to achieve a hierarchical system, *Bauch*:

(1) assigns constellation points multiple labels (referred to as non-unique mappings);

(2) assigns, for non-unique mappings, labels to have some bits in common and some bits that differ from other labels of the non-uniquely mapped constellation point; and

(3) couples this constellation with a weak code called a convolutional code – not a turbo code – and which has been *precisely* matched to the constellation.

With this constellation, the common bits are easier to resolve because there is a greater distance between point locations. (EX2001 at 36). However, the bits that differ are ambiguous. (EX2001 at 36). *Bauch* therefore relies on the error correcting capabilities of the convolutional code to resolve the ambiguous bits via iterative detection (*i.e.*, further iterations between the decoder and the demapper). (EX2001 at 36).

Because *Bauch* went to great care to precisely match the convolutional code to the proposed constellation, the system can resolve the common bits with a single pass of the decoder, and then rely on the error correcting capabilities of the convolutional code during *iterative detection* to resolve the ambiguous bits.

(EX1004 at 1:25-34; 11:6-10; EX2001 at 36). This approach creates (1) high priority data bits (the common bits) with robust error protection that can be resolved in a single pass of the decoder with a low complexity receiver and (2) lower priority data bits (the ambiguous bits) with less robust error protection that can only be resolved with a higher-complexity higher-cost receiver capable of performing iterative detection (*i.e.*, iterations between the decoder and the demapper). (EX1004 at 1:25-34, 14:19-25, and 20:28-32 to 21:1-8; EX2001 at 36). But *Bauch* explains that if the error correction code is not carefully chosen, error free communication may not be possible. (EX1004 at 10:31-35; EX2001 at 36-37).

1. *Bauch's Constellation*

In order to achieve a hierarchical system, *Bauch's* constellation includes at least one constellation point having multiple labels, and the assigned labels have some bits in common and some bits that differ from one another. (EX2001 at 37). Figure 6b (reproduced below) illustrates an example constellation having non-unique mappings. (EX2001 at 37). The illustrated example is an 8-PSK, that is, a constellation with 8 points. There are, however, only 8 unique locations such that each unique location has 2 associated labels. Each of the 8 unique locations are shown with the two labels associated with the point that resides at that location. (EX2001 at 37).

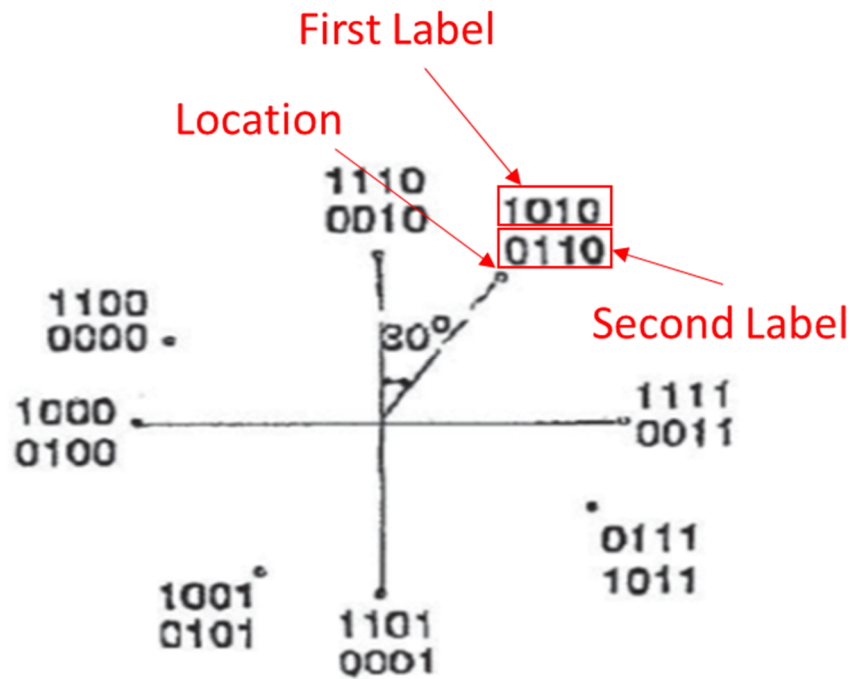


FIG. 6b

For each unique location, the labels include a first set of two bits that are different (ambiguous) and a second set of bits that are common. (EX1004 at 14:32-38, 20:28-34; EX2001 at 38).

