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(54) **DISTRIBUTED ANTENNA SYSTEM WITH COMBINATION OF BOTH ALL DIGITAL TRANSPORT AND HYBRID DIGITAL/ANALOG TRANSPORT**

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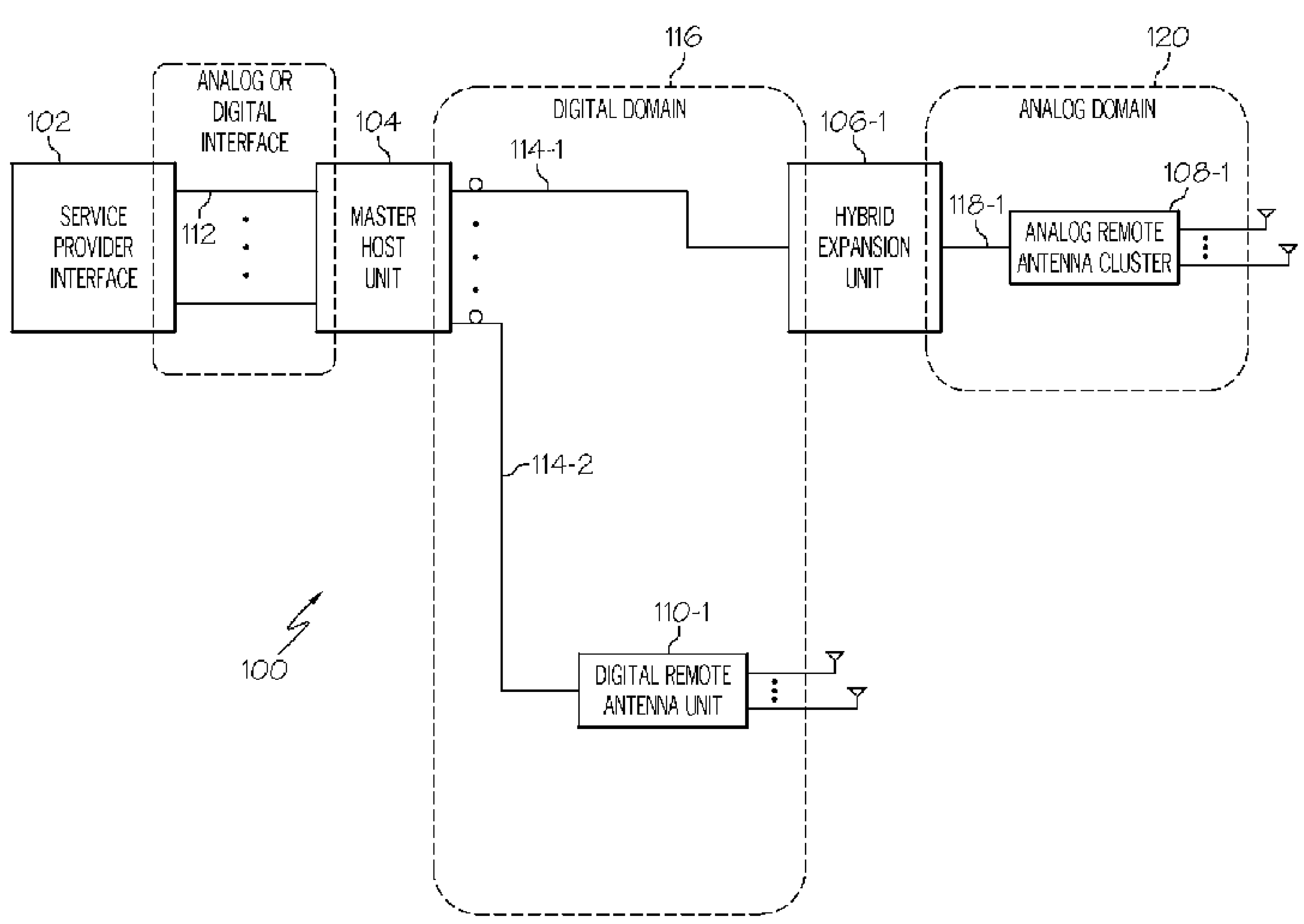
(57) **ABSTRACT**

A communication system includes master host unit, hybrid expansion unit, analog remote antenna unit, and digital remote antenna unit. Master host unit communicates analog signals with at least a first service provider interface using first bands of analog spectrum. Master host unit and hybrid expansion unit communicate first N-bit words of digitized spectrum over first digital link. Hybrid expansion unit converts between first N-bit words and second bands of analog spectrum. Hybrid expansion unit and analog remote antenna unit communicate second bands over analog medium. Analog remote antenna unit transmits and receives first plurality of wireless signals over air interfaces. Master host unit and digital remote antenna unit communicate second N-bit words of digitized spectrum over second digital link. Digital remote antenna unit converts between second N-bit words and third bands of analog spectrum. Digital remote antenna unit transmits and receives second wireless signals over air interfaces.

**62 Claims, 14 Drawing Sheets**



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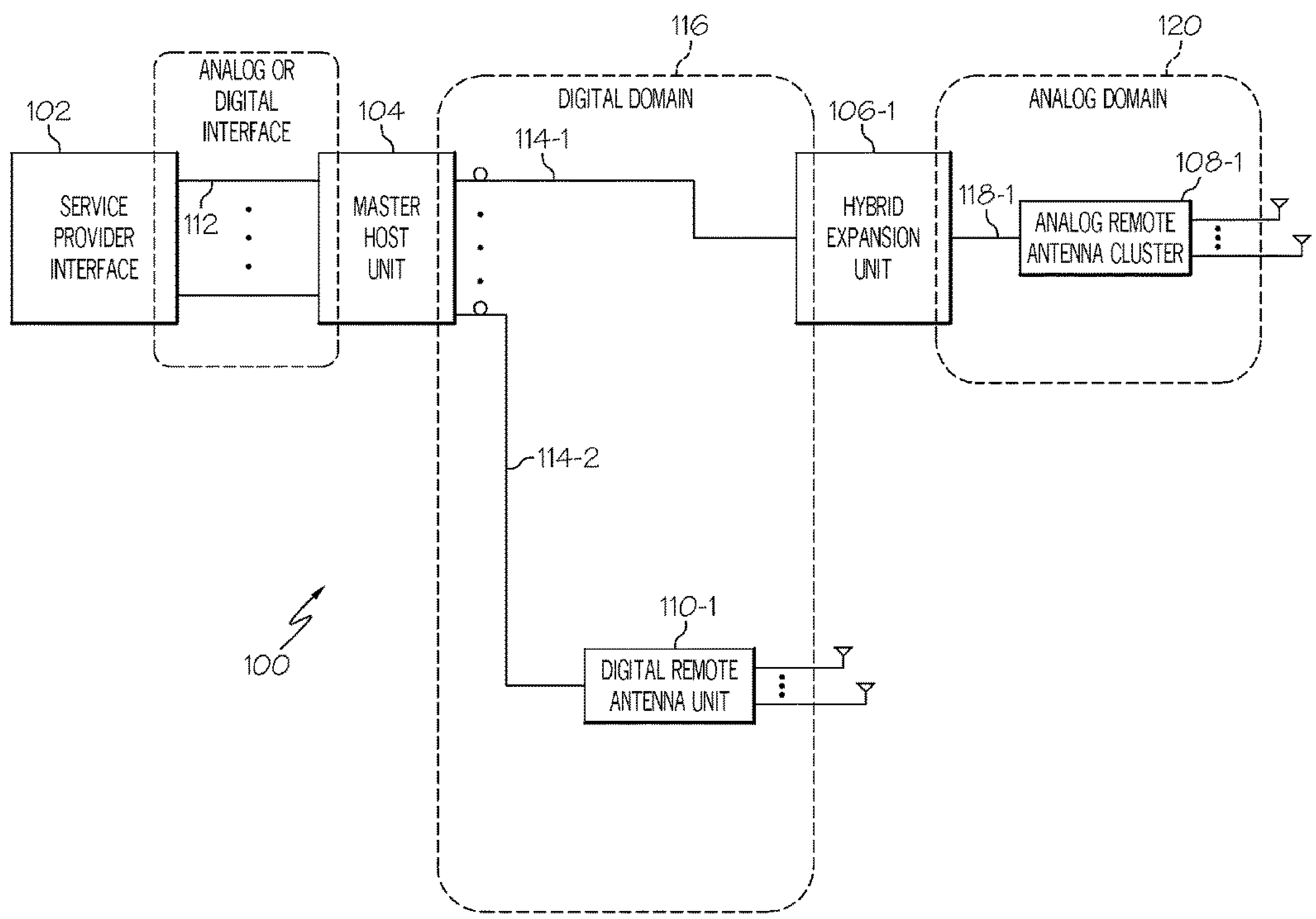
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INTERFACE
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UNIT
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106-1
HYBRID
EXPANSION
UNIT
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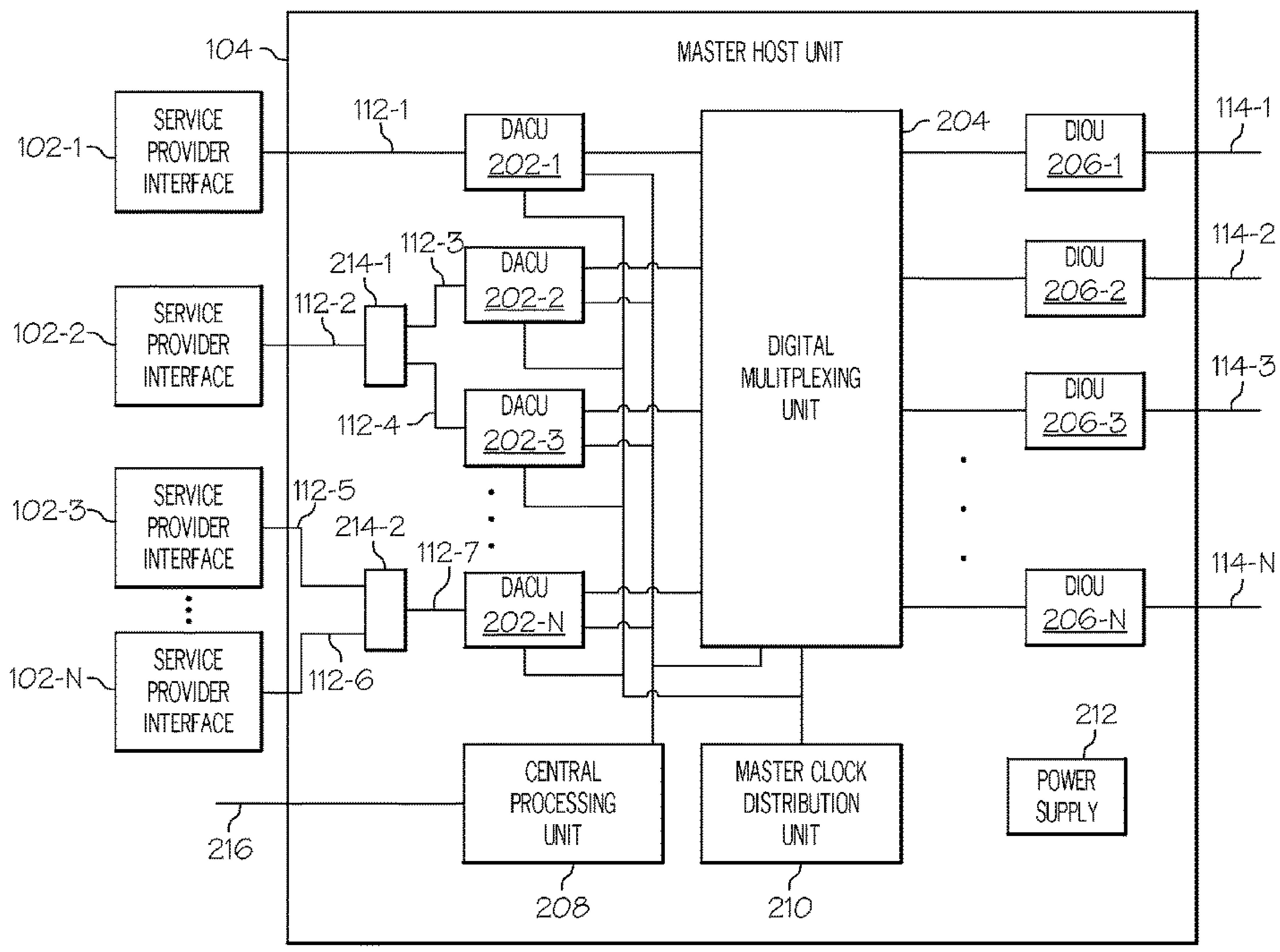
108-1
ANALOG REMOTE
ANTENNA CLUSTER
114-2
110-1
DIGITAL REMOTE
ANTENNA UNIT
100

