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U.S. Patent 7,295,518

U.S. Patent 7,295,518 ("*Entropic Communications*" or the "patent-at-issue") was filed on December 18, 2002 and claims the benefit of U.S. Provisional Pat. App. No. 60/316,820, filed on August 30, 2001. Claim 1 of the patent-at-issue is generally directed to a data communication network comprising at least two network devices each comprising a multi-carrier modulator for modulating data, an up converter for translating the modulated data to an RF carrier frequency, a down converter for translating an RF signal, and a multi-carrier demodulator for demodulating the translated RF signal to produce data. The network further comprises cable wiring comprising a splitter with a common port and a plurality of tap ports and a plurality of segments of coaxial cable connecting between the splitter tap ports and the network devices. The network devices communicate with each other through the cable wiring using multi-carrier signaling, transmit probe messages through the cable wiring, and analyze received probe message signals to determine channel characteristics. Bit loading is selected based on the determined channel characteristics.

The primary reference, U.S. Patent 6,865,232 ("*STMicroelectronics*"), was filed on July 15, 1997 and claims the benefit of Swedish Pat. App. No. 9603187-7, filed on September 2, 1996. The patent generally relates to a multi-carrier transmission system comprising a plurality of transceivers. Data is transmitted between the transceivers by modulating the data onto a multiplicity of carrier waves in the form of multi-bit symbols. Each carrier wave constitutes a channel, and the number of bits per symbol (bit loading) varies between channels and with time within a channel so that each channel has an associated bit loading parameter. In operation, the multi-carrier system is adapted to synchronously update the bit loading parameters associated with each channel at the transceivers by transmission of data over a control channel. The control channel is established on a predetermined one of the multiplicity of carrier waves known to the transceivers at system start-up and changed from the predetermined channel to a further channel selected by the first transceiver on the basis of channel characteristics after start-up.

The secondary reference, U.S. Patent 6,344,749 ("*Williams*"), was filed on December 6, 1997and claims the benefit of U.S. Pat. App. No. 08/865,237, filed on May 29, 1997. The patent generally relates to a test system for measuring a frequency response of a signal path by transmitting a short duration burst test signal from a remote point, capturing an impaired burst test signal on a digital signal acquisition unit, and analyzing the received signal by digitally processing it with an unimpaired burst test signal. A dynamic range test can also be performed with the same burst test signal by removing the energy in a part of the frequency band with a notch filter and then increasing the power of the burst test signal level until non-linear distortion occurs. The distortion products will fill-in the notch, allowing the clipping threshold of the signal path to be measured.

A sample claim chart comparing claim 1 of *Entropic Communications* to *STMicroelectronics* and *Williams* is provided below.

US7295518 (“*Entropic Communications*”)	A. **US6865232** (“*STMicroelectronics*”) B. **US6344749** (“*Williams*”)
1.pre. **A data communication network** comprising:	**A. US6865232** “**The system, to which the present invention relates, is for convenience referred to as MUSIC—MUlti-carrier System for the Installed Copper network. MUSIC is intended to provide high-speed communication on telephone copper wire pairs for supporting broadband multimedia services.**” *STMicroelectronics* at col. 10:4-8 “**The MUSIC system is a DMT-based, multi-carrier, VDSL system, using Discrete Fourier Transforms to create and demodulate individual carriers. This is illustrated in FIG. 2, which shows two transceivers each of which has a receiver, Rx, and a transmitter, Tx, connected to a twisted copper pair. Data is transmitted between the two transceivers using a plurality of carriers**, some of which may not be used, e.g. where channel quality is extremely poor. The number of bits conveyed by each carrier may also vary, depending on channel quality.” *STMicroelectronics* at col. 10:46-55 **B. US6344749** “**This invention relates to systems for testing cable networks**. More particularly, it relates to systems for testing the frequency response and dynamic range of signal paths.” *Williams* at col. 1:13-15 “**Cable systems currently in use typically allow two way communications between the headend or distribution hubs and many remote points that may be houses. A headend is a collection point for both upstream and downstream signals**. . . . **Digital carriers, such as digital audio, digital TV, cable telephone, and computer data, are increasingly being transported by the downstream system**.” *Williams* at col. 1:18-41
1.a. **at least two network devices, each network device comprising a multi-carrier modulator for modulating data, an up converter for translating the modulated data to an RF carrier frequency**,	**A. US6865232** “1. **A multi-carrier transmission system comprising a first and a second transceiver, each of said transceivers having a receiver and a transmitter, wherein data is transmitted between said transceivers by modulating said data onto a multiplicity of carrier waves in the form of multi-bit symbols**, ...” *STMicroelectronics* at claim 1