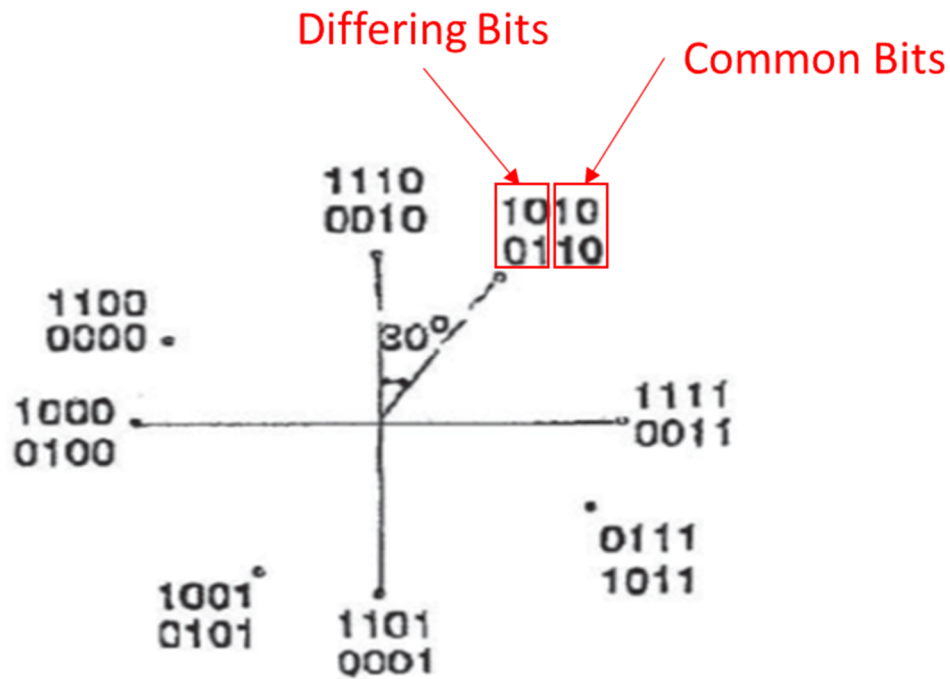


FIG. 6b

When a received signal is demapped, the location allows for the common bits to be resolved (e.g., after a single pass from the decoder, “10” can be determined from the location), whereas the differing bits remain ambiguous (e.g., after the first decoder pass, it is ambiguous whether the transmitted signal begins with “10” or “01”). (EX1004 at 14:32-15:3; EX2001 at 38).

2. *Bauch’s System Was Designed For Broadcast Communications*

Bauch, unlike *Eroz*, designed the constellation to operate with a point to multipoint digital communication system in which a transmitter may communicate data simultaneously to multiple receivers. (EX1004 at 20:20-

28; EX2001 at 39). This type of hierarchical communication system requires a different architecture than *Eroz*. (EX1004 at 13:30-34; 14:19-25; EX2001 at 39). A brief description of Figure 3a, reproduced below, is instructive. (EX2001 at 39).

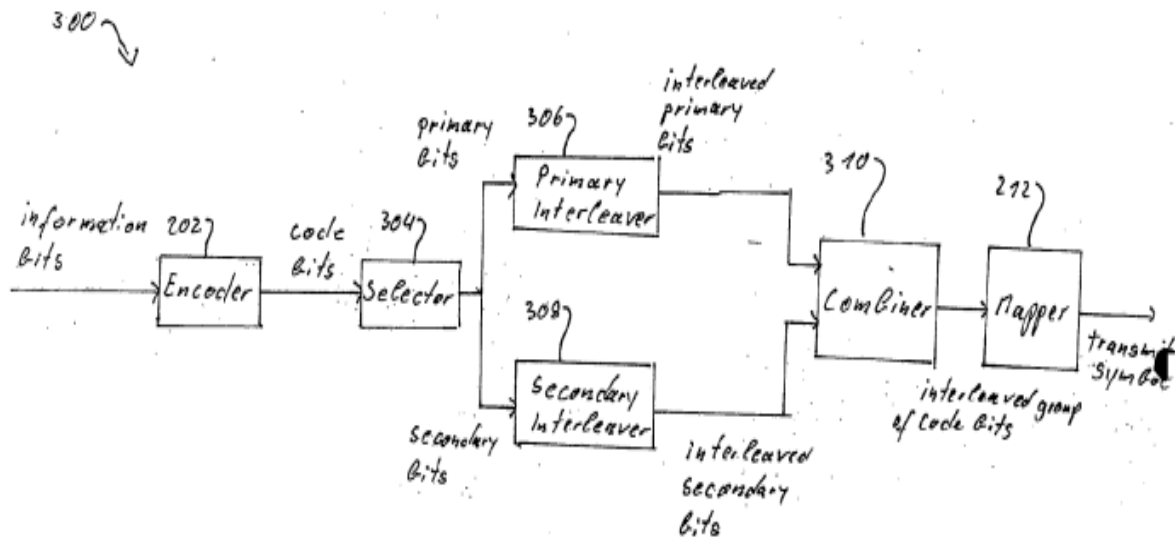


FIG. 3a

As shown in in Figure 3a above, the transmitter includes a selector configured to receive code bits and separate these bits into (1) primary bits that are mapped onto common (non-ambiguous) positions and (2) secondary bits are mapped onto different (ambiguous) positions. (EX1004 at 14:34 to 15:3; 15:14-36; EX2001 at 39). This is unlike the basic point-to-point digital communication system of *Eroz*, in which a single transmitter transmits data to a single receiver via a dedicated communication channel. (EX1005 at [0030];

EX2001 at 40). The transmitter of *Bauch* also includes a primary interleaver that operates to interleave a sequence of primary bits and a secondary interleaver that operates to interleave a sequence of secondary bits. (EX1004 at 20:34-38 to 21:1; EX2001 at 40).

