UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

NOKIA OF AMERICA CORPORATION,

Petitioner

v.

ALEXANDER SOTO AND WALTER SOTO,

Patent Owner

Case: IPR2023-00682

U.S. Patent No. 10,771,181

DECLARATION OF DR. PAUL R. PRUCNAL

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Exhibit	Short Name	Description
Ex. 1001	’181 Patent	U.S. Patent No. 10,771,181
Ex. 1002	’181 File History	File History of U.S. Patent No. 10,771,181
Ex. 1003	Prucnal Declaration	Declaration of Dr. Paul Prucnal
Ex. 1004	Prucnal CV	*Curriculum Vitae* of Dr. Paul Prucnal
Ex. 1005	Agazzi ’640	U.S. Patent No. 6,879,640
Ex. 1006	Wei	U.S. Patent No. 6,873,800
Ex. 1007		[Reserved]
Ex. 1008		[Reserved]
Ex. 1009	Agazzi ’341	U.S. Patent No. 7,933,341
Ex. 1010	Jiang	U.S. Patent No. 6,665,498
Ex. 1011	Liu	U.S. Patent No. 6,005,694
Ex. 1012	Poplawski	U.S. Patent No. 5,879,173
Ex. 1013	Lavoie	Renaud Lavoie, *The Evolution of the Pluggable Module*, Broadcast Engineering (2012)
Ex. 1014	SFP MSA	SFF Committee, INF-8074i Specification for SFP (Small Formfactor Pluggable) Transceiver, Rev. 1.0 (May 12, 2001)
Ex. 1015	Leon-Garcia	Alberto Leon-Garcia & Indra Widjaja, *Communication Networks Fundamental Concepts and Key Architectures* (2000)
Ex. 1016	Ramaswami	Rajiv Ramaswami & Kumar Sivarajan, *Optical Networks: A Practical Perspective* (2d ed. 2002)

Exhibit	Short Name	Description
Ex. 1017	Senior	John Senior, *Optical Fiber Communications: Principles and Practice* (1985)
Ex. 1018	Papadias	C. B. Papadias & D. T. M. Slock, *On the Decision-Directed Equalization of Constant Modulus Signals*, Proceedings of 1994 28th Asilomar Conference on Signals, Systems and Computers, Pacific Grove, CA, USA, pp. 1423-1427, Vol. 2 (1994)
Ex. 1019	Feldman	U.S. Patent No. 6,295,272
Ex. 1020	Martin	Martin P. Clark, *Wireless Access Networks: Fixed Wireless Access and WLL Networks—Design and Operation* (2000)
Ex. 1021		[Reserved]
Ex. 1022		[Reserved]
Ex. 1023	’795 Patent	U.S. Patent No. 9,887,795
Ex. 1024	’795 File History	File History of U.S. Patent No. 9,887,795
Ex. 1025	’723 Patent	U.S. Patent No. 10,263,723
Ex. 1026	’723 File History	File History of U.S. Patent No. 10,263,723
Ex. 1027		[Reserved]
Ex. 1028	Feuerstraeter	U.S. Patent No. 7,286,557
Ex. 1029		[Reserved]
Ex. 1030		[Reserved]
Ex. 1031		[Reserved]
Ex. 1032		[Reserved]

Exhibit	Short Name	Description
Ex. 1033	Samueli	Henry Samueli, Jeffrey Putnam, Mehdi Hatamian, *QAM-Based Transceiver Solutions for Full-Duplex Gigabit Ethernet Over 4 Pairs of UTP-5 Cable*, Broadcom Corporation Presentation (Nov. 1996)

DECLARATION OF PAUL PRUCNAL

I, Paul Prucnal, do hereby declare and say as follows:

I. Introduction

1. My name is Dr. Paul Prucnal, and I have been retained as a technical expert by counsel for Petitioner Nokia of America Corporation ("Nokia") to address certain issues regarding U.S. Patent No. 10,771,181 ("the '181 Patent").

2. I have personal knowledge of the facts contained in this Declaration, am of legal age, and am otherwise competent to testify.

3. Unless otherwise stated, the matters contained in this Declaration are of my own personal knowledge and, if called as a witness, I could and would testify completely and truthfully with regard to the matters set forth herein.

4. My opinions are based on my years of education, research, and experience, as well as my study of the relevant materials. A list of materials I considered is included at the beginning of this Declaration.

5. I reserve all available rights to supplement this Declaration if further information becomes available, or if I am asked to consider additional information. This Declaration represents only those opinions I have formed to date.

6. Further, I reserve all available rights to consider and comment on any additional expert statements or testimony of Patent Owner's expert(s) in this matter.

7. I am being compensated at my usual consulting rate of $725 per hour for my time spent working on issues in this matter. My compensation does not depend on the outcome of this matter or the opinions I express.

II. Qualifications

8. A true and correct copy of my curriculum vitae is attached as Ex. 1004 to this Declaration.

9. I have over 40 years of experience in communications and signal processing. I am currently a Professor of Electrical Engineering at Princeton University in Princeton, New Jersey. I graduated *summa cum laude* from Bowdoin College in 1974 with an A.B. in Mathematics and Physics. I then graduated from Columbia University in 1976 with an M.S. in Electrical Engineering. I went on to receive an M.Phil. from Columbia University in 1978 in Electrical Engineering and a Ph.D. from Columbia University in 1979 in Electrical Engineering. The title of my thesis was "Threshold Detection in Optical Communications and Psychophysics." My thesis investigated the quantum nature of light, the optimal detection of photons in optical communication systems, and the question of whether the human visual system, which I postulated could be modeled as a doubly stochastic Poisson point process, is capable of detecting a single photon.

10. Upon graduation from Columbia in 1979, I joined Columbia as an Assistant Professor of Electrical Engineering, and in 1984 I was promoted to Associate Professor.

11. In 1988, I joined the faculty of Princeton University as an Associate Professor of Electrical Engineering. My responsibilities there included teaching and research.

12. In 1989 and until 1991, I was a founding director of the New Jersey Advanced Technology Center for Photonics and Optoelectronic Materials. My responsibilities there included leading a $10 million research program involving approximately thirty faculty members.

13. In 1990, I was promoted to Professor of Electrical Engineering at Princeton University. My teaching responsibilities include courses in circuits, signal processing, quantum electronics, and fiber-optic communications.

14. While at Princeton University, I have received numerous awards and recognitions, including: (a) becoming a Fellow of the National Academy of Engineers, a Fellow of the IEEE, and a Fellow of the Optical Society of America; (b) receiving the Rudolf Kingslake Medal and Prize from the SPIE for the most noteworthy original paper in Optical Engineering; (c) receiving the Gold Medal Award from the Faculty of Mathematics, Physics, and Informatics at the Comenius University for leadership in the field of Optics; (d) receiving the Princeton

University Graduate Mentoring Award; (e) receiving numerous Engineering Council Awards; (f) receiving the Walter Curtis Johnson Prize for Excellence in Teaching; (g) receiving the Princeton School of Engineering and Applied Science Distinguished Teacher Award; and (h) receiving The President's Award for Distinguished Teaching, Princeton University (2015).

15. In 1991, I was a visiting professor in the Research Center for Advanced Science and Technology at the University of Tokyo, where I held the NEC Chair. My responsibilities there included research on optical packet switching and giving lectures on fiber-optic networks.

16. In 1992, I was a visiting professor at the University of Parma. My responsibilities there included research on photonic switching and giving lectures on fiber-optic networks.

17. In addition to the activities, education, and professional experience listed above, I have been involved in several research projects that contribute to my expertise relating to fiber-optic communications.

18. In 1992-1995, I worked with Siemens Corporate Research on a project that involved research on ultrafast optical switching technology. My responsibilities included the investigation of optoelectronic technologies for high-speed multiplexing and switching.

19. In 1998-2001, I worked with Sun Microsystems on a project that involved research on optical backplanes and computer interconnects. My responsibilities included the design of a high-performance multiprocessor interconnection system.

20. In 1999-2000, I worked with SAIC on a project which involved research on fiber-optic network architectures. My responsibilities included the investigation of novel switching and multiplexing techniques.

21. In 2000-2002, I worked with Ultra Fast Optical Systems on a project that involved research and development on optical switching technology. My responsibilities included the design and testing of an all-optical switch.

22. In 2000-2003, I was a member of the advisory board on optical network technology for Alphion, Inc. My responsibilities included providing guidance on the development of technology in the optical networks space.

23. In 2003-2006, I worked with Kailight Inc. on a project that involved research and development on optical switching technology. My responsibilities included the design and testing of a digital optical repeater.

24. In 2004-2011, I worked with NEC Laboratories on a project that involved research on physical layer security in optical networks. My responsibilities included the design and analysis of techniques for optical steganography and data encryption using digital optical logic.

25. My research interests include fiber-optic communications systems and networks. I have extensive experience researching and teaching about optical signal processing and optical communications techniques such as multilevel modulation, equalization, and error-correcting codes. I also have experience with optical transceiver modules, including pluggable-type modules.

26. To date, I have published books on Optical CDMA and Neuromorphic Photonics, and 36 book chapters and reviews in the area of fiber-optic communications systems. In addition, I have published approximately 419 papers in conference proceedings and 329 peer-reviewed journal papers. I am also a named inventor on 28 patents relating to fiber-optic communications.

27. Through my work, I have earned the respect of the optical communication and electrical engineering community more broadly. I am a member of the advisory board on advanced computing and communications research for the Center for Computing Sciences. I have also chaired or served as a member on several dozen boards and committees related to electrical engineering.

III. Scope of the Engagement

28. I have been retained by Alston & Bird LLP on behalf of Nokia to provide various analyses and opinions. Among other tasks, I have been asked to address the technology claimed in the ’181 Patent and to evaluate whether certain claims of the ’181 would have been obvious to a person of ordinary skill in the art.

29. All of the opinions I express in this Declaration have been made from the standpoint of a person of ordinary skill in the relevant art at the time of the invention of the '181 Patent, which I am informed is, for purposes of this matter, the earliest claimed priority date of June 10, 2003. With that said, none of my opinions would change if the proper priority date were found to be June 21, 2003.

30. I have been asked to identify the level of skill in the art pertinent to the '181 Patent. It is my opinion that a person of ordinary skill in the art pertinent to the '181 Patent would have had at least a bachelor's degree in electrical engineering, computer engineering, or similar discipline and had at least two years of optical communications, networking and signal processing experience. A person with a different degree but with additional relevant experience could still qualify if the additional experience compensates for the different educational background.

31. I consider myself a person of ordinary skill in the art as of at least the earliest claimed priority date (June 10, 2003).

32. My opinions are based on my experience and knowledge and the information I have reviewed as of the date of this Declaration. In connection with my analysis, I have reviewed the exhibits listed in the above list of exhibits, as well as each of the items referenced herein. I attest that the foregoing exhibits are true and accurate copies that I downloaded. My opinions directed to the invalidity of the challenged claims are based, at least in part, on the following prior art publications:

- **"Agazzi '640"** (Ex. 1005), which is U.S. Patent No. 6,879,640, filed on October 20, 2000 and issued on April 12, 2005;
- **"Wei"** (Ex. 1006), which is U.S. Patent No. 6,873,800, filed on September 7, 2000 and issued on March 29, 2005
- **"Agazzi '641"** (Ex. 1009), which is U.S. Patent No. 7,933,341, filed on February 28, 2001 and issued on April 26, 2011.

IV. Legal Standards Relied Upon

33. For purposes of this Declaration, counsel for Nokia have instructed me to make the following assumptions:

34. Claims are construed from the perspective of a person of ordinary skill in the art ("POSITA") as of the effective filing date of the patent application. Persons of ordinary skill in the art are deemed to read the claims in the context of the entire patent, including the specification and prosecution history. In other words, the terms are not considered in a vacuum.

35. It is my understanding that information that satisfies one of the categories of prior art set forth in 35 U.S.C. § 102 may be used in an invalidity analysis under §§ 102 or 103. If information is not properly classified as prior art under one of the subsections of § 102 of the Patent Act, then it may not form the basis of an anticipation or obviousness determination. It is also my understanding

that, for *inter partes* review, applicable prior art is limited to patents and printed publications.

36. I am also informed and understand that a patent claim is invalid under 35 U.S.C. § 103 if the differences between the invention and the prior art are such that the subject matter as a whole would have been obvious at the time of the invention to a POSITA to which the subject matter pertains. Obviousness, I am informed, is determined based on the scope and content of the prior art, the differences between the prior art and the claim, the level of ordinary skill in the art, and secondary indications of non-obviousness to the extent they exist.

37. I understand that whether there are any relevant differences between the prior art and the claimed invention is to be analyzed from the view of a POSITA at the time of the invention. A POSITA is a hypothetical person who is presumed to be aware of all of the relevant art at the time of the invention. The POSITA is not an automaton and may be able to fit together the teachings of multiple patents (or other printed publications) by employing ordinary creativity and the common sense that familiar items may have obvious uses in another context or beyond their primary purposes.

38. In analyzing the relevance of the differences between the claimed invention and the prior art, I understand that I must consider the impact, if any, of such differences on the obviousness or non-obviousness of the invention as a whole,

not merely some portion of it. The person of ordinary skill faced with a problem is able to apply his or her experience and ability to solve the problem and also look to any available prior art to help solve the problem.

39. I understand that an invention would have been obvious if a POSITA, facing the wide range of needs created by developments in the field, would have seen an obvious benefit to the solutions tried by the patent applicant. When there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, it would have been obvious to a POSITA to try the known options. If a technique has been used to improve one device, and a POSITA would recognize that it would improve similar devices in the same way, using the technique would have been obvious.

40. I understand that I do not need to look for precise teachings in the prior art directed to the subject matter of the claimed invention. I understand that I may consider the inferences and creative steps that a POSITA would have employed in reviewing the prior art at the time of the invention. For example, if the claimed invention combines elements that were known in the prior art and if the combination yields results that were predictable to a POSITA at the time of the invention, then this would make it more likely that the claim was obvious. On the other hand, if the combination of known elements yields unexpected or unpredictable results, or if the prior art teaches away from combining the known elements, then this would make it

more likely that the claim that successfully combined those elements was not obvious. I understand that hindsight must not be used when comparing the prior art to the invention during an obviousness analysis.

41. I understand that obviousness may be shown by demonstrating that it would have been obvious to modify what is taught in a single piece of prior art to create the patented invention. Obviousness may also be shown by demonstrating that it would have been obvious to combine the teachings of more than one item of prior art. I understand that a claimed invention may be obvious if some teaching, suggestion, or motivation exists that would have led a POSITA to combine the invalidating references. I also understand that this suggestion or motivation may come from sources such as explicit statements in the prior art, or from the knowledge of a person having ordinary skill in the art. Alternatively, any need or problem known in the field at the time and addressed by the patent may provide a reason for combining elements of the prior art. I also understand that when there is a design need or market pressure, and there are a finite number of predictable solutions, persons of ordinary skill may be motivated to apply both their skill and common sense in trying to combine the known options in order to solve the problem.

42. I understand that absent evidence of an invention date prior to the filing date of a patent, the invention date of the patent is presumed to be its filing date. A prior invention requires a complete conception of the invention and a reduction to

practice of that invention. The patent owner has the burden of establishing by clear and convincing evidence a date of conception earlier than the filing date of the patent.

V. Technical Background

43. In this technical background, I describe the pertinent technology as it existed as of June 2003, the assumed priority date of the '181 Patent.

44. The '181 Patent is generally related to communication over an optical network. Specifically, the '181 Patent claims a pluggable optical transceiver module that uses m-ary modulation and signal processing techniques to convert between electrical and optical signals. Ex. 1001 at cl. 1.

45. As I will describe, all these ideas were well known to a POSITA at the time of the alleged invention.

a. Optical Network

46. A fiber-optic network transmits information, in the form of modulated light, from one location to another. The modulated light, called signals, represents bits of data, such as voice, video, or computer data. Ex. 1011 at 1:14-24.

47. Fiber-optic networks have become more and more prevalent since the 1990s, due to an ability to convey significantly more information over longer distances than conventional electrical cables. For example, an optical fiber operating at 10 Gb/s can carry data equivalent to over 128,000 voice calls over hundreds of

kilometers. And dozens of fibers may be included in a single cable, thereby multiplying the amount of data that can be transmitted. *Id.* at 1:36-45. Because optical cables can convey considerably more data than conventional electrical cables, fiber-optic networks are used to transmit large amounts of data across cities, states, and continents. *Id.* at 1:24-30.

48. User devices, such as phones, computers, and televisions, use optical signals that traverse the fiber network. But these devices operate using electrical signals, which requires the fiber-optic network to have optical-to-electrical interfaces that convert electrical signals to optical signals, and vice versa. Ex. 1010 at 1:17-46.

b. Pluggable Optical Transceiver Modules

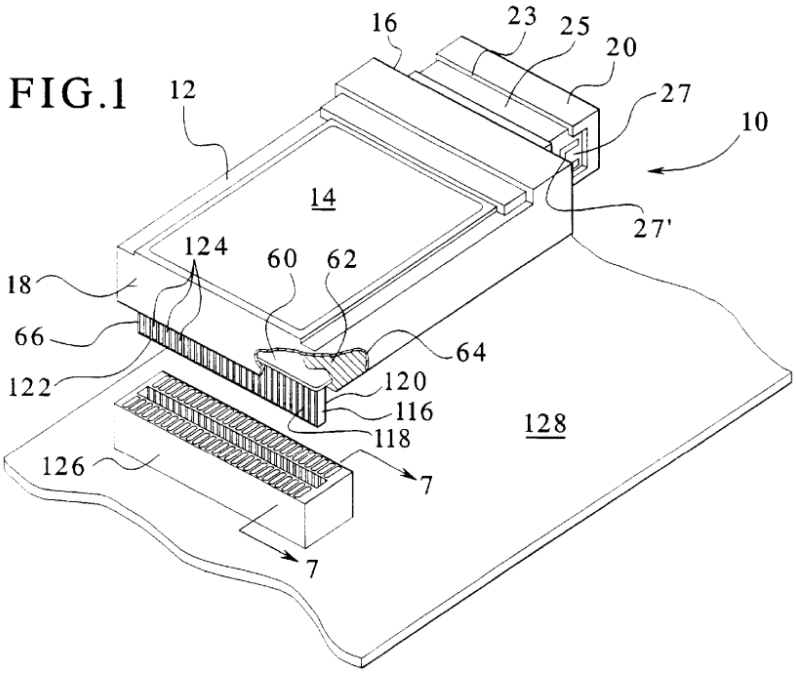
49. The optical-to-electrical interface is where electrical and fiber cables are connected to one another via an optical transceiver module. To allow the electrical and fiber cables to communicate with one another, the optical transceiver module converts signals between the optical and electrical domains. Ex. 1006 at 1:24-59.

50. For example, the transceiver module includes a transmitter system and a receiver system. The transmitter receives digital electrical signals, which includes electronic data (information) typically in the form of binary voltages that drive the optical transmitter. The optical transmitter converts the electrical signals to optical

signals, which are emitted onto an optical fiber. Ex. 1017 at 399-403. The receiver includes a light detecting device that receives optical signals and converts them to electrical signals. The transmitter and receiver, which together form the transceiver, thus send signals back and forth across the electrical-to-optical interface, allowing communication between the electrical components and optical fibers. Ex. 1006 at 1:24-59.

51. Traditionally, optical transceiver modules were bulky and mounted in a relatively fixed configuration, such as mounted on a circuit card located in a computer, peripheral device, or on a shelf in an equipment rack. But it was desirable to produce a smaller hot-pluggable optical transceiver that was easily removable. Ex. 1012 at 2:25-30. In 1995, one of the first such pluggable optical transceivers was produced, called the hot pluggable gigabit interface converter ("GBIC"). Ex. 1013 at 1.

52. Another example, from the late 1990s, of a "transceiver module which provides for a small, yet robust package, which is inexpensive to manufacture and can easily and quickly be installed and removed" is shown below. Ex. 1012 at 2:25-30, Fig. 1.



53. However, because the pluggable optical transceivers were still relatively large, users desired a more compact, high-throughput fiber-optic transceiver in a small form pluggable ("SFP") package. Ex. 1006 at 1:65-2:4. For example, a prior art patent filed in 2000 specifically addresses how "to package the functions of a GBIC into the compact size of an SFP." *Id.*; *Id.* at Fig. 4.

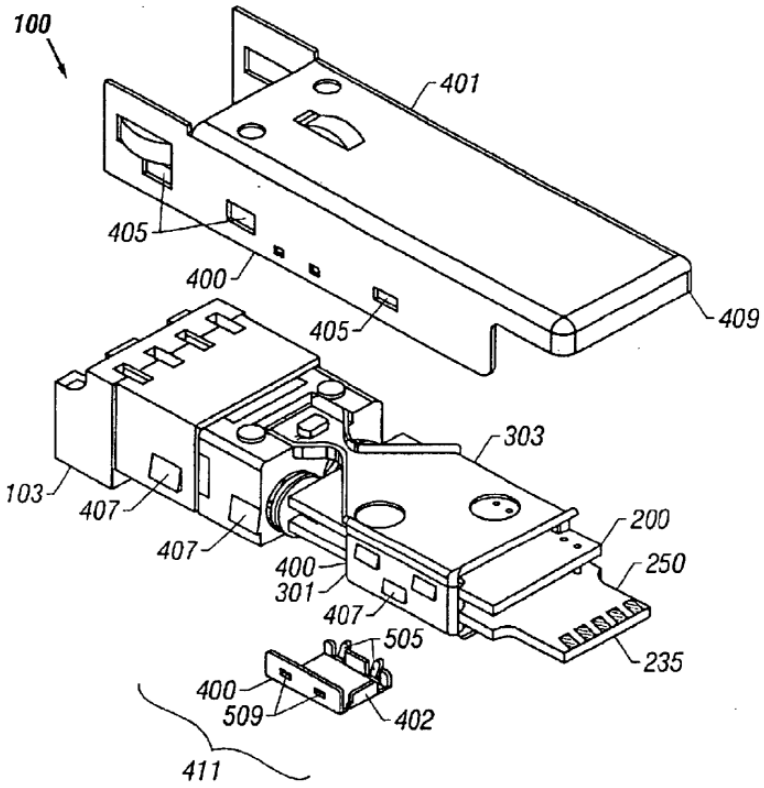


FIG. 4A

54. Around this same time, in the late 1990s and early 2000s, in an effort to standardize the industry, system vendors supported Multi-Source Agreements ("MSA") among several component suppliers to define and specify all the physical and electrical requirements for specific pluggable form factors. *See, e.g.*, Ex. 1014. One such example is the SFP MSA that defines the SFP form factor. *Id.*

c. M-ary Modulation

55. M-ary modulation is a process through which two or more bits of information are transmitted simultaneously. Ex. 1015 at 125-30. There are various schemes that may be employed to perform this modulation, including Quadrature Phase Shift Keying ("QPSK"), Quadrature Amplitude Modulation ("QAM"), and

Pulse Amplitude Modulation ("PAM"), which are some of the more common techniques. Ex. 1015 at 128; Ex. 1005 at 3:12-21,17:5-8. Each of these modulation techniques was well known to a POSITA by the priority date of the '181 Patent.

56. M-ary modulation is a kind of digital modulation where two or more bits are transmitted simultaneously. The two or more bits are converted into one of M possible symbols for transmission. In general, M possible symbols can carry $\log_2 M$ bits of information. For example, M=4 possible symbols can carry 2 bits, as in QPSK; M=8 possible symbols can carry 3 bits, as in 8-QAM; and M=64 possible symbols can carry 6 bits, as in 64-QAM. For QPSK, QAM, and PAM, these symbols can be modulated onto a carrier signal using a different amplitude and/or phase for each symbol over the symbol duration. These symbols can be represented in a constellation diagram, where each symbol is a constellation point in the complex plane, representing amplitude and phase. In this plane, the distance from the center of the diagram is the amplitude and the angle from the x-axis is the phase. Since the bandwidth of a signal is proportional to the inverse of the symbol duration, and the number of bits in each symbol increases as $\log_2 M$, a key advantage of m-ary modulation with M greater than 2 is that more data can be transmitted in the same bandwidth—typically, $\log_2 M$ times more data—as compared to binary modulation that carries only one bit per symbol (M=2). The main disadvantage of m-ary modulation, compared to binary modulation, is that the transmission power must be

increased to maintain the same spacing of the points in the constellation diagram, and therefore the same bit error rate.

57. With QPSK modulation, M=4 as there are 2 bits per symbol, and each symbol has the same amplitude but one of four different phases. The phases are separated by 90 degrees. Thus, the constellation points are four equally spaced points on a circle.

58. With QAM modulation, each symbol has a different amplitude and/or phase. Although m-ary QAM with M constellation points is referred to as M-QAM, 4-ary QAM, *i.e.*, 4-QAM, is often referred to as just QAM, for short. The typical constellation points for 4-QAM are four equally spaced constellation points with the same amplitude, as this provides the lowest bit error rate in standard cases. Note that QAM differs from QPSK in that the amplitude of the symbols can vary, but QPSK is the same as 4-QAM in its typical constellation.

59. With PAM, each symbol has the same phase but a different amplitude. Binary PAM is often referred to as just PAM, but PAM also covers m-ary PAM, where there are M different amplitudes for the symbols.

d. Equalization

60. I have also been asked to provide an overview of equalization, including blind and non-blind equalization, which are two well-known signal processing techniques used to remove distortion.