FIG. 1



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SERVICE PROVIDER INTERFACE
102-3
SERVICE PROVIDER INTERFACE
102-N
SERVICE PROVIDER INTERFACE
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112-2
112-3
112-4
112-5
112-6
112-7
214-1
214-2
DACU 202-1
DACU 202-2
DACU 202-3
DACU 202-N
204
DIGITAL MULITPLEXING UNIT
DIOU 206-1
DIOU 206-2
DIOU 206-3
DIOU 206-N
114-1
114-2
114-3
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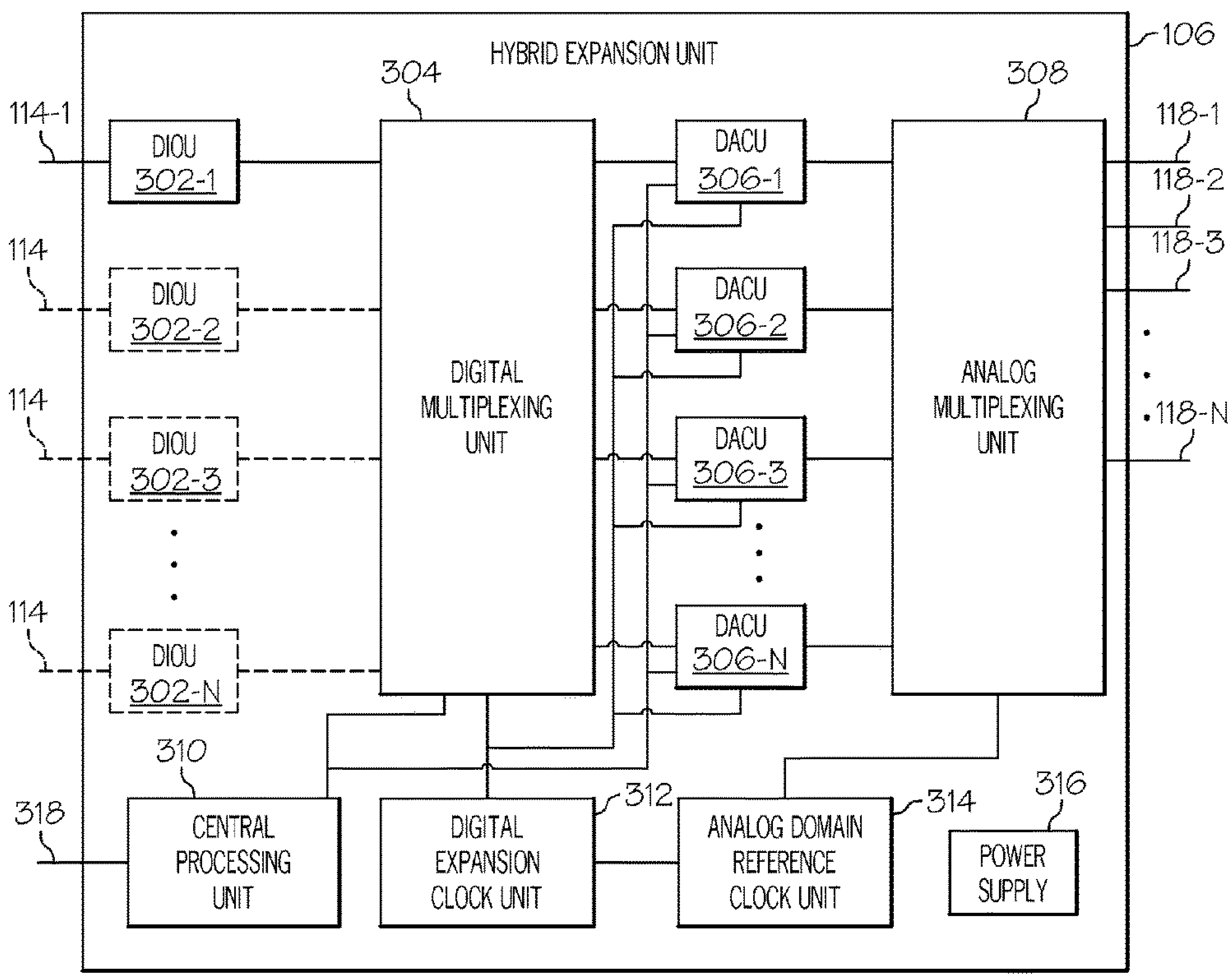
CENTRAL PROCESSING UNIT
MASTER CLOCK DISTRIBUTION UNIT
216
208
210


FIG. 2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DIOU
302-N
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MULTIPLEXING
UNIT
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DACU
306-2
DACU
306-3
DACU
306-N
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MULTIPLEXING
UNIT
118-1
118-2
118-3
118-N
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CENTRAL
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REFERENCE
CLOCK UNIT
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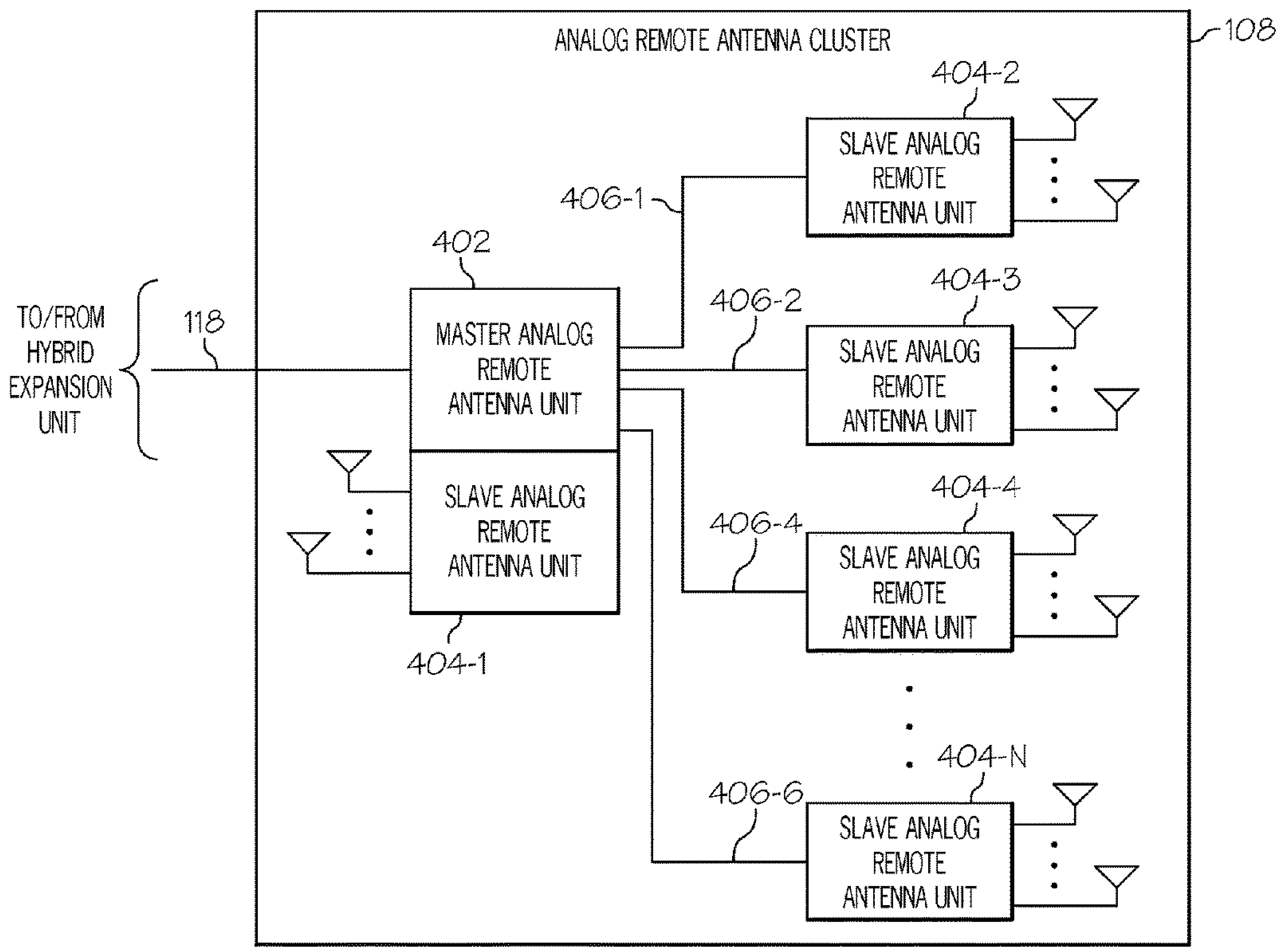
POWER
SUPPLY

FIG. 3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SLAVE ANALOG REMOTE ANTENNA UNIT
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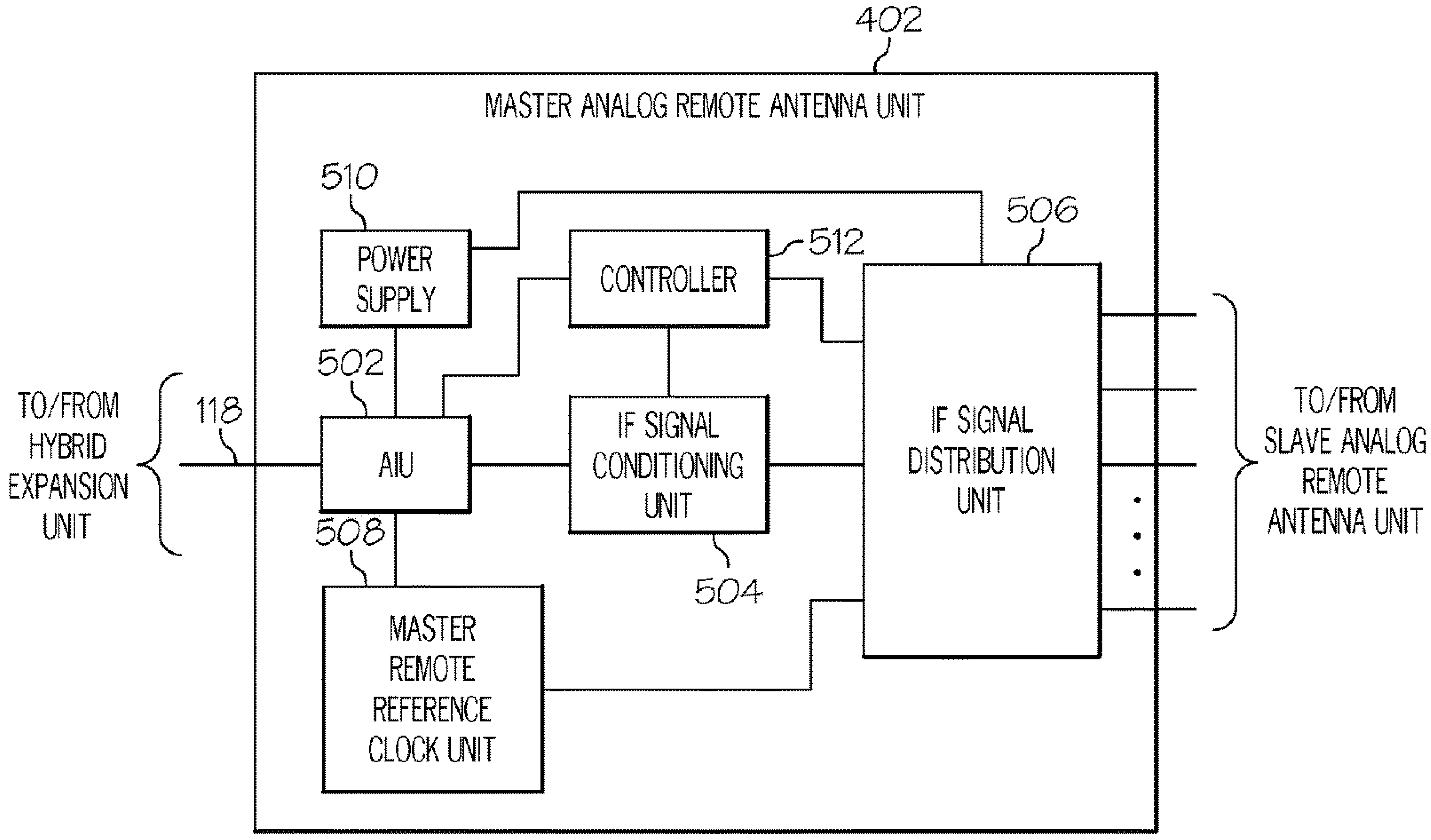
406-6
SLAVE ANALOG REMOTE ANTENNA UNIT

FIG. 4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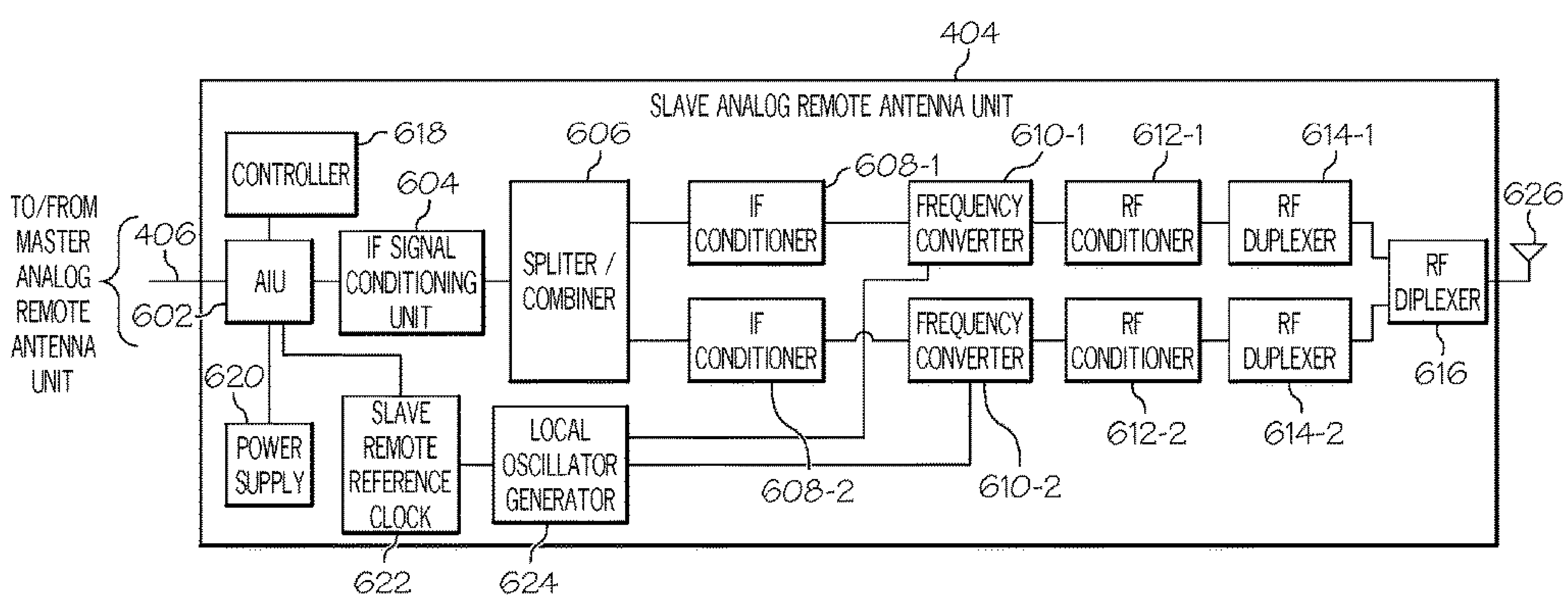
TO/FROM SLAVE ANALOG REMOTE ANTENNA UNIT