3. ***Bauch* Uses Convolutional Codes with Iterative Detection – Not Turbo Codes – to Resolve Ambiguous Bits**

With non-uniquely mapped constellation points some bits are ambiguous. *Bauch* teaches using an error correcting code with iterative detection (*i.e.*, further iterations between the decoder and the demapper) to resolve the ambiguous bits. (EX1004 at 1:25-34; 11:6-10; EX2001 at 40). And not just any error correcting code, but a code that has been *precisely* matched to the constellation in order to resolve the ambiguous bits. (EX1004 at 1:25-28, 10:31-35, 11:6-10; EX2001 at 40). *Bauch*'s precisely chosen code is a convolutional code – not a turbo code. (EX1004 at 1:25-28; 4:27-32; 15:7-11; 24:1-3; 26:33-36; EX2001 at 40).

Notably the Petition and LG's Expert incorrectly assume that *Bauch* uses a Turbo code. (Petition at 25, 61; EX1003 at ¶¶75, 87; EX2001 at 40). This is not true.

Bauch clearly describes that the code utilized is a convolutional code, for example, *Bauch* states:

- “A particularly interesting scheme is the concatenation of an error correction code, e.g., **a convolutional code.**” (EX1004 at 1:25-28; EX2001 at 41).
- “The block diagram is depicted in Figure 14. The data is encoded by the encoder 1402 of a ...forward error control (FEC) code, e.g. by a binary **convolutional code.**” (EX1004 at 1:25-28; EX2001 at 41).
- “According to this embodiment, a rate-compatible punctured **convolutional (RCPC) code** [is used] as defined in ‘J. Hagenauer. Rate-compatible punctured **convolutional codes** (RCPC codes) and their applications.’” (EX1004 at 15:8-12; EX2001 at 41).
- “It is proposed to use a rate-compatible punctured code for FEC coding, e.g. a rate-compatible punctured **convolutional (RCPC) code.**” (EX1004 at 24:1-3; EX2001 at 41).
- “Fig. 7 shows simulation results for the BER performance of the partially unique mappings in Figs. 6a-6d. For channel coding a rate 1/3 **convolutional code was used.**” (EX1004 at 26:33-36; EX2001 at 41).

Moreover, *Bauch* makes clear that any use of the word “turbo” in *Bauch* is with respect to iterative detection (*i.e.*, further iterations between the decoder and the demapper). (EX2001 at 41). For example, *Bauch* states “Bit interleaved coded modulation with iterative (“turbo”) detection is considered.” (EX1004 at 4:27-32;

EX2001 at 41). Indeed, *Bauch* refers to iterative detection, which is the iterative process of feeding information from the decoder back to the demapper, as “turbo detection” or “turbo iterations”, which should not be confused with “turbo codes”. (EX2001 at 41-42).

And the author of *Bauch*, Dr. Gerhard Bauch, has confirmed that his publication does not disclose using turbo codes. For example, in his declaration submitted with this Preliminary Response, Dr. Bauch states that “My co-authors and I did not develop and did not describe using turbo codes with the constellations described in the *Bauch* publication. In that publication, we refer only to turbo iterations or turbo detections, which are synonymous with iterative decoding and demapping, and refers to the feeding back of information from the decoder to the demapper. Instead, our disclosed approach required the use of a weak code such as a convolutional code. And that is what we disclosed. Indeed, a stronger code such as a turbo code or LDPC code would not have reasonably worked with the disclosed constellations.” (EX2002 at 13).

4. *Bauch* Considered and Rejected Using LDPC Codes Because *Bauch*’s Convolutional Codes Were Precisely Matched to His Constellation

Not only did *Bauch* disclose that convolutional codes were necessary in order to achieve error free communication, *Bauch* precisely matched the strength of his convolutional codes to the constellation. For example, *Bauch* teaches that “Extrinsic

information transfer (EXIT) charts.... are a powerful tool for evaluation of the convergence properties of turbo detectors.” (EX1004 at 9:5-10; EX2001 at 42). And “error free detection... is possible, if the trajectory can proceed through a tunnel between the two curves, i.e. the demapper and decoder curves do not cross.” (EX1004 at 9:31-35; EX2001 at 42). *Bauch* selected the convolutional code precisely for its convergence properties, that is, each iteration of the iterative detection (feeding of information from the decoder to the demapper) provided enough extrinsic information such that additional iterations would resolve further ambiguous bits. (EX1004 at 1:25-34; 2:30-33; 8:35 to 9:3; EX2001 at 42).

This is confirmed by a contemporaneous article published by Bauch et al. (“*Bauch2*”) entitled “Turbo Modulation and Coding: Design and Evaluation of Iterative Bit-Interleaved Coded Modulation Methods For Wireless Systems Beyond 3G.” (EX2001 at 42-43). In *Bauch2*, Dr. Bauch assessed whether he could improve the performance of the same constellations with non-uniquely mapped points disclosed in *Bauch* (and relied upon by the Petition) by, rather than using the weaker convolutional codes described in *Bauch*, using more powerful error correcting codes such turbo codes or LDPC codes. (EX2017 at 847-848; EX2001 at 43). *Bauch2* states:

Now the question arises, if it makes sense to combine powerful FEC codes such as turbo codes with iterative demapping. More precisely, should we do iterations with the turbo decoder and then feed

back extrinsic information to the demapper for a second outer turbo loop. The EXIT curve of a turbo code is close to the curve of an optimum code: It is very steep in the beginning and at the end, but almost horizontal in between. Consequently, the decoder curve crosses the steep curve of a demapper with the optimized mappings which have been proposed above. ***Hence, turbo iterations will not be effective... It can be concluded that turbo optimized mappings should be used with weak outer codes.***

(EX2017 at 848; EX2001 at 43).