(cont.) 1.a. **at least two network devices, each network device comprising a multi-carrier modulator for modulating data, an up converter for translating the modulated data to an RF carrier frequency**,	"**The MUSIC system is a DMT-based, multi-carrier, VDSL system, using Discrete Fourier Transforms to create and demodulate individual carriers. This is illustrated in FIG. 2, which shows two transceivers each of which has a receiver, Rx, and a transmitter, Tx, connected to a twisted copper pair. Data is transmitted between the two transceivers using a plurality of carriers**, some of which may not be used, e.g. where channel quality is extremely poor. The number of bits conveyed by each carrier may also vary, depending on channel quality." *STMicroelectronics* at col. 10:46-55 "FIG. 4 shows an overview of **a MUSIC modem** to which the present invention relates. **The main hardware blocks are ADC and DAC, synchronization, fourier transform processing, channel estimation/equalizer, symbol mapping and detection, coding and decoding with interleaving, network interface and system controller**." *STMicroelectronics* at col. 11:17-22 "**VDSL systems work in the spectrum from 0 to 40 MHz. In this band the MUSIC system, herein described, occupies the lower 10 MHz**, see FIG. 6." *STMicroelectronics* at col. 13:18-20 "**The modulated signal passes to a DAC which converts the signal with a minimum true dynamic range of 84 dB. The DAC is clocked by the system sample clock at 20 MHz**." *STMicroelectronics* at col. 12:5-7 "**An OFDM-frame is a sum of sinusoidal carriers modulated in phase and amplitude and spaced in the frequency domain with a minimum distance of separation between carriers**." *STMicroelectronics* at col. 15:15-18 **B. US6344749** "1. A system for testing a signal path to produce a complex frequency response of the signal path, said system comprising: **a transmitter connected to a first location of the signal path, said transmitter for transmitting a predefined test signal, having a short duration, along the signal path; a receiver connected to a second location of the signal path wherein the receiver receives the test signal as an impaired test signal**;" *Williams* at claim 1 "13. The system of claim 1 wherein **the test signal is**

(cont.) 1.a. **at least two network devices, each network device comprising a multi-carrier modulator for modulating data, an up converter for translating the modulated data to an RF carrier frequency**,	**upconverted to RF frequency before being transmitted** and further wherein the received test signal is downconverted into the impaired test signal before being processed." *Williams* at claim 13 "**A television signal RF output** 428 **from the modulator** 426 **is connected to a combiner network** 430 **which sums the television signal RF output** 428 **with other RF signals and applies the composite signal to a downstream laser transmitter** 108 **at headend signal insertion point** 160. In the field, a technician views the test result on a standard television tuned to the television RF output being supplied by the modulator 426." *Williams* at col. 8:65-67 through col. 9:1-6 "At a 20th step 540 **the technician may also decide to review the raw burst test signal data** or the raw impaired burst test signal data." *Williams* at col. 11:48-50 "8. **Any type of burst test signal may be used. This includes** the Koo signal invented by David Koo, quadratic chirps, stepped quadratic chirps as disclosed in the parent application, impulses, **OFDM (orthogonal frequency division multiplexing)** or any training signal with desirable properties that may be invented in the future." *Williams* at col. 18:29-35 "12. **The test system of the present invention tests an RF signal path with multiple channels at baseband. The test system may be used to test a higher frequency signal path, such as microwave, that is above the range of baseband techniques. This is done by connecting the transmitter device** 201 **to an upconverter. An output of the upconverter is connected to an RF signal path, and an output of the RF signal path is connected to an input of a downconverter. An output of the downconverter, which may produce both inphase (I) and quadrature (Q) outputs, is connected to the receiver system** 402. **Either double sideband, single sideband, or vestigial sideband modulation may be used by the upconverter and downconverter**. The use of double sideband demodulation requires both I and Q data capture, which can be done on a digital oscilloscope using channel 1 input for I and channel 2 input for Q. Triggering may occur on the external trigger input." *Williams* at col. 18:61-67 through col. 19:1-11