FIG. 5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AIU
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SPLITER / COMBINER
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IF CONDITIONER
IF CONDITIONER
608-2
610-1
FREQUENCY CONVERTER
FREQUENCY CONVERTER
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612-1
RF CONDITIONER
RF CONDITIONER
612-2
614-1
RF DUPLEXER
RF DUPLEXER
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RF DIPLEXER
616
626
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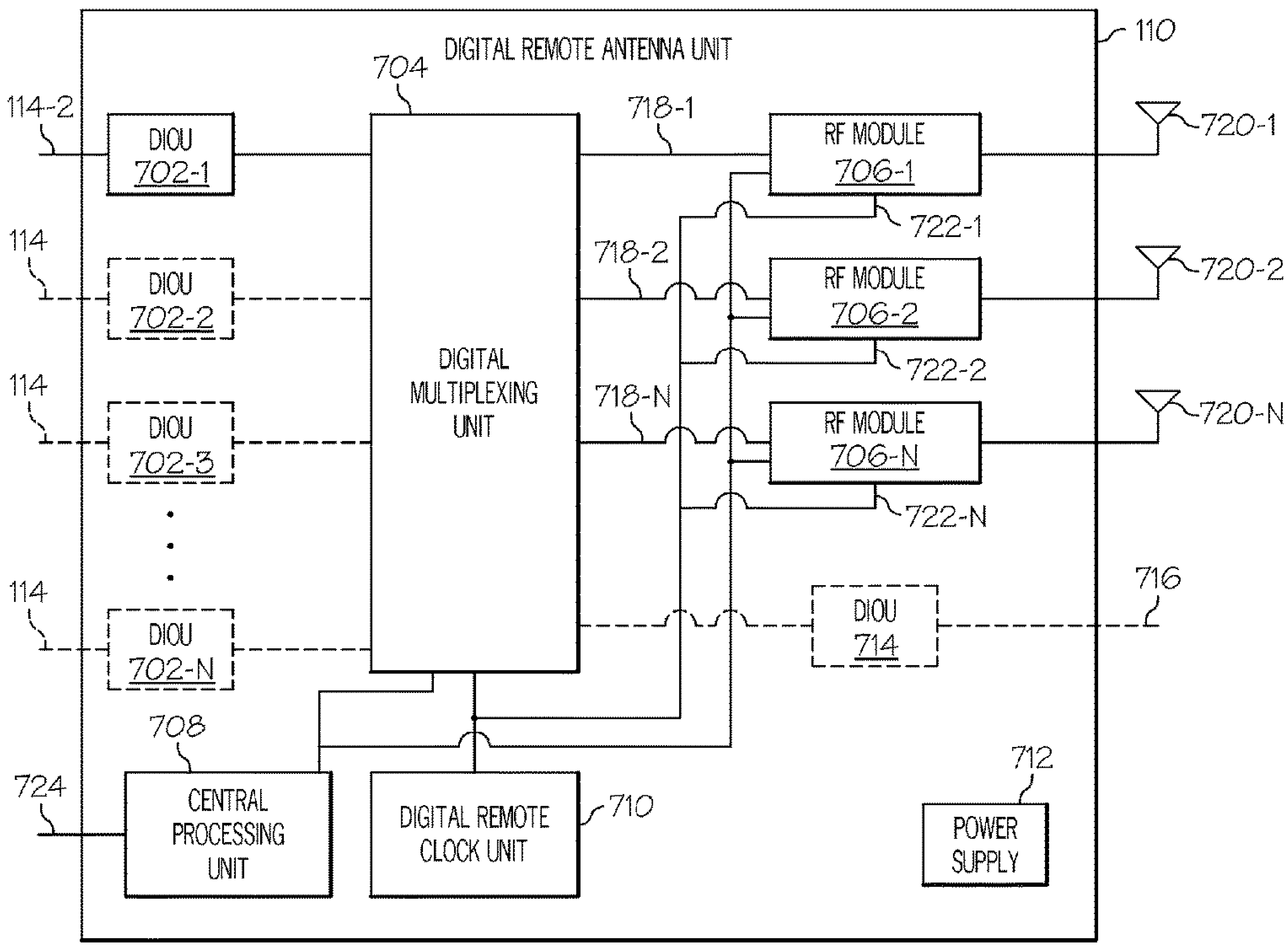
SLAVE REMOTE REFERENCE CLOCK
622
LOCAL OSCILLATOR GENERATOR
624

FIG. 6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UNIT
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702-N
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PROCESSING
UNIT
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CLOCK UNIT
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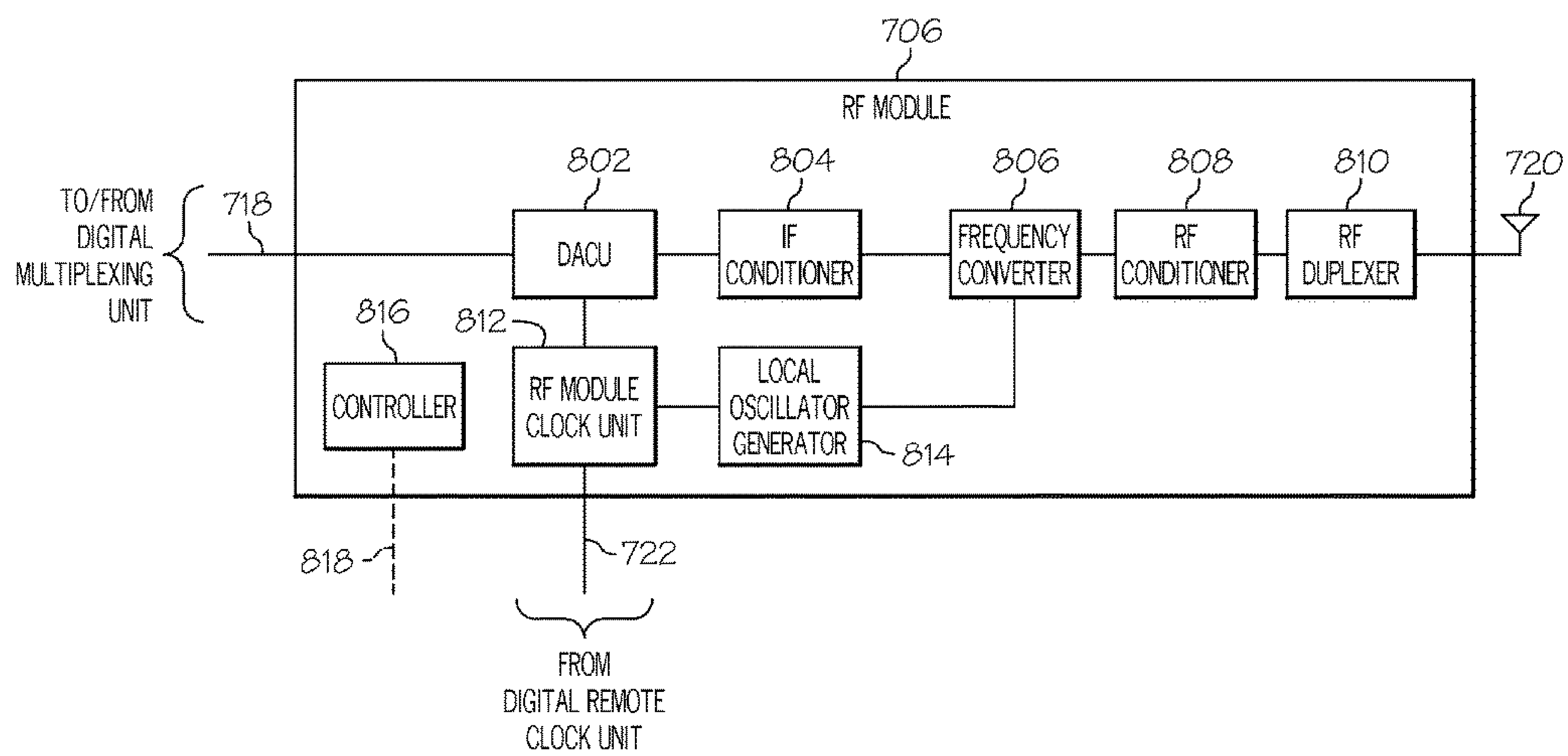
POWER
SUPPLY

FIG. 7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RF DUPLEXER
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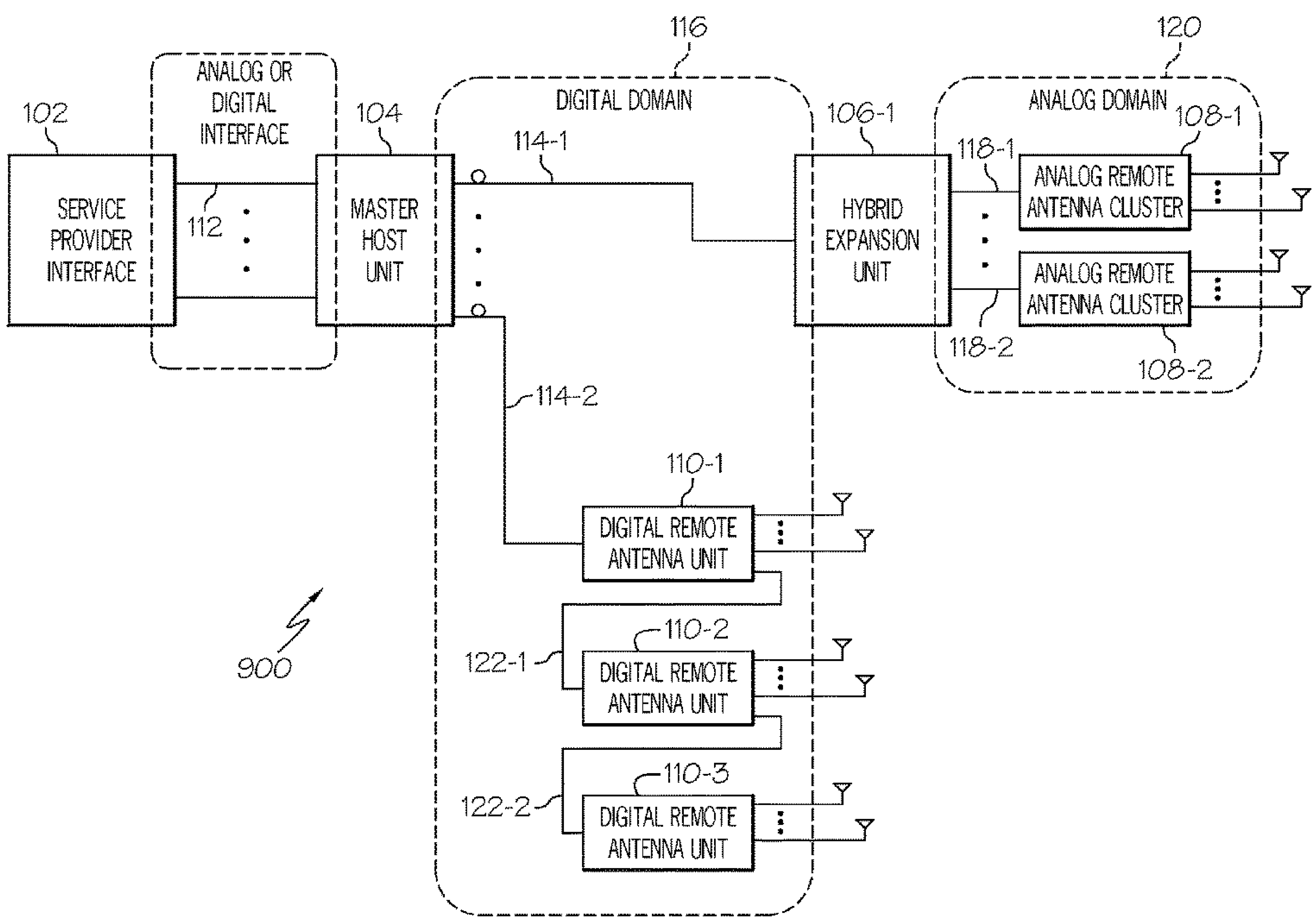
814
818
722
FROM DIGITAL REMOTE CLOCK UNIT

FIG. 8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HYBRID EXPANSION UNIT
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ANALOG REMOTE ANTENNA CLUSTER
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FIG. 9