And Dr. Bauch, the author of *Bauch* and *Bauch2*, confirms: (1) that his approach described in his publication (*Bauch*) requires a code precisely matched to his constellation with non-unique mappings; and (2) that he considered, and rejected, using LDPC codes. For example, in his declaration submitted with this Preliminary Response, Dr. Bauch states:

[O]ne should not use the constellations with non-unique mappings that I disclose in my publications with a stronger code such as a turbo code or LDPC code. This is because my constellations require the code to be precisely matched with the constellation in order to achieve error free decoding. Such matching could not be achieved by a stronger turbo code or LDPC code because they do not have the characteristics necessary to allow iterative decoding and demapping to provide the appropriate amount of extrinsic information to pass between the decoder and the demapper at each iteration. As a result, and as I have published previously, use of the constellations with non-unique mappings with a powerful FEC code such as a turbo code or LDPC code will not be effective. Further, the constellations should be used with a weak code, such as a convolutional code.

(EX2002 at 16-17).

C. Combination of *Eroz* and *Bauch* Is Ineffective

The Petition proposes to replace the traditional equally spaced constellation of *Eroz* with the constellation of *Bauch* to result in a system utilizing the *Bauch* constellation with a LDPC decoder. (Petition at 24-25). But the resulting system would be ineffective because *Bauch*'s constellations simply cannot be used with LDPC codes in order to achieve error free communication. (EX2001 at 43).

1. *Bauch*'s Constellation Cannot be Used With LDPC Codes

Fundamental to communicating using *Bauch*'s non-uniquely mapped constellation is the matching of the error correcting code to the constellation to enable iterative detection to resolve the ambiguous bits of the points with non-unique mappings. LDPC codes lack this characteristic. (EX1004 at 8:35 to 9:3; 11:6-10; 20: EX2002 at 15). In particular, LDPC codes are too strong, lacking characteristics that enable iterative decoding and demapping to provide an appropriate amount of extrinsic information to pass between the decoder and the demapper at each iteration. (EX2002 at 15). As a result, any attempt to use powerful codes like turbo codes or LDPC codes with *Bauch*'s constellation is ineffective. (EX2001 at 44; EX2002 at 15-16).

Only weaker codes, such as convolutional codes, which are weaker than LDPC codes but possess suitable convergence characteristics, measure up to the task. In fact, *Bauch* precisely matched convolutional codes with *Bauch*'s non-

uniquely mapped constellation because the selected convolutional codes provide appropriate error correction at each iteration such that each additional iteration operates to resolve an additional number of ambiguous bits. As such, only certain codes, such as convolutional codes – not LDPC codes or Turbo codes – are effective to enable error free resolution of ambiguous bits, and by extension, error free decoding and errorless communication. (EX1004 at 1:25-28, 4:27-32, 9:31-35, 11:6-10, 15:7-11, 24:1-3, 26:33-36; EX2001 at 44; EX2002 at 16).

The Petition's assertion that it would be obvious for a person of ordinary skill in the art to combine *Eroz* with *Bauch* because a person of ordinary skill in the art would have predictably incorporated *Bauch*'s coding technique into *Eroz*'s system is in error. Even a cursory comparison of *Eroz*'s LDPC codes and *Bauch*'s convolutional codes indicates that these are not interchangeable, especially in light of *Bauch*'s teachings regarding his disclosed constellation.

D. Even if Combination of *Eroz* and *Bauch* Were Effective (It Is Not), There Is No Reason To Combine *Eroz* and *Bauch*

Petitioners assert that it would be obvious to modify *Eroz* with *Bauch* and that various advantages would be realized as a result of combining *Eroz* and *Bauch*. (Petition at 24-27). But even if it were possible to combine *Eroz* and *Bauch*, which it is not, there is no reason to combine *Eroz* and *Bauch* because:

(1) *Eroz* and *Bauch* teach systems that are designed to achieve opposite objectives;

(2) combining *Eroz* and *Bauch* would require substantial and unexplainable functional changes to *Eroz*; and

(3) the alleged benefits the Petition identifies as purportedly motivating a person of ordinary skill in the art would not be achieved by the combination.

1. *Eroz* and *Bauch* Aim for Opposing Objectives

The Petition asserts that it would be obvious to a person of ordinary skill in the art to combine *Eroz* and *Bauch* to achieve benefits consistent with *Eroz*'s objectives of "support[ing] higher data rates, without introducing greater complexity" and "a need to improve performance." (Petition at 24).