1.b. **a down converter for translating an RF signal, and a multi-carrier demodulator for demodulating the translated RF signal to produce data**; and	**A. US6865232** "**The MUSIC system is a DMT-based, multi-carrier, VDSL system, using Discrete Fourier Transforms to create and demodulate individual carriers. This is illustrated in FIG. 2, which shows two transceivers each of which has a receiver, Rx, and a transmitter, Tx, connected to a twisted copper pair. Data is transmitted between the two transceivers using a plurality of carriers**, some of which may not be used, e.g. where channel quality is extremely poor. The number of bits conveyed by each carrier may also vary, depending on channel quality." *STMicroelectronics* at col. 10:46-55 "FIG. 4 shows an overview of **a MUSIC modem** to which the present invention relates. **The main hardware blocks are ADC and DAC, synchronization, fourier transform processing, channel estimation/equalizer, symbol mapping and detection, coding and decoding with interleaving, network interface and system controller**." *STMicroelectronics* at col. 11:17-22 "**A discrete multi-tone (DMT) system modulates N complex data symbols onto N carriers (here we use N=1024 carriers). This mapping is computed as an inverse discrete Fourier transform by using the Inverse Fast Fourier Transform (IFFT). In the receiver the N carriers are demodulated by a FFT**." *STMicroelectronics* at col. 19:38-43 **B. US6344749** "13. The system of claim 1 wherein **the test signal is upconverted to RF frequency before being transmitted and further wherein the received test signal is downconverted into the impaired test signal before being processed**." *Williams* at claim 13 "7. **The output of the software can be data files with magnitude, phase, group delay, impulse response, raw temporal data, and raw spectral data These data files can be put into a format compatible with spread-sheet computer programs**." *Williams* at col. 18:24-28 "8. **Any type of burst test signal may be used. This includes** the Koo signal invented by David Koo, quadratic chirps, stepped quadratic chirps as disclosed in the parent application, impulses, **OFDM (orthogonal frequency division multiplexing)** or any training signal with desirable properties