61. In communications, equalization is the mitigation of distortion of a signal transmitted through a communications channel. Ex. 1016 at 266-67; Ex. 1017 at 412-14. Equalizers typically attempt to make the frequency response of the channel in combination with the equalizer constant in amplitude and linear in phase across the channel, thus removing signal distortion. Two types of equalizers are linear tapped delay line and decision feedback equalizers, which multiply different versions of the signal with weights, *i.e.*, coefficients, and then sum these weighed signals to form the output signal. For a variable channel, these equalizers require some type of reference signal to be able to adapt the coefficients to mitigate distortion, and these types of reference signals can be split into two basic types: blind and non-blind.

62. In non-blind equalization, a training sequence of symbols known by the equalizer is included in the transmitted signal so that the equalizer can calculate the coefficients based on the distortion in the received training sequence and then correct the distortion in the rest of the transmitted signal. In blind equalizers, the equalizer estimates the coefficients without knowledge of the channel statistics—it uses only the transmitted signal characteristics without a training sequence. Examples of such characteristics are that the signal is constant amplitude, as with QPSK, or consists of digital symbols with a given modulation and symbol duration. For the latter case, the detected, *i.e.*, decided, symbols at the receiver can be used as the reference for

estimating and correcting the distortion, assuming that the bit error rate of the receiver is not too high. A POSITA would have understood that this technique is decision directed equalization, as it is commonly referred to in the literature. Ex. 1018 at Abstract ("Decision-directed (DD) equalization is the most primitive blind equalization (BE) method for the cancelling of inter-symbol-interference (ISI) in data communication systems."). A hybrid approach uses a training sequence to get an initial estimate of the coefficients and then adjusts the coefficients with the changing channel based on the decided data symbols received after the training sequence. A POSITA would have understood that such an equalizer uses both blind and non-blind techniques.

e. Error Correction Techniques

63. Additionally, I have been asked to provide an overview of known error correction techniques. Detection errors in the received signals can be caused by a number of factors, including noise, interference, channel distortion, and decoding issues.

64. There are many ways to correct errors, including repeat requests, forward error correction ("FEC"), and hybrid schemes that utilize both. Repeat requests can be triggered by the detection of errors using, for example, a cyclic redundancy check ("CRC") or other form of error detection. The system then

requests a retransmission of the message that was previously received with an error to attempt to avoid the detection error with the retransmitted message.

65. FEC is the process of using redundant or duplicate data to allow for the receiving side of a system to reconstruct the transmitted data to be nearly error-free, *i.e.*, correcting any errors that occur. Ex. 1020 at 353-58. FEC does not require the retransmission of data, although it does require a larger message (to account for the data redundancy). Ex. 1016 at 267-68.

66. There are two general types of FECs: block codes and convolutional codes. Ex. 1016 at 267-72; Ex. 1015 at 153. In a block code, the message is divided into fixed-size blocks of bits to which redundant bits are added for error correction. *Id.* In a convolutional code, the message comprises data streams of arbitrary length and parity symbols are generated by the sliding application of a Boolean function in the data stream. *Id.*

67. Reed-Solomon and low-density parity-check ("LDPC") codes are types of block codes, whereas a trellis code is a type of convolution code. Ex. 1016 at 270-71; Ex. 1015 at 131. Each of the aforementioned codes was well-known to a POSITA.

68. To implement error correction, encoding and decoding processing is performed by encoders and decoders. Ex. 1015 at 153-54. These techniques allow

for the correction of errors in the detected received signal as long as there are not too many errors in the detected signal before error correction.

VI. The ’181 Patent

69. The ’181 Patent is generally directed towards communication over an optical network. Specifically, the ’181 Patent discloses a pluggable optical transceiver module that uses m-ary modulation and signal processing techniques to convert between electrical and optical signals. Ex. 1001 at Abstract, cl. 1.

70. I understand the filing date of Provisional Application No. 60/477,845, to which the ’181 Patent claims priority, is June 10, 2003.

71. The claims of the ’181 Patent that are being challenged and that I have been asked to evaluate are claims 1-3, 5-6, 8, 10-17, and 22-23. I have reproduced the challenged claims below:

Claim	Recitation
[1.Pre]	A pluggable optical transceiver module comprising of:
[1.A]	an electrical system interface for receiving a first electrical data signal and for transmitting a second electrical data signal;
[1.B]	an m-ary modulator for increasing the number of bits per symbol in the first electrical data signal to produce a first m-ary modulation signal;
[1.C]	a digital to analog converter for converting the first m-ary modulation signal to a first electrical m-ary analog modulation signal;
[1.D]	a driver for amplifying the first electrical m-ary analog modulation signal to an amplified first electrical m-ary analog modulation signal to drive an optical transmitter;
[1.E]	the optical transmitter for emitting a first optical signal on a first wavelength responsive to and representative of the amplified first electrical m-ary analog modulation signal from the driver;
[1.F]	an optical detector for receiving a second optical signal on a second wavelength to produce an electrical analog signal;
[1.G]	an amplifier for amplifying the electrical analog signal to an amplified electrical analog signal;
[1.H]	a clock data recovery unit for recovering clock and data information to produce a second m-ary modulation signal from the amplified electrical analog signal;
[1.I]	an equalizer for performing equalization on the second m-ary modulation signal to remove noise; and
[1.J]	an m-ary demodulator for decreasing the number of bits per symbol in the equalized second m-ary modulation signal to produce the second electrical data signal.
2	The pluggable optical transceiver module of claim 1, wherein the form factor of the pluggable optical transceiver module is a pluggable form factor standard.
3	The pluggable optical transceiver module of claim 2, wherein the pluggable form factor standard of the pluggable optical transceiver module is a small form factor pluggable (SFP) or SFP+ form factor standard.
5	The pluggable optical transceiver module of claim 1, wherein the m-ary modulator and the m-ary demodulator perform m-ary quadrature amplitude modulation and de-modulation, respectively, that uses two or more bits per symbol.

6	The pluggable optical transceiver module of claim 1, wherein the m-ary modulator and the m-ary demodulator perform m-ary quadrature phase shift keying modulation and de-modulation, respectively, that uses two or more bits per symbol.
8	The pluggable optical transceiver module of claim 1, wherein the electrical system interface includes parallel signals.
10	The pluggable optical transceiver module of claim 1, wherein the first electrical data signal and second electrical data signal includes parallel electrical data signals.
11	The pluggable optical transceiver module of claim 1, wherein the electrical system interface includes an attachment unit interface (AUI) based interface.
12	The pluggable optical transceiver module of claim 1, wherein the first optical signal on a first wavelength is configured to emit into a first optical fiber and the second optical signal on a second wavelength is configured to be received from the first optical fiber.
13	The pluggable optical transceiver module of claim 1, wherein the first optical signal on a first wavelength is configured to emit into a first optical fiber and the second optical signal on a second wavelength is configured to be received from a second optical fiber.
14	The pluggable optical transceiver module of claim 1, wherein the noise removed by the equalizer includes intersymbol interference (ISI).
15	The pluggable optical transceiver module of claim 1, wherein the equalizer performs decision directed equalization on the second m-ary modulation signal to remove noise.
16	The pluggable optical transceiver module of claim 1, wherein the equalizer performs blind equalization on the second m-ary modulation signal to remove noise.
17	The pluggable optical transceiver module of claim 1, wherein the digital to analog converter is configured to shape, condition, or emphasize the first electrical m-ary analog modulation signal for improved transmission performance.
[22.Pre]	A pluggable optical transceiver module comprising of:
[22.A]	an electrical system interface for receiving a first electrical data signal and for transmitting a second electrical data signal;
[22.B]	an m-ary modulator for increasing the number of bits per symbol in the first electrical data signal to produce a first m-ary modulation signal;

[22.C]	a digital to analog converter for converting the first m-ary modulation signal to a first electrical m-ary analog modulation signal;
[22.D]	a driver for amplifying the first electrical m-ary analog modulation signal to an amplified first electrical m-ary analog modulation signal to drive an optical transmitter;
[22.E]	the optical transmitter for emitting a first optical signal on a first wavelength responsive to and representative of the amplified first electrical m-ary analog modulation signal from the driver;
[22.F]	an optical detector for receiving a second optical signal on a second wavelength to produce an electrical analog signal;
[22.G]	an amplifier for amplifying the electrical analog signal to an amplified electrical analog signal;
[22.H]	a clock data recovery unit for recovering clock and data information to produce a second m-ary modulation signal from the amplified electrical analog signal;
[22.I]	an equalizer for performing equalization on the second m-ary modulation signal to remove noise;
[22.J]	an m-ary demodulator for decreasing the number of bits per symbol in the equalized second m-ary modulation signal to produce the second electrical data signal; and
[22.K]	wherein the m-ary modulator and the m-ary demodulator perform m-ary pulse amplitude modulation and de-modulation, respectively, that uses two or more bits per symbol.
[23.Pre]	A pluggable optical transceiver module comprising of:
[23.A]	an electrical system interface for receiving a first electrical data signal and for transmitting a second electrical data signal;
[23.B]	an m-ary modulator for increasing the number of bits per symbol in the first electrical data signal to produce a first m-ary modulation signal;
[23.C]	a digital to analog converter for converting the first m-ary modulation signal to a first electrical m-ary analog modulation signal;
[23.D]	a driver for amplifying the first electrical m-ary analog modulation signal to an amplified first electrical m-ary analog modulation signal to drive an optical transmitter;
[23.E]	the optical transmitter for emitting a first optical signal on a first wavelength responsive to and representative of the amplified first electrical m-ary analog modulation signal from the driver;
[23.F]	an optical detector for receiving a second optical signal on a second wavelength to produce an electrical analog signal;

[23.G]	an amplifier for amplifying the electrical analog signal to an amplified electrical analog signal;
[23.H]	a clock data recovery unit for recovering clock and data information to produce a second m-ary modulation signal from the amplified electrical analog signal;
[23.I]	an equalizer for performing equalization on the second m-ary modulation signal to remove noise;
[23.J]	an m-ary demodulator for decreasing the number of bits per symbol in the equalized second m-ary modulation signal to produce the second electrical data signal; and
[23.K]	wherein the equalizer includes coefficients or weights configured to remove noise from the second m-ary modulation signal.

VII. Prosecution History

72. U.S. Patent Application No. 16/297,610 (the "'610 Application"), which matured into the '181 Patent, was filed on March 9, 2019. Ex. 1001. The Examiner solely rejected the claims of the '181 Patent application for nonstatutory double patenting over U.S. Patent 10,263,723 ("'723 Patent"), which is the immediate parent of the '181 Patent. Ex. 1002 at 76, 124. Applicants filed a terminal disclaimer to overcome the rejection. *Id.* at 64.

73. I also reviewed the file history for the '723 patent, *i.e.*, application Serial No. 15/884,351 ("the '351 Application"). Ex. 1025; Ex. 1026. There were no rejections for this application. *See generally* Ex. 1026.

74. I also have reviewed the prosecution history of the parent application for the '723 patent, U.S. Application No. 15/095,137 ("the '137 Application"),

which eventually issued as U.S. Patent No. 9,887,795 ("the '795 patent"). Ex. 1023; Ex. 1024.

75. Unlike the applications that led to the '723 and '181 Patents, the '137 Application was rejected twice. The '137 Application was filed with five claims. Ex. 1024 at 240-41. Independent claim 1 disclosed a method for m-ary modulation by an optical transceiver module that performed a number of signal processing steps. *Id.* Dependent claim 2 disclosed a number of optical transceiver form factors. *Id.* The remaining dependent claims (claims 3-5) disclosed m-ary modulation techniques and equalization methods. *Id.* None of the original claims included a "pluggable" limitation. *Id.*

76. During prosecution, the '137 Application was rejected twice. In a first rejection, claims 1 and 3-5 were rejected as anticipated by Brede (U.S. Patent No. 6,603,822). Ex. 1024 at 174-78. Claim 2 was rejected as obvious over Brede in view of Aronson (U.S. Pub. No. 2007/0031153) as Aronson disclosed the specific form factors of the optical transceiver module. *Id.*

77. Applicant amended claims 1-5 to include the "pluggable" limitation, arguing that the HDT disclosed in Brede was an OLT, not a pluggable transceiver. Ex. 1024 at 174-78, 152. For example, Applicant distinguished the OLT in Brede, where the optical elements are separate and distinct from the OLT, from the claimed

pluggable optical transceiver module, where the optical elements are included within the module.

> While Applicants' acknowledge that an OLT is a device that transmits and receives and thus can be considered a transceiver, however, the Brede optical elements (14, 16 of Fig. 3) are described as distinct elements that transmit and receive separately and NOT as a transceiver as in Applicants' claims. Additionally, these optical elements (14, 16) are connected to the OLT 12 via a coaxial cable interface (22, 28), again distinguished as distinct from the OLT 12 and again NOT as a pluggable optical transceiver module as in the Applicants' claims.

Ex. 1024 at 153. Applicant's argument for claim 2 was that the secondary reference lacked the network interface of the primary reference. Ex. 1024 at 154.

78. In a second rejection, claims 1, 3-7, 10, 13-16, 18, and 20-21 were rejected as anticipated by Brede. Ex. 1024 at 121-28. Claims 11-12, 17, and 19 were rejected as obvious over Brede. *Id.* Claims 2, 8, and 9, which related to form factors, were rejected as obvious over Brede in view of Sheth (U.S. Patent No. 7,729,617) as Sheth taught that standardized pluggable form factors were well known in the art. *Id.*

79. In response, Applicant reiterated the arguments from the first office action response. Ex. 1024 at 69-74. Specifically, that the HDT (*i.e.*, OLT) disclosed in Brede was not a pluggable transceiver, and the secondary reference lacked the network interface. *Id.* Moreover, Applicant further noted that no reference refers to the rack mounted HDT in Brede as an optical transceiver.

> [T]he HDT is a rack mounted unit that is securely mounted using eight screws to the metal frame of a shelf of a rack … Additionally, it should be noted that Brede's optical transmitters 14 and optical receivers 16 are yet more rack mounted units that connect to the HDT 12 via coaxial cables 22, 28 respectively, and importantly that none of these references refer to [sic] this entirety of rack mounted units as a pluggable optical transceiver, nor even just an optical transceiver as in the Examiner's interpretation, on the contrary these references teach away from this interpretation.

Ex. 1024 at 70.

80. After this response, the Examiner issued an allowance without any further explanation or remarks. Ex. 1024 at 56.

81. As explained in detail below, none of the primary references in this Petition disclose a rack mounted OLT with optical elements separate and distinct from the optical transceiver module. Instead, the primary references disclose optical transmitter and receiver elements that are integrated together within the transceiver module which, according to the Applicant, is what differentiates an optical transceiver module from an OLT. For example, Agazzi '341 discloses an "optical transceiver module" where "the transmitter and receiver sections … are implemented as a transceiver integrated circuit constructed as a single chip" (Ex. 1009 at 3:34-36, 4:61-65) and Agazzi '640 discloses an "optical communications transceiver" where "the receivers and transmitters are integrated on a single integrated circuit" (Ex. 1005 at 16:9-14, Abstract).

82. This would have changed to motivation-to-combine calculus as a POSITA would have understood the small optical transceiver modules with integrated optoelectronics as taught by the primary references in this Petition are more easily implemented in a pluggable form factor. Additionally, the argument raised by the Applicant to differentiate between the prior art OLT in Brede and an optical transceiver module would not apply to the primary references in this Petition because the primary references in this Petition disclose smaller optical transceiver modules with integrated optoelectronics, not OLTs which are larger devices used at the end of a point-to-point link to multiplex and demultiplex wavelengths. Ex. 1016 at 406.

VIII. Claim Construction

83. Based on my review of the ’181 Patent and its file history, a POSITA would have understood the claim terms in light of the specification, and interpreted them by using their plan and ordinary meaning in accordance with the then current state of the art.

IX. Prior Art References

a. Agazzi ’640 Overview

84. U.S. Patent No. 6,879,640 to Agazzi et al. (“Agazzi ’640”), titled “Method, Apparatus and System for High-Speed Transmission on Fiber Optic Channel,” issued on April 12, 2005, and derives from U.S. Patent Application No.

09/693,709, which was filed on October 20, 2000. Ex. 1005 at 1. Agazzi '640 was not considered during prosecution of the '181 Patent.

85. Agazzi '640 teaches an optical transceiver module that processes signals for an optical channel using m-ary modulation/demodulation, equalization, and forward error correction codes. *Id.* at 16:7-19, 3:12-49. The goal of the invention in Agazzi '640 is use "channel coding and bandwidth efficient modulation techniques to overcome the limitations of low quality optical channels and result in higher transmission rates and reduced system costs." *Id.* at 1:44-48. Specifically, Agazzi '640 teaches "complex digital signal processing (DSP) and coding algorithms" implemented "in a singled monolithic chip" to reduce costs and increase bandwidth. *Id.* at 3:40-4:4. Agazzi '640 further teaches a small optical transceiver module where the "transmitters and receivers can be integrated on a single integrated circuit." *Id.* at Abstract.

b. Wei Overview

86. U.S. Patent No. 6,873,800 to Wei et al. ("Wei"), titled "Hot Pluggable Optical Transceiver in a Small Form Pluggable Package," issued on March 29, 2005, and derives from U.S. Patent Application No. 09/656,779, which was filed on September 7, 2000. Ex. 1006 at 1. Wei was not considered during prosecution of the '181 Patent.

87. Wei teaches a hot pluggable small form factor optical transceiver module. *Id.* 3:29-32. The goal of the invention in Wei is to create a pluggable optical transceiver module that is more compact and has a higher data throughput than other pluggables on the market at the time to allow for easier servicing of communication systems and shorter downtimes. *Id.* at 1:60-2:11. To accomplish this, Wei teaches how to produce a SFP transceiver. *Id.* at 3:29-32. Specifically, Wei teaches "vertically stacked receiver and transmitter printed circuit boards" allows packaging the functions of larger pluggables, like a GBIC, into smaller form factors. *Id.* at 2:28-35.

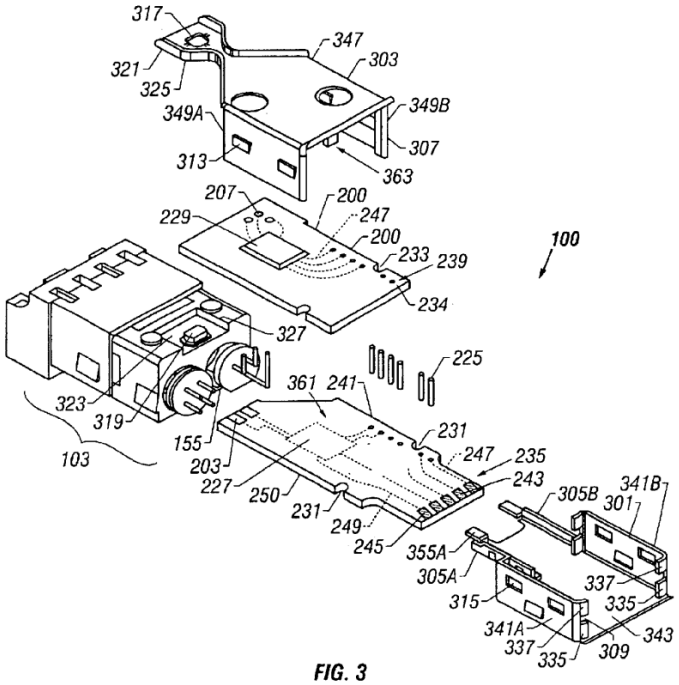


FIG. 3

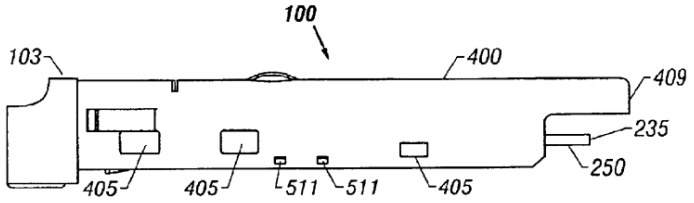


FIG. 6C

c. Agazzi '341 Overview

88. U.S. Patent No. 7,933,341 to Agazzi et al. ("Agazzi '341"), titled "System and Method for High Speed Communications using Digital Signal Processing," issued on April 26, 2011, and derives from U.S. Patent Application No. 09/797,428, which was filed on February 28, 2001, and published as U.S. Patent Application Publication No. 2001/0035994 on November 1, 2001. Ex. 1009 at 1. Agazzi '341 was not considered during prosecution of the '181 Patent. Agazzi '341 does not share priority with Agazzi '640.

89. Agazzi '341 teaches an optical transceiver module that processes signals for an optical channel using m-ary modulation, equalization, and forward error correction codes. *Id.* at 2:8-29, 4:33-39. The goal of the invention in Agazzi '341 is to increase the bandwidth and transfer rate of data across existing communications systems and to do so "in a cost effective manner." *Id.* at 1:31-51. Agazzi '341 further teaches a small optical transceiver module with a transmitter and receiver on an "integrated circuit constructed as a single chip." *Id.* at 4:63-65.

For example, "the transmitter and receiver sections 50 and 82 typically would be implemented as a CMOS PHY transceiver integrated circuit." *Id.* at 14:50-52.

X. Grounds 1-2 render the challenged claims obvious.

a. Ground 1: The combination of Agazzi '640 and Wei render claims 1-3, 5-6, 8, 10-14, 17, and 22 obvious.

90. Both Agazzi '640 and Wei are directed to optical transceiver modules with integrated optoelectronics that interface optical fibers to electronic circuitry by converting between optical signals and electrical signals. Ex. 1006 at 1:24-30; Ex. 1005 at 4:15-32, 12:18-23, 15:7-10, 16:7-14, Figs. 1D, 2A, 3. Indeed, Agazzi '640 and Wei both teach transceiver modules that include an electrical system interface, an optical transmitter, an optical receiver, and an amplifier. Ex. 1005 at Figs. 1D, 2A, 3, 2:1-11, 7:14-24, 2:66-3:4; Ex. 1006 at 1:24-45, 4:40-55.

91. As explained *supra*, Wei specifically discloses vertically stacked transmitter and receiver printed circuit boards that allow for the functionality of larger GBIC modules to be included inside an SFP package. This accomplishes the stated goal in Wei—creating a smaller, more compact transceiver module that is hot pluggable with "reduce[d] manufacturing costs" in order to allow service technicians to quickly replace damaged transceiver modules with limited down time. Ex. 1006 at 1:53-2:11.

92. Agazzi '640 specifically teaches a transceiver module that performs signal processing, including m-ary modulation, equalization, and error correction.

This allows the transceiver module in Agazzi ’640 to transmit data at higher rates through existing fiber infrastructure, which is a specific goal of Agazzi ’640. Ex. 1005 at 2:66-3:55. Agazzi ’640 also teaches that “it is desirable to achieve high levels of chip integration, which requires that all analog processing functions, such as amplifiers, mixers, analog filters and data converters be integrated in a single chip.” Ex. 1005 at 4:9-13. Agazzi ’640 further teaches that “[a]ll of the electronics illustrated in FIG. 2 and encompassed within the dotted line 225 may be integrated into a single integrated circuit, for example a CMOS integrated circuit chip. By integrating all the electronics within the block 225 on a single chip, the system cost may be reduced. By placing as much of the processing as possible within the integrated circuit 225, costs of assembly, alignment and multiple optical parts may be greatly reduced.” Ex. 1005 at 9:33-41.

93. Agazzi ’640 does not, however, expressly disclose a pluggable transceiver module in a small form factor package as taught in Wei. Nor does Wei expressly disclose the signal processing techniques taught in Agazzi ’640. A POSITA would have understood that the transceiver as contemplated in Agazzi ’640, which was taught as constructed as a single chip, would have been implemented in a SFP transceiver as taught in Wei. And a POSITA would have been motivated to combine the transceiver module of Agazzi ’640 with the SFP package of Wei to

create a smaller transceiver with greater data throughput that was easily removable and cost-effective.

94. There are several reasons a POSITA would have been motivated to combine Agazzi '640 with Wei. First, market pressures were increasing the demand for compact pluggable transceivers with high data throughput rates in a standardized form factor as users desired a high throughput pluggable transceiver which led the industry to standardize the SFP form factor to ensure compatibility across fiber-optic systems. Ex. 1006, 1:66-2:4; Ex. 1014. Accordingly, as a result of consumer preferences and industry standards, a POSITA would have understood that higher throughput pluggable transceivers in an SFP form factor were needed. Second, an m-ary pluggable transceiver module would be easier to install, repair, and replace than a mounted transceiver. Ex. 1006 at 2:5-11. This would decrease the chances for improper installation. It also decreases the likelihood that other components near the transceiver would be damaged during servicing. An m-ary pluggable transceiver would also take less time to install, repair, and/or replace. Ex. 1006 at 2:5-11. This, in turn, means less down time for the fiber-optic system during maintenance or servicing of the transceiver. Ex. 1011 at 1:45-52.

95. Third, an m-ary pluggable transceiver in a SFP package was more compact and takes less room than other transceivers. Decreasing the size was a stated goal in both Agazzi '640 and Wei. Ex. 1005 at 9:33-41; Ex. 1006 at 1:67-2:4.

Thus, a POSITA would have been motivated to combine Agazzi '640 with Wei to create a smaller transceiver. This is because Wei discloses how to efficiently package transceiver components to fit within a pluggable form factor: "separate vertically stacked printed circuit boards allows packaging the functions of [larger modules] within an LC or other small form factor package" like the SFP. Ex. 1006 at 2:1-2, 2:28-32. A POSITA would have understood how to package the components of a module like Agazzi '640 into an SFP based on the disclosure in Wei. This was important because OLTs and ONTs often have many components, such as switches and routers, located in large racks. Therefore, space was a limiting factor in many cases and smaller optical components were desired.