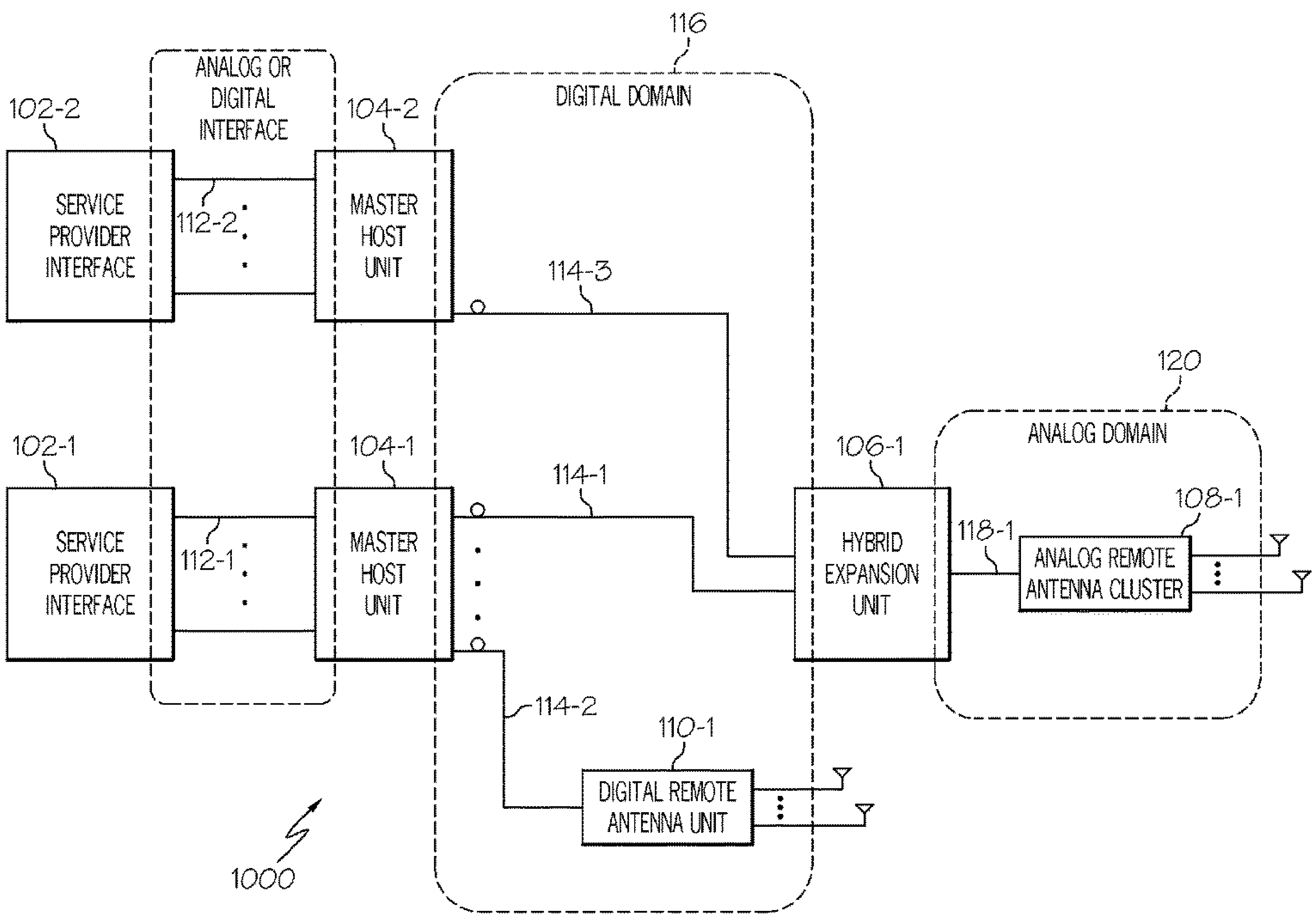
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FIG. 10

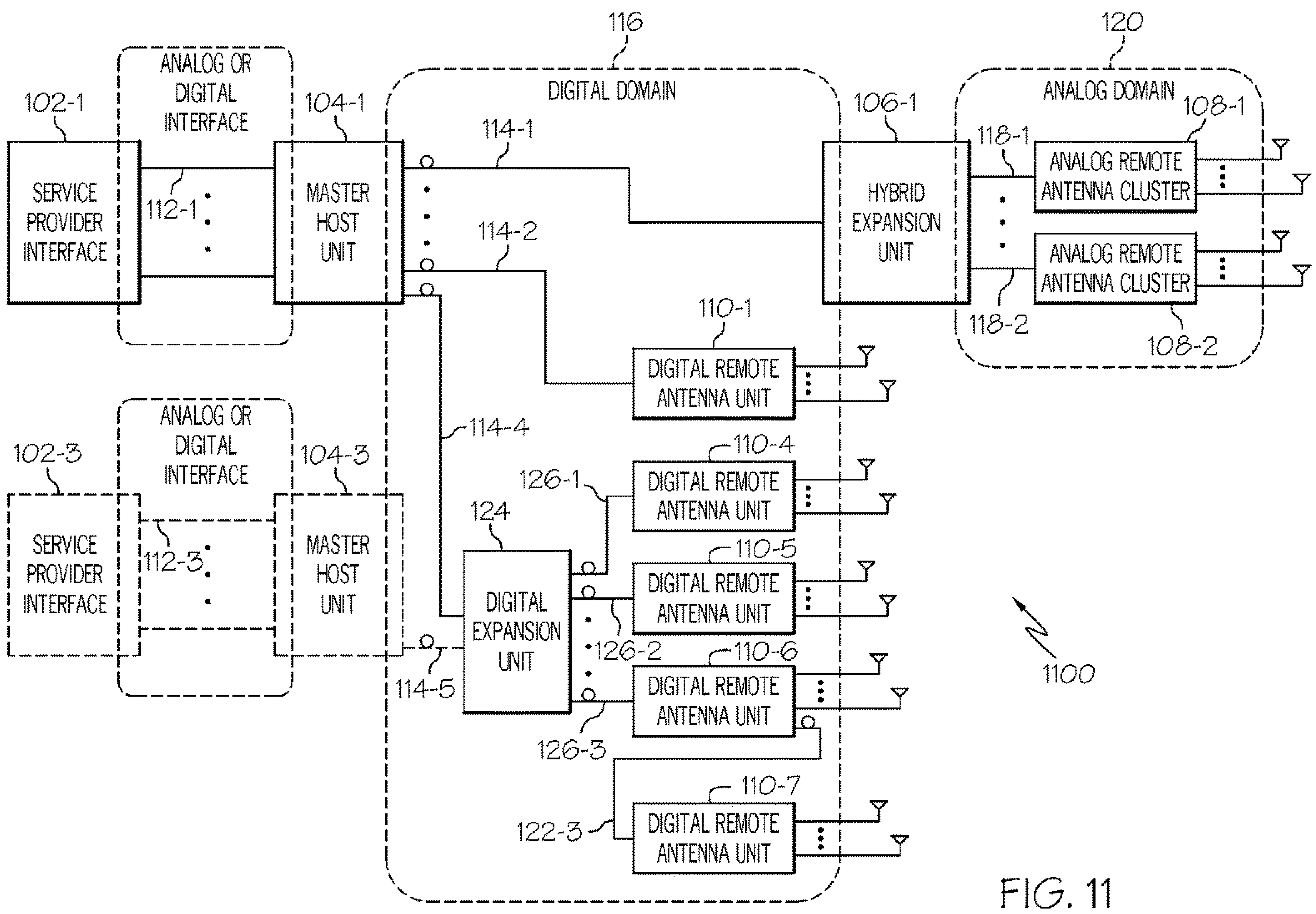
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FIG. 11

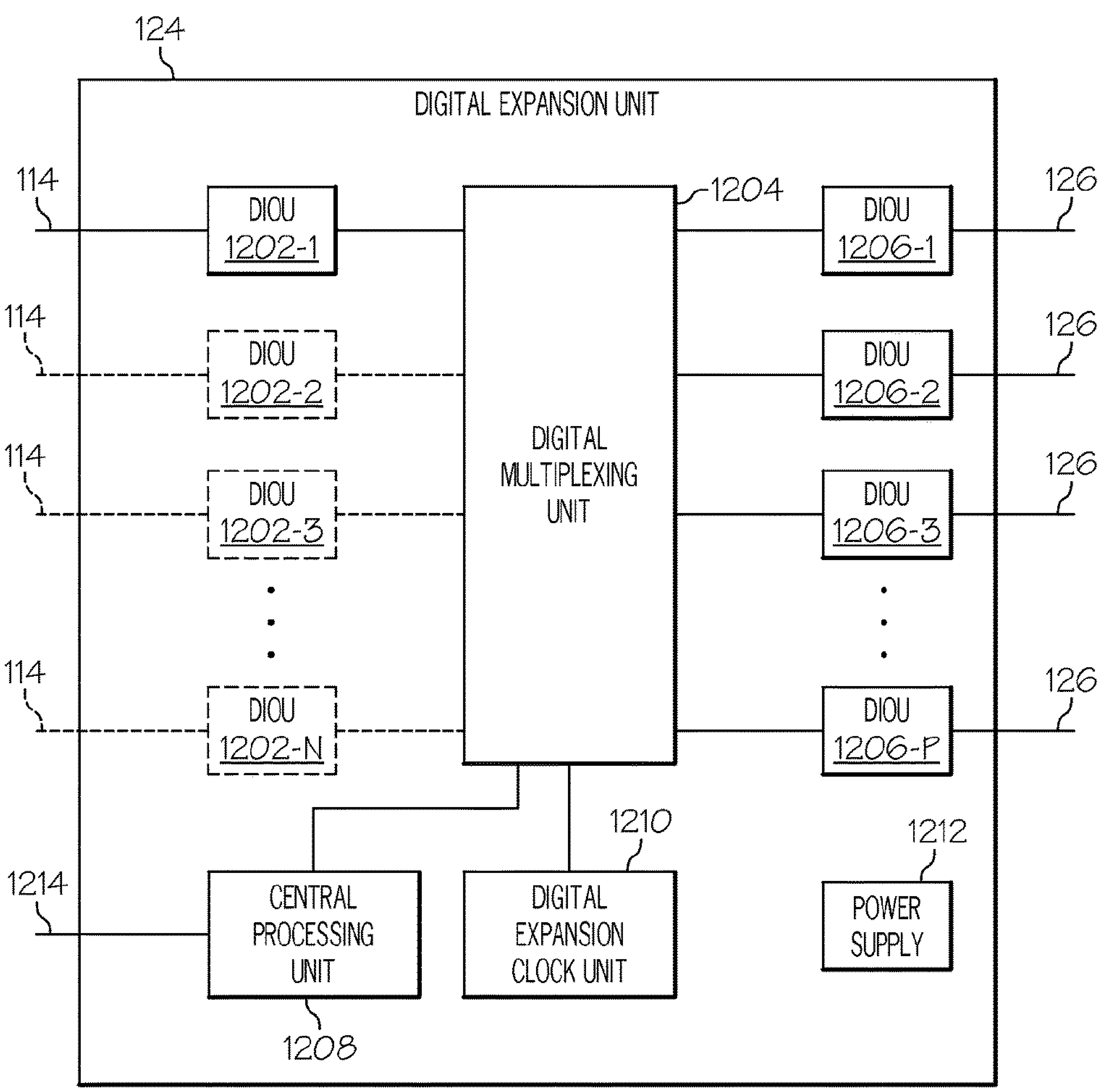
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FIG. 12