(cont.) 1.b. **a down converter for translating an RF signal, and a multi-carrier demodulator for demodulating the translated RF signal to produce data**; and	that may be invented in the future." *Williams* at col. 18:29-35 "12. **The test system of the present invention tests an RF signal path with multiple channels at baseband. The test system may be used to test a higher frequency signal path, such as microwave, that is above the range of baseband techniques. This is done by connecting the transmitter device** 201 **to an upconverter. An output of the upconverter is connected to an RF signal path, and an output of the RF signal path is connected to an input of a downconverter. An output of the downconverter, which may produce both inphase (I) and quadrature (Q) outputs, is connected to the receiver system** 402. **Either double sideband, single sideband, or vestigial sideband modulation may be used by the upconverter and downconverter. The use of double sideband demodulation requires both I and Q data capture, which can be done on a digital oscilloscope using channel 1 input for I and channel 2 input for Q**. Triggering may occur on the external trigger input." *Williams* at col. 18:61-67 through col. 19:1-11
1.c. **cable wiring comprising a splitter with a common port and a plurality of tap ports, and a plurality of segments of coaxial cable connecting between the splitter tap ports and the network devices**;	**A. US6865232** "**Early versions of VDSL will use frequency division multiplexing to separate downstream from upstream channels and both of them from POTS and ISDN. Echo cancellation may be required for later generation systems featuring symmetric data rates. A rather substantial distance, in frequency, will be maintained between the lowest data channel and POTS to enable very simple and cost effective POTS splitters. Normal practice would locate the downstream channel above the upstream channel. However, the DAVIC specification reverses this order to enable premises distribution of VDSL signals over coaxial cable systems**." *STMicroelectronics* at col. 2:1-11 "**The system, to which the present invention relates, is for convenience referred to as MUSIC—MUlti-carrier System for the Installed Copper network. MUSIC is intended to provide high-speed communication on telephone copper wire pairs for supporting broadband multimedia services**." *STMicroelectronics* at col. 10:4-8 "**The MUSIC system is a DMT-based, multi-carrier, VDSL system, using Discrete Fourier Transforms to create and demodulate individual carriers. This is illustrated in FIG. 2, which shows two transceivers each of which has a**

(cont.) 1.c. **cable wiring comprising a splitter with a common port and a plurality of tap ports, and a plurality of segments of coaxial cable connecting between the splitter tap ports and the network devices**;	**receiver, Rx, and a transmitter, Tx, connected to a twisted copper pair. Data is transmitted between the two transceivers using a plurality of carriers**, some of which may not be used, e.g. where channel quality is extremely poor. The number of bits conveyed by each carrier may also vary, depending on channel quality." *STMicroelectronics* at col. 10:46-55 "**At the receiver end, the splitter/hybrid transceiver separates the frequencies used by POTS, from 0 to 4 kHz, from the frequencies used by the system**. It also extracts the low level receive signal from the combined high level transmit signal and the low level receive signal." *STMicroelectronics* at col. 12:13-16 **B. US6344749** "**The signal is distributed from the fiber node to a plurality of remote points, which may be homes, via coaxial cable by splitting**." *Williams* at col. 1:32-34 "**The downstream electrical signals are applied to a diplex filter** 116 **which allows bi-directional signal flow on a same hard line coaxial cable** 118. The diplex filter consists of a high-pass section 136 and a low-pass section 138. **Upstream signals taken from the hard line coaxial cable** 118 **pass through the diplex filter** 116 **into the upstream laser transmitter** 114." *Williams* at col. 5:54-61 "**Splitter/combiners, consisting of a splitter/combiner** 120 **and a splitter/combiner** 122 **split the downstream signals and combine the upstream signals. A set of two way amplifiers** 124, 126, 128, 130, 132, **and** 134 **boost the signal level in both directions to overcome the loss of the coaxial cable** 118 **and the splitter/combiners** 120 **and** 122. **Taps, such as a tap** 140, **are also splitting/combining devices that allow signal extraction and insertion. A coaxial cable plant** 142 **can be defined as the coaxial portion of the bidirectional cable system** 100, **which extends from the fiber node** 106 **to the Insides of the houses such as a house** 144. **Typically, the coaxial cable plant** 142 **is constructed of solid sheath hard-line aluminum coaxial cable from the fiber node** 106 **to the tap** 140, **and a braided shield drop cable** 146 **is used from the tap** 140 **to the house** 144 **as well as inside the house** 144. **House** 144 **and drop cable** 146 **form a remote point** 152." *Williams* at col. 5:64-67 through col. 6:1-12