96. Fourth, an m-ary pluggable transceiver was more cost effective. Decreasing costs was a stated goal in both Agazzi '640 and Wei. Ex. 1005 at 1:45-49; Ex. 1006 at 1:50-69. Thus, a POSITA would have been motivated to combine Agazzi '640 with Wei to create an m-ary pluggable transceiver because pluggable transceivers were easier to install, repair, and replace, which allowed less skilled technicians to be able to service the communication system. Ex. 1006 at 2:5-11. Moreover, technicians did not have to repair and replace larger equipment, like a switch or router, when an optoelectrical component in a mounted transceiver failed. Instead, the technician simply replaced the hot pluggable transceiver with a new transceiver. And manufacturing costs were decreased when transceivers were

produced separate from other optoelectrical equipment on printed circuit boards. Ex. 1006 at 1:45-60. Further, the smaller size of the transceiver allowed the optical equipment to take up less space, thus saving on rent and utilities. And, importantly, the increased data throughput rates of m-ary pluggable transceivers allowed for higher data speeds without the need to replace older fiber channels.

97. Fifth, an m-ary pluggable transceiver would have higher data throughput rates in a small form factor. Increasing the data throughput rate in the transceiver was a stated goal in both Agazzi '640 and Wei. Ex. 1005 at 2:66-3:55; Ex. 1006 at 1:66-2:4. Accordingly, a POSITA who wanted to maintain high data throughput rates, as taught by Agazzi '640's use of m-ary modulation, would have looked to Wei when evaluating how to package a high throughput transceiver in a SFP form factor as Wei also taught high data throughput. This allowed for more data to be transferred in the same channel over the same amount of time as traditional binary modulation and was a simple way to increase data speeds in a communication system because it did not require replacement of older fiber channels.

98. Moreover, a POSITA would have had a reasonable expectation of success in combing the transceivers in Agazzi '640 and Wei to produce expected results. In fact, many of the expected results of the combination were stated goals in the references.

99. A POSITA also would have been motivated to combine transceivers that perform advanced signal processing, like in Agazzi '640, with a pluggable transceiver, like in Wei, after reviewing the prior art. For example, U.S. Patent No. 6,665,498 to Jiang ("Jiang") discloses a high speed transceiver module that has a transmitter, receiver, amplifier, and clock data recovery unit. Ex. 1010 at 3:34-4:3. In addition to signal processing techniques, Jiang teaches that is it important to provide a smaller transceiver that is capable of conveying information at similar rates to larger transceivers, wherein the transceiver is "inexpensive to manufacture." Ex. 1010 at 1:54-61. Jiang also recommends making the transceiver pluggable, stating: "It is also easier to make the transceiver pluggable." Ex. 1010 at 5:34-41. A POSITA would thus have been motivated to combine signal processing capabilities inside a small pluggable transceiver.

100. As another example, U.S. Patent No. 6,295,272 to Feldman et al. ("Feldman") discloses a pluggable transceiver module in the form of a GBIC (the larger predecessor of the SFP) that conveys m-ary modulated signals from a subcarrier channel to a high speed channel. Ex. 1019 at Abstract, 6:21-29, Fig. 13. Although the m-ary modulation disclosed in Feldman occurs before the signal is conveyed by the GBIC, a POSITA would have understood that it is a simple step to add the m-ary functionality into the pluggable, thus reducing the number of

components. Moreover, Wei teaches "package[ing] the functions of a GBIC into the compact size of an SFP." Ex. 1006 at 2:1-4.

101. For at least these reasons, in reading Agazzi '640, a POSITA would have been motivated to look to the pluggable transceiver module in Wei and would have had a reasonable expectation of success in combining the two optical transceiver modules.

i. Claim 1: [1.pre] A pluggable optical transceiver module comprising of:

102. To the extent the preamble is limiting, a POSITA would have understood Wei discloses this limitation. Wei discloses a "fiber optic transceiver module" where the module is a "pluggable optical transceiver in a small form pluggable." Ex. 1006 at 2:17-20, 3:29-32. Specifically, Wei discloses an optical transceiver module "in a small form pluggable (SFP), LC package." Ex. 1006 at 2:1-4, 2:28-35. This is a standardized industry form factor set out in a multisource agreement. Ex. 1014. While I do not rely on Agazzi '640 for this limitation, Agazzi '640 also discloses an "optical communications transceiver." Ex. 1005 at 12:20.

ii. Claim 1: [1.A] an electrical system interface for receiving a first electrical data signal and for transmitting a second electrical data signal;

103. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses an optical transceiver module that includes an optical transmitter that receives an electrical data signal through the electrical system

interface, performs signal processing, converts it to an optical signal, and then transmits the optical signal onto the optical fiber. *See*, *e.g.*, Ex. 1005 at Fig. 2A, 10, 8:36-9:41. For example, in Figure 10 below, Agazzi '640 discloses the optical transmitter portion of the transceiver includes an "XGMII (Ten Gigabit Media Independent Interface) module" that receives digital electrical signals. Ex. 1005 at 8:36-49.

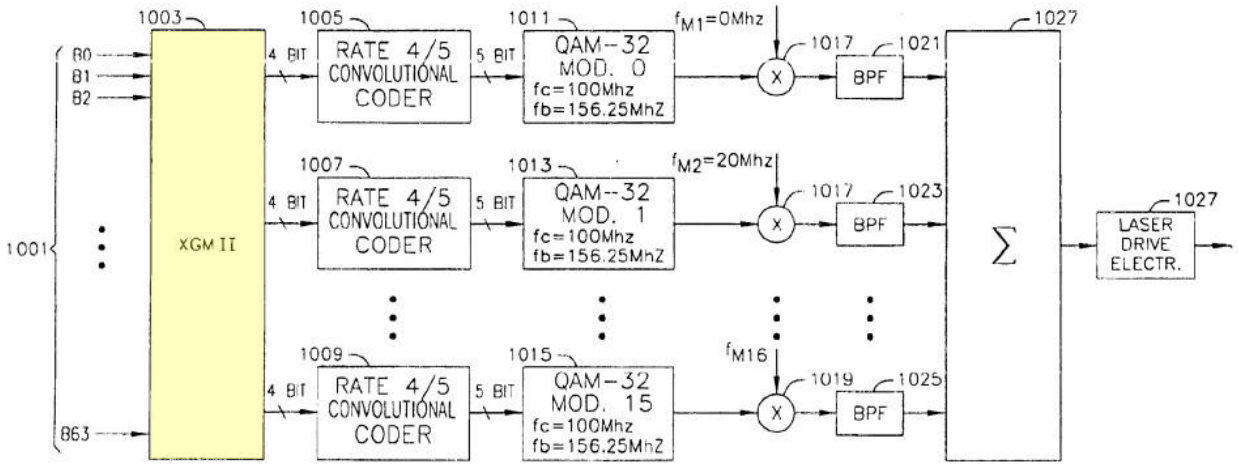


FIG. 10

Agazzi '640 further discloses that "[o]ther system interfaces besides the XGMII" can be used including, for example, the XAUI interface. Ex. 1005 at 8:51-65.

104. A POSITA would have understood the XGMII interface (in yellow above) to be an electrical system interface for the receipt of electrical data signals because the '181 Patent explicitly notes that the XGMII interface is a conventional system interface. Ex. 1001 at 9:22-26. A POSITA would further have understood that the electrical system interface receives many electrical data signals, each of

which is an example of the claimed "first electrical data signal." The "first" electrical data signal is an arbitrary name for a signal that passes through the electrical system interface.

105. Agazzi '640 also discloses an optical transceiver module that includes an optical receiver that receives an optical signal, converts it to an electrical signal, performs signal processing, and then transmits the electrical signal through the electrical system interface. *See, e.g.*, Ex. 1005 at Fig. 3A, 12, 10:14-57. For example, in Figure 12 below, Agazzi '640 discloses the optical receiver portion of the transceiver includes an "XGMII (Ten Gigabit Media Independent Interface) unit" that transmits digital electrical signals. Ex. 1005 at 10:46-57.

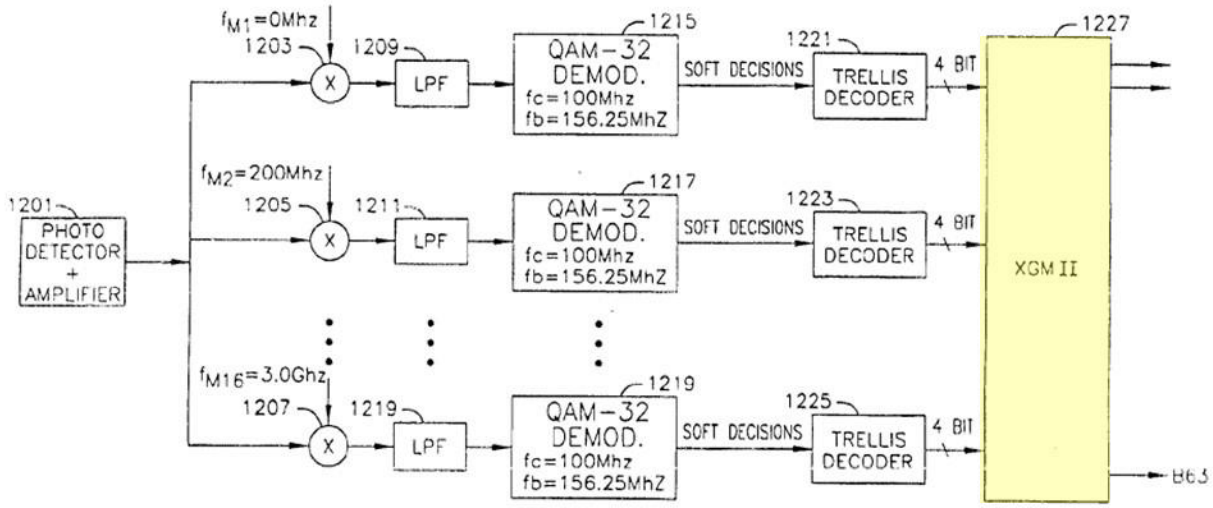


FIG. 12

106. A POSITA would have understood the XGMII interface (in yellow above) to be an electrical interface for the transmission of electrical data signals

because, as previously stated, the '181 Patent explicitly notes that the XGMII interface is a conventional system interface. Ex. 1001 at 9:22-26. A POSITA would further have understood that the electrical system interface transmits many electrical data signals, each of which is an example of the claimed "second electrical data signal." The "second" electrical data signal is an arbitrary name for a signal that passes through the electrical system interface.

iii. Claim 1: [1.B] an m-ary modulator for increasing the number of bits per symbol in the first electrical data signal to produce a first m-ary modulation signal;

107. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses a QAM-32 modulator (in yellow below) in the transmitter portion of the transceiver. Ex. 1005 at Fig. 10.

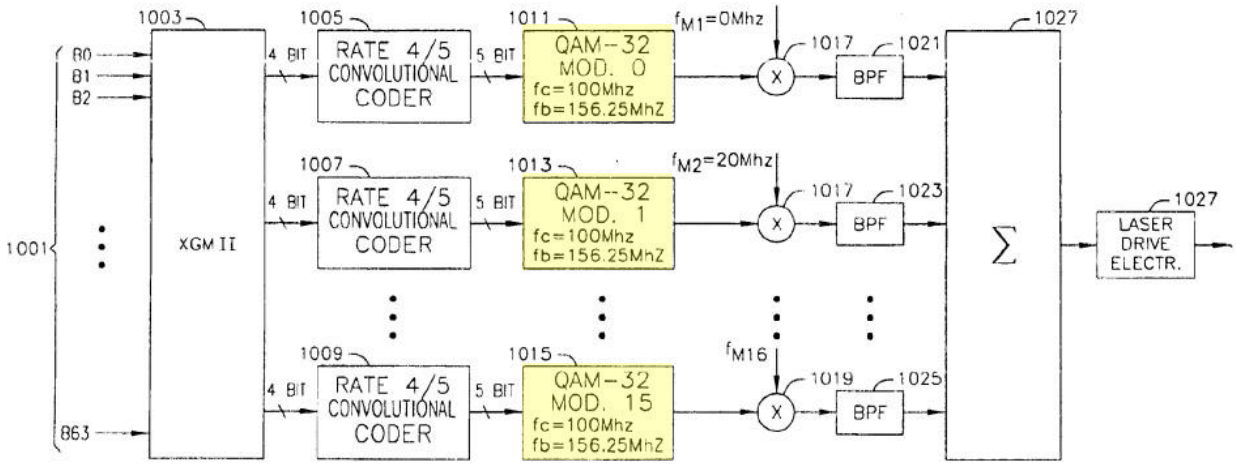


FIG. 10

108. Agazzi '640 teaches that the modulator can perform "Pulse Amplitude Modulation (***PAM***) or Quadrature Amplitude Modulation (***QAM***) to ***encode several***

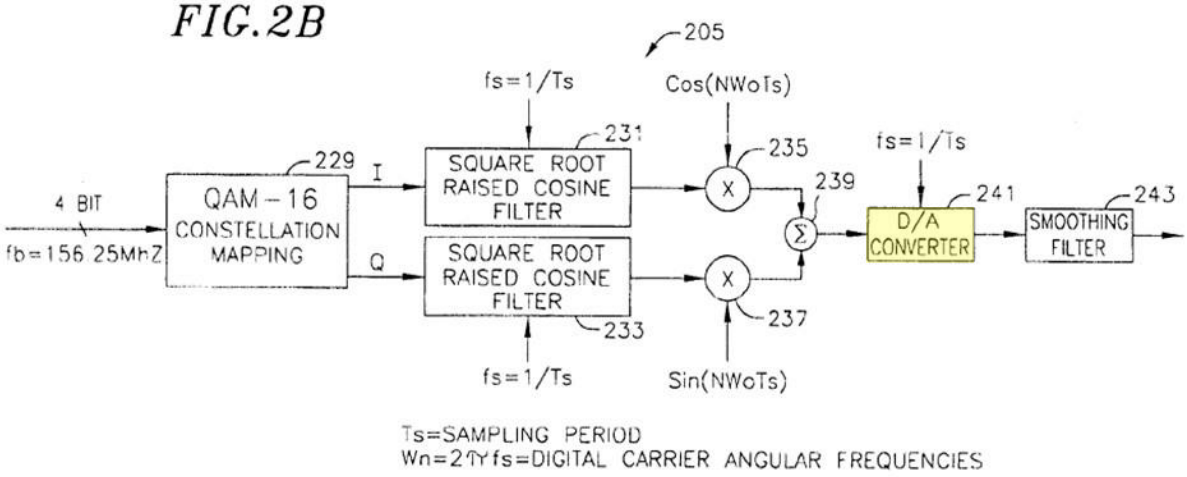
bits per transmitted ***symbol***." Ex. 1005 at 3:15-20 (emphasis added), Figs. 2A, 3, 10. Agazzi '640 further teaches that the modulator can perform QAM-16, QAM-32, PAM, and QPSK modulation. Ex. 1005 at 3:17, 9:1, 12:9, 17:7.

109. The modulators disclosed in Agazzi '640 include m-ary modulators because the '181 Patent identifies QAM, PAM, and QPSK as examples of m-ary modulation techniques. Ex. 1001 at 10:20-28. A POSITA would have understood that the m-ary modulator in Agazzi '640 converts a received signal (*i.e.*, first electrical data signal) to a modulated signal (*i.e.*, first m-ary modulation signal) using m-ary modulation.

iv. Claim 1: [1.C] a digital to analog converter for converting the first m-ary modulation signal to a first electrical m-ary analog modulation signal;

110. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses a block diagram of a m-ary modulator. Ex. 1005 at Fig. 2B, 2:28-29. As shown in Figure 2B, after passing through the m-ary modulator, the signals pass through a digital to analog ("D/A") converter that converts digital signals to analog signals (in yellow below). Ex. 1005 at Fig. 2B.

FIG. 2B



111. Figure 2B is a block diagram of the QAM modulator in Figure 2A, which depicts a transmitter system. Ex. 1005, 2:26-29. Figure 10 which I reference earlier is directly related to Figure 2A. *Id.*, 2:54-55. Agazzi '640 teaches that Figure 10 illustrates a slight modification of Figure 2A—it incorporates a coder. *Id.* Accordingly, the depiction of the QAM modulator in Figure 2B is applicable to Figure 10 as well because Figure 10 also includes a QAM modulator. A POSITA would have understood that the D/A converter (*i.e.*, digital to analog converter) converts a received digital signal (*i.e.*, first m-ary modulation signal) to an analog signal (*i.e.*, first electrical m-ary analog modulation signal).

v. Claim 1: [1.D] a driver for amplifying the first electrical m-ary analog modulation signal to an amplified first

electrical m-ary analog modulation signal to drive an optical transmitter;

112. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses an optical transmitter that includes a laser, and a laser driver (in yellow below). Ex. 1005 at 2:54-55, 7:18-21, 10:14-16, Fig. 10.

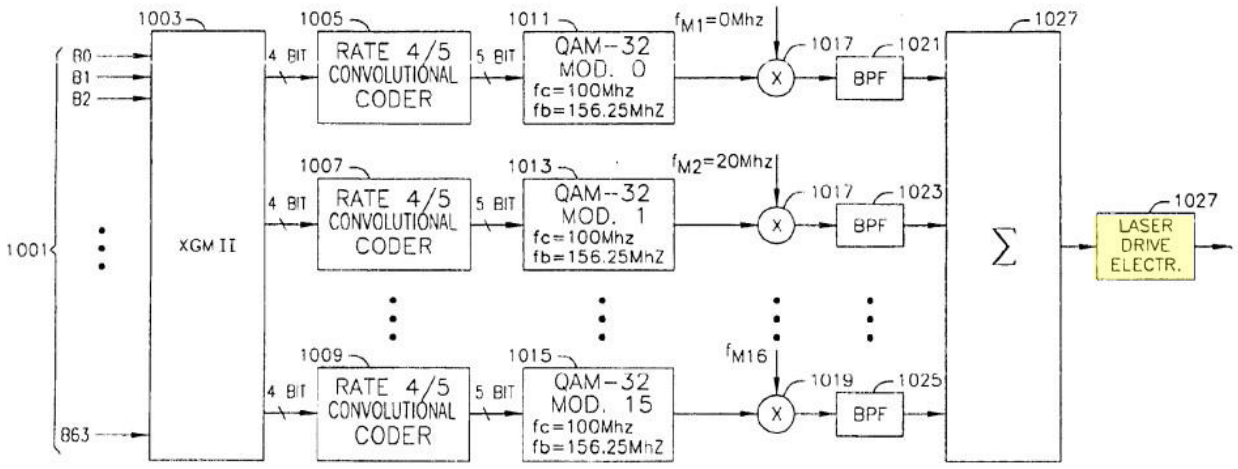


FIG. 10

113. Agazzi '640 further discloses that "[t]he analog waveform is then coupled into laser drive electronics[] and is used to modulate the laser intensity using drive electronics … [where] the laser drive electronics[] intensity modulates the laser beam." Ex. 1005 at 11:4-15. A POSITA would have understood that the encoded analog m-ary modulation signals are amplified by the laser drive electronics to ensure the signals are sufficiently strong to drive the laser, which emits optical signals that must be able to travel long distances through optical fibers. Optical transmitters are based on lasers that must be driven by a sufficient amount of current to cause lasing. Laser drive circuits are designed to amplify the modulated signal so

that it exceeds this lasing threshold. Ex. 1017, 399-403. For example, a prior art textbook teaches a "laser drive circuit … consists of two differential amplifiers … The two differential amplifiers provide sufficient modulation current amplitude for the laser." Ex. 1017, 400. A POSITA would also have understood that the laser drive electronics (*i.e.*, driver) in Agazzi '640 amplifies a received signal (*i.e.*, first electrical m-ary analog modulation signal) to produce an amplified signal (*i.e.*, amplified first electrical m-ary analog modulation signal) to drive the laser (*i.e.*, optical transmitter).

vi. Claim 1: [1.E] the optical transmitter for emitting a first optical signal on a first wavelength responsive to and representative of the amplified first electrical m-ary analog modulation signal from the driver;

114. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses an "optical transmitter" that includes a laser that "transmits the data across a fiber optic channel." Ex. 1005, 7:18-19, 10:14-16. Agazzi '640 further discloses the "signal from the laser drive electronics [] is provided to a laser … The output of the laser is coupled to a fiber optic channel." Ex. 1005, 10:14-16. As I explain in the technical background section, the optical transmitter produces optical signals based received electrical signals, where the optical signal is representative of the electrical signal. *See supra*, SectionV(b). A POSITA would have understood that the laser (*i.e.*, optical transmitter) is driven by (*i.e.*, is responsive to) an electrical signal (*i.e.*, amplified first electrical m-ary analog

modulation signal) from the laser drive electronics (*i.e.*, driver), produces a corresponding (*i.e.*, representative) optical signal, and then emits the optical signal (*i.e.*, first optical signal on a first wavelength) onto an optical fiber.

vii. Claim 1: [1.F] an optical detector for receiving a second optical signal on a second wavelength to produce an electrical analog signal;

115. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses an optical receiver that includes a photo detector (*i.e.*, optical detector, which is shown in yellow below) that receives optical signals (*i.e.*, second optical signal on a second wavelength) and converts the optical signals to electrical signals (*i.e.*, electrical analog signal). Ex. 1005 at Fig. 12.

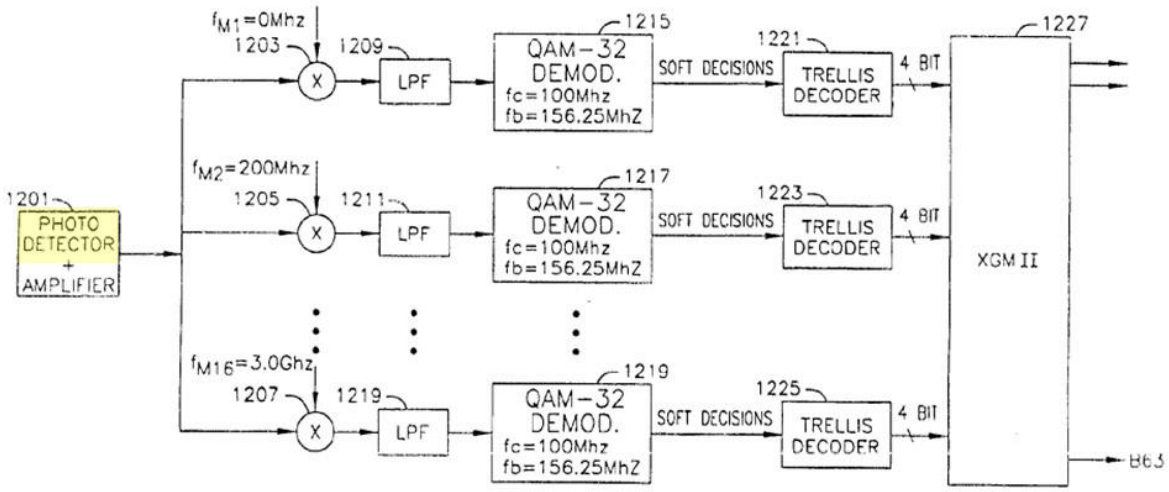


FIG. 12

116. For example, Agazzi '640 discloses "[t]he photo detector and amplifier[] receive the multi-carrier modulated signal from the fiber optic and

convert it into an electrical signal." Ex. 1005 at 11:17-22. Agazzi '640 further teaches that the "photodetector and amplifier[] converts the optical signal into a voltage level." *Id.* at 10:18-20. A POSITA would have understood the voltage level corresponds to analog signals as Agazzi '640 teaches performing analog to digital conversion after the signal is received by the photodetector. Ex. 1005 at Fig. 5. A POSITA would have understood that the photodetector (*i.e.*, optical detector) receives the signal when it is an optical signal, then produces an electrical analog signal that corresponds to the received optical signal. A POSITA would further have understood that the photodetector receives many optical signals, one of which is the claimed "second optical signal on a second wavelength."

viii. Claim 1: [1.G] an amplifier for amplifying the electrical analog signal to an amplified electrical analog signal;

117. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses an amplifier (shown in yellow below) that amplifies the electrical analog signals received from the photodetector. Ex. 1005 at 2:66-3:11, Fig. 3, 12.