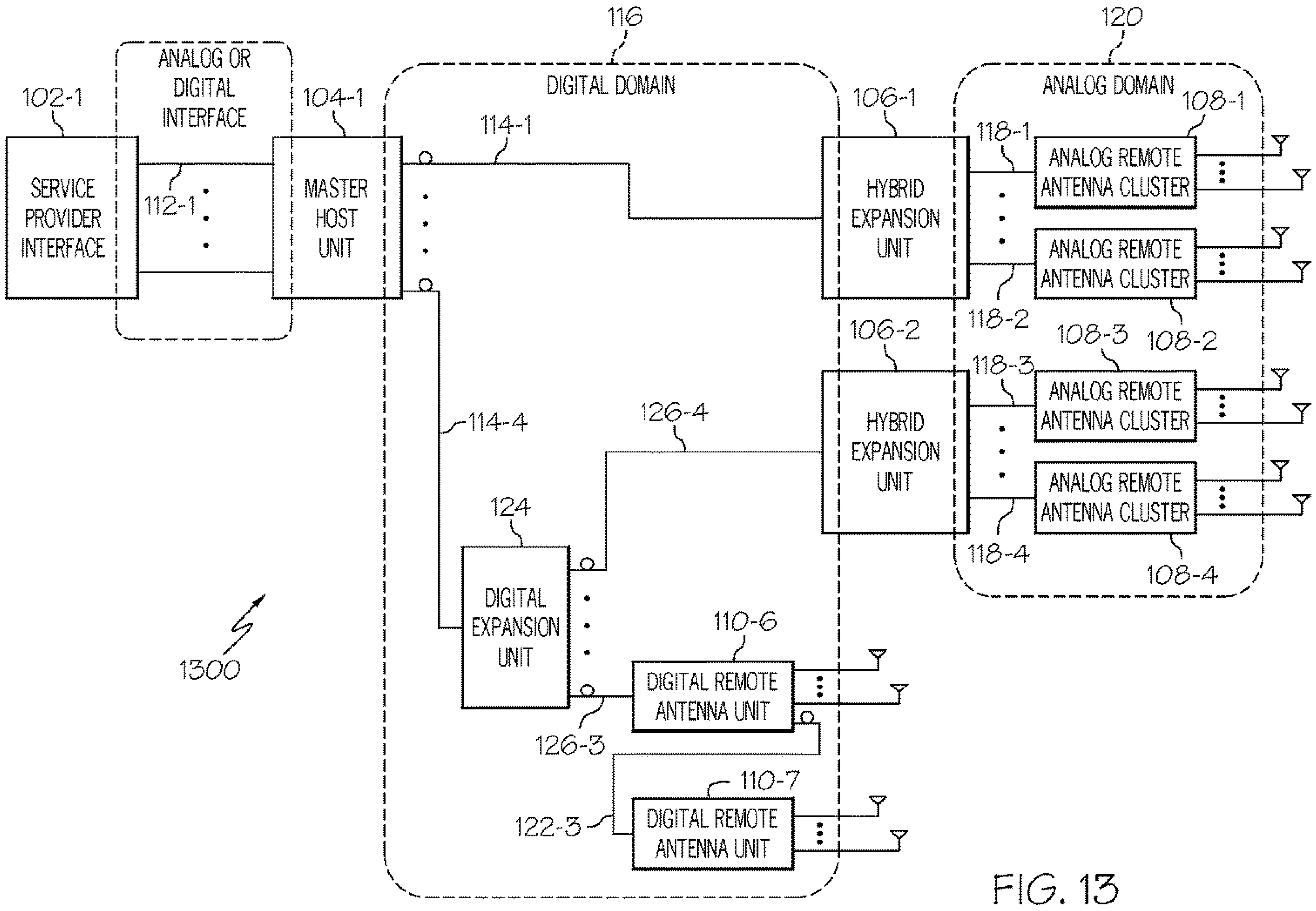

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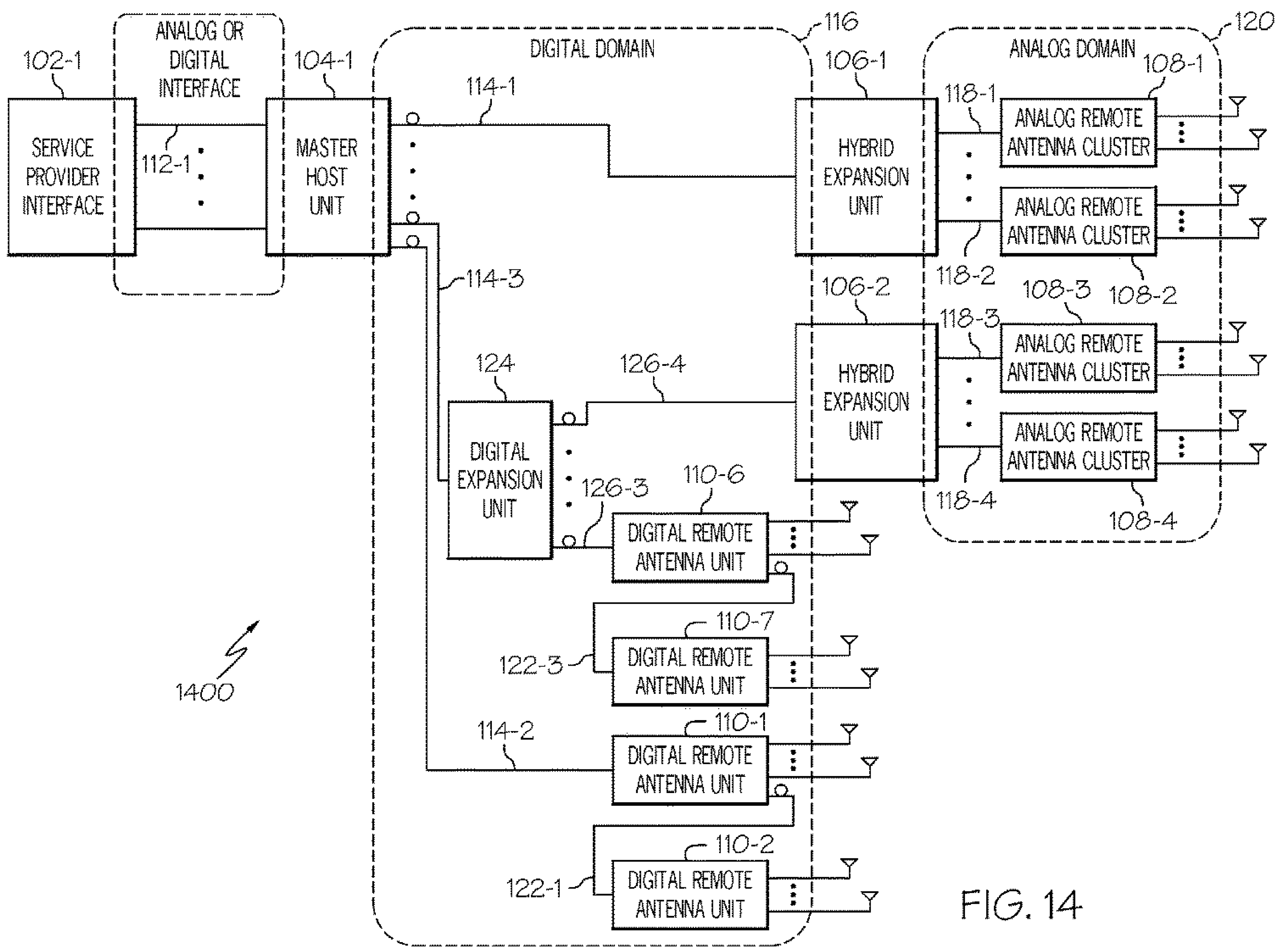
FIG. 13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110-2
122-1
DIGITAL REMOTE ANTENNA UNIT
1400

FIG. 14

# DISTRIBUTED ANTENNA SYSTEM WITH COMBINATION OF BOTH ALL DIGITAL TRANSPORT AND HYBRID DIGITAL/ANALOG TRANSPORT

**Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.**

## CROSS-REFERENCE TO RELATED APPLICATIONS

*This Reissue Application is a reissue of application Ser. No. 12/913,179, filed Oct. 27, 2010, which issued as U.S. Pat. No. 8,532,242.* The present application is related to commonly assigned and co-pending U.S. patent application Ser. No. 11/150,820 (hereafter "the '820 application") entitled "PROVIDING WIRELESS COVERAGE INTO SUBSTANTIALLY CLOSED ENVIRONMENTS", filed on Jun. 10, 2005 (currently pending). The present application is also related to commonly assigned and co-pending U.S. patent application Ser. No. 12/775,897 (hereafter "the '897 application") entitled "PROVIDING WIRELESS COVERAGE INTO SUBSTANTIALLY CLOSED ENVIRONMENTS", filed on May 7, 2010 (currently pending). The present application is also related to commonly assigned and co-pending U.S. patent application Ser. No. 12/845,060 (hereafter "the '060 application") entitled "DISTRIBUTED DIGITAL REFERENCE CLOCK", filed Jul. 28, 2010 (currently pending). The '820 application, the '897 application, and the '060 application are all incorporated herein by reference in their entirety.

## BACKGROUND

Distributed Antenna Systems (DAS) are used to distribute wireless signal coverage into buildings or other substantially closed environments. For example, a DAS may distribute antennas within a building. The antennas are typically connected to a radio frequency (RF) signal source, such as a service provider. Various methods of transporting the RF signal from the RF signal source to the antennas have been implemented in the art.

## SUMMARY

A communication system includes a master host unit, a first hybrid expansion unit coupled to the master host unit by a first digital communication link, a first analog remote antenna unit coupled to the first hybrid expansion unit by a first analog communication link, and a first digital remote antenna unit coupled to the master host unit by a second digital communication link. The master host unit is adapted to communicate analog signals with at least a first service provider interface using a first set of bands of analog spectrum. The master host unit and the first hybrid expansion unit are adapted to communicate first N-bit words of digitized spectrum over the first digital communication link. The first hybrid expansion unit is further adapted to convert between the first N-bit words of digitized spectrum and a second set of bands of analog spectrum. The first hybrid expansion unit and the first analog remote antenna unit are adapted to communicate the second set of bands of analog spectrum over the analog communication medium. The first analog remote antenna unit is further adapted to transmit and receive a first plurality of wireless signals over a first plurality of air interfaces. The master host unit and the first digital remote antenna unit are adapted to communicate second N-bit words of digitized spectrum over the second digital communication link. The first digital remote antenna unit is further adapted to convert between the second N-bit words of digitized spectrum and a third set of bands of analog spectrum. The first digital remote antenna unit if further adapted to transmit and receive second wireless signals over a second plurality of air interfaces.



## DRAWINGS

FIG. **1** is a block diagram of one embodiment of a system for providing wireless coverage into a substantially enclosed environment.

FIG. **2** is a block diagram of one embodiment of a master host unit for the system of FIG. **1**.

FIG. **3** is a block diagram of one embodiment of a hybrid expansion unit for the system of FIG. **1**.

FIG. **4** is a block diagram of one embodiment of an analog remote antenna cluster for the system of FIG. **1**.

FIG. **5** is a block diagram of one embodiment of a master analog remote antenna unit for the analog remote antenna unit cluster of FIG. **4**.

FIG. **6** is a block diagram of one embodiment of a slave analog remote antenna unit for the analog remote antenna unit cluster of FIG. **4**.

FIG. **7** is a block diagram of one embodiment of a digital remote antenna unit for the system of FIG. **1**.

FIG. **8** is a block diagram of one embodiment of a RF module for the digital remote antenna unit of FIG. **7**.

FIG. **9** is a block diagram of another embodiment of a system for providing wireless coverage into a substantially enclosed environment.

FIG. **10** is a block diagram of another embodiment of a system for providing wireless coverage into a substantially enclosed environment.

FIG. **11** is a block diagram of another embodiment of a system for providing wireless coverage into a substantially enclosed environment.

FIG. **12** is a block diagram of one embodiment of a digital expansion unit for the system of FIG. **8**.

FIG. **13** is a block diagram of another embodiment of a system for providing wireless coverage into a substantially enclosed environment.

FIG. **14** is a block diagram of another embodiment of a system for providing wireless coverage into a substantially enclosed environment.

## DETAILED DESCRIPTION

FIG. **1** is a block diagram of one embodiment of a system **100** for providing wireless coverage into a substantially enclosed environment. The system **100** includes at least one service provider interface **102**, at least one master host unit (MHU) **104**, at least one hybrid expansion unit (HEU) **106**, at least one analog remote antenna cluster (ARAC) **108**, and at least one digital remote antenna unit **110**. Specifically, example system **100** includes hybrid expansion unit **106-1**, analog remote antenna cluster **108-1**, and digital remote antenna unit **110-1**. Other example systems include greater or fewer service provider interfaces **102**, master host units **104**, hybrid expansion units **106**, analog remote antenna clusters **108**, and digital remote antenna units **110**.

Service provider interface **102** may include an interface to one or more of a base transceiver station (BTS), a repeater, a bi-directional amplifier, a base station hotel or other appropriate interface for one or more service provider networks. In one embodiment, service provider interface **102** provides an interface to a plurality of services from one or more service providers. The services may operate using various wireless protocols and in various bands of frequency spectrum. For example, the services may include, but are not limited to, 800 MHz cellular service, 1.9 GHz Personal Communication Services (PCS), Specialized Mobile Radio (SMR) services, Enhanced Special Mobile Radio (ESMR) services at both 800 MHz and 900 MHz, 1800 MHz and 2100 MHz Advanced Wireless Services (AWS), 700 MHz uC/ABC Single Input Single Output (SISO) and Multiple Input Multiple Output (MIMO) services, two way paging services, video services, Public Safety (PS) services at 450 MHz, 900 MHz and 1800 MHz Global System for Mobile Communications (GSM), 2100 MHz Universal Mobile Telecommunications System (UMTS), Worldwide Interoperability for Microwave Access (WiMAX), 3rd Generation Partnership Projects (3GPP) Long Term Evolution (LTE), or other appropriate communication services.

In system **100**, service provider interface **102** is connected to master host unit **104** over at least one analog communication link **112**. Each analog communication link **112** includes two analog communication media, such as coaxial cables or fiber optic cables. One analog communication media is for downstream communication and the other is for upstream communication. The downstream and upstream analog communication media have been shown as a single analog communication link **112** for simplicity. In other embodiments, each analog communication link **112** only includes a single physical media, which is used to carry both the downlink and uplink streams between the service provider interface **102** and the master host unit **104**.

The master host unit **104** receives downstream bands of radio frequency (RF) spectrum from the at least one service provider interface **102** over the at least one analog communication link **112**. In addition, the master host unit **104** sends upstream bands of radio frequency (RF) spectrum to the at least one service provider interface **102** over the at least one analog communication link **112**. In other embodiments, the service provider interface **102** and the master host unit **104** are connected over at least one digital communication link using at least one digital communication media. In some embodiments, separate analog communications links **112** are used for each service provider interface **102**. Thus, while this disclosure describes at least one analog communication link **112**, the format of this interface is not essential to operation of system **100**. If an analog interface is used, the master host unit **104** converts the analog signal to a digital format as described below. If a digital interface is used, the master host unit **104** will either communicate the digital data as is or reformat the data into a representation that can be used for transport within the digital domain **116** described below. In example embodiments using a single physical medium for each analog communication link **112**, frequency division multiplexing (FDM), time division multiplexing (TDM), and optical wavelength division multiplexing (WDM) are used to achieve a duplex connection over the single medium.

System **100** uses both digital and analog transport to extend the coverage of the wireless services into the substantially enclosed environment. First, system **100** uses digital transport over at least one digital communication link **114** to transport digitized RF spectrum between the master host unit **104** and the at least one hybrid expansion unit **106** and between the master host unit **104** and the at least one digital expansion unit **124**. Each digital communication link **114** includes two digital communication media, such as fiber optic cables. One digital communication medium is for downstream communication and the other is for upstream communication. The downstream and upstream digital communication media have been shown as a single digital communication link **114** for simplicity. The areas of digital transport are called the digital domain **116**. In other implementations, digital transport can be used to transport between other components as well and the digital domain **116** is more expansive. In other embodiments, each digital communication link **114** only includes a single physical media, which is used to carry both the downlink and uplink streams between the master host unit **104** and the at least one digital expansion unit **124**. In example embodiments using a single physical media for each digital communication link **114**, optical multiplexing techniques (i.e., wavelength division multiplexing (WDM), coarse wavelength division multiplexing (CWDM), or dense wavelength division multiplexing (DWDM)) are used to achieve a duplex connection over the single medium.

While an optical fiber is used in the example system **100**, other appropriate communication media can also be used for the digital transport. For example, other embodiments use free space optics, high speed copper or other wired, wireless, or optical communication media for digital transport instead of the optical fibers used in each of the at least one digital communication link **114**. By using digital transport over the at least one digital communication link **114**, the bands of RF spectrum provided by the service provider interface **102** can be transported over long distances with minimal errors and more resiliency and robustness to signal loss and distortion of the physical medium. Thus, system **100** may extend coverage for wireless services to buildings located significant distances from the service provider interface **102**.