(cont.) 1.c. **cable wiring comprising a splitter with a common port and a plurality of tap ports, and a plurality of segments of coaxial cable connecting between the splitter tap ports and the network devices**;	"FIG. 2 is a transmitter block diagram 200 of **the transmitter device** 201 that is transported by a technician to the remote point 152 **to generate a burst trigger signal** 244 **and a burst test signal** 234 **to test the frequency response and dynamic range of a signal path**. . . . **The burst trigger signal** 244 **on a burst trigger signal lead** 248 **is connected to first tap port** 214 **on the tap** 140, **where it proceeds upstream to the receiver system** 402 **to cause the digital signal acquisition unit to be triggered**." *Williams* at col. 6:29-50
1.d. **whereby network devices communicate with each other through the cable wiring using multi-carrier signaling**;	**A. US6865232** **"The system, to which the present invention relates, is for convenience referred to as MUSIC—MUlti-carrier System for the Installed Copper network. MUSIC is intended to provide high-speed communication on telephone copper wire pairs for supporting broadband multimedia services**." *STMicroelectronics* at col. 10:4-8 "**The MUSIC system is a DMT-based, multi-carrier, VDSL system, using Discrete Fourier Transforms to create and demodulate individual carriers. This is illustrated in FIG. 2, which shows two transceivers each of which has a receiver, Rx, and a transmitter, Tx, connected to a twisted copper pair. Data is transmitted between the two transceivers using a plurality of carriers**, some of which may not be used, e.g. where channel quality is extremely poor. The number of bits conveyed by each carrier may also vary, depending on channel quality." *STMicroelectronics* at col. 10:46-55 "1. **A multi-carrier transmission system comprising a first and a second transceiver, each of said transceivers having a receiver and a transmitter, wherein data is transmitted between said transceivers by modulating said data onto a multiplicity of carrier waves in the form of multi-bit symbols**, ..." *STMicroelectronics* at claim 1 **B. US6344749** "1. A system for testing a signal path to produce a complex frequency response of the signal path, said system comprising: **a transmitter connected to a first location of the signal path, said transmitter for transmitting a predefined test signal, having a short duration, along the signal path**; **a receiver connected to a second location of the signal path wherein the receiver receives the test signal as an impaired**

(cont.) 1.d. **whereby network devices communicate with each other through the cable wiring using multi-carrier signaling**;	**test signal**;" *Williams* at claim 1 "**The downstream electrical signals are applied to a diplex filter** 116 **which allows bi-directional signal flow on a same hard line coaxial cable** 118. The diplex filter consists of a high-pass section 136 and a low-pass section 138. **Upstream signals taken from the hard line coaxial cable** 118 **pass through the diplex filter** 116 **into the upstream laser transmitter** 114." *Williams* at col. 5:54-61 "8. **Any type of burst test signal may be used. This includes** the Koo signal invented by David Koo, quadratic chirps, stepped quadratic chirps as disclosed in the parent application, impulses, **OFDM (orthogonal frequency division multiplexing)** or any training signal with desirable properties that may be invented in the future." *Williams* at col. 18:29-35
1.e. **wherein network devices transmit probe messages through the cable wiring and analyze received probe message signals to determine channel characteristics and bit loading is selected based on the determined channel characteristics**.	**A. US6865232** "**In a multi-carrier system there is always a need to exchange control information between a transmitter and a receiver. This information is generated in the receiver and terminated in the transmitter. This information contains data on the instantaneous characteristics of the channel and information about system change decisions needed to handle the changes in channel characteristics**." *STMicroelectronics* at col. 2:12-18 "**The present invention achieves this requirement, in a multi-carrier modulated system with bit-loading capacity, by dynamically changing the number of coded/decoded bits per carrier wave. The receiver continuously measures and estimates the characteristics and changes of/in the channel. From this information, performance for each sub-channel (sub-wave) is identified. Then, on the basis of this information, reconfigurations of the transmitted number of bits per symbol for each single carrier wave are decided. To transmit this information, from a transmitter to a receiver, a special control channel is established. The control channel is primarily used for the exchange of channel information and bit allocation changes for carrier waves**." *STMicroelectronics* at col. 2:31-43 "According to a first aspect of the present invention, **there is provided a multi-carrier transmission system having a first and a second transceiver, each of said transceivers having a receiver and a transmitter, wherein data is transmitted**