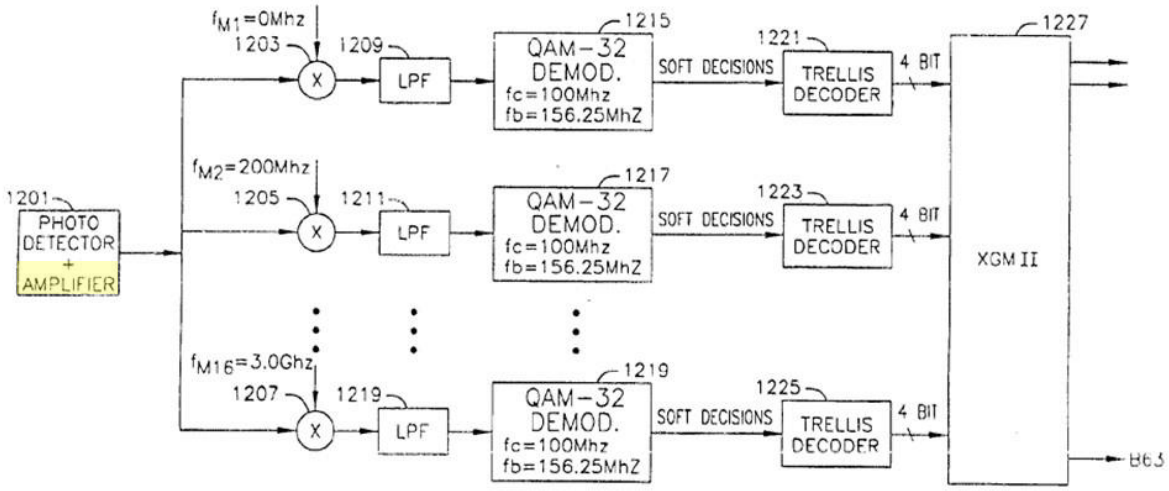


FIG. 12

118. A POSITA would have understood that the amplifier amplifies a received signal (*i.e.*, electrical analog signal) to produce an amplified signal (*i.e.*, amplified electrical analog signal).

ix. Claim 1: [1.H] a clock data recovery unit for recovering clock and data information to produce a second m-ary modulation signal from the amplified electrical analog signal;

119. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses "an optical communications transceiver." Ex. 1005 at 16:10-11. Agazzi '640 further discloses that "[o]ptical communications systems may achieve very high data rates as a result of the high bandwidth of the optical fibers and the availability of high-speed lasers and photo detectors, as well as wideband laser drivers, transimpedance amplifiers, postamplifiers, and ***clock and data recovery circuits.***" Ex. 1005 at 2:66-3:4 (emphasis added). In particular,

Agazzi '640 depicts recovered clock data information (in yellow below) in the demodulation block. *Id.* at Fig. 12, 13:20-22.

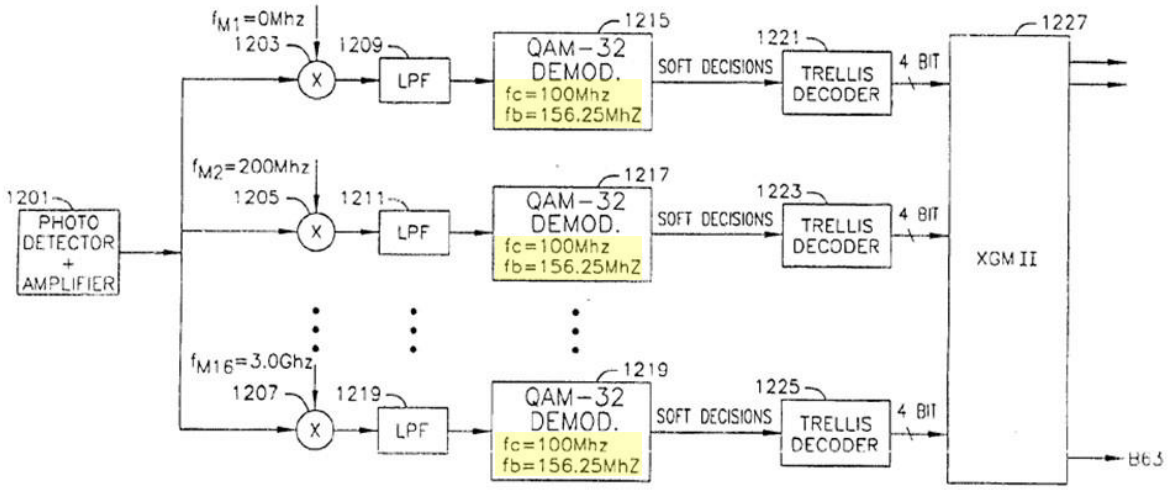


FIG. 12

Moreover, it was well-known to a POSITA that clock data recovery was a routine part of the signal processing performed at the receiver, which occurs before data is recovered during demodulation. *See, e.g.*, Ex. 1016 at 265-66. For example, a prior art textbook teaches that "the clock must be extracted from the received signal." *Id.* at 266. And the '181 Patent teaches that clock recovery occurs before demodulation. Ex. 1001, 10:47-11:7. As depicted in Figure 12 of Agazzi '640, clock data information is recovered from an input signal (*i.e.*, amplified electrical signal) to produce an output signal (*i.e.*, second m-ary modulation signal) that is ready for demodulation.

x. Claim 1: [1.I] an equalizer for performing equalization on the second m-ary modulation signal to remove noise; and

120. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses that "[t]he present invention also describes … equalization." Ex. 1005 at 4:55-59. Agazzi '640 further discloses that "[i]t is desirable to replace optical equalization techniques by DSP-based equalization techniques, in order to take advantage of electronic components which are generally less expensive that their optical counterparts." Ex. 1005 at 4:5-8. Performing equalization on the second m-ary modulation signal is a DSP-based equalization technique. Figure 12 below illustrates the digital signal processing that occurs in the receiver system. As QAM modulation is a high data throughput technique, and Agazzi '640 teaches that increased data rates results in increased distortion and inter-symbol interference, an equalizer is required to remove the distortion. Ex. 1005, 1:33-37. A POSITA would have understood the equalizer was located within the boxed area as distortion must be removed before demodulation. For example, a Broadcom presentation from 1996 illustrates a QAM receiver, like that in Agazzi '640, that includes an equalizer before the decoder. Ex. 1033, 2.

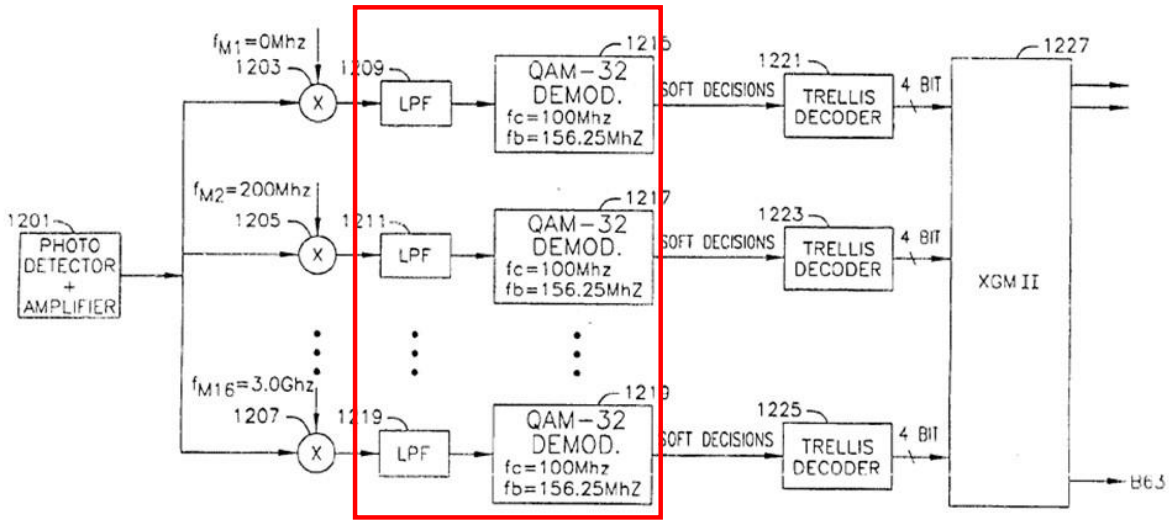


FIG. 12

121. Agazzi '640 also discloses that "channel equalization techniques may also be used to compensate pulse dispersion and the resulting inter-symbol interference caused by frequency-dependent attenuation and phase distortion introduced by the channel." Ex. 1005 at 3:20-26. As the '181 Patent characterizes ISI as noise, the equalizer in Agazzi '641 reduces noise by compensating for ISI. Ex. 1001 at 12:20-26, 16:14-17. Moreover, it was well-known in the art at the time that equalizers are used to reduce noise. *See supra*, Section V(d). A POSITA would have understood that the equalizer in Agazzi '640 equalizes a received signal (*i.e.*, second m-ary modulation signal) to reduce noise.

xi. Claim 1: [1.J] an m-ary demodulator for decreasing the number of bits per symbol in the equalized second m-ary modulation signal to produce the second electrical data signal.

122. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses a QAM-32 demodulator (shown in yellow below) in the receiver portion of the transceiver. Ex. 1005 at Fig. 12.

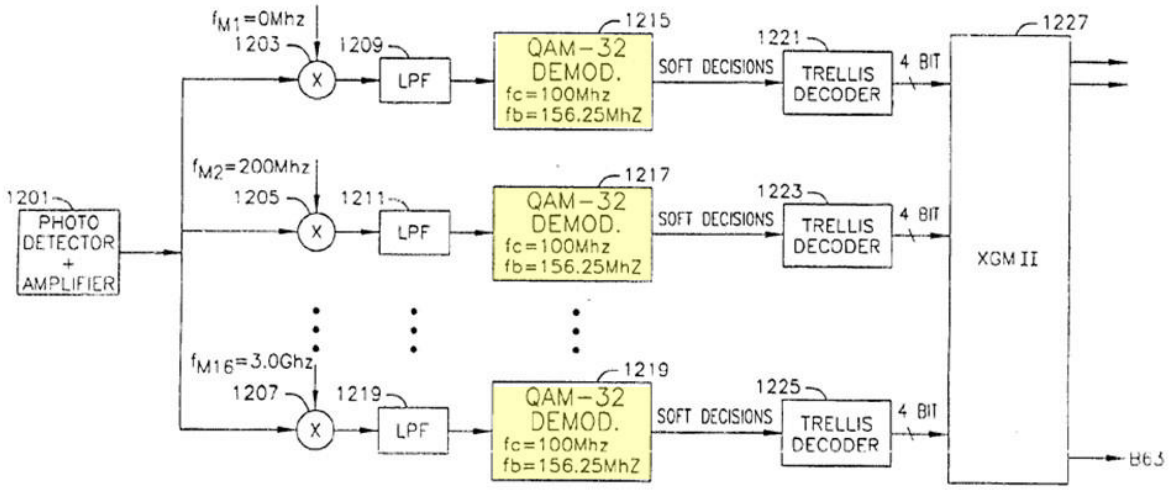


FIG. 12

123. Agazzi '640 further discloses "demodulators, which will demodulate the signal according to the modulation used by the transmit apparatus." Ex. 1005 at 2:1-11, Figs. 3, 12. The QAM-32 demodulators disclosed in Agazzi '640 are m-ary demodulators because the '181 Patent identifies QAM, PAM, and QPSK as examples of m-ary modulation techniques. Ex. 1001 at 10:20-28. The '181 Patent also explains that m-ary demodulators decrease the number of bits per symbol. Ex. 1001 at 15:31-33. A POSITA would have understood that the QAM-32 demodulator

(*i.e.*, m-ary demodulator) demodulates the input signal (*i.e.*, equalized second m-ary modulation signal) to produce a demodulated output signal (*i.e.*, second electrical data signal).

xii. Claim 2: The pluggable optical transceiver module of claim 1, wherein the form factor of the pluggable optical transceiver module is a pluggable form factor standard.

124. A POSITA would have understood Wei discloses this limitation. Wei discloses a "fiber optic transceiver module" with "vertically stacked printed circuit boards allows packaging the [transceiver] within an LC or other ***small form factor package***." Ex. 1006 at 2:17-35 (emphasis added). Specifically, Wei discloses a "***small form pluggable (SFP)***" transceiver. Ex. 1006 at 2:1-4. As I explain in the technical background section, multisource agreements define the physical requirements for standardized pluggable form factors, which include the SFP. *See supra*, Section V(b). A POSITA would have understood that an SFP was a pluggable form factor standard for optical transceiver modules.

xiii. Claim 3: The pluggable optical transceiver module of claim 2, wherein the pluggable form factor standard of the pluggable optical transceiver module is a small form factor pluggable (SFP) or SFP+ form factor standard.

125. A POSITA would have understood Wei discloses this limitation. Wei discloses a "fiber optic transceiver module" with "vertically stacked printed circuit boards allows packaging the [transceiver] within an LC or other ***small form factor package***." Ex. 1006 at 2:17-35 (emphasis added). Specifically, Wei discloses a

"***small form pluggable (SFP)***" transceiver. Ex. 1006 at 2:1-4. As I explain in the technical background section, multisource agreements define the physical requirements for standardized pluggable form factors, which include the SFP. *See supra*, Section V(b). A POSITA would have understood that an SFP was a pluggable form factor standard for optical transceiver modules.

xiv. Claim 5: The pluggable optical transceiver module of claim 1, wherein the m-ary modulator and the m-ary demodulator perform m-ary quadrature amplitude modulation and de-modulation, respectively, that uses two or more bits per symbol.

126. A POSITA would have understood the combination of Agazzi '640 and Wei discloses this limitation. Agazzi '640 discloses performing multilevel modulation within the transmitter portion of the optical transceiver, including "***Quadrature Amplitude Modulation*** (QAM) to ***encode several bits per*** transmitted ***symbol***." Ex. 1005 at 3:15-20 (emphasis added), Figs. 2A, 10. Agazzi '640 further discloses, in the receiver portion of the optical transceiver, "demodulators, which will demodulate the signal according to the modulation used by the transmit apparatus." Ex. 1005 at 2:1-11, Figs. 3, 12.

127. The '181 Patent identifies QAM as an example of m-ary modulation. Ex. 1001 at 10:20-28. A POSITA would have understood the QAM modulator/demodulator disclosed in Agazzi '640 to cover m-ary QAM modulation/demodulation because the '181 Patent disclosed QAM modulation as a type of m-ary modulation.

128. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xv. Claim 6: The pluggable optical transceiver module of claim 1, wherein the m-ary modulator and the m-ary demodulator perform m-ary quadrature phase shift keying modulation and de-modulation, respectively, that uses two or more bits per symbol.

129. A POSITA would have understood the combination of Agazzi '640 and Wei discloses this limitation. Agazzi '640 discloses performing multilevel modulation within the transmitter portion of the optical transceiver, including "***quadrature phase shift keying*** (QPSK)." Ex. 1005 at 17:5-8 (emphasis added). Agazzi '640 further teaches that multilevel modulation, like QPSK, is used "to ***encode several bits per*** transmitted ***symbol***." Ex. 1005 at 3:15-20 (emphasis added), Figs. 2A, 10. Agazzi '640 further discloses, in the receiver portion of the optical transceiver, "demodulators, which will demodulate the signal according to the modulation used by the transmit apparatus." Ex. 1005 at 2:1-11, Figs. 3, 12.

130. The '181 Patent identifies QPSK as an example of m-ary modulation. Ex. 1001 at 10:20-28. A POSITA would have understood the QPSK modulator/demodulator disclosed in Agazzi '640 to cover m-ary QPSK modulation/demodulation because the '181 Patent disclosed QPSK modulation as a type of m-ary modulation.

131. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xvi. Claim 8: The pluggable optical transceiver module of claim 1, wherein the electrical system interface includes parallel signals.

132. A POSITA would have understood the combination of Agazzi '640 and Wei discloses this limitation. Agazzi '640 discloses an optical transceiver module that employs "parallel processing architectures" in order to "process the higher data rates available in optical fibers." Ex. 1005 at 4:15-21, Figs. 2A, 3. Agazzi '640 further discloses transmitters and receivers that operate "in a parallel type format." Ex. 1005 at 7:1-9, 7:51-58, 11:17-44. A POSITA would have understood that the electrical interface was configured to receive/transmit parallel signals and that there would be multiple such signals. For example, in Figures 10 and 12 below, the electrical system interface (shown in yellow), where the electrical data signals are received/transmitted, show a number of parallel signals. Ex. 1005 at Figs. 10, 12.

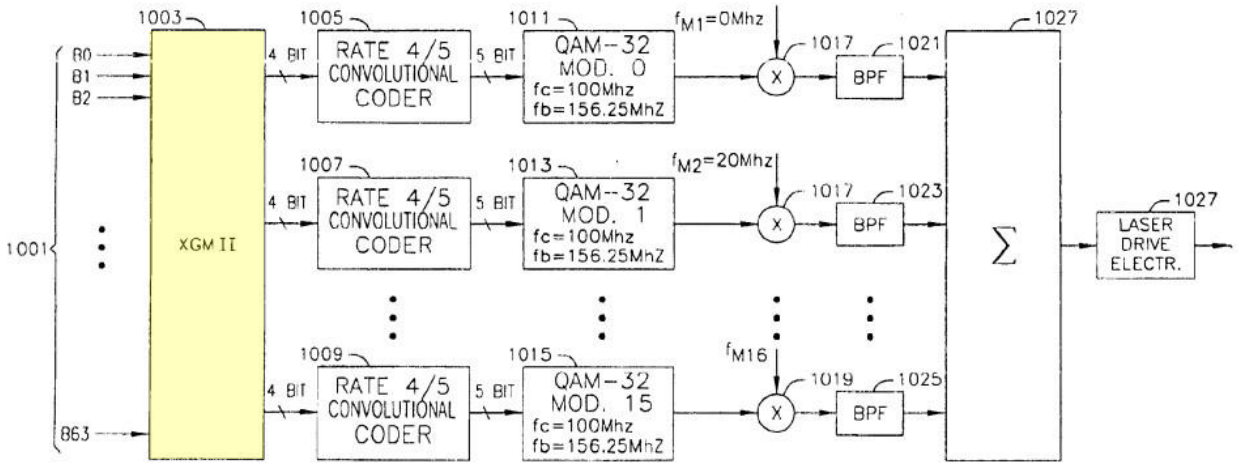


FIG. 10

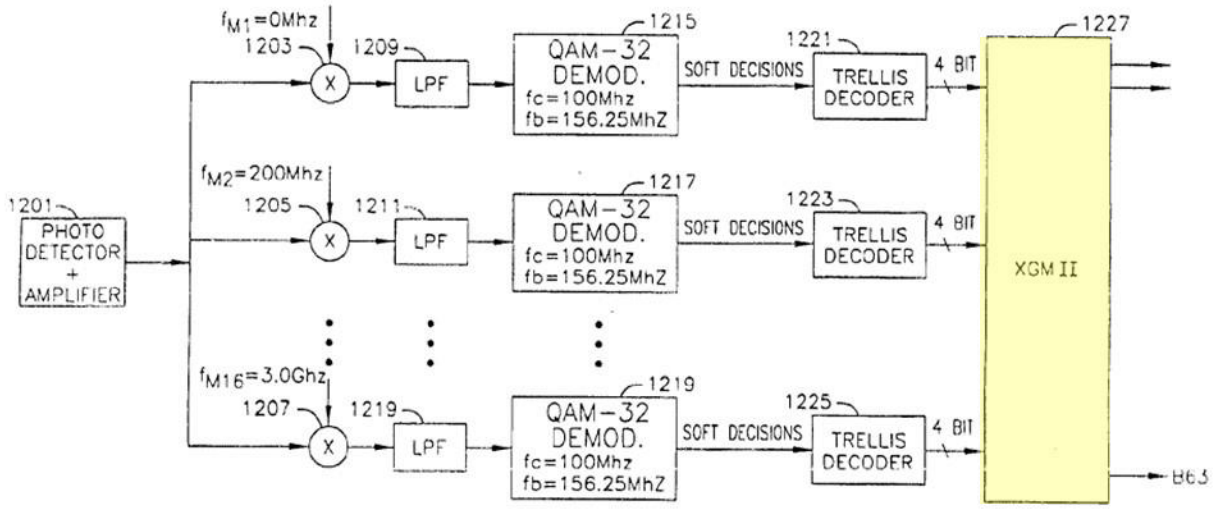


FIG. 12

133. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xvii. Claim 10: The pluggable optical transceiver module of claim 1, wherein the first electrical data signal and second electrical data signal includes parallel electrical data signals.

134. A POSITA would have understood the combination of Agazzi '640 and Wei discloses this limitation. Agazzi '640 discloses an optical transceiver module that employs "parallel processing architectures" in order to "process the higher data rates available in optical fibers." Ex. 1005 at 4:15-21, Figs. 2A, 3. Agazzi '640 further discloses transmitters and receivers that operate "in a parallel type format." Ex. 1005 at 7:1-9, 7:51-58, 11:17-44. A POSITA would have understood that the electrical interface was configured to receive/transmit parallel signals and that there would be multiple such signals. This is depicted in Figures 10 and 12 below. For example, the system interfaces (shown in yellow in Figs. 10 and 12 below), where the first electrical data signal is received into the transmitter and the second electrical data signal is transmitted out of the receiver, show that the signals include parallel signals. Ex. 1005 at Figs. 10, 12.

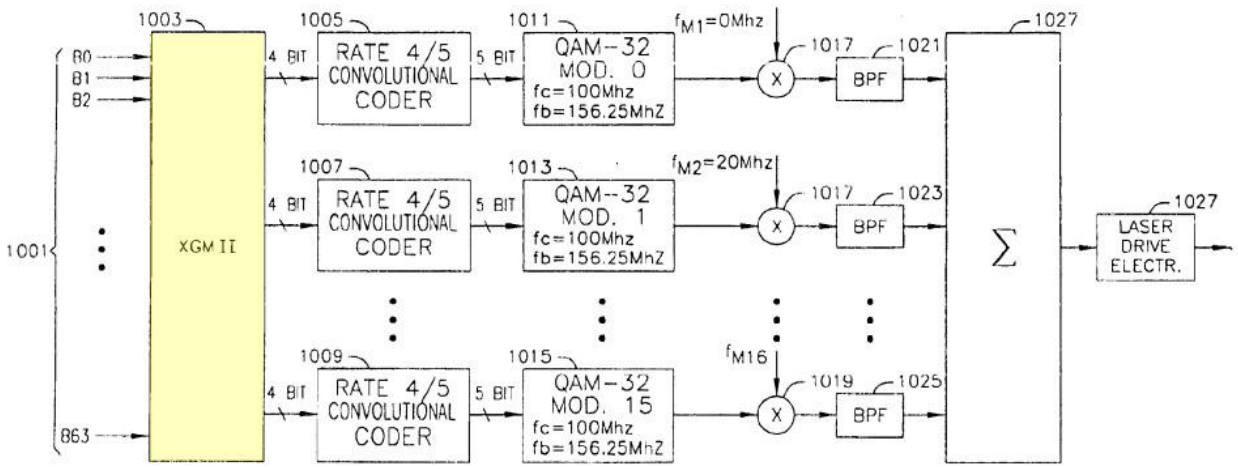


FIG. 10

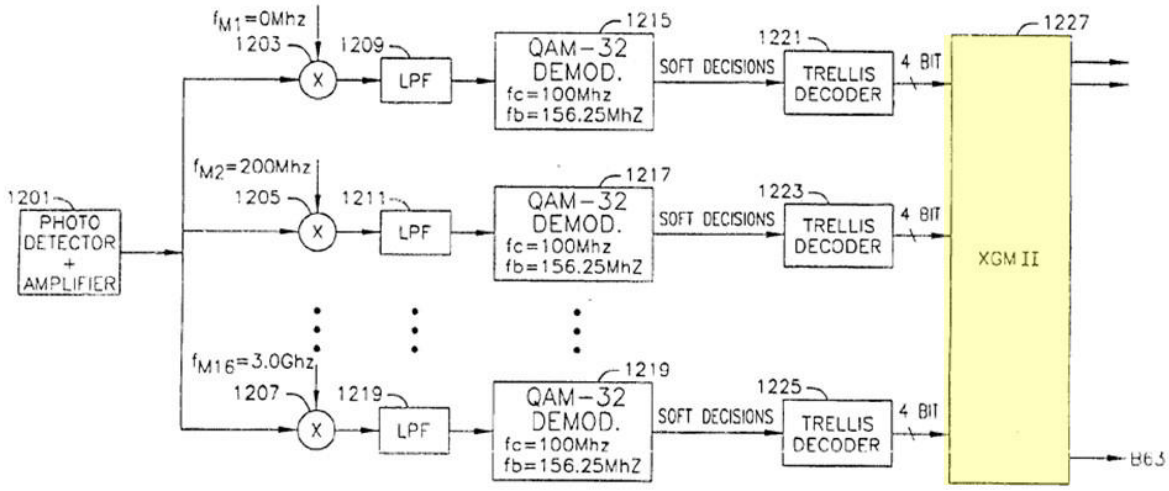


FIG. 12

135. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xviii. Claim 11: The pluggable optical transceiver module of claim 1, wherein the electrical system interface includes an attachment unit interface (AUI) based interface.

136. A POSITA would have understood the combination of Agazzi '640 and Wei discloses this limitation. The '181 Patent discloses that one type of AUI interface is the "XAUI" interface. Ex. 1001 at 9:25. Moreover, the prior art identifies the "10Gb/s attachment unit interface (XAUI)" in a standard defined by IEEE 802.3. Ex. 1028 at 1:39-45. Agazzi '640 discloses the "XAUI interface" as an option for the "system interface." Ex. 1005 at 8:52-56. A POSITA would have been familiar with the XAUI standard as it was defined by IEEE 802.3 and would have understood the XAUI interface in Agazzi '640 discloses the AUI limitation.

137. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xix. Claim 12: The pluggable optical transceiver module of claim 1, wherein the first optical signal on a first wavelength is configured to emit into a first optical fiber and the second optical signal on a second wavelength is configured to be received from the first optical fiber.

138. A POSITA would have understood the combination of Agazzi '640 and Wei renders this limitation obvious. Agazzi '640 discloses that "[t]he optical transmitter 123 transmits the data across a fiber optic channel 125 [and] the optical

receiver 107 accepts the data from the fiber optic channel 125." Ex. 1005 at 7:14-24, Fig. 1D.