Second, system **100** uses analog transport over at least one analog communication link **118** between the at least one hybrid expansion unit **106** and the at least one analog remote antenna cluster **108** to extend the reach of the digital transport into the substantially enclosed environment. Each analog communication link **118** includes two analog communication media, such as coaxial cable. One analog communication media is for downstream communication and the other is for upstream communication. The downstream and upstream analog communication media have been shown as a single analog communication link **118** for simplicity. While coaxial cable is used in the example system **100**, other appropriate communication media can also be used for the analog transport. The areas of analog transport are called the analog domain **120**. In other implementations, analog transport can be used to transport between other components as well and the analog domain **120** is more expansive. In other embodiments, each analog communication link **118** only includes a single physical medium, which is used to carry both the downlink and uplink streams between each hybrid expansion unit **106** and each analog remote antenna cluster **108**. In example embodiments using a single physical medium for each analog communication link **118**, frequency division multiplexing (FDM), time division multiplexing (TDM), and optical wavelength division multiplexing (WDM) are used to achieve a duplex connection over the single medium.

As discussed in further detail below, the various components of system **100** convert the various bands of RF spectrum between radio frequencies (RF), various intermediate frequencies (IF), digitized bands of RF spectrum, and digitized IF. As baseband representations of the signals can also be used, the invention can be generalized to convert between analog and digital signals. These various conversions require that the digital domain **116** and the analog domain **120** be synchronized in time and frequency. Time synchronization is important to the sampling and reconstruction of the signals. Time synchronization is also important when time alignment of signals in the various parallel branches of the system is necessary. Frequency synchronization is important to maintaining the absolute frequency of the signals at the external interfaces of the system. In order to synchronize the digital domain **116** and the analog domain **120**, a common reference clock is distributed throughout both the digital domain **116** and the analog domain **120** as described in detail below. This common clock allows for accurate conversion and recovery between RF, IF, digitized bands of RF spectrum, and digitized IF, or more broadly between analog spectrum and digital spectrum.

FIG. **2** is a block diagram of one embodiment of the Master host unit **104** of system **100**. Master host unit **104** includes at least one digital-analog conversion unit (DACU) **202**, at least one digital multiplexing unit (DMU) **204**, at least one digital input-output unit (DIOU) **206**, at least one central processing unit (CPU) **208**, at least one master clock distribution unit (MCDU) **210**, and at least one power supply **212**. In addition, the example master host unit **104** also includes at least one splitter/combiner **214**.

The master host unit **104** communicates at least one band of analog spectrum with the at least one service provider interface **102**. In the example system **100**, there are a plurality of service provider interfaces **102-1**, **102-2**, **102-3**, through **102**-N. In addition, there are a plurality of DACUs **202-1**, **202-2**, **202-3**, through **202**-N. Each DACU **202** is coupled with at least one service provider interface **102**. These couplings may be accomplished in various ways. For example, service provider interface **102-1** is directly coupled to DACU **202-1** through analog communication link **112-1**. In contrast, service provider interface **102-2** is coupled to a first side of splitter/combiner **214-1** through analog communication link **112-2**, DACU **202-2** is coupled to a second side of splitter/combiner **214-1** through analog communication link **112-3**, and DACU **202-3** is coupled to the second side of splitter/combiner **214-1** through analog communication link **112-4**. In addition, service provider interface **102-3** is coupled to a first side of splitter/combiner **214-2** through analog communication link **112-5**, service provider interface **102**-N is coupled to the first side of splitter/combiner **214-2** through analog communication link **112-6**, and DACU **202**-N is coupled to a second side of splitter/combiner **214-2** through analog communication link **112-7**. As noted above, each analog communication link **112** of system **100** represents two analog media, one for downstream communication and one for upstream communication. In other embodiments, each link includes greater or fewer analog medium. In other embodiments, the master host unit communicates at least one band of digital spectrum with at least one service provider interface across at least one digital communication link using digital data or digitized spectrum. In these embodiments, the signals from the service provider interfaces **102-1**, **102-2**, **102-3**, through **102**-N are first converted from analog to digital before being transmitted across the at least one digital communication link to the master host unit **104**.

Each DACU **202** operates to convert between at least one band of analog spectrum and N-bit words of digitized spectrum. In some embodiments, each DACU **202** is implemented with a Digital/Analog Radio Transceiver (DART board) commercially available from ADC Telecommunications, Inc. of Eden Prairie, Minn. as part of the FlexWave™ Prism line of products. The DART board is also described in U.S. patent application Ser. No. 11/627,251, assigned to ADC Telecommunications, Inc., published in U.S. Patent Application Publication No. 2008/0181482, and incorporated herein by reference. In some implementations, this occurs in stages, such that the analog spectrum is first converted to an IF frequency and subsequently converted to N-bit words of digitized spectrum. The bands of analog spectrum include signals in the frequency spectrum used to transport a wireless service, such as any of the wireless services described above. In some embodiments, master host unit **104** enables the aggregation and transmission of a plurality of services to a plurality of buildings or other structures so as to extend the wireless coverage of multiple services into the structures with a single platform.

The DMU **204** multiplexes N-bit words of digitized spectrum received from a plurality of DACU **202** (DACU **202-1** through DACU **202**-N) and outputs at least one multiplexed signal to at least one DIOU **206** (DIOU **206-1** through DIOU **206**-N). The DMU **204** also demultiplexes at least one multiplexed signal received from at least one DIOU **206** and outputs demultiplexed N-bit words of digitized spectrum to a plurality of DACU **202**. In some embodiments, each DMU **204** is implemented with a Serialized RF (SeRF board) commercially available from ADC Telecommunications, Inc. of Eden Prairie, Minn. as part of the FlexWave™ Prism line of products. The SeRF board is also described in U.S. patent application Ser. No. 11/627,251, assigned to ADC Telecommunications, Inc., published in U.S. Patent Application Publication No. 2008/0181482, and incorporated herein by reference.

Each DIOU **206** communicates at least one digitized multiplexed signal across at least one digital communication link **114** (digital communication link **114-1** through digital communication link **114**-N) using digital transport. The digitized multiplexed signal communicated across the digital communication link **114** includes N-bit words of digitized spectrum. Each DIOU **206** also receives at least one digitized multiplexed signal from the at least one digital communication link **114** using digital transport and sends the at least one digitized multiplexed signal to the DMU **204**. In system **100** shown in FIG. **1**, the digital communication link **114-1** is connected to hybrid expansion unit **106-1** and digital communication link **114-2** is connected to digital remote antenna unit **110-1**. DIOU **206-1** communicates using digital transport with hybrid expansion unit **106-1** and DIOU **206-2** communicates using digital transport with digital remote antenna unit **110-1**. As noted above, each digital communication link **114** represents two digital media, one for downstream communication and one for upstream communication. In addition to carrying the digitized multiplexed signals, each digital communication link **114** may also used to communicate other types of information such as system management information, control information, configuration information and telemetry information. The hybrid expansion unit **106** and digital remote antenna unit **110** are described in detail below.

Each DACU **202** and DMU **204** is synchronized with the other components of master host unit **104** and system **100** generally. Master clock distribution unit **210** generates a digital master reference clock signal. This signal is generated using any stable oscillator, such as a temperature compensated crystal oscillator (TCXO), an oven controlled crystal oscillator (OCXO), or a voltage controlled crystal oscillator (VCXO). In the embodiment shown in FIG. **2**, the stable oscillator is included in the master clock distribution unit **210**. In other embodiments, a reference clock external to the master host unit is used, such as a clock from a base station, a GPS unit, or a cesium atomic clock. In embodiments where digital data is communicated between service provider interface **102** and master host unit **104**, the master clock distribution unit **210** may derive the reference clock signal from the digital data stream itself or an external clock signal may be used.

The digital master reference clock signal is supplied to each DACU **202** and each DMU **204** in the master host unit **104**. Each DACU **202** uses the clock to convert between at least one band of analog spectrum and N-bit words of digitized spectrum. The DMU **204** uses the clock to multiplex the various streams of N-bit words of digitized spectrum together and outputs the multiplexed signal to each DIOU **206**. Thus, the downstream digital data streams output by each DIOU **206** are synchronized to the digital master reference clock signal. Thus, through the clocking of the downstream digital data streams, the digital master reference clock signal is distributed to each hybrid expansion unit **106** and each digital expansion unit **124** through each corresponding digital communication link **114**.

CPU **208** is used to control each DACU **202** and each DMU **204**. An input/output (I/O) line **216** coupled to CPU **208** is used for network monitoring and maintenance. Typically, I/O line **216** is an Ethernet port used for external communication with the system. Other communication protocols such as Universal Serial Bus (USB), IEEE 1394 (FireWire), and serial may also be used. Power supply **212** is used to power various components within master host unit **104**.

FIG. **3** is a block diagram of one embodiment of a hybrid expansion unit **106** of system **100**. Hybrid expansion unit **106** of system **100** includes at least one digital input-output unit (DIOU) **302**, at least one digital multiplexing unit (DMU) **304**, at least one digital-analog conversion unit (DACU) **306**, at least one analog multiplexing unit (AMU) **308**, at least one central processing unit (CPU) **310**, at least one digital expansion clock unit (DECU) **312**, at least one analog domain reference clock unit (ADRCU) **314**, and at least one power supply **316**.

Each hybrid expansion unit **106** communicates at least one band of digitized spectrum with the master host unit **104** in the form of a multiplexed digitized signal containing N-bit words of digitized spectrum. The multiplexed digitized signal is received at the at least one DIOU **302** through at least one digital communication link **114**. In the embodiment shown in FIG. **3**, only one DIOU **302-1** is necessary if the hybrid expansion unit **106** is only coupled with a single upstream master host unit **104** (or single upstream digital expansion unit **124** as described in detail below). DIOU **302-2** through DIOU **302**-N are optional. For example, in other embodiments, hybrid expansion unit **106** has multiple DIOUs **302** (DIOU **302-1** through DIOU **302**-N) and is connected to multiple upstream master host units **104** or digital expansion units **124** through digital communication links **114**. In other embodiments (such as system **900** shown in FIG. **9** and described in detail below), hybrid expansion unit **106** is connected to other hybrid expansion units through DIOU **302**. In some embodiments including multiple upstream connections, the hybrid expansion unit **106** selects one DIOU **302** to extract the clock signal from.

The at least one DIOU **302** communicates the multiplexed digitized signal containing N-bit words of digitized spectrum to the DMU **304**. The DMU **304** demultiplexes N-bit words of digitized spectrum received from the at least one DIOU **302** and sends N-bit words of digitized spectrum to the at least one DACU **306**. The at least one DACU **306** converts the N-bit words of digitized spectrum to at least one band of analog spectrum. In some embodiments, the at least one DACU **306** converts the digitized signal back to the original analog frequency provided by the at least one service provider interface **102**. In other embodiments, the at least one DACU **306** converts the digitized signal to an intermediate frequency (IF) for transport across the at least one analog communication link **118**. In other embodiments, other components are included in the hybrid expansion unit **106** that frequency convert at least one band of analog spectrum output by the DACU **306** into an intermediate frequency for transport.

Each DACU **306** is coupled with the AMU **308**. Each DACU **306** also converts at least one band of analog spectrum received from the AMU **308** into N-bit words of digitized spectrum. AMU **308** receives multiple bands of analog spectrum from multiple DACU **306** and multiplexes the bands of analog spectrum together into at least one multiplexed analog signal including multiple bands of analog spectrum. In some embodiments, there are a plurality of multiplexed analog signals output from the AMU **308**. In some embodiments, all of the bands of analog spectrum from each DACU **306** are included on each multiplexed signal output by AMU **308**. In other embodiments, a subset of the bands of analog spectrum from a plurality of DACU **306** are multiplexed onto one signal output on one of the at least one analog communication link **118**, while a different subset of bands of analog spectrum from a plurality of DACU **306** are multiplexed onto another signal output on another of the at least one analog communication link **118**. In other embodiments, different combinations of bands of analog spectrum from various DACU **306** are multiplexed onto various analog communication links **118**.

In some embodiments, each DACU **306** converts a band of digitized spectrum to a different analog frequency from the other DACU **306**. Each band of analog spectrum is pre-assigned to a particular analog frequency. Then, the AMU **308** multiplexes the various pre-assigned analog frequencies together, in addition to the analog domain reference clock and any communication, control, or command signals and outputs them using at least one analog communication link **118**. In other embodiments, each DACU **306** converts a band of analog spectrum to the same analog frequency as the other DACU **306**. Then, the AMU **308** shifts the received signals into distinct analog frequencies and multiplexes them together and outputs them using at least one analog communication link **118**. In the embodiment shown in FIG. **3**, the AMU **308** multiplexes the analog frequencies received from each DACU **306** onto each analog communication link **118**.

In other embodiments, bands of frequency spectrum from certain DACU **306** are selectively distributed to certain analog communication links **118**. In one example embodiment, analog communication link **118-1** is coupled to analog remote antenna cluster **108-1** and only a first subset of bands of analog spectrum are transported using analog communication link **118-1**. Further, analog communication link **118-2** is coupled to analog remote antenna cluster **108-2** (shown in FIG. **8** and described below) and only a second subset of bands of analog spectrum are transported using analog communication link **118-2**. In another embodiment, a first subset of bands of analog spectrum are transported to analog remote antenna cluster **108-1** using analog communication link **118-1** and a second subset of bands of analog spectrum are transported to the same analog remote antenna cluster

**108-1** using analog communication link **118-2**. It is understood that these examples are not limiting and that other system hierarchies and structures are used in other embodiments.