(cont.) 1.e. **wherein network devices transmit probe messages through the cable wiring and analyze received probe message signals to determine channel characteristics and bit loading is selected based on the determined channel characteristics**.	**between said transceivers by modulating said data onto a multiplicity of carrier waves in the form of multi-bit symbols, wherein each of said carrier waves constitutes a channel, and wherein the number of bits per symbol, (the bit loading), varies between channels and, within a channel, with time, so that each channel has associated therewith a bit loading parameter, characterised in that, in operation, said multi-carrier system is adapted to synchronously update, at said first and second transceivers, the bit loading parameters associated with each channel by transmission of data over a control channel, in that said control channel is established, at system start-up, on a predetermined one of said multiplicity of carrier waves whose identity is known to said first and second transceivers, and in that said control channel is, after start-up, changed from said predetermined channel to a further channel, selected by said first transceiver on the basis of channel characteristics**." *STMicroelectronics* at col. 3:6-26 "**Decisions relating to changes in bit loading and control channel selection may be initiated by said first transceiver transmitting command signals over said control channel, said second transceiver may effect changes in bit loading and control channel carrier wave selection, and said second transceiver may measure changes in channel characteristics and forwards data relating thereto over said control channel to said first transceiver**." *STMicroelectronics* at col. 3:27-34 "**The MUSIC system is a DMT-based, multi-carrier, VDSL system, using Discrete Fourier Transforms to create and demodulate individual carriers. This is illustrated in FIG. 2, which shows two transceivers each of which has a receiver, Rx, and a transmitter, Tx, connected to a twisted copper pair. Data is transmitted between the two transceivers using a plurality of carriers, some of which may not be used, e.g. where channel quality is extremely poor. The number of bits conveyed by each carrier may also vary, depending on channel quality**." *STMicroelectronics* at col. 10:46-55 "**The receiver continuously estimates the channel. Equalization changes are made for each new estimate. Using the characteristics, the SC calculates the optimal bit-loading factor. This value is transferred to the transmitter using the CCH and a synchronous change is made**."

(cont.) 1.e. **wherein network devices transmit probe messages through the cable wiring and analyze received probe message signals to determine channel characteristics and bit loading is selected based on the determined channel characteristics**.	*STMicroelectronics* at col. 26:67 through col. 27:1-4 **B. US6344749** "1. **A system for testing a signal path to produce a complex frequency response of the signal path, said system comprising**: **a transmitter connected to a first location of the signal path, said transmitter for transmitting a predefined test signal, having a short duration, along the signal path;** **a receiver connected to a second location of the signal path wherein the receiver receives the test signal as an impaired test signal;**" *Williams* at claim 1 "**One way known in the art to characterize the frequency response of a channel is to use a reference, or training, signal combined with digital signal processing techniques. The frequency response of the channel is characterized as an intermediate step in programming an adaptive equalizer. The function of the adaptive equalizer is to flatten the frequency response of the channel. The reference signal is sent by a transmitter in a quiet period while no other signals are using the frequency band, and received by a receiver. The acquired reference signal is processed with a stored reference signal that is free of impairments**." *Williams* at col. 2:40-50 "**The downstream electrical signals are applied to a diplex filter** 116 **which allows bi-directional signal flow on a same hard line coaxial cable** 118. The diplex filter consists of a high-pass section 136 and a low-pass section 138. **Upstream signals taken from the hard line coaxial cable** 118 **pass through the diplex filter** 116 **into the upstream laser transmitter** 114." *Williams* at col. 5:54-61 "Likewise **the digital sum signal** 1020 **is the desired impulse response which may be captured by a digital signal acquisition unit with a digital input, such as a logic analyzer, and downloaded by the digital signal processor** 420 **to compute the frequency response via an FFT**." *Williams* at col. 17:36-41