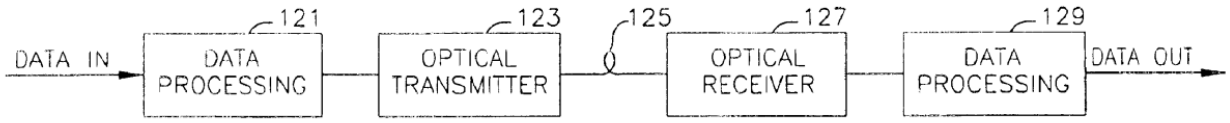


FIG. 1D

139. As shown in Figure 1D, Agazzi '640 discloses an optical transmitter that emits optical signals (*i.e.*, one of which is the first optical signal on a first wavelength) into the optical channel (*i.e.*, first optical fiber) and an optical receiver that receives optical signals (*i.e.*, one of which is the second optical signal on a second wavelength) from the optical channel (*i.e.*, first optical fiber). A POSITA would have understood that the optical channel, or cable, can include a single optical fiber or multiple optical fibers and that the two optical signals can traverse either different or the same optical fibers, as this was an obvious selection from a finite number of choices. For example, U.S. Patent No. 6,005,694 teaches that "dozens of fibers may be included in a single cable." Ex. 1011 at 1:39-41.

140. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xx. Claim 13: The pluggable optical transceiver module of claim 1, wherein the first optical signal on a first wavelength is configured to emit into a first optical fiber and the second optical signal on a second wavelength is configured to be received from a second optical fiber.

141. A POSITA would have understood the combination of Agazzi '640 and Wei renders this limitation obvious. Agazzi '640 discloses that "[t]he optical transmitter 123 transmits the data across a fiber optic channel 125 [and] the optical receiver 107 accepts the data from the fiber optic channel 125." Ex. 1005 at 7:14-24, Fig. 1D. Agazzi '640 also teaches "the block diagram of FIG. 1D may have a variety of possible implementations. Ex. 1005 at 7:25-26.

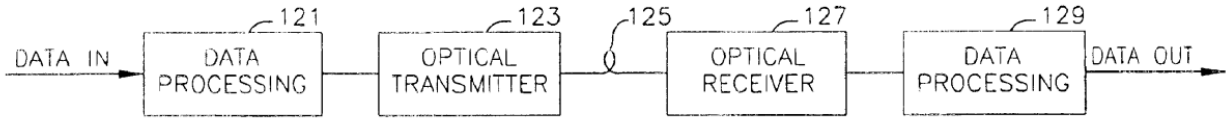


FIG. 1D

142. As shown in Figure 1D, Agazzi '640 discloses an optical transmitter that emits optical signals (*i.e.*, one of which is the first optical signal on a first wavelength) into the fiber optic channel (*i.e.*, first optical fiber) and an optical receiver that receives optical signals (*i.e.*, one of which is the second optical signal on a second wavelength) from the fiber optic channel (*i.e.*, second optical fiber). A POSITA would have understood that the optical channel, or cable, can include a single optical fiber or multiple optical fibers and that the two optical signals can traverse either different or the same optical fibers, as this was an obvious selection

from a finite number of choices. For example, U.S. Patent No. 6,005,694 teaches that "dozens of fibers may be included in a single cable." Ex. 1011 at 1:39-41.

143. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xxi. Claim 14: The pluggable optical transceiver module of claim 1, wherein the noise removed by the equalizer includes intersymbol interference (ISI).

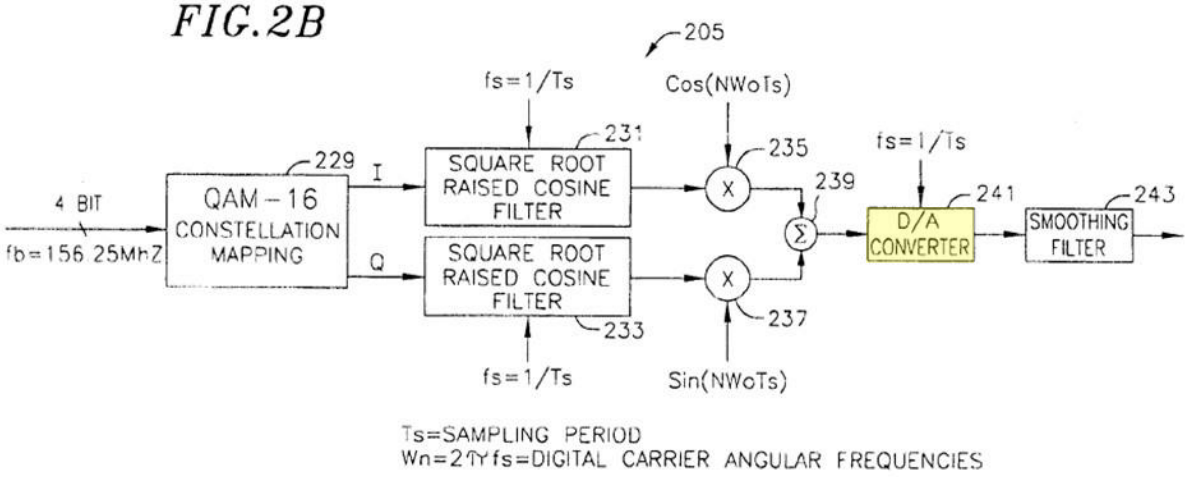
144. A POSITA would have understood the combination of Agazzi '640 and Wei discloses this limitation. Reducing inter-symbol interference ("ISI") was a stated goal in Agazzi '640 as Agazzi '640 discloses that "channel equalization techniques may also be ***used to compensate*** pulse dispersion and ***the resulting inter-symbol interference*** caused by frequency-dependent attenuation and phase distortion introduced by the channel." Ex. 1005 at 3:20-26 (emphasis added). Agazzi '640 teaches that implementing an equalizer in the optical transceiver module makes "the most efficient use possible of the available channel bandwidth." *Id.* As the '181 Patent characterizes ISI as noise, a POSITA would have understood that the equalizer in Agazzi '640, which uses coefficients to reduce ISI, discloses this limitation. Ex. 1001 at 12:20-26, 16:14-17.

145. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xxii. Claim 17: The pluggable optical transceiver module of claim 1, wherein the digital to analog converter is configured to shape, condition, or emphasize the first electrical m-ary analog modulation signal for improved transmission performance.

146. A POSITA would have understood the combination of Agazzi '640 and Wei discloses this limitation. Agazzi '640 discloses a block diagram of a m-ary modulator. Ex. 1005 at Fig. 2B, 2:28-29. As shown in Figure 2B, after passing through the m-ary modulator, the signals pass through a digital to analog ("D/A") converter that converts digital signals to analog signals (in yellow below). Ex. 1005 at Fig. 2B. A POSITA would understand the digital to analog converter conditions the signal from the digital to analog domain to assist with transmission in subsequent steps as analog signals are required to drive the laser. Moreover, the smoothing filter, which can be understood as part of the digital to analog step, filters (*i.e.*, shapes) the signals before they are sent to the optical transmitter. The filtering assists in transmission by eliminating potential noise.

FIG. 2B



147. Specifically, Fig. 2B is a block diagram of a digital implementation of a QAM-16 modulator. Ex. 1005 at 9:42-43. The QAM 16 modulator accepts a four bit input signal, and the constellation mapping block (229) maps the four bits into their in-phase and quadrature representations, which are provided to raised cosine filters. Ex. 1005 at 9:43-49. The raised cosine filters are designed for pulse-shaping to avoid inter-symbol interference. The outputs of the raised cosine filters are converted from digital to analog form by the D/A converters 245 and 247, whereby the D/A converters condition the signal from a digital to analog signal domain. Ex. 1005 at 10:3-5. The signals are then shaped by the filter to further enhance transmission, which is described in claim limitations [1.D] and [1.E]. The digital QAM-16 data needs to be converted into analog form for transmission in order to realize the main benefit of QAM modulation, which is to simultaneously transmit orthogonal I and Q sine and cosine carriers of varying amplitude that can carry more bits than binary On/Off modulation, while using the same channel bandwidth. In

this way, QAM 16 achieves more efficient transmission performance by sending four times as much information as a binary On/Off modulation in the same bandwidth.

148. A POSITA would have understood that the D/A converter (*i.e.*, digital to analog converter) is configured to shape, condition, or emphasize the signal (*i.e.*, the first electrical m-ary analog modulation signal) to improve the transmission performance of the signal.

149. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xxiii. Claim 22[1]: [22.pre] A pluggable optical transceiver module comprising of:

150. *See supra* claim 1[pre] at Section X(a)(i).

xxiv. Claim 22: [22.A] an electrical system interface for receiving a first electrical data signal and for transmitting a second electrical data signal;

151. *See supra* claim 1[a] at Section X(a)(ii).

[1] Claim 22 is practically identical to Claim 1. The only difference is that claim 22 adds limitation [22.K], "wherein the m-ary modulator and the m-ary demodulator perform m-ary pulse amplitude modulation and de-modulation, respectively, that uses two or more bits per symbol."

xxv. Claim 22: [22.B] an m-ary modulator for increasing the number of bits per symbol in the first electrical data signal to produce a first m-ary modulation signal;

152. *See supra* claim 1[b] at Section X(a)(iii).

xxvi. Claim 22: [22.C] a digital to analog converter for converting the first m-ary modulation signal to a first electrical m-ary analog modulation signal;

153. *See supra* claim 1[c] at Section X(a)(iv).

xxvii. Claim 22: [22.D] a driver for amplifying the first electrical m-ary analog modulation signal to an amplified first electrical m-ary analog modulation signal to drive an optical transmitter;

154. *See supra* claim 1[d] at Section X(a)(v).

xxviii. Claim 22: [22.E] the optical transmitter for emitting a first optical signal on a first wavelength responsive to and representative of the amplified first electrical m-ary analog modulation signal from the driver;

155. *See supra* claim 1[e] at Section X(a)(vi).

xxix. Claim 22: [22.F] an optical detector for receiving a second optical signal on a second wavelength to produce an electrical analog signal;

156. *See supra* claim 1[f] at Section X(a)(vii).

xxx. Claim 22: [22.G] an amplifier for amplifying the electrical analog signal to an amplified electrical analog signal;

157. *See supra* claim 1[g] at Section X(a)(viii).

xxxi. Claim 22: [22.H] a clock data recovery unit for recovering clock and data information to produce a second m-ary modulation signal from the amplified electrical analog signal;

158. *See supra* claim 1[h] at Section X(a)(ix).

xxxii. Claim 22: [22.I] an equalizer for performing equalization on the second m-ary modulation signal to remove noise;

159. *See supra* claim 1[i] at Section X(a)(x).

xxxiii. Claim 22: [22.J] an m-ary demodulator for decreasing the number of bits per symbol in the equalized second m-ary modulation signal to produce the second electrical data signal; and

160. *See supra* claim 1[j] at Section X(a)(xi).

xxxiv. Claim 22: [22.K] wherein the m-ary modulator and the m-ary demodulator perform m-ary pulse amplitude modulation and de-modulation, respectively, that uses two or more bits per symbol.

161. A POSITA would have understood Agazzi '640 discloses this limitation. Agazzi '640 discloses performing multilevel modulation within the transmitter portion of the optical transceiver, including "***Pulse Amplitude Modulation*** (PAM) … to ***encode several bits per*** transmitted ***symbol***." Ex. 1005 at 3:15-20 (emphasis added), Figs. 2A, 10. Agazzi '640 further discloses, in the receiver portion of the optical transceiver, "demodulators, which will demodulate the signal according to the modulation used by the transmit apparatus." Ex. 1005 at 2:1-11, Figs. 3, 12.

162. The '181 Patent identifies PAM as an example of m-ary modulation. Ex. 1001 at 10:20-28. A POSITA would have understood the PAM modulator/demodulator disclosed in Agazzi '640 to cover m-ary PAM

modulation/demodulation because the ’181 Patent disclosed PAM modulation as a type of m-ary modulation.

b. Ground 2: The combination of Agazzi ’640, Wei, and Agazzi ’341 render claims 15-16 and 23 obvious.

163. As previously described, both Agazzi ’640 and Wei relate to fiber-optic communications, and in particular optical transceiver modules with integrated optoelectronics. And both Agazzi ’640 and Wei attempt to increase the data throughput rates in an efficient and cost effective manner. Ex. 1005 at 1:23-49; Ex. 1006 at 1:66-2:4. For example, Agazzi ’640 discloses making “the most efficient use possible of the available channel bandwidth [using] channel equalization techniques.” Ex. 1005 at 3:21-26. However, Agazzi ’640 and Wei do not expressly disclose an equalizer that uses decision directed, or blind equalization, with coefficients.

164. Agazzi ’341 specifically teaches a transceiver module that performs signal processing, including m-ary modulation, equalization, and error correction. Ex. 1009 at 3:11-32, 12:5-23. This allows the transceiver module in Agazzi ’341 to transmit data at higher rates through existing fiber infrastructure, which is a specific goal of Agazzi ’341. Ex. 1009 at 1:44-49, 3:20-26. For example, Agazzi ’341 discloses a “decision feedback equalizer” that uses “coefficients” to perform equalization. Ex. 1009 at 10:11-22.

165. Agazzi ’341 also teaches implementing the transmitter and receiver sections of the transceiver together as an “integrated circuit constructed as a single chip” and discloses an “ever present economic motivation to achieve such results in a cost effective manner.” Ex. 1009 at 4:62-65, 1:46-51. There were several reasons a POSITA would have been motivated to combine Agazzi ’341 with Agazzi ’640 and Wei.

166. First, decreasing the size of the transceiver was a stated goal in Agazzi ’341, Agazzi ’640, and Wei. Ex. 1005 at 9:33-41; Ex. 1009 at 4:62-65; Ex. 1006 at 1:67-2:4. Accordingly, a POSITA would naturally have looked from Agazzi ’640 and Wei to Agazzi ’341 because all three references disclose optical transceiver modules, and in particular smaller compact modules. This was an important consideration because space is a limiting factor in many optical systems.

167. Second, both Agazzi ’640 and Agazzi ’341 disclose multilevel modulation techniques that can be used to increase the data throughput. And Agazzi ’341 discloses additional equalization methods that can be used to remove noise caused by higher order modulation techniques. As increasing the data throughput rate was a stated goal in both Agazzi ’640 and Agazzi ’341, a POSITA would naturally have look to Agazzi ’341 to determine equalization techniques that can be used to remove noise in system that performs higher order modulation, which Agazzi ’640 and Agazzi ’341 both teach.

168. Moreover, increasing the data transmission rate was also a stated goal in Wei. Thus, a POSITA would have been motivated to add one of the equalization techniques described in Agazzi '341 with a m-ary pluggable transceiver as taught by Agazzi '640 and Wei to remove noise that occurs in m-ary modulation systems. This allowed for more data to be efficiently transferred in the same channel over the same amount of time and was a simple way to increase data speeds in a communication system without going through the costly and resource intensive activity of replacing older fiber channels while still maintaining data reliability.

169. Third, the equalization techniques disclosed in Agazzi '341 were cost effective ways to maintain data reliability while increasing data throughput. Decreasing costs was a stated goal in both Agazzi '640 and Wei as well as Agazzi '341. Ex. 1009 at 1:50-51; Ex. 1006 at 1:50-69; Ex. 1005 at 1:45-49. Agazzi '341 was cost effective because it allowed for increased data speeds without the need to replace older fiber channels, which can be costly endeavor. Thus, a POSITA would have naturally looked to Agazzi '341 and would have been motivated to combine it with Agazzi '640 and Wei because an m-ary pluggable transceiver that performs equalization as taught by Agazzi '640 can transmit data at high transmission speeds accurately with less errors. This allowed for more data to be transferred in the same channel over the same amount of time and was a simple way to increase data speeds without replacing older fiber channels.

170. Moreover, a POSITA would have had a reasonable expectation of success in adding the equalization capabilities to the m-ary pluggable transceiver to produce expected results. In fact, many of the expected results of the combination were stated goals in the references.

i. Claim 15: The pluggable optical transceiver module of claim 1, wherein the equalizer performs decision directed equalization on the second m-ary modulation signal to remove noise.

171. A POSITA would have understood the combination of Agazzi '640, Wei, and Agazzi '341 discloses this limitation. Agazzi '640 and Wei disclose the limitations in claim 1. Agazzi '341 discloses an equalizer "for compensating for intersymbol interference introduced by the limited bandwidth of the multimode fiber." Ex. 1009 at 4:40-42. Agazzi '341 also discloses a "***decision feedback equalizer***" (*i.e.*, decision directed equalizer) where "channel information [is] generated by a feedback filter 148 in the decision feedback equalizer." Ex. 1009 at 10:11-22 (emphasis added). Agazzi '341 further teaches that "channel information consists of coefficients generated by an adaptive equalization algorithm." Ex. 1009 at 10:36-38. As I explain in the technical background section, in decision directed equalization, the equalizer estimates the coefficients without knowledge of the channel statistics—it uses only the transmitted signal characteristics without a training sequence. *See supra*, Section V(d). A POSITA would have understood that the decision feedback equalization in Agazzi '341 was equivalent to the claimed

decision directed equalization because it generates coefficients representative of channel characteristics without a training sequence. Moreover, as the '181 Patent characterizes ISI as noise, a POSITA would also have understood that the equalizer in Agazzi '341, which uses coefficients to reduce ISI, was adapted to remove noise. Ex. 1001 at 12:20-26, 16:14-17.

172. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed by the combination of Agazzi '640 and Agazzi '641 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

ii. Claim 16: The pluggable optical transceiver module of claim 1, wherein the equalizer performs blind equalization on the second m-ary modulation signal to remove noise.

173. A POSITA would have understood the combination of Agazzi '640, Wei, and Agazzi '341 discloses this limitation. Agazzi '640 and Wei disclose the limitations in claim 1. Agazzi '341 discloses an equalizer "for compensating for intersymbol interference introduced by the limited bandwidth of the multimode fiber." Ex. 1009 at 4:40-42. Agazzi '341 also discloses a "decision feedback equalizer" where "channel information [is] generated by a feedback filter 148 in the decision feedback equalizer." Ex. 1009 at 10:11-22. Agazzi '341 further teaches that "channel information consists of coefficients generated by an adaptive equalization algorithm." Ex. 1009 at 10:36-38. As I explain in the technical

background section, decision directed equalization is a type of blind equalization because the equalizer estimates the coefficients without knowledge of the channel statistics—it uses only the transmitted signal characteristics without a training sequence. *See supra*, Section V(d). A POSITA would have understood the decision feedback equalization in Agazzi '341 was a type of blind equalization because it generates coefficients representative of channel characteristics without a training sequence. Moreover, as the '181 Patent characterizes ISI as noise, a POSITA would also have understood that the decision feedback equalizer (*i.e.*, blind equalizer) in Agazzi '341, which uses coefficients to reduce ISI, was adapted to remove noise. Ex. 1001 at 12:20-26, 16:14-17.

174. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed by the combination of Agazzi '640 and Agazzi '641 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

iii. Claim 23[2]: [23.pre] A pluggable optical transceiver module comprising of:

175. *See supra* claim 1[pre] at Section X(a)(a.i).

[2] Claim 23 is practically identical to Claim 1. The only difference is that claim 23 adds limitation [23.K], "wherein the equalizer includes coefficients or weights configured to remove noise from the second m-ary modulation signal."

iv. Claim 23: [23.A] an electrical system interface for receiving a first electrical data signal and for transmitting a second electrical data signal;

176. *See supra* claim 1[a] at Section X(a)(a.ii).

v. Claim 23: [23.B] an m-ary modulator for increasing the number of bits per symbol in the first electrical data signal to produce a first m-ary modulation signal;

177. *See supra* claim 1[b] at Section X(a)(a.iii).

vi. Claim 23: [23.C] a digital to analog converter for converting the first m-ary modulation signal to a first electrical m-ary analog modulation signal;

178. *See supra* claim 1[c] at Section X(a)(a.iv).

vii. Claim 23: [23.D] a driver for amplifying the first electrical m-ary analog modulation signal to an amplified first electrical m-ary analog modulation signal to drive an optical transmitter;

179. *See supra* claim 1[d] at Section X(a)(a.v).

viii. Claim 23: [23.E] the optical transmitter for emitting a first optical signal on a first wavelength responsive to and representative of the amplified first electrical m-ary analog modulation signal from the driver;

180. *See supra* claim 1[e] at Section X(a)(a.vi).

ix. Claim 23: [23.F] an optical detector for receiving a second optical signal on a second wavelength to produce an electrical analog signal;

181. *See supra* claim 1[f] at Section X(a)(a.vii).

x. Claim 23: [23.G] an amplifier for amplifying the electrical analog signal to an amplified electrical analog signal;

182. *See supra* claim 1[g] at Section X(a)(a.viii).

xi. Claim 23: [23.H] a clock data recovery unit for recovering clock and data information to produce a second m-ary modulation signal from the amplified electrical analog signal;

183. *See supra* claim 1[h] at Section X(a)(a.ix).

xii. Claim 23: [23.I] an equalizer for performing equalization on the second m-ary modulation signal to remove noise;

184. *See supra* claim 1[i] at Section X(a)(a.x).

xiii. Claim 23: [23.J] an m-ary demodulator for decreasing the number of bits per symbol in the equalized second m-ary modulation signal to produce the second electrical data signal; and

185. *See supra* claim 1[j] at Section X(a)(a.xi).

xiv. Claim 23: [23.K] wherein the equalizer includes coefficients or weights configured to remove noise from the second m-ary modulation signal.

186. A POSITA would have understood the combination of Agazzi '640, Wei, and Agazzi '341 discloses this limitation. Agazzi '640 and Wei disclose the other limitations in claim [23.pre]-[23.J] for the same reasons as in claim [1.pre]-[1.J]. Agazzi '341 discloses an equalizer "for compensating for intersymbol interference introduced by the limited bandwidth of the multimode fiber." Ex. 1009 at 4:40-42. Agazzi '341 also discloses "***equalizer coefficients***." Ex. 1009 at 10:11-15 (emphasis added). Agazzi '341 teaches that "channel information consists of ***coefficients generated by*** an adaptive ***equalization*** algorithm." Ex. 1009 at 10:36-38 (emphasis added). As explained in the technical background section, equalizers

that remove noise by multiplying different versions of the signal with coefficients or weights based on channel characteristics, and then sum these weighed signals to form the output signal. *See supra*, Section V(b). As the '181 Patent characterizes ISI as noise, a POSITA would have understood that the equalizer in Agazzi '341, which uses coefficients to reduce ISI, was adapted to remove noise. Ex. 1001 at 12:20-26, 16:14-17.

187. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed by the combination of Agazzi '640 and Agazzi '641 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

XI. Grounds 3-4 render the challenged claims obvious.

a. Ground 3: The combination of Agazzi '341 and Wei render claims 1-3, 8, 10-17, and 22-23 obvious.

188. Both Agazzi '341 and Wei are directed to optical transceiver modules with integrated optoelectronics that interface optical fibers to electronic circuitry by converting between optical signals and electrical signals. Ex. 1006 at 1:24-30; Ex. 1009 at Fig. 23. Indeed, Agazzi '341 and Wei both teach transceiver modules that include an electrical system interface, an optical transmitter, an optical receiver, and an amplifier. Ex. 1009 at Figs. 5, 23, 1:66-2:7; Ex. 1006 at 1:24-45, 4:40-55.

189. As explained, *supra*, Wei specifically discloses vertically stacked transmitter and receiver printed circuit boards that allow for the functionality of

larger GBIC modules to be included inside a SFP package. This accomplishes the stated goal in Wei—creating a smaller, more compact transceiver module that is hot pluggable with "reduce[d] manufacturing costs" in order to allow service technicians to quickly replace damaged transceiver modules with limited down time. Ex. 1006 at 1:53-2:11.

190. Agazzi '341 specifically teaches a transceiver module that performs signal processing, including m-ary modulation/demodulation, equalization, and error correction. Ex. 1009 at 3:11-32, 12:5-23. This allows the transceiver module in Agazzi '341 to transmit data at higher rates through existing fiber infrastructure, which is a specific goal of Agazzi '341. Ex. 1009 at 1:44-49, 3:20-26. Agazzi '341 also teaches implementing the transmitter and receiver sections of the transceiver together as an "integrated circuit constructed as a single chip" and discloses an "ever present economic motivation to achieve such results in a cost effective manner." Ex. 1009 at 4:62-65, 1:46-51.

191. Agazzi '341 does not, however, expressly disclose a pluggable transceiver module in a small form factor package as taught in Wei. Nor does Wei expressly disclose the signal processing techniques taught in Agazzi '341. A POSITA would have understood that the transceiver as contemplated in Agazzi '341, which was taught as constructed as a single chip, would have been implemented in a SFP transceiver as taught in Wei. And a POSITA would have been motivated to

combine the transceiver module of Agazzi '341 with the SFP package of Wei to create a smaller transceiver with greater data throughput that is easily removable and cost-effective.

192. There were several reasons a POSITA would have been motivated to make such a combination. First, market pressures were increasing the demand for compact pluggable transceivers with high data throughput rates in a standardized form factor as users desired a high throughput pluggable transceiver which led the industry to standardize the SFP form factor to ensure compatibility across fiber-optic systems. Ex. 1006, 1:66-2:4; Ex. 1014. Accordingly, as a result of consumer preferences and industry standards, a POSITA would have understood that higher throughput pluggable transceivers in an SFP form factor were needed. Second, an m-ary pluggable transceiver module would be easier to install, repair, and replace than a mounted transceiver. Ex. 1006 at 2:5-11. This would decrease the chances for improper installation. It also decreases the likelihood that other components near the transceiver would be damaged during servicing. An m-ary pluggable transceiver would also take less time to install, repair, and/or replace. This, in turn, means less down time for the fiber-optic system during maintenance or servicing of the transceiver. Ex. 1011 at 1:45-52.