But there is a fundamental and unbridgeable gap between the system objectives of *Eroz* and *Bauch*. *Eroz* attempts to improve system performance using specific LDPC arrangements that increase data transmission rates and lower system complexity while *Bauch* designs constellations that, while achieving a hierarchical system, lowers performance and increases complexity when compared to a system that does not utilize iterative detection. (EX1005 at [0006], [0007], [0127]; EX1004 at 13:30-38; 14:19-25; 15:14-23; EX2001 at 45-46; EX2002 at 17). In particular, *Eroz* proposes a LDPC system to increase performance with reduced complexity

while providing uniform error protection for all bits. (EX1005 at [0006], [0007], [0058], [0127]; EX2001 at 46; EX2002 at EX2002 at 14-15).

Bauch sacrifices performance and intentionally designs a more complicated system (when compared to a system that does not utilize iterative detection) that treats bit relevance differently. (EX1004 at 13:17-19; 14:34 to 15:3; 15:14-36; 20:28-33; EX2001 at 46). *Eroz*'s treats all bits as having a similar relevance. *Bauch*'s system is hierarchical and comprises a uniquely designed constellation of non-uniquely mapped points that are unequally spaced while *Eroz*'s system is just the opposite – a non-hierarchical system with an equally spaced constellation of uniquely mapped points. (EX1004 at 13:30-34, 14:19-25, 24:24-32; EX1005 at [0006], [0007], and [0069]; EX2001 at 46).

2. Combining *Eroz* and *Bauch* Requires Substantial and Unexplainable Functional Changes

The Petition entirely fails to explain how *Bauch*'s error correction approach can be implemented using the *Eroz*'s digital communication system. (EX2001 at 46).

Instead, the Petition asserts that the *Eroz* and *Bauch* combination would have “been predictable because elements of the combined system would have performed similar functions... for example, *Eroz*'s communication system (with transmitter and receiver) would still perform in the same or similar manner but use the constellations specified by *Bauch*.” (Petition at 25-26). And the Petition asserts that

the combination would have been predictable because making modifications would have “merely involved implementing software code for configuring desired code rates, modulation, and constellation types.” (Petition at 26). But, even if a person of ordinary skill in the art could use *Bauch*’s constellations with LDPC codes (they cannot), the proposed modifications would require substantial unexplained functional changes to *Eroz* in order to implement the constellation of *Bauch*. (EX2001 at 47).

As stated above, *Eroz* describes an elementary non-hierarchical digital communications system in which a single transmitter communicates with a single receiver, while *Bauch* describes a point-to-multipoint digital communication system in which a transmitter communicates simultaneously with multiple receivers. (EX1004 at [0030]; EX1005 at 20:20 to 21:8; EX2001 at 47). Moreover, use of *Bauch*’s constellation requires the transmitter to include a selector that operates to separate a bit stream into primary bits (high priority bits) that are mapped onto common (non-ambiguous) positions and secondary bits (low priority bits) that are mapped onto different (ambiguous) bits. (EX1004 at 15:14-23; 20:28-33; EX2001 at 47). *Eroz* does not include a way of separating the bit because *Eroz* simply does not teach or require a selector comparable to the one in *Bauch*. (EX2001 at 47-48). Unexplained in the Petition are the substantial functional changes necessary to *Eroz* to convert *Eroz* from the simple point-to-point low complexity system into the

advanced, broadcast (point-to-multipoint) high-complexity transmitter and receivers necessary to communicate using the *Bauch* constellations. (EX2001 at 48). Were a person of ordinary skill in the art to make the combination as proposed without addressing these many unexplained changes, the result would fail to sort the streams into the high priority bits and low priority bits resulting in randomized bit errors, which would prevent the entire sequence from being decoded. (EX2001 at 48). Said another way, the lack of a selector and its accompanying processing would prevent error free communication. (EX2001 at 48).

3. Alleged Benefits Would Not Be Achieved by the Combination

The Petition asserts that the combination of *Eroz* and *Bauch* would result in a number of advantages including improved performance, improved bandwidth-efficient transmission, and reduced detection complexity. (Petition at 24-28). But many of these advantages would, in fact, not be achieved by the combination.

a. *Bauch*'s Constellation Does Not Provide Improved Performance When Compared to *Eroz*'s Constellation

As stated above, there is a fundamental difference between the system objectives of *Eroz* and *Bauch*. *Eroz* attempts to improve system performance with the use of LDPC arrangements that increase overall data transmission rates while lowering system complexity, while *Bauch* does the opposite, designing constellations that sacrifice data transmission rates and increase complexity (when

compared to a system that does not use iterative detection) in order to achieve varying levels of error protection (a hierarchical system). (EX1004 at 13:17-19, 14:34-15:3, 20:28-33, EX1005 at [0006], [0007]; EX2001 at 48-49).

Making the proposed combination would in fact replace *Eroz*'s traditional equally spaced constellation, which was widely believed to be the best performing constellation, with a constellation providing lower performance. (EX2001 at 49).