Each DMU **304**, DACU **306**, and AMU **308** is synchronized with the other components of hybrid expansion unit **106** and system **100** generally. In the example embodiment shown in FIG. **3**, DIOU **302-1** receives the data stream from a master host unit **104** via a digital communication link **114** in an optical format. DIOU **302-1** converts the data stream from the optical format to an electrical format and passes the data stream onto the DMU **304**. The DMU **304** extracts the digital master reference clock signal from the data stream itself. Because the data stream was synchronized with the digital master reference clock signal at the master host unit **104**, it can be recovered from the data stream itself. The extracted digital master reference clock signal is sent to the digital expansion clock unit **312**. Each DIOU **302** is not required to be synchronized to the other parts of the hybrid expansion unit unless it performs some type of function that requires it to be synchronized. In one embodiment, the DIOU **302** performs the extraction of the digital master reference clock in which case it would be synchronized to the remainder of the hybrid expansion unit.

The digital expansion clock unit **312** receives the digital master reference clock signal extracted from the data stream received from the master host unit **104**. The digital expansion clock unit **312** communicates the digital master reference clock signal to various components of the hybrid expansion unit **106**, including the DMU **304** and each DACU **306**. Each DMU **304** and DACU **306** uses the digital master reference clock signal to synchronize itself with the system **100**. In other embodiments, the digital expansion clock unit **312** could receive a copy of the data stream from the DMU **304** and extract the digital master reference clock signal from the data stream itself. In some embodiments, each DIOU **302** is selectable and configurable, so that one DIOU **302** can be selected to receive the digital master reference clock signal and other DIOUs **302** can be used to send the digital master reference clock signal upstream to other system components, such as secondary master host units, digital expansion units, or other hybrid expansion units.

In addition, the digital expansion clock unit **312** distributes the digital master reference clock signal to the analog domain reference clock unit **314**. The analog domain reference clock unit **314** in turn generates an analog domain reference clock signal based on the digital master reference clock signal. This analog domain reference clock signal is used to synchronize analog components in the hybrid expansion unit **106**, such as analog frequency conversion functions in the AMU **308**. In addition, the AMU multiplexes the analog domain reference clock signal onto the multiplexed signals sent on each analog communication link **118** to the at least one analog remote antenna cluster **108**.

In the embodiment of hybrid expansion unit **106** shown in FIG. **3**, the analog domain reference clock unit **314** generates the analog domain reference clock signal by running the digital master reference clock signal through a phase locked loop circuit. In some embodiments, the digital master reference clock signal is approximately 184.32 MHz and the analog domain reference clock signal is generated as a 30.72 MHz clock based on the 184.32 MHz digital master reference clock signal. Thus, the 30.72 MHz clock is multiplexed onto the multiplexed signals sent on each analog communication link **118** to at least one analog remote antenna cluster **108**.

CPU **310** is used to control each DMU **304** and each DACU **306**. An input/output (I/O) line **318** coupled to CPU **310** is used for network monitoring and maintenance. Typically, I/O line **318** is an Ethernet port used for external communication with the system. Power supply **316** is used to power various components within hybrid expansion unit **106**.

In addition to performing the analog frequency conversion functions described above, the AMU **308** couples power onto the analog communication link **118**. This power is then supplied through the analog communication link **118** to the downstream analog remote antenna cluster **108**, including master analog remote antenna unit **402** and slave analog remote antenna units **404-1** as described below. The power coupled onto the analog communication link **118** is supplied from the power supply **316**. In the example embodiment shown, 28 volts DC is received by AMU **308** from the power supply **316** and is coupled to the analog communication link **118** by AMU **308**.

The hybrid expansion unit **106** shown in FIG. **3** sends and receives digital signals from the upstream and sends and receives analog signals in the downstream. In other example hybrid expansion units, both analog and digital signals can be sent in the downstream across various media. In one example embodiment a digital downstream output line (not shown) is connected to the downstream side of the DMU **304** and goes through a DIOU before being output in the downstream. This digital downstream line does not go through a DACU **306** or the AMU **308**. In other example embodiments of the hybrid expansion unit **106**, various other combinations of upstream and downstream digital and analog signals can be aggregated, processed, routed.

In the embodiments described and depicted in FIGS. **4-6**, the term analog intermediate frequency (IF) spectrum is used to describe the analog signals transported in the analog domain **120** between the hybrid expansion units **106** and the analog remote antenna clusters **108**. The term analog IF spectrum is used to distinguish the signals from the analog RF spectrum format that is communicated to the service provider interface and the mobile devices over the air. Example system **100** uses analog IF spectrum for transport within the analog domain **120** that is lower in frequency than the analog RF spectrum. In other example embodiments, the RF spectrum can be transmitted at its native frequency within the analog domain **120** or using an analog IF spectrum that is higher in frequency than the analog RF spectrum.

FIG. **4** is a block diagram of one embodiment of an analog remote antenna cluster **108** for system **100**. Analog remote antenna cluster **108** includes a master analog remote antenna unit **402** and a plurality of slave analog remote antenna units **404-1** through **404**-N. In other embodiments, other configurations are used instead of this master/slave configuration.

In example analog remote antenna cluster **108**, the master analog remote antenna unit **402** is coupled to at least one analog communication link **118**. In the embodiment shown in FIG. **4**, the at least one coaxial cable includes two coaxial cables. A first coaxial cable is used to transport downstream communication from a hybrid expansion unit **106** and the analog remote antenna cluster **108**, including the bands of downstream analog spectrum associated with the service providers. A second coaxial cable is used to transport upstream communication from the analog remote antenna cluster **108** to the hybrid expansion unit **106**, including the bands of upstream analog spectrum associated with the service providers. The downstream analog spectrum and the upstream analog spectrum are transported on separate coaxial cables in this example embodiment due to bandwidth limitations of the coaxial cable being used as media. In other example embodiments, a single analog communication link **118** is used to transport both the downstream and upstream analog spectrum. In other example embodiments, the at least one analog communication link **118** includes greater than two coaxial cables in order to transport even more bands. In other example embodiments, different media such as twisted pair (i.e., unshielded twisted pair (UTP) or screened unshielded twisted pair (ScTP)), CATV fibers, or optical fibers are used to transport the analog signals instead of coaxial cables.

In example analog remote antenna cluster **108**, the master analog remote antenna unit **402** coordinates the distribution of various bands of analog RF spectrum to various slave analog remote antenna units **404** through analog communication links **406**. The master analog remote antenna unit **402** is discussed in further detail below. In the example analog remote antenna cluster **108**, each slave analog remote antenna unit **404-1** through **404**-N receive at least one band of analog RF spectrum from the master analog remote antenna unit **402**. Each slave analog remote antenna unit **404-1** through **404**-N then transmits and receives the at least one band of analog RF spectrum wirelessly across an air medium using at least one antenna. The slave analog remote antenna unit **404** is discussed in further detail below.

FIG. **5** is a block diagram of one embodiment of a master analog remote antenna unit **402** from the analog remote antenna cluster **108**. Master analog remote antenna unit **402** includes an analog interface unit (AIU) **502**, an IF signal conditioning unit **504**, an IF signal distribution unit **506**, a master remote reference clock **508**, a power supply **510**, and a controller **512**. Other example embodiments of master analog remote antenna unit include greater or fewer components.

The at least one analog communication link **118** is connected to the master analog remote antenna unit **402** through the AIU **502**. One of the primary functions of the AIU is to handle any type of media conversion that may be necessary which in some embodiments may involve impedance transformation. Specifically, in the example embodiment shown in FIG. **5**, the AIU **502** performs impedance conversion from the 75 ohms of the coaxial cables carrying the downstream and upstream bands of analog spectrum to the 50 ohms used within the master analog remote antenna unit **402**. The AIU **502** also includes a coupler that is used to extract the DC power received from the hybrid expansion unit **106** across the at least one analog communication link **118**.

In addition, the analog reference clock signal is extracted from the signal received from the hybrid expansion unit **106** across the at least one analog communication link **118**. This analog reference clock signal is sent to the master remote reference clock unit **508**. Any control signals received from the hybrid expansion unit **106** across the at least one analog communication link **118** are also extracted and sent to the controller **512**.

Power supply **510** receives DC power from the AIU **502** and then generates the necessary DC power for operation of the various components onboard the master analog remote antenna unit **402**. Thus, master analog remote antenna unit **402** does not need a separate power source other than the power that is received across the at least one analog communication link **118**. In the example embodiment shown, 28 volts DC is extracted from the signal received across the at least one analog communication link **118** by the AIU **502**. This 28 volts DC is then used by the power supply **510** to generate 5 volts DC and 12 volts DC to power the various devices in the master analog remote antenna unit. In addition, the power received across the analog communication link **118** is sent by the power supply **510** to the IF signal distribution unit **506** where it is coupled onto the analog communication links **406** that connect to each slave analog remote antenna unit **404** so that each slave analog remote antenna units **404** can also derive power from the cable instead of having a separate external power source. Thus, power for both the master analog remote antenna unit **402** and each slave analog remote antenna unit **404** is provided by the hybrid expansion unit **106** through the analog communication links **118** and **406**.

As noted above, the AIU **502** extracts the clock signal and supplies it to the master remote reference clock unit **508**. The master remote reference clock unit **508** refines the original clock signal received from the hybrid expansion unit **106** across the at least one analog communication link **118**. In example embodiments, the master remote reference clock unit **508** processes the clock signal through a phase locked loop to refine the signal. In this way, noise, distortion, and other undesirable elements are removed from the reference clock signal. In other embodiments, the clock signal is processed through a filter to remove adjacent spurious signals. The refined signal output from the master remote reference clock unit **508** is sent to the IF signal distribution unit **506**, where it is coupled onto the outputs of the IF signal distribution unit **506** that are connected to the slave analog remote antenna units **404**. In this way, the master reference clock signal is redistributed by the master analog remote antenna unit **402** to all the slave analog remote antenna units **404**.

IF signal conditioning unit **504** is configured to remove distortion in the analog IF signals that traverse the analog communication link **118**. In the example master analog remote antenna unit **402** shown in FIG. **5**, IF signal conditioning unit **504** performs cable equalization for signals sent and received across the at least one analog communication link **118**. The at least one analog communication link **118** is generally quite long, causing the gain to vary as a function of frequency. IF signal conditioning unit **504** adjusts for gain at various frequencies to equalize the gain profile. IF signal conditioning unit **504** also performs filtering of the analog IF signals to remove adjacent interferers or spurious signals before the signals are propagated further through the system **100**.

Controller **512** receives control signals from the AIU **502** that are received from hybrid expansion unit **106** across the at least one analog communication link **118**. Controller **512** performs control management, monitoring, and can configure parameters for the various components of the master analog remote antenna unit **402**. In the example master analog remote antenna unit **402**, the controller **512** also drives the cable equalization algorithm.

IF signal distribution unit **506** is used to distribute the signals processed by the IF signal conditioning unit **504** to various slave analog remote antenna units **404** across analog communication links **406-1** through **406**-N. In the example embodiment shown in FIG. **5**, two bands are sent across each analog communication link **406** at two different analog IF frequencies. As noted above, the IF signal distribution unit **506** is also used to couple the DC power, the analog reference clock, and any other communication signals from the master analog remote antenna unit **402** onto analog communication link **406**. The IF signal conditioning occurs at the IF signal conditioning unit **504** before the various analog signals are distributed at the IF signal distribution unit **506** in the embodiment shown in FIG. **5**. In other embodiments, the IF signal conditioning could be done after the distribution of the analog signals.

FIG. **6** is a block diagram of one embodiment of a slave analog remote antenna unit **404** for the analog remote antenna unit cluster **108**. The slave analog remote antenna unit **404** includes an analog interface unit (AIU) **602**, an IF signal conditioning unit **604**, a splitter/combiner **606**, a plurality of IF conditioners **608**, a plurality of frequency converters **610**, a plurality of RF conditioners **612**, a plurality of RF duplexers **614**, and a RF diplexer **616**. While the slave analog remote antenna unit **404** is described as a separate component, in some example embodiments, a slave analog remote antenna unit **404** is integrated with a master analog remote antenna unit **402**.

The AIU **602** is connected to the analog communication link **406**. The AIU **602** includes a coupler that is used to extract the DC power received from the master analog remote antenna unit **402** across the analog communication link **406**. The AIU **602** passes the extracted DC power to the power supply **620**. The power supply **620** in turn powers the various components of the slave analog remote antenna unit **404**. The AIU **602** also extracts control signals received from the master analog remote antenna unit **402** across the analog communication link **406**. The control signals are sent by the AIU **602** to the controller **618**. The controller **618** uses the control signals to control various components of the slave analog remote antenna unit **404**. In particular, the control signals are used by the controller **618** to control the gain in the IF signal conditioning unit **604**. Adjustments may be made based on temperature changes and other dynamic factors. The control signals are also used for the configuration of the subsequent frequency converters **610**, IF conditioners **608**, and RF conditioners **612**.

The AIU **602** also extracts the analog reference clock and sends it to the slave remote reference clock unit **622**. In the embodiment shown in FIG. **6**, the slave remote reference clock unit **622** refines the reference clock signal using a band pass filter. In other embodiments, the reference clock signal drives a phase locked loop to generate a refined reference clock signal. The slave remote reference clock unit **622** distributes the refined reference clock signal to the local oscillator generator **624**, which generates local oscillator signals for the mixers used for frequency conversion. The local oscillator signals are generated using a phase locked loop. In the example shown in FIG. **6**, the local oscillator generator **624** generates four local oscillator frequencies for each of the carrier signals of a first and second band. A first local oscillator frequency is used for downlink data in a first band and a second local oscillator frequency is used for the uplink data in the first band. A third local oscillator frequency is used for the downlink data in a second band and a fourth local oscillator frequency is used for the uplink data in the second band. In other example embodiments, greater or fewer bands are used and greater or fewer local oscillator signals are created by the local oscillator generator **624**. For example, some embodiments may require diversity, so that two uplinks are needed for each downlink and three local oscillators would need to be generated for each band. In example embodiments, the AIU **602** is also used to impedance convert between the signal received on the analog communication link **406** and the signal processed by various components of the slave analog remote antenna unit **404**.