193. Third, an m-ary pluggable transceiver in an SFP package was more compact and takes less room than other transceivers. Decreasing the transceiver size

was a stated goal in both Agazzi '341 and Wei. Ex. 1009 at 4:62-65; Ex. 1006 at 1:67-2:4. Thus, a POSITA would have been motivated to combine Agazzi '341 with Wei to create a smaller transceiver. This is because Wei discloses how to efficiently package transceiver components to fit within a pluggable form factor: "separate vertically stacked printed circuit boards allows packaging the functions of [larger modules] within an LC or other small form factor package" like the SFP. Ex. 1006, 2:1-2, 2:28-32. A POSITA would have understood how to package the components of a module like Agazzi '341 into an SFP based on the disclosure in Wei. This was important because OLTs and ONTs often have many components, like switches and routers, located in large racks. Therefore, space was a limiting factor in many cases and smaller optical components were desired.

194. Fourth, an m-ary pluggable transceiver was more cost effective. Decreasing costs was a stated goal in both Agazzi '341 and Wei. Ex. 1009 at 1:50-51; Ex. 1006 at 1:50-69. Thus, a POSITA would have been motivated to combine Agazzi '341 with Wei to create an m-ary pluggable transceiver because pluggable transceivers were easier to install, repair, and replace, which allowed less skilled technicians to be able to service the communication system. Ex. 1006 at 2:5-11. Moreover, technicians did not have to repair and replace larger equipment, like a switch or router, when an optoelectrical component in a mounted transceiver failed. Instead, the technician simply replaced the hot pluggable transceiver with a new

transceiver. And manufacturing costs were decreased when transceivers were produced separate from other optoelectrical equipment on printed circuit boards. Ex. 1006 at 1:45-60. Further, the smaller size of the transceiver allowed the optical equipment to take up less space, thus saving on rent and utilities. And, importantly, the increased data throughput rates of m-ary pluggable transceivers allowed for higher data speeds without the need to replace older fiber channels.

195. Fifth, an m-ary pluggable transceiver would have higher data throughput rates in a small form factor. Increasing the data throughput rate in the transceiver was a stated goal in both Agazzi '341 and Wei. Ex. 1009 at 1:46-51; Ex. 1006 at 1:66-2:4. Accordingly, a POSITA who wanted to maintain high data throughput rates, as taught by Agazzi '341's use of m-ary modulation, would have looked to Wei when evaluating how to package a high throughput transceiver in a SFP form factor as Wei also taught high data throughput. This allows for more data to be transferred in the same channel over the same amount of time as traditional binary modulation and as a simple way to increase data speeds in a communication system because it did not require replacement of older fiber channels.

196. Moreover, a POSITA would have had a reasonable expectation of success in combing the transceivers in Agazzi '341 and Wei to produce expected results. In fact, many of the expected results of the combination were stated goals in the references.

197. A POSITA also would have been motivated to combine transceivers that perform advanced signal processing, like in Agazzi '341, with a pluggable transceiver, like in Wei, after reviewing the prior art. For example, U.S. Patent No. 6,665,498 to Jiang discloses a high-speed transceiver module that has a transmitter, receiver, amplifier, and clock data recovery unit. Ex. 1010 at 3:34-4:3. In addition to signal processing techniques, Jiang teaches that is it important to provide a smaller transceiver that is capable of conveying information at similar rates to larger transceivers, wherein the transceiver is "inexpensive to manufacture." Ex. 1010 at 1:54-61. Jiang also recommends making the transceiver pluggable, stating: "It is also easier to make the transceiver pluggable." Ex. 1010 at 5:34-41. A POSITA would thus have been motivated to combine signal processing capabilities inside a small pluggable transceiver.

198. As another example, U.S. Patent No. 6,295,272 to Feldman discloses a pluggable transceiver module in the form of a GBIC (the larger predecessor of the SFP) that conveys m-ary modulated signals from a subcarrier channel to a high-speed channel. Ex. 1019 at Abstract, 6:21-29, Fig. 13. Although the m-ary modulation disclosed in Feldman occurs before the signal is conveyed by the GBIC, a POSITA would have understood that the m-ary functionality can be added into the pluggable to reduce the number of components. Moreover, Wei teaches

"package[ing] the functions of a GBIC into the compact size of an SFP." Ex. 1006 at 2:1-4.

199. For at least these reasons, in reading Agazzi '341, a POSITA would have been motivated to look to the pluggable transceiver module in Wei and would have had a reasonable expectation of success in combining the two optical transceiver modules.

i. Claim 1: [1.pre] A pluggable optical transceiver module comprising of:

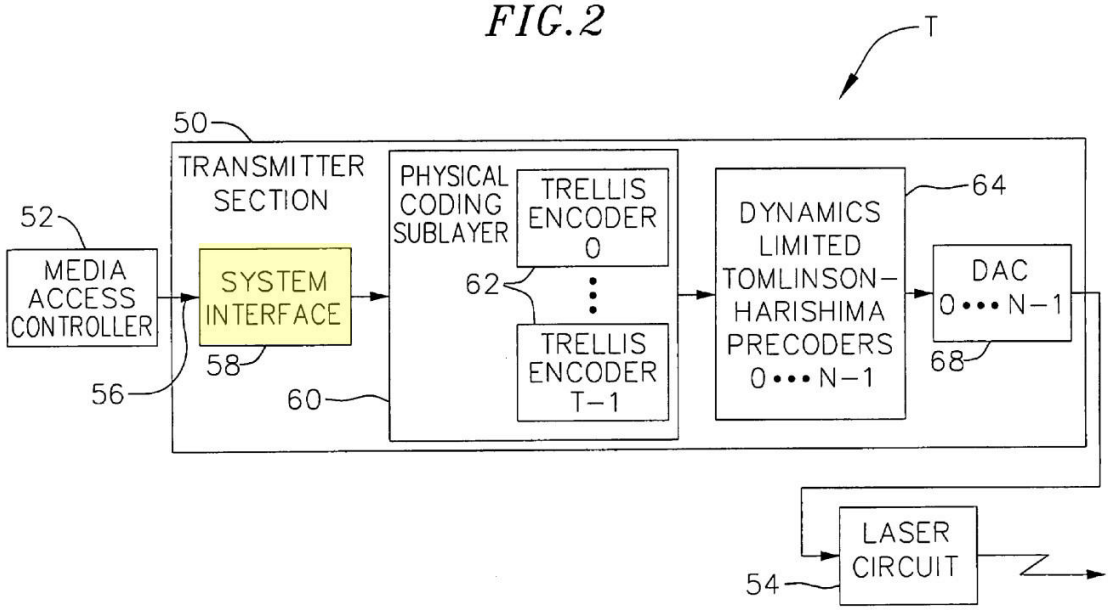
200. To the extent the preamble is limiting, a POSITA would have understood Wei discloses this limitation. Wei discloses a "fiber optic transceiver module" where the module is a "pluggable optical transceiver in a small form pluggable." Ex. 1006 at 2:17-20, 3:29-32. Specifically, Wei discloses an optical transceiver module "in a small form pluggable (SFP), LC package." Ex. 1006 at 2:1-4, 2:28-35. This is a standardized industry form factor set out in a multisource agreement. Ex. 1014.

ii. Claim 1: [1.A] an electrical system interface for receiving a first electrical data signal and for transmitting a second electrical data signal;

201. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses an optical transceiver module that includes a transmitter that receives an electrical data signal through the system interface, performs signal processing, converts it to an optical signal, and then transmits the

optical signal onto the optical fiber. *See, e.g.*, Ex. 1009 at Fig. 23. For example, Agazzi '341 discloses an electrical system interface (shown in yellow below) that receives electrical data signals. Ex. 1009 at Fig. 2.

FIG. 2



202. Agazzi '341 teaches that the system interface "may comprise X-GMII interfaces." Ex. 1009 at 15:1-7. The '181 Patent teaches that the XGMII interface is a conventional system interface for receiving and transmitting signals. Ex. 1001 at 9:22-26. A POSITA would have understood that the system interface in Agazzi '341 (*i.e.*, electrical system interface), which can be an X-GMII interface, receives many electrical data signals, one of which is the claimed "first electrical data signal." A POSITA would further have understood the electrical data signals are digital which are understood to be binary. Ex. 1009 at 1:55-65.

203. Agazzi ’341 also discloses a receiver system that receives an optical signal, converts it to an electrical signal, performs signal processing, and then transmits the electrical signal through the system interface (shown in yellow below). *See, e.g.*, Ex. 1009 at Fig. 23.

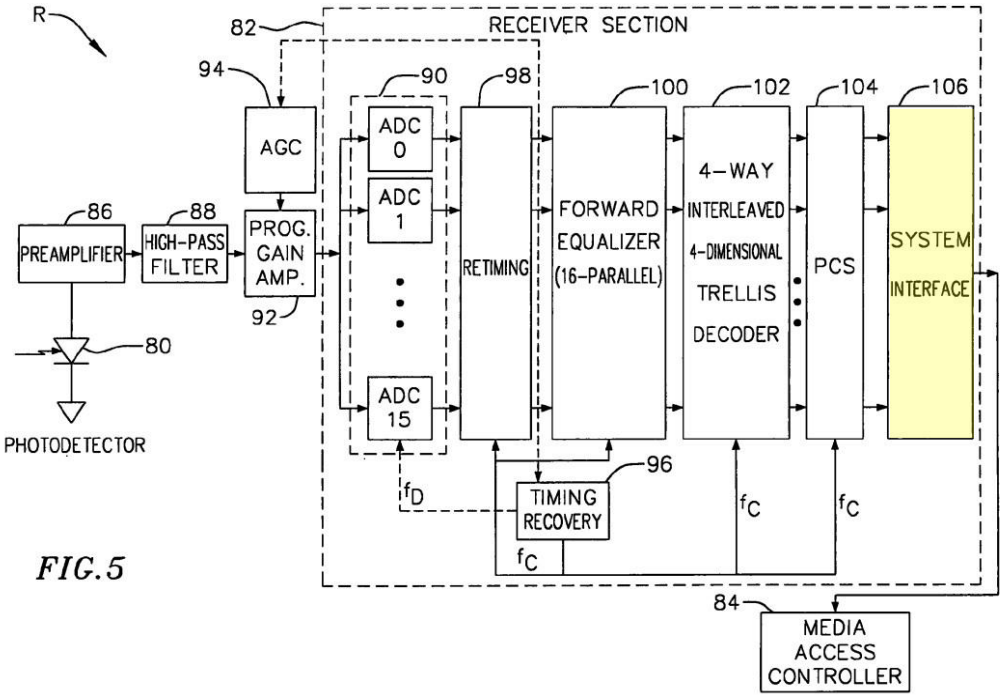


FIG.5

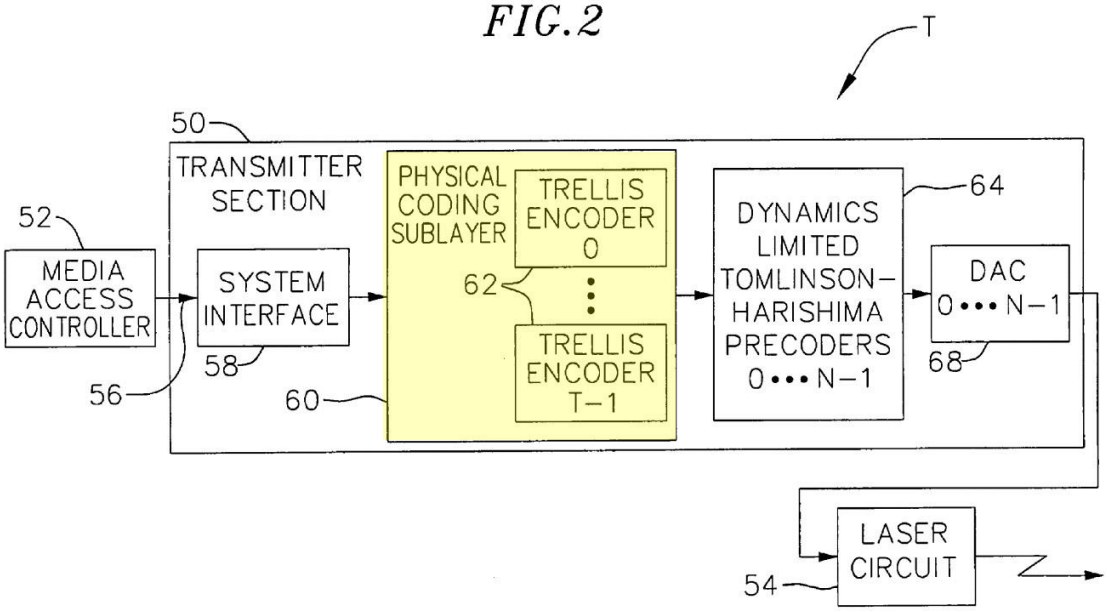
204. Agazzi ’341 teaches that the system interface “may comprise X-GMII interfaces.” Ex. 1009 at 15:1-7. The ’181 Patent teaches that the XGMII interface is a conventional system interface for receiving and transmitting signals. Ex. 1001 at 9:18-26. A POSITA would have understood that the system interface, which can be an X-GMII interface, transmits many electrical data signals, one of which is the claimed “second electrical data signal.” A POSITA would further have understood

the electrical data signals are digital which are understood to be binary. Ex. 1009 at 1:55-65.

iii. Claim 1: [1.B] an m-ary modulator for increasing the number of bits per symbol in the first electrical data signal to produce a first m-ary modulation signal;

205. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses an optical transceiver module that "utilizes five-level pulse amplitude modulation (PAM-5)." Ex. 1009 at 4:33-39. Agazzi '341 further discloses that "[t]he invention may be practiced with different data modulation schemes. Including, for example, any level of PAM coding (e.g., PAM-3, PAM-7)." Ex. 1009 at 15:47-49. A POSITA would have understood that Agazzi '341 includes modulators as modulators are necessary to perform PAM modulation. While not specifically disclosed in Figure 2 below, Agazzi '341 teaches that trellis coding (in yellow below) is conducted in combination with a PAM-5 system. Ex. 1009, 4:54-57. This is consistent with the prior art as Leon-Garcia teaches that trellis encoding systems "combine error-correction coding with the modulation." Ex. 1015, 131.

FIG.2



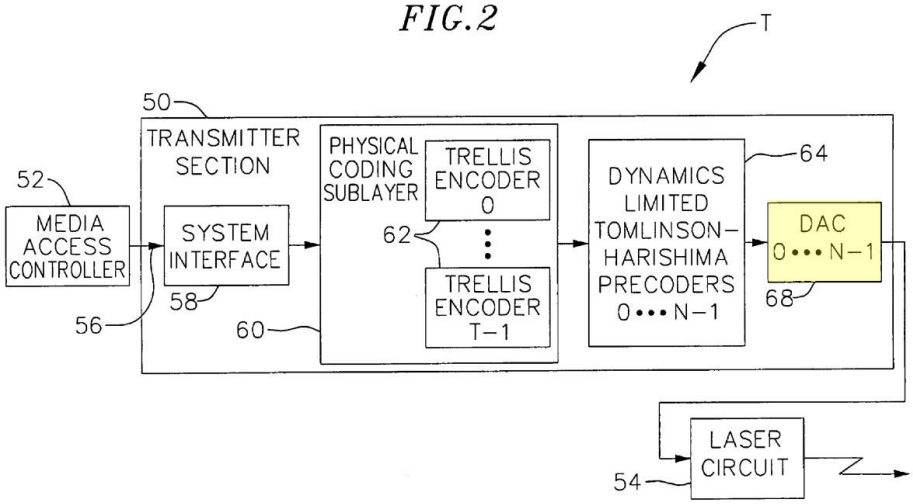
206. Moreover, Agazzi '341 also discloses that the transmitter portion of the optical receiver module performs PAM-5 modulation. Ex. 1009 at 4:28-35, Figs. 2-6. The PAM modulation disclosed in Agazzi '341 covers m-ary modulation because the '181 Patent identifies PAM as an example of m-ary modulation. Ex. 1001 at 10:11-19. A POSITA would have understood that the m-ary modulator in the trellis encoder in Agazzi '341 converts a received signal (*i.e.*, first electrical data signal) to a modulated signal (*i.e.*, first m-ary modulation signal) using m-ary modulation.

iv. Claim 1: [1.C] a digital to analog converter for converting the first m-ary modulation signal to a first electrical m-ary analog modulation signal;

207. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses a transmitter with "digital to analog converters (DACs)." Ex. 1009 at 4:12-20. As shown in Figure 2, after passing through the

processing elements in the transmitter, the signals pass through a D/A converter (in yellow below) that converts digital signals to analog signals. Ex. 1009 at Fig. 2 (annotated).

FIG. 2

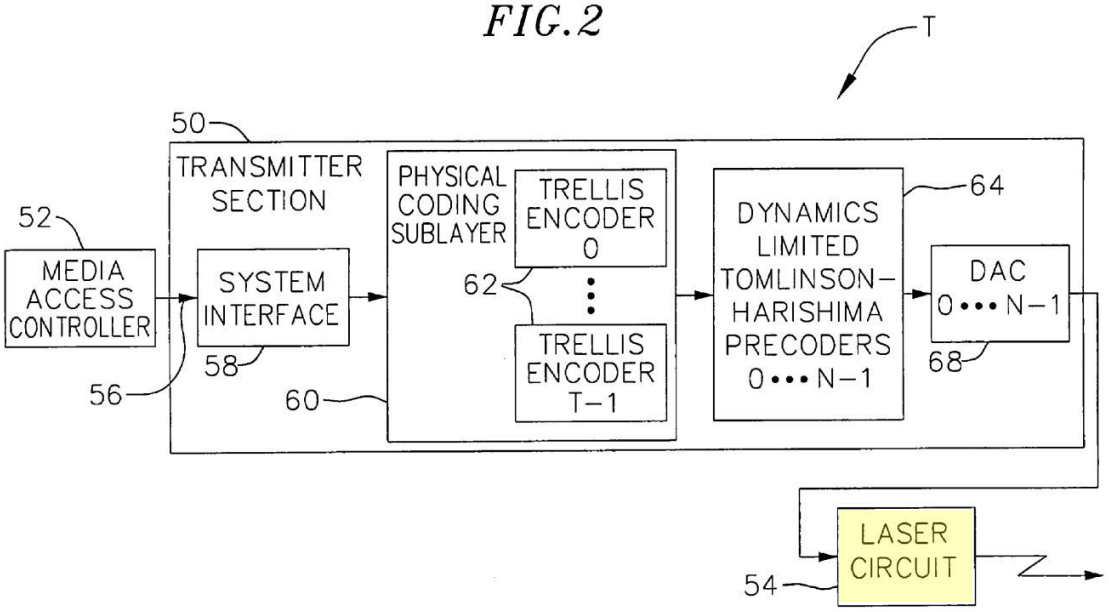


208. A POSITA would have understood that the DAC (*i.e.*, digital to analog converter) converts a received digital signal (*i.e.*, first m-ary modulation signal) to an analog signal (*i.e.*, first electrical m-ary analog modulation signal).

v. Claim 1: [1.D] a driver for amplifying the first electrical m-ary analog modulation signal to an amplified first electrical m-ary analog modulation signal to drive an optical transmitter;

209. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses a transmitter system that provides an encoded data stream to drive a laser circuit (in yellow below). Ex. 1009 at 4:66-5:3, Fig. 2 (annotated).

FIG. 2



Agazzi '341 teaches that the transmitter system includes "a laser driver." Ex. 1009 at 13:14. Agazzi '341 also teaches that the laser is an "optical transmitter." *Id.*, 15:52-54.

210. Agazzi '341 further discloses that encoded PAM-5 symbols drive the laser circuit, where the laser circuit "generates optical signals that are sent over an optical channel." Ex. 1009 at 4:35-39, 4:66-5:3, 11:38-42. A POSITA would have understood that the encoded analog m-ary modulation signals are amplified by the optical driver to ensure the signals are sufficiently strong to drive the optical transmitter, which emits optical signals that must be able to travel long distances through optical fibers. For example, a prior art textbook teaches a "laser drive circuit … consists of two differential amplifiers … The two differential amplifiers provide sufficient modulation current amplitude for the laser." Ex. 1017, 400. A POSITA

would also have understood that the laser driver in Agazzi '341 amplifies a received signal (*i.e.*, first electrical m-ary analog modulation signal) to produce an amplified signal (*i.e.*, amplified first electrical m-ary analog modulation signal) to drive the laser (*i.e.*, optical transmitter).

vi. Claim 1: [1.E] the optical transmitter for emitting a first optical signal on a first wavelength responsive to and representative of the amplified first electrical m-ary analog modulation signal from the driver;

211. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses an "optical transmitter" in the form of a laser. Ex. 1009 at 15:50-54. Specifically, Agazzi '341 discloses that the "transmitter 20 sends data to a receiver 22 over an optical channel." Ex. 1009 at 3:52-53. Agazzi '341 further discloses that "digital input signals" are received by the transmitter (Ex. 1009 at 14:7-9), "are processed by one or more processing elements" (*id.*), and then "optical signals [] are sent over an optical channel" (Ex. 1009 at 6:66-5:3). As I explain in the technical background section, the transmitter system receives electrical signals and converts them to optical signals where the optical signal is representative of the electrical signal. *See supra*, Section V(b). A POSITA would have understood that the optical transmitter is driven by (*i.e.*, is responsive to) an electrical signal (*i.e.*, amplified first electrical m-ary analog modulation signal) from the driver that it converts to a corresponding (*i.e.*, representative) optical signal (*i.e.*, first optical signal on a first wavelength) and then emits onto an optical fiber.

vii. Claim 1: [1.F] an optical detector for receiving a second optical signal on a second wavelength to produce an electrical analog signal;

212. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses an optical receiver that includes a photodetector (*i.e.*, optical detector, which is shown in yellow below) that receives optical signals (*i.e.*, second optical signal on a second wavelength) and converts the optical signals to electrical signals (*i.e.*, electrical analog signal). Ex. 1009 at 6:41-44, Fig. 5.

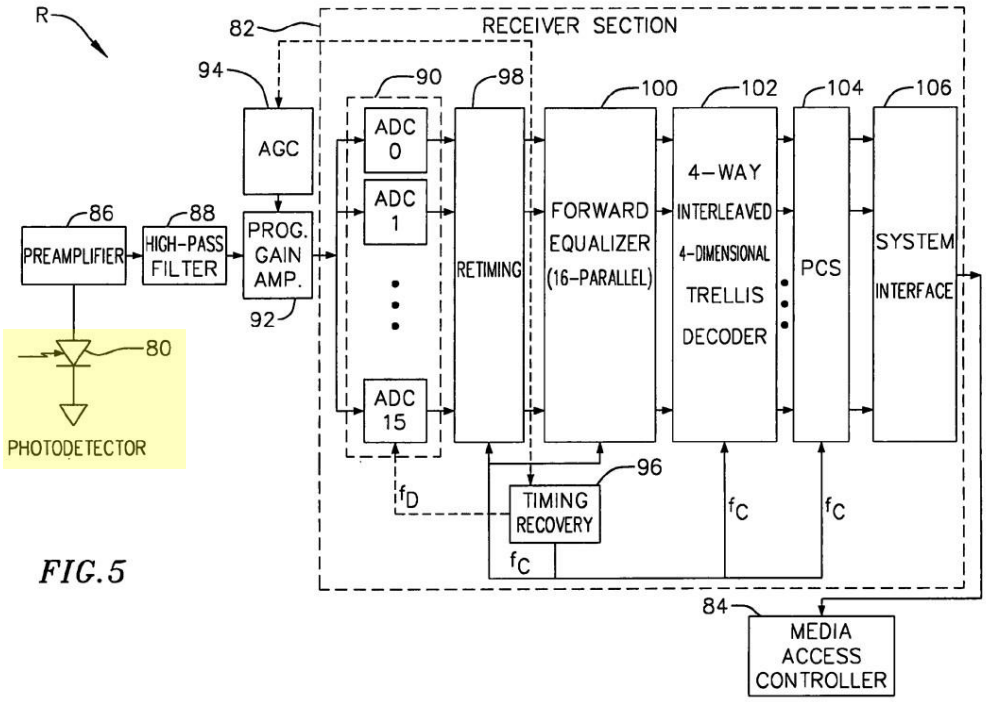


FIG.5

213. For example, Agazzi '341 discloses that "a photodetector 80 receives optical signals form an optical channel … to provide an encoded data stream to the receiver section." Ex. 1009 at 6:40-49. The encoded data stream is an electrical analog signal because the signal later passes through analog to digital converters

(ADC). *Id.* at Fig. 5. A POSITA would have understood that the photodetector (*i.e.*, optical detector) receives the signal when it is an optical signal, then produces an electrical analog signal that corresponds to the received optical signal. A POSITA would further have understood that the photodetector receives many optical signals, one of which is the claimed "second optical signal on a second wavelength."

viii. Claim 1: [1.G] an amplifier for amplifying the electrical analog signal to an amplified electrical analog signal;

214. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses a preamplifier (shown in yellow below) that amplifies the electrical signals received from the photodetector, where the amplitude of the signals is controlled by a programmable gain amplifier (shown in blue below). Ex. 1009 at 6:46-60, Fig. 5.