This is confirmed by Dr. Bauch, who states: "The constellations I proposed were not designed for capacity-achieving performance when compared to a traditional equally spaced constellation. Rather, we aimed for a pragmatic and flexible system, where increased complexity (resulting from iterative detection and when compared to a system that does not utilize iterative detection) is utilized to achieve varying levels of error protection. This scheme sacrificed the objective of performance in order to achieve a hierarchical system." (EX2002 at 18).

b. Bauch's Constellation Does Not Provide Improvements in Bandwidth-Efficient Transmission When Compared to Eroz's Constellation

Prior to the present invention, using hierarchical modulation schemes, such as those described in *Bauch*, were understood as inherently less efficient than uniform spacing as described in *Eroz*. (EX2001 at 49). The current approach of *Bauch* is no different. As stated above, *Bauch* deliberately increases system complexity and sacrifices performance (when compared to a system that does not utilize iterative

detection) to provide varying levels of error correction capability. (EX1004 at 13:17-19; 14:34 to 15:3; 20:28-33; EX2001 at 49; EX2002 at 18).

Bauch describes a scheme that is similar to a hybrid automatic repeat request (HARQ) scheme, however, the incremental redundancy is not separately transmitted over the channel, which would reduce the bandwidth-efficiency. (EX1004 at 14:24-29; EX2001 at 49; EX2002 at 19). But it was known that a uniform constellation would provide better bandwidth-efficient transmission. (EX2001 at 49). The Petition thus takes *Bauch*'s statements out of context because a uniform constellation (such as *Eroz*) would have more bandwidth-efficient transmission when compared to the constellations of *Bauch*.

This too is confirmed by Dr. Bauch, who states: "The constellations I proposed were not designed to provide more bandwidth efficient transmission when compared to a non-hierarchical and traditional equally spaced constellation." (EX2002 at 19).

c. Bauch's Constellation Does Not Provide Reduced Detection Complexity When Compared to Eroz's Constellation

As established above, iterative decoding and demapping with a convolutional code is central to the use of the constellations of *Bauch*. (EX1004 at 1:25-34, 11:6-10; EX2001 at 50; EX2002 at 19). And while a single pass of a convolutional code decoder has lower complexity than a single pass of a LDPC decoder, iterative

decoding and demapping using a LDPC code, when compared to a LDPC decoder that does not require iterative decoding and demapping, represents a substantially higher detection complexity. (EX1004 at 1:25-34, 11:6-10, 14:30-15:23; EX2001 at 50; EX2002 at 19). This is because the passing of information from the decoder to the demapper represents a series of complex steps that must be repeatedly performed. (EX1004 at 1:25-34, 11:6-10; 14:30-15:23; EX2017 at 847; EX2001 at 50; EX2002 at 19-20). Thus, use of *Bauch*'s constellations would require higher detection complexity as compared to a traditional equally spaced constellations such as used in *Eroz*. (EX1004 at 1:25-34, 11:6-10; 14:30-15:23; EX2017 at 847; EX2001 at 50; EX2002 at 20).

This is confirmed by *Bauch2*, which states “the complexity of the detection scheme is mainly determined by the iterations rather than the components within one iteration.” (EX2017 at 847).

And this is further confirmed by Dr. Bauch, who states:

The constellation with non-unique mappings that I proposed would require a greater detection complexity when compared to a traditional equally spaced constellation using the same error correcting code. This is because fundamental to using my constellation is the use of iterative decoding and demapping to resolve the ambiguous bits. But because the complexity of my detection scheme arises from the number of iterations between the decoder and the demapper during iterative detection, use of my constellation would require a higher detection complexity when compared to an equally spaced constellation using the same error correcting code.

(EX2002 at 20).

VI. The Board Should Deny Institution

The Board should deny institution because the Petition fails to establish the required reasonable likelihood of success under any of the asserted grounds for at least the following independent reasons:

- Petition fails to identify evidence showing **how** a person of ordinary skill in the art could modify *Eroz* by *Bauch*; and
- Petition fails to identify evidence showing **why** a person of ordinary skill in the art would want to modify *Eroz* by *Bauch*.

The Petition concedes that *Eroz* fails to disclose a constellation having unequal spacing and at least two overlapping points. The Petition attempts to rely on *Bauch* to cure these deficiencies. But *Bauch* cannot cure these deficiencies because (1) all evidence shows *Bauch* cannot be combined with *Eroz*; and (2) the Petition identifies no valid rationale or evidence supporting the proposed (and necessary) combination of *Bauch* with *Eroz*.

A. Bauch Could Not Modify Eroz: The Board Should Deny Institution Because the Petition has Failed to Show How Person of Ordinary Skill in the Art Could Modify *Eroz* with *Bauch*

The combination of *Eroz* and *Bauch* is solely relied upon with respect to each asserted Ground. However, the Petition wholly fails to establish any reasonable

likelihood of success that Petitioner LG will meet its burden of proving that a person of ordinary skill in the art could modify the teaching of *Eroz* with *Bauch*.

1. The *Bauch* Constellation Could Not Be Substituted for the Equally Spaced Constellation of *Eroz*

Bauch's constellation with non-unique mappings requires the use of a weak code, such as a convolutional code, that is precisely matched to the constellation of *Bauch*. (EX1004 at 1:25-34, 11:6-10; 18:29-32; 20:30-34). Further, *Bauch* emphasizes that the use of a weak code, such as a convolutional code, with *iterative detection* is essential to error free resolution of ambiguous bits, and by extension, errorless communication. (EX1004 at 1:25-34, 11:6-10).

The Petition asserts that (1) it is *predictable* to modify *Eroz* with *Bauch* and that (2) *Eroz*'s communication system would perform in the same or similar manner as *Bauch* but use constellations specific to *Bauch*. Nothing is further from the truth. (Petition at 25-26).

First, *Bauch* explains that *Bauch*'s constellations are unsuitable for use with *Eroz*'s LDPC codes because they lack characteristics that enable iterative decoding and demapping to provide an appropriate amount of extrinsic information to pass between the decoder and the demapper at each iteration. (EX1004 at 9:31-35; EX2001 at 51). The appropriately matched code that *Bauch* chose is a convolutional

code, not a turbo code. (EX1004 at 1:25-34; 4:27-32; 15:7-11; 24:1-3; EX2001 at 51).

Second, the unsuitability of using *Bauch*'s constellation with LDPC codes is confirmed by *Bauch2*, in which the same author, Dr. Gerhard Bauch, expressly considered and rejected the proposed combination. *Bauch* concludes that the use of powerful FEC codes such as Turbo codes or LDPC codes are wholly ineffective with *Bauch*'s constellation because LDPC codes (1) were not precisely matched to *Bauch*'s constellation and (2) lack the convergence characteristics necessary to achieve the required amount of error correction during iterative detection. (EX2017 at 847-848; EX2001 at 51-52).

Third, in his declaration, Dr. Bauch speaks clearly and definitively: one "should not" use *Bauch*'s constellation with a stronger code such as a turbo code or LDPC code because the constellation requires a code to be *precisely* matched with it. (EX2002 at 16). Such precise matching cannot simply be achieved with the use of a LDPC code.

The Petition provides no evidence to the contrary. Instead, the Petition incorrectly identifies the codes utilized in *Bauch* as turbo codes and equates them as similar to LDPC codes. Worse yet, the Petition fails to recognize the necessity of matching the *Bauch* constellation to the code. This faulty understanding of *Bauch*

underpins the Petition's faulty conclusion that it would be obvious to combine *Eroz* and *Bauch* and is fatal to the Petition.

Because the combination of *Eroz* and *Bauch* is used with respect to every asserted Ground, and the Petition has utterly failed to show how a person of ordinary skill in the art could combine *Eroz* and *Bauch*, the Petition should be denied.

B. Person of Ordinary Skill in the Art Would Not Want To Combine *Bauch* with *Eroz*: The Board Should Deny Institution Because the Petition has Failed to Show Why Person of Ordinary Skill in the Art Would Want To Combine *Eroz* and *Bauch*

Petitioner LG has failed to its burden of showing why a person of ordinary skill in the art would modify the teaching of *Eroz* with *Bauch* because the Petition identifies no valid rationale or evidence to show why a person of ordinary skill in the art would want to make the proposed combination.

1. The Teachings of *Eroz* and *Bauch* are Opposite

A person of ordinary skill in the art looking to improve *Eroz* to, as the Petition asserts, improve performance and reduce complexity would not have reason to replace *Eroz*'s constellation with *Bauch*'s non-uniquely mapped constellation because *Eroz* and *Bauch*'s approaches teach opposing objectives.

As relied on by the Petition, *Eroz* teaches that a higher performance and lower complexity system is needed. (EX1004 at [0006], [0007], [0030], [0058]). *Bauch*'s constellation was designed to sacrifice performance and increase complexity

(relative to a system that did not perform iterative detection) to achieve a hierarchical system. (EX1004 at 13:17-19; 14:34 to 15:3; 20:28-33). *Bauch* accomplished this objective by changing the constellation to have non-unique mappings, selecting a weaker code, and implementing iterative detection, all of which sacrifices performance and complexity but enables a hierarchical system. (EX1004 at 1:25-34; 13:17-19; 14:34 to 15:3; 15:14-36; 20:28-33; EX2002 at 18-19).

A person of ordinary skill in the art looking to improve the performance of *Eroz*'s LDPC system having a traditional equally spaced constellation would not view using *Bauch*'s constellation as an improvement, contrary to the Petition's assertions. Indeed, the use of *Bauch*'s non-uniquely mapped constellation would decrease system performance.

A person of skill in the art looking to improve *Eroz* in order to "improve performance of LDPC encoders and decoders," including to "support high data rates, without introducing greater complexity" as the Petition asserts, would not view using *Bauch*'s constellation as being able to achieve either improvement. Indeed, a person of ordinary skill in the art would have understood that the use of *Bauch*'s non-uniquely mapped constellation would decrease *Eroz*'s performance and increase *Eroz*'s complexity. And a person of ordinary skill in the art would therefore not have wanted to combine *Eroz* and *Bauch*.

2. Many Unexplained Substantial Functional Changes Would be Required By the Combination, Which Would lead Person of Ordinary Skill in the Art Away From the Combination

The Petition asserts that a person of ordinary skill in the art would find it predictable to combine *Eroz* and *Bauch* because “*Eroz*’s communication system (with a transmitter and a receiver) would still perform in the same or similar manner but use constellations specified by *Bauch*”, and the modifications “would have merely involved implementing software code for configuring the desired code rates, modulation and constellation types.” (Petition at 25-26).

As established above, *Eroz* is a simple non-hierarchical point-to-point communication system. Given *Eroz*’s simplicity of design, *Eroz* only required transmitter and receiver components to support a single data stream. (EX2001 at 53).