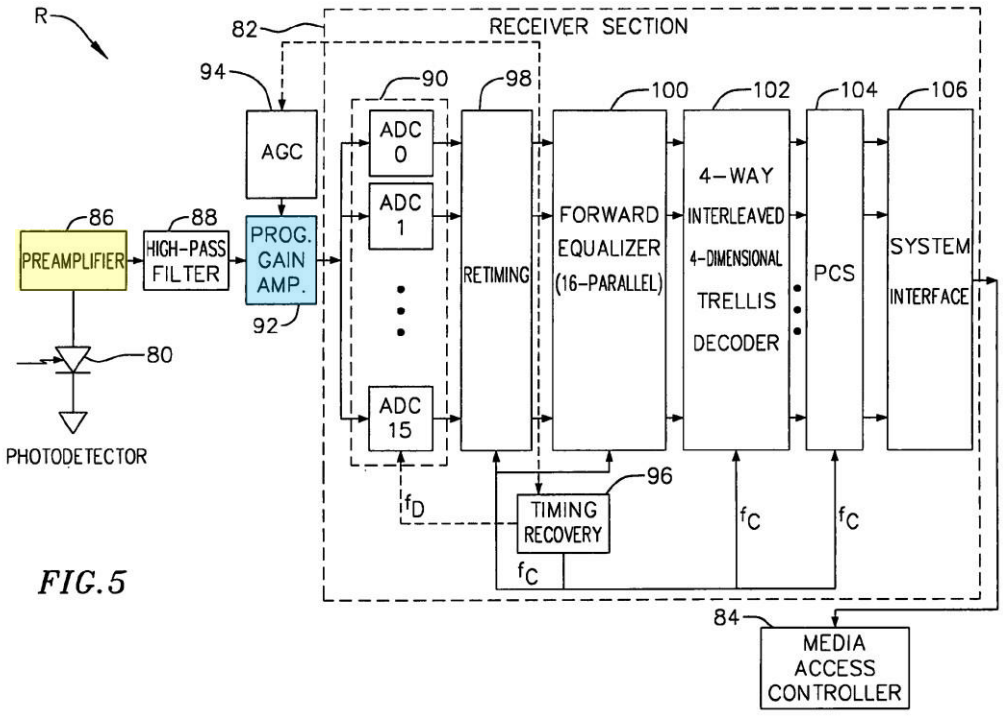


FIG.5

215. A POSITA would have understood that the preamplifier amplifies a received signal (*i.e.*, electrical analog signal) to produce an amplified signal (*i.e.*, amplified electrical analog signal).

ix. Claim 1: [1.H] a clock data recovery unit for recovering clock and data information to produce a second m-ary modulation signal from the amplified electrical analog signal;

216. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses a receiver system that amplifies the electrical signals received from the photodetector, where the amplitude of the signals is controlled by a programmable gain amplifier. Ex. 1009 at 6:46-60, Fig. 5. The gain of the amplifier is, in turn, controlled by an automatic gain control AGC. Ex. 1009 at 6:46-60. The amplified electrical signal is then sent to pretiming and a timing recovery circuit (shown in yellow below) to recover clock and data information (Ex. 1009 at 6:61-7:17). *Id.* at Fig. 5 (annotated). Specifically, Agazzi '341 discloses that, after the electrical signals are amplified, they pass through "retiming … to, in effect, align the signals … during each clock cycle" and through a "timing recovery circuit" that "provides a number of clocks to the components of the receiver." Ex. 1009, 6:61, Fig. 5.

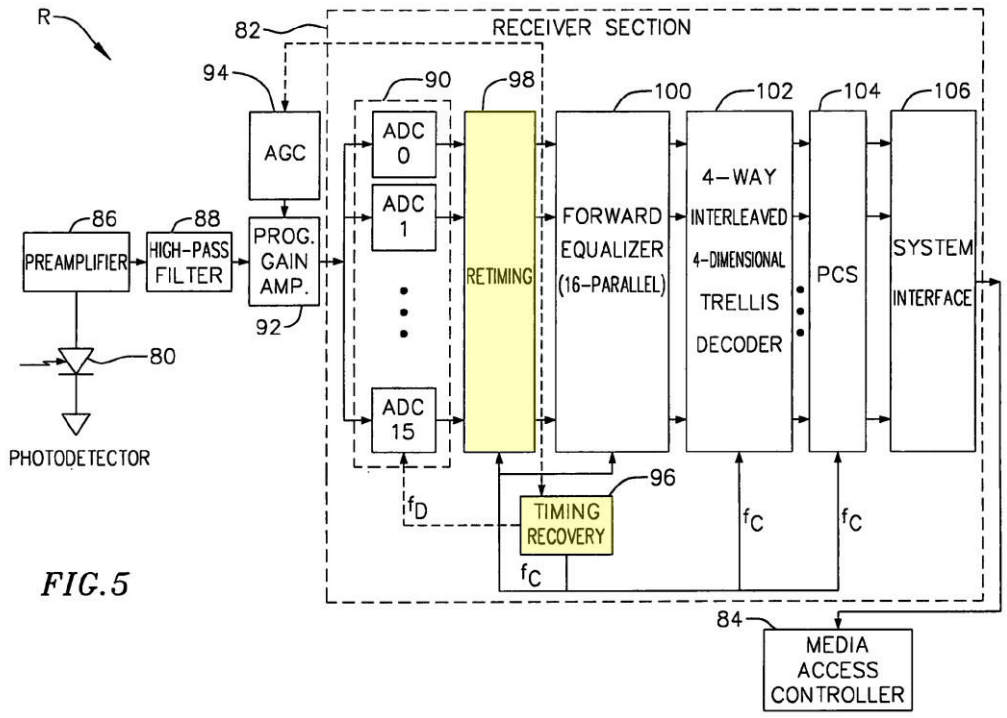
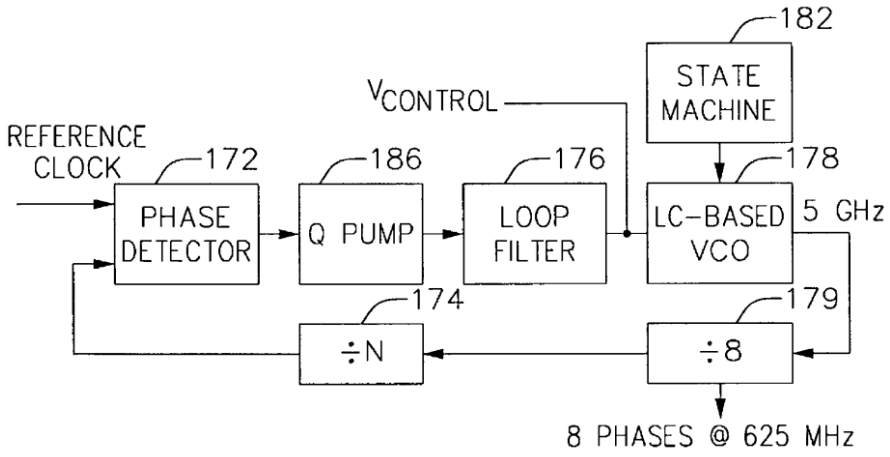


FIG. 5

217. Agazzi '341 further discloses a receiver system that uses a phase locked loop architecture with a reference clock signal for timing recovery between the transmitter clock signal and the receiver clock signal. Ex. 1009 at 11:21-29, Fig. 17.

FIG. 17



218. It was also well-known in the art at the time that clock and data recovery was a routine part of signal processing that occurs in the receiver, and a POSITA would have understood that the retiming and timing recovery circuit (*i.e.*, clock data recovery unit) receive an input signal (*i.e.*, amplified electrical analog signal), recover clock and data information, and produce an output signal (*i.e.*, second m-ary modulation signal).

x. Claim 1: [1.I] an equalizer for performing equalization on the second m-ary modulation signal to remove noise; and

219. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses "a forward equalizer that may be used in the receiver of FIG. 5." Ex. 1009 at 2:57-58, Fig. 5 (annotated).

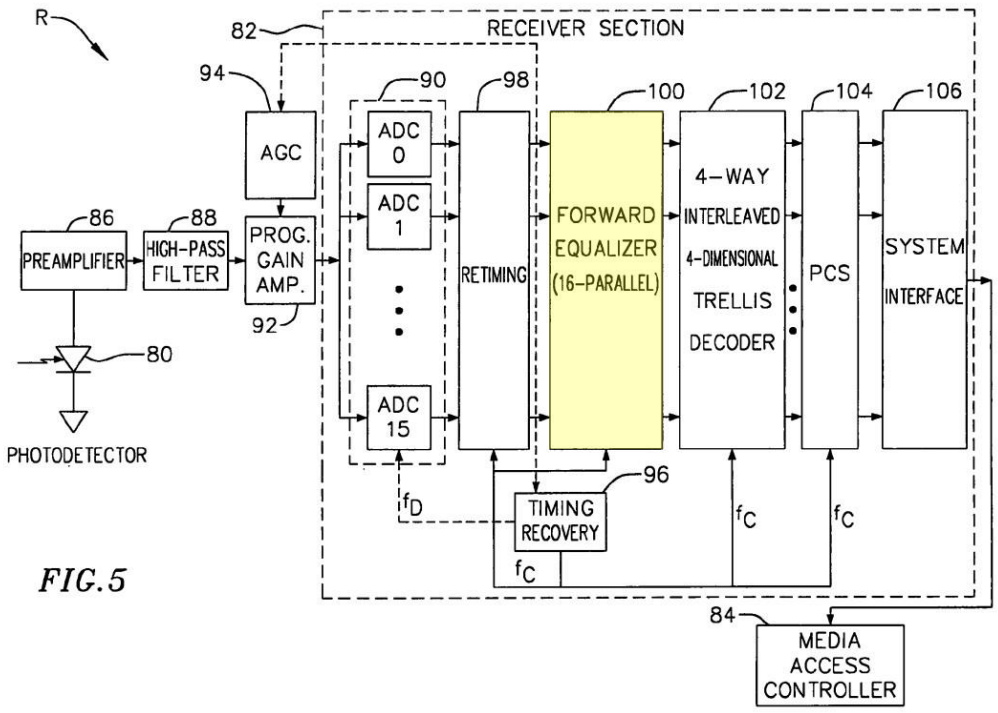


FIG. 5

220. Agazzi ’341 further discloses incorporating “equalization for compensating for intersymbol interference introduced by the limited bandwidth of the multimode fiber.” Ex. 1009 at 4:40-49. As the ’181 Patent characterizes ISI as noise, the equalizer in Agazzi ’341 reduces noise because it compensates for ISI. Ex. 1001 at 12:20-26, 16:14-17. Moreover, it was well-known in the art at the time that equalizers are used to reduce noise. *See supra*, Section V(d). A POSITA would have understood that the equalizer in Agazzi ’341 equalizes a received signal (*i.e.*, second m-ary modulation signal) to reduce noise.

xi. Claim 1: [1.J] an m-ary demodulator for decreasing the number of bits per symbol in the equalized second m-ary modulation signal to produce the second electrical data signal.

221. A POSITA would have understood Agazzi ’341 discloses this limitation. Agazzi ’341 discloses that the invention may be practiced with different levels of modulation including any level of PAM coding, such as PAM-3 or PAM-5. Ex. 1009 at 15:47-49. Agazzi ’341 also discloses a receiver system with a “symbol-by-symbol decoder … that compares the input signal with threshold levels to determine, for example, the PAM level of the received signal.” Ex. 1009 at 14:35-48. A POSITA would have known that the decoder (shown in yellow below) includes a demodulator to process the m-ary modulated signal. For example, a prior art textbook teaches that trellis encoding systems “are more complex in that they combine error-correction with the modulation.” Ex. 1015, 121.

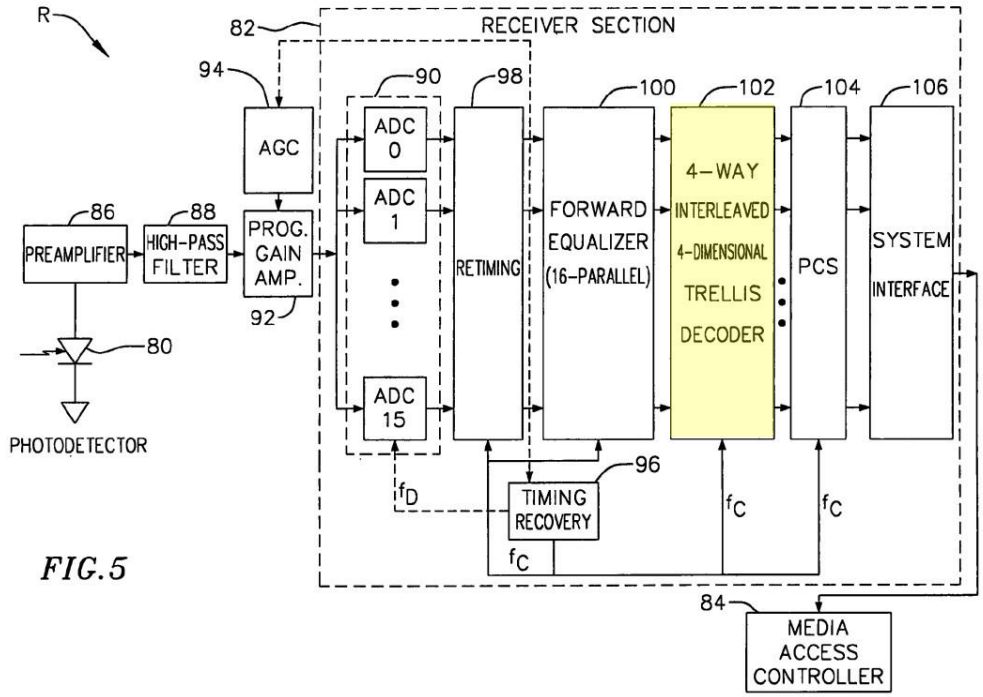


FIG.5

Moreover, the ’181 Patent teaches that m-ary demodulators decrease the number of bits per symbol. Ex. 1001, 15:31-33.

222. The PAM-demodulators disclosed in Agazzi ’341 are m-ary demodulators because the ’181 Patent identifies PAM as an example of a m-ary modulation technique. Ex. 1001 at 10:20-28. A POSITA would have understood that the PAM-demodulator (*i.e.*, m-ary demodulator) in the trellis decoder demodulates the input signal (*i.e.*, equalized second m-ary modulation signal) to produce a demodulated output signal (*i.e.*, second electrical data signal).

xii. Claim 2: The pluggable optical transceiver module of claim 1, wherein the form factor of the pluggable optical transceiver module is a pluggable form factor standard.

223. A POSITA would have understood Wei discloses this limitation. Wei discloses a "fiber optic transceiver module" with "vertically stacked printed circuit boards allows packaging the [transceiver] within an LC or other ***small form factor package***." Ex. 1006 at 2:17-35 (emphasis added). Specifically, Wei discloses a "***small form pluggable (SFP)***" transceiver. Ex. 1006 at 2:1-4. As I explain in the technical background section, multisource agreements define the physical requirements for standardized pluggable form factors, which include the SFP. *See supra*, Section V(b). A POSITA would have understood that an SFP was a pluggable form factor standard for optical transceiver modules.

xiii. Claim 3: The pluggable optical transceiver module of claim 2, wherein the pluggable form factor standard of the pluggable optical transceiver module is a small form factor pluggable (SFP) or SFP+ form factor standard.

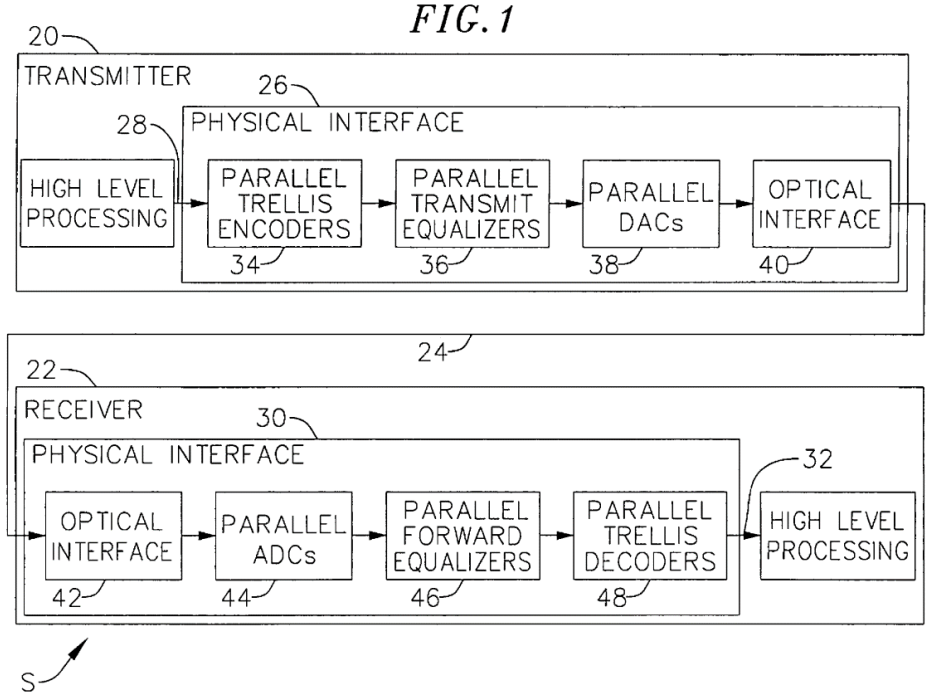
224. A POSITA would have understood Wei discloses this limitation. Wei discloses a "fiber optic transceiver module" with "vertically stacked printed circuit boards allows packaging the [transceiver] within an LC or other ***small form factor package***." Ex. 1006 at 2:17-35 (emphasis added). Specifically, Wei discloses a "***small form pluggable (SFP)***" transceiver. Ex. 1006 at 2:1-4. As I explain in the technical background section, multisource agreements define the physical requirements for standardized pluggable form factors, which include the SFP. *See*

supra, Section V(b). A POSITA would have understood that an SFP was a pluggable form factor standard for optical transceiver modules.

xiv. Claim 8: The pluggable optical transceiver module of claim 1, wherein the electrical system interface includes parallel signals.

225. A POSITA would have understood the combination of Agazzi '341 and Wei discloses this limitation. Agazzi '341 discloses an optical transceiver module that employs "***parallel processing*** to achieve reliable data transmission at relatively high data transfer rates." Ex. 1009 at 1:55-2:7 (emphasis added). Specifically, Agazzi '341 discloses "***parallel processing*** in the transmitter, receiver and data converters." Ex. 1009 at 4:50-57 (emphasis added). For example, Agazzi '341 discloses that "[o]ne embodiment of the transceiver incorporates parallel encoding and decoding." Ex. 1009 at 2:21-23. Figure 1, reproduced below, shows the parallel processing capabilities disclosed in Agazzi '341.

FIG. 1



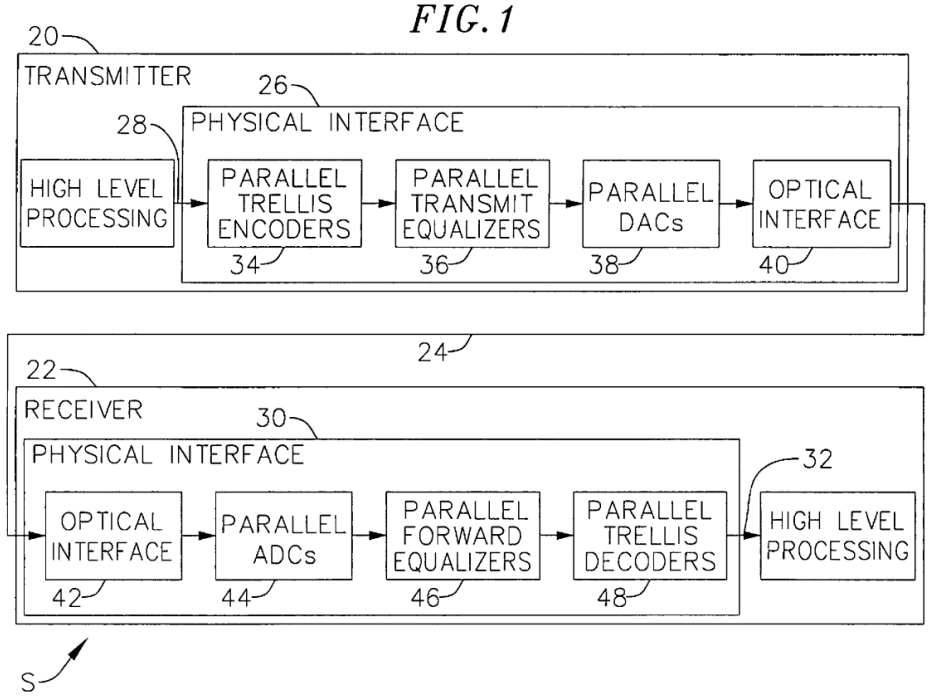
226. Figure 1 also shows electrical binary data signals that are received into and transmitted out of the transceiver and which are parallel signals. Ex. 1009 at Fig. 1. Because the transceiver has parallel processing capabilities, the transceiver must have an electrical interface configured to receive and transmit parallel signals. Accordingly, a POSITA would have understood the electrical system interface includes parallel signals as the transceiver receives and transmits parallel signals, and there are multiple such signals.

227. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '341 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xv. Claim 10: The pluggable optical transceiver module of claim 1, wherein the first electrical data signal and second electrical data signal includes parallel electrical data signals.

228. A POSITA would have understood the combination of Agazzi '341 and Wei discloses this limitation. Agazzi '341 discloses an optical transceiver module that employs "***parallel processing*** to achieve reliable data transmission at relatively high data transfer rates." Ex. 1009 at 1:55-2:7 (emphasis added). Specifically, Agazzi '341 discloses "***parallel processing*** in the transmitter, receiver and data converters." Ex. 1009 at 4:50-57. For example, Agazzi '341 discloses that "[o]ne embodiment of the transceiver incorporates parallel encoding and decoding." Ex. 1009 at 2:21-23. Figure 1, reproduced below, shows the parallel processing capabilities disclosed in Agazzi '341.

FIG. 1



229. Figure 1 also shows electrical binary data signals that are received into and transmitted out of the transceiver and which are parallel signals. Ex. 1009 at Fig. 1. Because the transceiver has parallel processing capabilities, the transceiver must have an electrical interface configured to receive and transmit parallel signals. Accordingly, a POSITA would have understood the electrical system interface includes parallel signals as the transceiver receives and transmits parallel signals, and there are multiple such signals (*i.e.*, first electrical binary data signal and second electrical binary data signal).

230. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '341 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xvi. Claim 11: The pluggable optical transceiver module of claim 1, wherein the electrical system interface includes an attachment unit interface (AUI) based interface.

231. A POSITA would have understood the combination of Agazzi '341 and Wei discloses this limitation. The '181 Patent discloses that one type of AUI interface is the "XAUI" interface. Ex. 1001 at 9:25. Moreover, the prior art identifies the "10Gb/s attachment unit interface (XAUI)" in a standard defined by IEEE 802.3. Ex. 1028 at 1:39-45. Agazzi '341 discloses the "XAUI interface" as an option for the system interface. Ex. 1009 at 15:1. A POSITA would have been

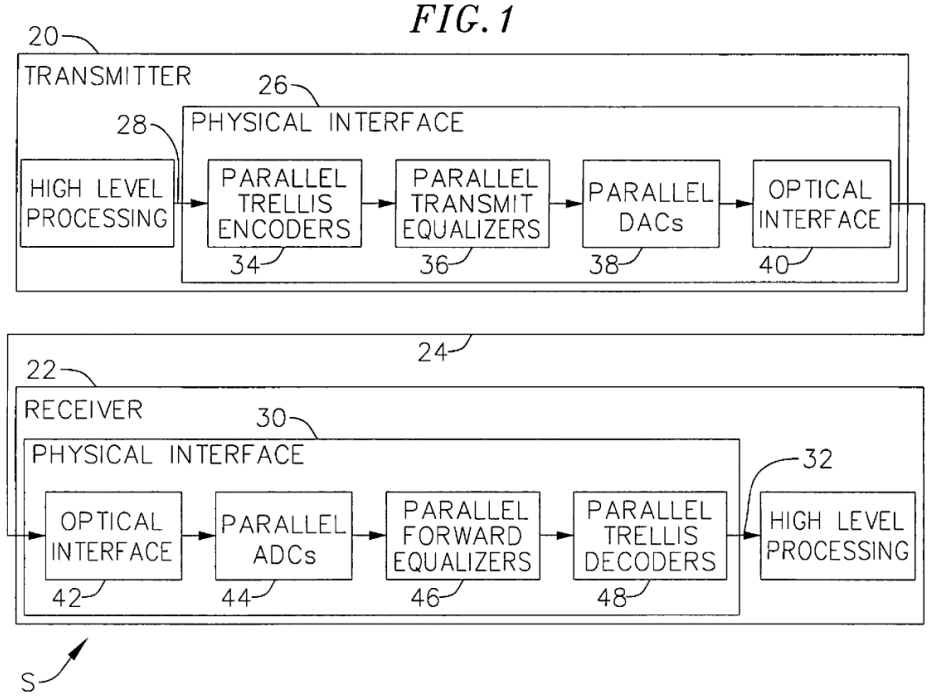
familiar with the XAUI standard as it was defined by IEEE 802.3 and would have understood the XAUI interface in Agazzi ’341 discloses the AUI limitation.

232. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi ’341 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xvii. Claim 12: The pluggable optical transceiver module of claim 1, wherein the first optical signal on a first wavelength is configured to emit into a first optical fiber and the second optical signal on a second wavelength is configured to be received from the first optical fiber.

233. A POSITA would have understood the combination of Agazzi ’341 and Wei renders this limitation obvious. Agazzi ’341 discloses: “A transmitter 20 sends data to a receiver 22 over an optical channel 24” (Ex. 1009 at 3:52-53) where the “optical channel typically consists of a standard … fiber optic cable.” (Ex. 1009 at 4:33-35).

FIG. 1



234. As shown in Figure 1 above, Agazzi '341 discloses a transmitter that emits optical signals (*i.e.*, one of which is the first optical signal on a first wavelength) into the optical channel (*i.e.*, first optical fiber) and a receiver that receives optical signals (*i.e.*, one of which is the second optical signal on a second wavelength) from the optical channel (*i.e.*, first optical fiber). A POSITA would have understood that the optical channel, or cable, can include a single optical fiber or multiple optical fibers and that the two optical signals can traverse either different or the same optical fibers, as this was an obvious selection from a finite number of choices. For example, U.S. Patent No. 6,005,694 teaches that "dozens of fibers may be included in a single cable." Ex. 1011 at 1:39-41.

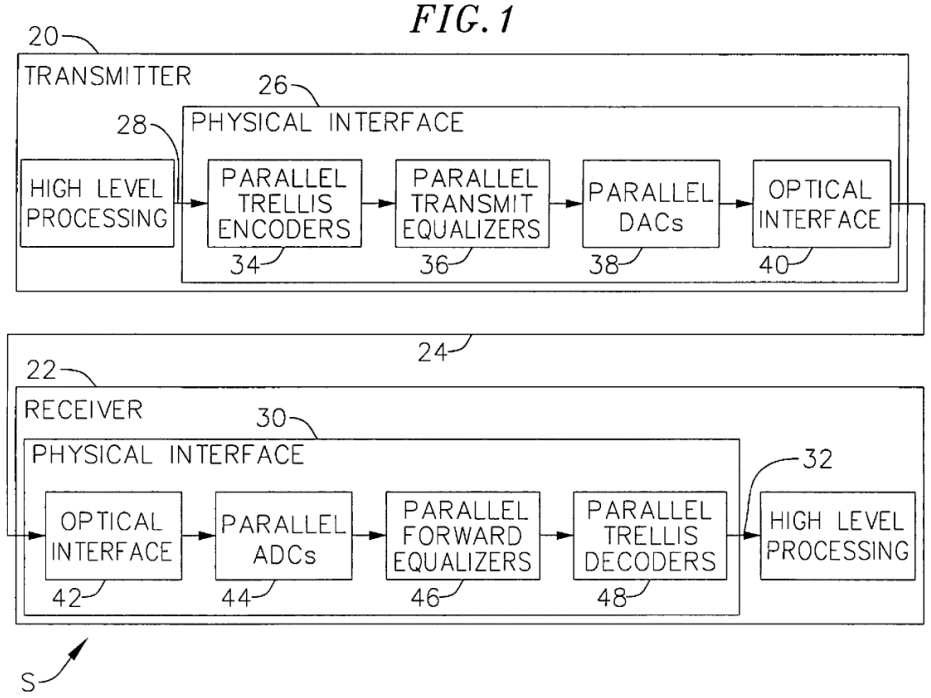
235. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in

Agazzi ’341 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xviii. Claim 13: The pluggable optical transceiver module of claim 1, wherein the first optical signal on a first wavelength is configured to emit into a first optical fiber and the second optical signal on a second wavelength is configured to be received from a second optical fiber.

236. A POSITA would have understood the combination of Agazzi ’341 and Wei discloses renders this limitation obvious. Agazzi ’341 discloses: “A transmitter 20 sends data to a receiver 22 over an optical channel 24” (Ex. 1009 at 3:52-53) where the “optical channel typically consists of a standard … fiber optic cable.” (Ex. 1009 at 4:33-35).

FIG. 1



237. As shown in Figure 1 above, Agazzi ’341 discloses a transmitter that emits optical signals (*i.e.*, one of which is the first optical signal on a first

wavelength) into the optical channel (*i.e.*, first optical fiber) and a receiver that receives optical signals (*i.e.*, one of which is the second optical signal on a second wavelength) from the optical channel (*i.e.*, second optical fiber). A POSITA would have understood that the optical channel, or cable, can include a single optical fiber or multiple optical fibers and that the two optical signals can traverse either different or the same optical fibers, as this was an obvious selection from a finite number of choices. For example, U.S. Patent No. 6,005,694 teaches that "dozens of fibers may be included in a single cable." Ex. 1011 at 1:39-41..

238. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '341 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xix. Claim 14: The pluggable optical transceiver module of claim 1, wherein the noise removed by the equalizer includes intersymbol interference (ISI).

239. A POSITA would have understood the combination of Agazzi '341 and Wei discloses this limitation. Agazzi '341 discloses an equalizer "for ***compensating for intersymbol interference*** introduced by the limited bandwidth of the multimode fiber." Ex. 1009 at 4:40-42 (emphasis added). As explained in the technical background section, equalizers remove noise by multiplying different versions of the signal with coefficients or weights based on channel characteristics, and then

sum these weighed signals to form the output signal. *See supra*, Section V(d). As the '181 Patent characterizes ISI as noise, a POSITA would have understood that the equalizer in Agazzi '341, which reduces ISI, was adapted to remove noise. Ex. 1001 at 12:20-26, 16:14-17.

240. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '341 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xx. Claim 15: The pluggable optical transceiver module of claim 1, wherein the equalizer performs decision directed equalization on the second m-ary modulation signal to remove noise.

241. A POSITA would have understood the combination of Agazzi '341 and Wei discloses this limitation. Agazzi '341 discloses an equalizer "for compensating for intersymbol interference introduced by the limited bandwidth of the multimode fiber." Ex. 1009 at 4:40-42. Agazzi '341 also discloses a "***decision feedback equalizer***" (*i.e.*, decision directed equalizer) where "channel information [is] generated by a feedback filter 148 in the decision feedback equalizer." Ex. 1009 at 10:11-22 (emphasis added). Agazzi '341 further teaches that "channel information consists of coefficients generated by an adaptive equalization algorithm." Ex. 1009 at 10:36-38. As I explain in the technical background section, in decision directed equalization, the equalizer estimates the coefficients without knowledge of the

channel statistics—it uses only the transmitted signal characteristics without a training sequence. *See supra,* Section V(d). A POSITA would have understood that the decision feedback equalization in Agazzi '341 was equivalent to the claimed decision directed equalization because it generates coefficients representative of channel characteristics without a training sequence. Moreover, as the '181 Patent characterizes ISI as noise, a POSITA would also have understood that the equalizer in Agazzi '341, which uses coefficients to reduce ISI, was adapted to remove noise. Ex. 1001 at 12:20-26, 16:14-17.

242. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '341 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xxi. Claim 16: The pluggable optical transceiver module of claim 1, wherein the equalizer performs blind equalization on the second m-ary modulation signal to remove noise.

243. A POSITA would have understood the combination of Agazzi '341 and Wei discloses this limitation. Agazzi '341 discloses an equalizer "for compensating for intersymbol interference introduced by the limited bandwidth of the multimode fiber." Ex. 1009 at 4:40-42. Agazzi '341 also discloses a "decision feedback equalizer" where "channel information [is] generated by a feedback filter 148 in the decision feedback equalizer." Ex. 1009 at 10:11-22. Agazzi '341 further teaches

that "channel information consists of coefficients generated by an adaptive equalization algorithm." Ex. 1009 at 10:36-38. As I explain in the technical background section, decision directed equalization is a type of blind equalization because the equalizer estimates the coefficients without knowledge of the channel statistics—it uses only the transmitted signal characteristics without a training sequence. *See supra*, Section V(d). A POSITA would have understood the decision feedback equalization in Agazzi '341 was a type of blind equalization because it generates coefficients representative of channel characteristics without a training sequence. Moreover, as the '181 Patent characterizes ISI as noise, a POSITA would also have understood that the decision feedback equalizer (*i.e.*, blind equalizer) in Agazzi '341, which uses coefficients to reduce ISI, was adapted to remove noise. Ex. 1001 at 12:20-26, 16:14-17.

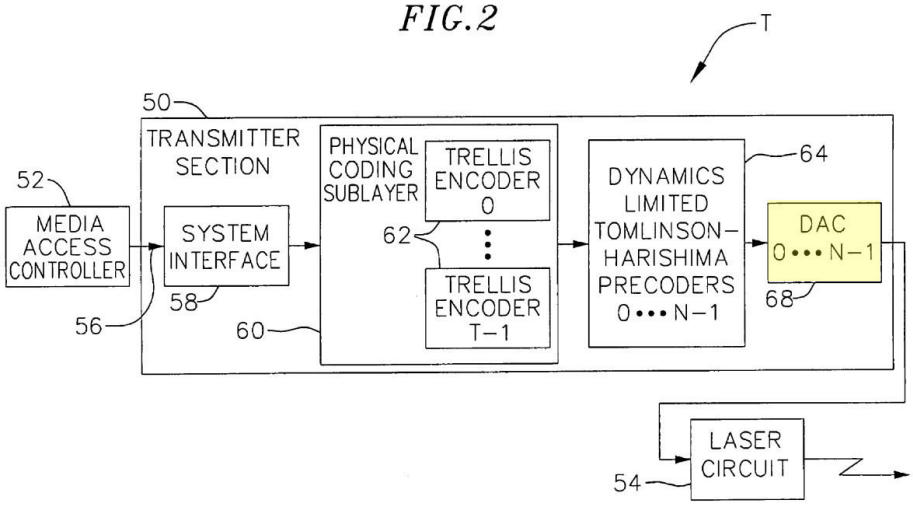
244. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '341 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xxii. Claim 17: The pluggable optical transceiver module of claim 1, wherein the digital to analog converter is configured to shape, condition, or emphasize the first electrical m-ary analog modulation signal for improved transmission performance.

245. A POSITA would have understood the combination of Agazzi '341 and Wei discloses this limitation. Agazzi '341 discloses a transmitter with "digital to

analog converters (DACs)." Ex. 1009 at 4:12-20. As shown in Figure 2, after passing through the processing elements in the transmitter, the signals pass through a D/A converter (in yellow below) that converts digital signals to analog signals. Ex. 1009 at Fig. 2 (annotated). A POSITA would understand the digital to analog converter conditions the signal from the digital to analog domain to assist with transmission in subsequent steps as analog signals are required to drive the laser.

FIG. 2



246. Specifically, depicts a set of parallel dynamics limited Tomlinson-Harashima precoders (64) that are used to condition the signal for transmission. Ex. 1009 at 5:45-47. The purpose of these precoders is to provide filtering that corresponds to the inverse of the channel characteristic, and, in that way compensate for analog distortions inherent to the transmission channel. For example, if the z-transform of the channel is 1+D(z), then the precoder would have a response 1/(1+D(z)). Ex. 1009 at 5:54-57. Following the precoder, the digital signal must then be converted into an analog form by a D/A converter so that the analog

distortions of the channel will be mediated or conditioned by the analog pre-compensated signal.

247. A POSITA would have understood that the D/A converter (*i.e.*, digital to analog converter) in Agazzi '341 is configured to shape, condition, or emphasize the signal (*i.e.*, the first electrical m-ary analog modulation signal) to improve the transmission performance of the signal.

248. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in Agazzi '341 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

xxiii. Claim 22[3]: [22.pre] A pluggable optical transceiver module comprising of:

249. *See supra* claim 1[pre] at Section XI(a)(i).

xxiv. Claim 22: [22.A] an electrical system interface for receiving a first electrical data signal and for transmitting a second electrical data signal;

250. *See supra* claim 1[a] at Section XI(a)(ii).

[3] Claim 22 is practically identical to Claim 1. The only difference is that claim 22 adds limitation [22.K], "wherein the m-ary modulator and the m-ary demodulator perform m-ary pulse amplitude modulation and de-modulation, respectively, that uses two or more bits per symbol."

xxv. Claim 22: [22.B] an m-ary modulator for increasing the number of bits per symbol in the first electrical data signal to produce a first m-ary modulation signal;

251. *See supra* claim 1[b] at Section XI(a)(iii).

xxvi. Claim 22: [22.C] a digital to analog converter for converting the first m-ary modulation signal to a first electrical m-ary analog modulation signal;

252. *See supra* claim 1[c] at Section XI(a)(iv).

xxvii. Claim 22: [22.D] a driver for amplifying the first electrical m-ary analog modulation signal to an amplified first electrical m-ary analog modulation signal to drive an optical transmitter;

253. *See supra* claim 1[d] at Section XI(a)(v).

xxviii. Claim 22: [22.E] the optical transmitter for emitting a first optical signal on a first wavelength responsive to and representative of the amplified first electrical m-ary analog modulation signal from the driver;

254. *See supra* claim 1[e] at Section XI(a)(vi).

xxix. Claim 22: [22.F] an optical detector for receiving a second optical signal on a second wavelength to produce an electrical analog signal;

255. *See supra* claim 1[f] at Section XI(a)(vii).

xxx. Claim 22: [22.G] an amplifier for amplifying the electrical analog signal to an amplified electrical analog signal;

256. *See supra* claim 1[g] at Section XI(a)(viii).

xxxi. Claim 22: [22.H] a clock data recovery unit for recovering clock and data information to produce a second m-ary modulation signal from the amplified electrical analog signal;

257. *See supra* claim 1[h] at Section XI(a)(ix).

xxxii. Claim 22: [22.I] an equalizer for performing equalization on the second m-ary modulation signal to remove noise;

258. *See supra* claim 1[i] at Section XI(a)(x).

xxxiii. Claim 22: [22.J] an m-ary demodulator for decreasing the number of bits per symbol in the equalized second m-ary modulation signal to produce the second electrical data signal; and

259. *See supra* claim 1[j] at Section XI(a)(xi).

xxxiv. Claim 22: [22.K] wherein the m-ary modulator and the m-ary demodulator perform m-ary pulse amplitude modulation and de-modulation, respectively, that uses two or more bits per symbol.

260. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses an optical transceiver module that "utilizes five-level ***pulse amplitude modulation*** (PAM-5)." Ex. 1009 at 4:33-39 (emphasis added). Agazzi '341 further discloses that "[t]he invention may be practiced with different data modulation schemes. Including, for example, any level of PAM coding (e.g., PAM-3, PAM-7)." Ex. 1009 at 15:47-49. Ex. 1009 at 15:47-49. Agazzi '341 also discloses a receiver system with a "symbol-by-symbol decoder … that compares the input signal with threshold levels to determine, for example, the PAM level of the received signal." Ex. 1009 at 14:35-48. A POSITA would have understood that the symbol by symbol decoder must include a PAM-demodulator to process the m-ary modulated signal.

261. The ’181 Patent identifies PAM as an example of m-ary modulation. Ex. 1001 at 10:22-28. A POSITA would have understood the PAM modulation disclosed in Agazzi ’341 to cover m-ary PAM modulation/demodulation because the ’181 Patent disclosed PAM modulation as a type of m-ary modulation.

xxxv. Claim 23[4]: [23.pre] A pluggable optical transceiver module comprising of:

262. *See supra* claim 1[pre] at Section XI(a)(i).

xxxvi. Claim 23: [23.A] an electrical system interface for receiving a first electrical data signal and for transmitting a second electrical data signal;

263. *See supra* claim 1[a] at Section XI(a)(ii).

xxxvii. Claim 23: [23.B] an m-ary modulator for increasing the number of bits per symbol in the first electrical data signal to produce a first m-ary modulation signal;

264. *See supra* claim 1[b] at Section XI(a)(iii).

xxxviii. Claim 23: [23.C] a digital to analog converter for converting the first m-ary modulation signal to a first electrical m-ary analog modulation signal;

265. *See supra* claim 1[c] at Section XI(a)(iv).

xxxix. Claim 23: [23.D] a driver for amplifying the first electrical m-ary analog modulation signal to an amplified first

[4] Claim 23 is practically identical to Claim 1. The only difference is that claim 23 adds limitation [23.K], “wherein the equalizer includes coefficients or weights configured to remove noise from the second m-ary modulation signal.”

electrical m-ary analog modulation signal to drive an optical transmitter;

266. *See supra* claim 1[d] at Section XI(a)(v).

xl. Claim 23: [23.E] the optical transmitter for emitting a first optical signal on a first wavelength responsive to and representative of the amplified first electrical m-ary analog modulation signal from the driver;

267. *See supra* claim 1[e] at Section XI(a)(vi).

xli. Claim 23: [23.F] an optical detector for receiving a second optical signal on a second wavelength to produce an electrical analog signal;

268. *See supra* claim 1[f] at Section XI(a)(vii).

xlii. Claim 23: [23.G] an amplifier for amplifying the electrical analog signal to an amplified electrical analog signal;

269. *See supra* claim 1[g] at Section XI(a)(viii).

xliii. Claim 23: [23.H] a clock data recovery unit for recovering clock and data information to produce a second m-ary modulation signal from the amplified electrical analog signal;

270. *See supra* claim 1[h] at Section XI(a)(ix).

xliv. Claim 23: [23.I] an equalizer for performing equalization on the second m-ary modulation signal to remove noise;

271. *See supra* claim 1[i] at Section XI(a)(x).

xlv. Claim 23: [23.J] an m-ary demodulator for decreasing the number of bits per symbol in the equalized second m-ary modulation signal to produce the second electrical data signal; and

272. *See supra* claim 1[j] at Section XI(a)(xi).

xlvi. Claim 23: [23.K] wherein the equalizer includes coefficients or weights configured to remove noise from the second m-ary modulation signal.

273. A POSITA would have understood Agazzi '341 discloses this limitation. Agazzi '341 discloses an equalizer "for compensating for intersymbol interference introduced by the limited bandwidth of the multimode fiber." Ex. 1009 at 4:40-42. Agazzi '341 also discloses "***equalizer coefficients***." Ex. 1009 at 10:11-15 (emphasis added). Agazzi '341 teaches that "channel information consists of ***coefficients generated by*** an adaptive ***equalization*** algorithm." Ex. 1009 at 10:36-38 (emphasis added). As explained in the technical background section, equalizers remove noise by multiplying different versions of the signal with coefficients or weights based on channel characteristics, and then sum these weighed signals to form the output signal. *See supra*, Section V(d). As the '181 Patent characterizes ISI as noise, a POSITA would have understood that the equalizer in Agazzi '341, which uses coefficients to reduce ISI, was adapted to remove noise. Ex. 1001 at 12:20-26, 16:14-17.

b. Ground 4: The combination of Agazzi '341, Wei, and Agazzi '640 render claims 5-6 obvious.

274. As previously described, both Agazzi '341 and Wei relate to fiber-optic communications. And both Agazzi '341 and Wei attempt to increase the data throughput rates. Ex. 1009 at 1:46-51; Ex. 1006 at 1:66-2:4. In particular, Agazzi '341 teaches a transceiver module that performs m-ary modulation, including "five-

level pulse amplitude modulation (PAM-5)." Ex. 1009 at 4:33-35. Agazzi '341 further teaches that "any level of PAM coding (e.g., PAM-3, PAM-7)" can be used. Ex. 1009 at 15:47-49. This allows the transceiver module in Agazzi '341 to transmit data at higher rates through existing fiber infrastructure, which is a specific goal of Agazzi '341. However, Agazzi '341 and Wei do not expressly disclose QAM or QPSK.

275. Agazzi '640, like Agazzi '341 and Wei, relates to fiber-optic communications. Ex. 1005 at 4:15-32, 12:18-23, 15:7-10, 16:7-14, Figs. 1D, 2A, 3. Specifically, Agazzi '640 discloses performing multilevel modulation within the transmitter/receiver portions of the optical transceiver, including "Pulse Amplitude Modulation (PAM) or Quadrature Amplitude Modulation (QAM) to encode several bits per transmitted symbol." Ex. 1005 at 3:15-20, Figs. 2A, 3. Agazzi '640 further discloses performing "quadrature phase shift keying (QPSK)" modulation. Ex. 1005 at 17:7. There were several reasons a POSITA would have been motivated to combine Agazzi '640 with Agazzi '341 and Wei.

276. First, both Agazzi '341 and Agazzi '640 disclose multilevel modulation techniques that can be used to increase the data throughput. And Agazzi '640 discloses additional multilevel modulation techniques (e.g., QAM and QPSK) that allow for increased data transmission compared to the PAM modulation disclosed in Agazzi '341. Ex. 1006 at 1:66-2:4. As increasing the data throughput rate was a

stated goal in both Agazzi ’341 and Agazzi ’640, a POSITA would naturally have look to Agazzi ’640 to find higher order modulation techniques to further increase the data transmission rate.

277. Moreover, increasing the data transmission rate was also a stated goal in Wei. Thus, a POSITA would have been motivated to add one of the higher order modulation techniques described in Agazzi ’640 to the m-ary pluggable transceiver taught by the combination of Agazzi ’341 and Wei to create an m-ary pluggable transceiver with increased data rates. This allowed for more data to be transferred in the same channel over the same amount of time and was a simple way to increase data speeds in a communication system without going through the costly and resource intensive activity of replacing older fiber channels.

278. Second, the higher order modulation techniques disclosed in Agazzi ’640 were cost effective ways to increase data throughput. Decreasing costs was a stated goal in both Agazzi ’341 and Wei as well as Agazzi ’640. Ex. 1009 at 1:50-51; Ex. 1006 at 1:50-69; Ex. 1005 at 1:45-49. Agazzi ’640 was cost effective because it allowed for increased data speeds without the need to replace older fiber channels, which can be costly endeavor. Thus, a POSITA would have been motivated to combine Agazzi ’640 with Agazzi ’341 and Wei because an m-ary pluggable transceiver with the advanced modulation techniques taught by Agazzi ’640 allows for greater data transmission rates. This allowed for more data to be

transferred in the same channel over the same amount of time and was a simple way to increase data speeds without replacing older fiber channels.

279. Moreover, a POSITA would have had a reasonable expectation of success in adding the QAM and/or QPSK modulation capabilities to the m-ary pluggable transceiver to produce expected results. In fact, many of the expected results of the combination were stated goals in the references.

i. Claim 5: The pluggable optical transceiver module of claim 1, wherein the m-ary modulator and the m-ary demodulator perform m-ary quadrature amplitude modulation and de-modulation, respectively, that uses two or more bits per symbol.

280. A POSITA would have understood the combination of Agazzi '341, Wei, and Agazzi '640 discloses this limitation. Agazzi '341 and Wei disclose the limitations in claim 1. Agazzi '640 discloses performing multilevel modulation within the transmitter portion of the optical transceiver, including "***Quadrature Amplitude Modulation*** (QAM) to ***encode several bits per*** transmitted ***symbol***." Ex. 1005 at 3:15-20 (emphasis added), Figs. 2A, 10. Agazzi '640 further discloses, in the receiver portion of the optical transceiver, "demodulators, which will demodulate the signal according to the modulation used by the transmit apparatus." Ex. 1005 at 2:1-11, Figs. 3, 12.

281. The '181 Patent identifies QAM as an example of m-ary modulation. Ex. 1001 at 10:20-26. A POSITA would have understood the QAM modulator/demodulator disclosed in Agazzi '640 to cover m-ary QAM

modulation/demodulation because the ’181 Patent disclosed QAM modulation as a type of m-ary modulation.

282. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed by the combination of Agazzi ’341 and Agazzi ’640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

ii. Claim 6: The pluggable optical transceiver module of claim 1, wherein the m-ary modulator and the m-ary demodulator perform m-ary quadrature phase shift keying modulation and de-modulation, respectively, that uses two or more bits per symbol.

283. A POSITA would have understood the combination of Agazzi ’341, Wei, and Agazzi ’640 discloses this limitation. Agazzi ’341 and Wei disclose the limitations in claim 1. Agazzi ’640 discloses performing multilevel modulation within the transmitter portion of the optical transceiver, including “***quadrature phase shift keying*** (QPSK).” Ex. 1005 at 17:5-8 (emphasis added). Agazzi ’640 further teaches that multilevel modulation is used “to ***encode several bits per*** transmitted ***symbol***.” Ex. 1005 at 3:15-20 (emphasis added), Figs. 2A, 10. Agazzi ’640 further discloses, in the receiver portion of the optical transceiver, “demodulators, which will demodulate the signal according to the modulation used by the transmit apparatus.” Ex. 1005 at 2:1-11, Figs. 3, 12.

284. The ’181 Patent identifies QPSK as an example of m-ary modulation. Ex. 1001 at 10:20-26. A POSITA would have understood the QPSK

modulator/demodulator disclosed in Agazzi ’640 to cover m-ary QPSK modulation/demodulation because the ’181 Patent disclosed QPSK modulation as a type of m-ary modulation.

285. Wei discloses a pluggable optical transceiver module, and a POSITA would have been motivated to combine the optical transceiver module disclosed in the combination of Agazzi ’341 and Agazzi ’640 with the pluggable form factor disclosed in Wei for the reasons previously stated above.

XII. Revision or Supplementation

286. In this report, I have presented my opinions regarding the invalidity of the challenged claims of the ’181 Patent based on the information available to me. My opinions are subject to change in view of opinions provided by the Patent Owner or its expert, or any additional information that I may receive. I reserve the right to supplement my opinions accordingly.

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

Executed March 13, 2023

Dr. Paul R. Prucnal