Bauch, in contrast, is a complex hierarchical one-to-many (broadcast) communication system. *Bauch* requires substantially different transmitter and receiver components to support the hierarchical modulation with multiple code bit streams. (EX2001 at 54). Further, each stream must then be processed with separate processing components. (EX2001 at 54). Indeed, *Bauch* requires a selector, which operates to separate a bit stream into primary bits (high priority bits) that are mapped onto common (non-ambiguous) positions and secondary bits (low priority bits) that are mapped onto different (ambiguous) bits. (EX1004 at 14:34-38; 15:14-18).

(EX2001 at 54). No teaching or suggestion of any component comparable to the selector is described in *Eroz*. (EX2001 at 54). And unlike *Eroz*'s LDPC decoder which does not require iterative detection, *Bauch* requires iterative detection in order to resolve the *Bauch* constellation's ambiguous bits. (EX2001 at 54).

Notwithstanding the inability of *Bauch*'s constellations to even be effectively used with *Eroz*' LDPC codes, the Petition fails to explain how a person of ordinary skill in the art could make many of these additional substantial functional changes in the proposed modification of *Eroz*. (EX2001 at 54). A person of ordinary skill in the art looking to improve upon *Eroz* and considering *Bauch* would understand that there are many substantial functional changes required and that any combination would require *Eroz*'s communication system (with a transmitter and a receiver) to perform in a different and dissimilar manner were they to use *Bauch*'s constellations. (EX2001 at 54). Not only would these changes to components of *Eroz* cause them not to perform similar functions, but these required changes would require well beyond "merely [] implementing software code for configuring the desired code rates, modulation and constellation types." (Petition at 22).

These required substantial and unexplained (by the Petition) functional changes required of *Eroz* would lead a person of ordinary skill in the art away from the proposed combination. And a person of ordinary skill in the art would therefore **not** have wanted to combine *Eroz* and *Bauch*. (EX2001 at 55).

3. Unachieved Benefits: The Board Should Deny Institution Because Many Benefits Alleged by the Petition Would Not Be Realized by the Combination.

Many of the benefits alleged by the Petition would simply not be realized by combining *Eroz* and *Bauch*. (EX2001 at 55).

First, combining *Eroz* and *Bauch* would not result in improved performance because the systems of *Eroz* and *Bauch* are built to achieve entirely different objectives. (EX2001 at 55). As previously stated, *Eroz*'s attempt to improve system performance by using LDPC arrangements that increase overall data transmission rates and lower complexity is fundamentally different from *Bauch*'s approach of increasing complexity and sacrificing performance (when compared to a system having a similar code that does not use iterative detection) in order to provide varying levels of error protection for different bits, namely robust error protection for high priority bits and less robust error protection for lower priority bits. (EX1004 at 20:28-34; 21:22-25; EX2001 at 55-56). Making the proposed combination would in fact replace *Eroz*'s traditional equally spaced constellation, which was widely recognized as the most suitable constellation, with a constellation providing lower performance. (EX2001 at 56).

Additionally, any attempt to use *Eroz*'s approach with *Bauch*'s unique constellation is futile because *Eroz* describes the use of LDPC codes, which are not matched to *Bauch*'s constellation, and, as a result lack the characteristics necessary

to achieve the requisite levels of extrinsic information to make *Bauch*'s approach viable.

Second, combining *Eroz* and *Bauch* would not result in bandwidth efficient transmission. As previously stated, hierarchical modulation schemes, such as those described in *Bauch*, were understood to be inherently less efficient than uniformly spaced constellations and the current approach of *Bauch* is no different. (EX2001 at 56).

Third, combining *Eroz* and *Bauch* would not result in reduced detection complexity. As previously stated, the use of iterative detection to achieve additional gain at each iteration is central to the error correction approach described in *Bauch*. (EX1004 at 7:33 – 8:16; 8:35 to 9:3; 11:6-10; EX2001 at 56). But this approach requires multiple decoding and demapping steps which results in greater complexity when compared to single pass decoding, not less. (EX2001 at 56).

Accordingly, a person of ordinary skill in the art would understand that many of the advantages relied upon by the Petition as allegedly motivating the combination, would in fact **not** be achieved by the combination. As a result, the Petition has not shown that a person of ordinary skill in the art would want to make the proposed combination, and in fact, the evidence shows that they would not.

Because the combination of *Eroz* and *Bauch* is used with respect to every asserted Ground, and the combination would not provide many of the Petitioner's purported advantages, the Petition should be denied.

VII. CONCLUSION

For any of the foregoing reasons, the Board should deny institution of the Petition.

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Respectfully submitted,

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Pursuant to 37 C.F.R. §42.24(d), Patent Owner hereby certifies, in reliance on the word count of the word-processing system (Microsoft Office Word 2010) used to prepare this preliminary response, that the number of words in this paper is 12,388. This word count excludes the tables of contents, tables of authorities, certificate of word count, certificate of service, and table of exhibits.

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CERTIFICATE OF SERVICE

I certify that copies of Patent Owner's Preliminary Response and accompanying Constellation Exhibits 2001 through 2017 are being served by electronic mail on the following counsel of record:

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