Various analog spectrum received across the analog communication link **406** by the AIU **602** is passed to the IF signal conditioning unit **604**. The IF signal conditioning unit **604** filters out noise, distortion, and other undesirable elements of the signal using amplification and filtering techniques. The IF signal conditioning unit **604** passes the analog spectrum to the splitter/combiner **606**, where the various bands are split out of the signal in the downlink and combined together in the uplink. In the downstream, a first band is split out and passed to the IF conditioner **608-1** and a second band is split out and passed to the IF conditioner **608-2**. In the upstream, a first band is received from the IF conditioner **608-1**, a second band is received from the IF conditioner **608-2**, and the two upstream bands are combined by the splitter/combiner **606**.

In the downstream for band A, IF conditioner **608-1** passes the IF signal for band A to the frequency converter **610-1**. The frequency converter **610-1** receives a downstream mixing frequency for band A from local oscillator generator **624**. The frequency converter **610-1** uses the downstream mixing frequency for band A to convert the downstream IF signal for band A to a downstream RF signal for band A. The downstream RF signal for band A is passed onto the RF conditioner **612-1**, which performs RF gain adjustment and filtering on the downstream RF signal for band A. The RF conditioner **612-1** passes the downstream RF signal for band A to the RF duplexer **614-1**, where the downstream RF signal for band A is combined onto the same medium with an upstream RF signal for band A. Finally, the RF diplexer **616** combines band A and band B together. Thus, both band A and band B are transmitted and received across an air medium using a single antenna **626**. In other embodiments, multiple antennas are used. In one specific embodiment, the RF diplexer **616** is not necessary because band A and band B are transmitted and received using independent antennas. In other embodiments, the downstream signals are transmitted from one antenna and the upstream signals are received from another antenna. In embodiments with these types of alternative antenna configurations, the requirements and design of the RF duplexers **614** and the RF diplexers **616** will vary to meet the requirements of the antenna configuration.

In the downstream for band B, IF conditioner **608-2** passes the IF signal for band B to the frequency converter **610-2**. The frequency converter **610-2** receives a downstream mixing frequency for band B from local oscillator generator **624**. The frequency converter **610-2** uses the downstream mixing frequency for band B to convert the downstream IF signal for band B to a downstream RF signal for band B. The downstream RF signal for band B is passed onto the RF conditioner **612-2**, which performs more RF adjustment and filtering on the downstream RF signal for band B. The RF conditioner **612-2** passes the downstream RF signal for band B to the RF duplexer **614-2**, where the downstream RF signal for band B is combined onto the same medium with an upstream RF signal for band B. Finally, the RF diplexer **616** combines band A and band B together as described above, such that both band A and band B are transmitted and received across an air medium using antenna **626**.

In the upstream, antenna **626** receives the RF signal for both band A and band B and passes both onto RF diplexer **616** which separates band A from band B. Then, band A is passed to RF duplexer **614-1**, where the upstream RF and downstream RF signals for band A are separated onto different signal lines. The upstream RF signal for band A is then passed to the RF conditioner **612-1**, which performs gain adjustment and filtering on the upstream RF signal for band A. Finally, the upstream RF signal for band A is passed to frequency converter **610-1**, which frequency converts the upstream RF signal for band A into an upstream IF signal for band A using an upstream mixing frequency generated by the local oscillator generator **624**.

In addition, band B is passed from the RF diplexer **616** to the RF duplexer **614-2**, where the upstream RF and downstream RF signals for band B are separated onto different signal lines. The upstream RF signal for band B is then passed to the RF conditioner **612-1**, which performs gain adjustment and filtering on the upstream RF signal for band B. Finally, the upstream RF signal for band B is passed to frequency converter **610-2**, which frequency converts the upstream RF signal for band B into an upstream IF signal for band B using an upstream mixing frequency generated by the local oscillator generator **624**.

In embodiments where the functions of the master analog remote antenna unit **402** and the slave analog remote antenna unit **404-1** are integrated into the same physical package, as depicted in FIG. **4**, some of the redundant functions in the master analog remote antenna unit **402** and the slave analog remote antenna unit **404-1** may be removed. For example, the two units may share the same controller and power supply. The slave remote reference clock **622** may not be required as the signal from the master remote reference clock unit **508** could be routed directly to the local oscillator generator **624**.

FIG. **7** is a block diagram of one embodiment of a digital remote antenna unit **110** of system **100**. Digital remote antenna unit **110** includes at least one digital input-output unit (DIOU) **702**, at least one digital multiplexing unit (DMU) **704**, at least one RF module **706**, at least one central processing unit (CPU) **708**, at least one digital remote clock unit (DRCU) **710**, and at least one power supply **712**. In some embodiments, at least one digital input-output unit (DIOU) **714** is used to facilitate a digital output line **716**. The digital output line **716** allows daisy-chaining multiple digital remote antenna units **110** together. The digital output line **716** of one digital remote antenna unit **110** can be coupled to the input of a DIOU **702** of another digital remote antenna unit **110**. The digital output line **716** will be described in further detail below with regards to embodiments having daisy-chained digital remote antenna units **110**.

Each digital remote antenna unit **110** communicates at least one band of digitized spectrum with the master host unit **104** in the form of a multiplexed digitized signal containing N-bit words of digitized spectrum. The multiplexed digitized signal is received at the at least one DIOU **702** through at least one digital communication link **114**. In the embodiment shown in FIG. **7**, only one DIOU **702-1** is necessary if the digital remote antenna unit **110** is only coupled with a single upstream master host unit **104** (or single upstream digital expansion unit **124** as described in detail below). DIOU **702-1** receives the data stream from a master host unit **104** via a digital communication link **114** in an optical format. DIOU **702-1** converts the data stream from the optical format to an electrical format and passes the data stream onto the DMU **704**. DIOU **702-2** through DIOU **702**-N are optional. For example, in other embodiments, digital remote antenna unit **110** has multiple DIOUs **702** (DIOU **702-1** through DIOU **702**-N) and is connected to multiple upstream master host units **104** or digital expansion units **124** through digital communication links **114**. In other embodiments, digital remote antenna unit **110** is connected to digital expansion units **124** through DIOU **702**. In some embodiments including multiple upstream connections, the digital remote antenna unit **110** selects one DIOU **702** to extract the clock signal from.

As noted above, the at least one DIOU **702** communicates the multiplexed digitized signal containing N-bit words of digitized spectrum to the DMU **704**. The DMU **704** demultiplexes N-bit words of digitized spectrum received from the at least one DIOU **702** and sends N-bit words of digitized spectrum across the at least one communication link **718** to the at least one RF module **706** (described in further detail with reference to FIG. **8** below). Each RF module **706** is also coupled to the digital remote clock unit **710** by a communication link **722**.



The DMU **704** extracts the digital master reference clock signal from the data stream itself. Because the data stream was synchronized with the digital master reference clock signal at the master host unit **104**, it can be recovered from the data stream itself. The extracted digital master reference clock signal is sent to the digital remote clock unit **710**. The digital remote clock unit **710** receives the digital master reference clock signal extracted from the data stream received from the master host unit **104**. The digital expansion clock unit **312** communicates the digital master reference clock signal to various components of the digital remote antenna unit **110**, including the DMU **704** and each RF module **706**. Each DMU **704** uses the digital master reference clock signal to synchronize itself with the system **100**. Each RF module receives the digital master reference clock signal from the digital remote clock unit **710** across a communication link **722** (i.e., communication link **722-1**, communication link **722-2**, and communication link **722**-N). While each communication link **718** and communications link **722** are shown as separate lines in FIG. **7**, in some embodiments a single multi-conductor cable is connected between the DMU **704** and each RF module **706**. This multi-conductor cable includes both the communication link **718** and communications link **722** and carries the clock signals, data signals, control/management signals, etc.

In some embodiments, each DIOU **702** is selectable and configurable, so that one DIOU **702** can be selected to receive the digital master reference clock signal and other DIOUs **702** can be used to send the digital master reference clock signal upstream to other system components, such as secondary master host units, digital expansion units, hybrid expansion units, or other digital remote antenna units. Each DIOU **702** is not required to be synchronized to the other parts of the digital remote antenna unit **110** unless it performs some type of function that requires it to be synchronized. In one embodiment, the DIOU **702** performs the extraction of the digital master reference clock in which case it would be synchronized to the remainder of the hybrid expansion unit.

In the downstream, each RF module **706** receives N-bit words of digitized spectrum and outputs an RF signal that is transmitted across an air medium using at least one respective antenna **720**. In the upstream, each RF module **706** receives RF signals received across an air medium using the at least one respective antenna **720** and outputs N-bit words of digitized spectrum to the DMU **704**. In the digital remote antenna unit **110** shown in FIG. **7**, each RF module **706** converts between N-bit words of digitized spectrum and RF signals for a single band. In other embodiments, at least one RF module **706** converts between N-bit words of digitized spectrum and RF signals for multiple bands. A different antenna element is used for each signal path in some example embodiments having multiple bands, such as embodiments having diversity channels or multiple signal branches used for smart antennas where signals overlap spectrally. In the digital remote antenna unit **110** shown in FIG. **7**, each RF module **706** is connected to a separate respective antenna **720**. In other embodiments, splitters and combiners are used to couple the outputs of a plurality of RF modules **706** together to a single antenna.

As noted above, some embodiments of digital remote antenna unit **110** include at least one DIOU **714** and at least one digital output line **716** that allow daisy-chaining multiple digital remote antenna units **110** together. In example embodiments, DIOU **714** is coupled to digital multiplexing unit **704**. In the downstream, DIOU **714** converts the data stream coming from the DMU **704** from an electrical format to an optical format and outputs the data stream across digital output line **716**. In the upstream, DIOU **714** converts the data stream coming across digital output line **716** from an optical format to an electrical format and passes the data stream onto the DMU **704**. Thus, as described below, a plurality of digital remote antenna units **110** can be daisy-chained together using the digital output line **716** on at least one digital remote antenna unit **110**.

CPU **708** is used to control each DMU **704** and each RF module **706**. While the links between the CPU **708** and the DMU **704** and each RF module **706** are shown as separate links from the communication links **718** and the communications links **720**, it can be part of a multi-conductor cable as described above. An input/output (I/O) line **724** coupled to CPU **708** is used for network monitoring and maintenance. Typically, I/O line **724** is an Ethernet port used for external communication with the system. Power supply **712** is used to power various components within digital remote antenna unit **110**.

FIG. **8** is a block diagram of one embodiment of a RF module **706** for digital remote antenna unit **110**. The RF module **706** includes a digital-analog conversion unit (DACU) **802**, an IF conditioner **804**, a frequency converter **806**, a RF conditioner **808**, a RF duplexer **810**, a RF module clock unit, a local oscillator generator **814**, and a controller **816**. While the RF module **706** is described as a separate component, in some example embodiments, some or all of the components included in RF module **706** are integrated directly in digital remote antenna unit **110**. In other embodiments, other components are used to perform the same or similar functions to the components of RF module **706** described below.

The DACU **802** is connected to a communication link **718**, where it communicates N-bit words of digitized spectrum with the DMU **704**. The DACU **802** is also connected to the RF module clock unit **812**, where it receives a digital master reference clock signal from the digital remote clock unit **710** of the digital remote antenna unit **110** across a communication link **722**. In other embodiments, DACU **802** can also communicate to or from other components of the digital remote antenna unit **110**. The DACU **802** converts between the N-bit words of digitized spectrum and an analog intermediate frequency (IF) spectrum using the digital master reference clock signal. In the downstream, the analog intermediate frequency (IF) is passed through the IF conditioner **804** that filters, amplifies, and attenuates the IF spectrum prior to frequency up-conversion. In the upstream, the analog intermediate frequency (IF) is passed through the IF conditioner **804** that filters, amplifies, and attenuates the IF spectrum prior to analog to digital conversion by the DACU **802**.

The RF module clock unit **812** receives the digital master reference clock signal across the communication link **722** and distributes the signal to the DACU **802**. The RF module clock unit **812** also generates an analog domain reference clock signal based on the digital master reference clock signal. This analog domain reference clock signal is used to synchronize analog components in the RF module **706**. In the embodiment of RF module **706** shown in FIG. **8**, the RF module clock unit **812** generates the analog domain reference clock signal by running the digital master reference clock signal through a phase locked loop circuit. The generated analog domain reference clock signal is then passed onto the local oscillator generator **814**. In some embodiments, the digital master reference clock signal is approximately 184.32 MHz and the analog domain reference clock signal is generated as a 30.72 MHz clock based on the 184.32 MHz digital master reference clock signal. Thus, the 30.72 MHz clock is sent to the local oscillator generator **814**.

The frequency converter **806** converts between IF spectrum and RF spectrum. The frequency converter **806** is connected to the local oscillator generator **814**. The local oscillator generator **814** receives the analog domain reference clock from the RF module clock unit **812**. In example embodiments, the analog domain reference clock signal is first refined using a band pass filter or other appropriate filter. In other embodiments, the analog domain reference clock signal drives a phase locked loop to generate a refined reference clock signal. In the example shown in FIG. **8**, the local oscillator generator **824** generates two local oscillator frequencies for each of the carrier signals of the band serviced by the RF module **706**. A first local oscillator frequency is used for downlink data and a second local oscillator frequency is used for the uplink data. While the RF module **706** is described as only servicing a single band, other embodiments include greater numbers of bands where greater numbers of oscillator signals are created by the local oscillator generator **814**. For example, some embodiments may require diversity, so that two uplinks are needed for each downlink and three local oscillators would need to be generated for each band.

The frequency converter **806** uses the downstream mixing frequency to convert the downstream IF signal to a downstream RF signal. The downstream RF signal is passed onto the RF conditioner **808**, which performs RF gain adjustment and filtering on the downstream RF signal. The RF conditioner **808** passes the downstream RF signal to the RF duplexer **810**, where the downstream RF signal is combined onto the same medium with the upstream RF signal. In example RF module **706**, the RF signals are transmitted and received across an air medium using a single antenna **720**.

In the upstream, antenna **720** receives the RF signal and passes it onto the RF duplexer **810**, where the upstream RF and downstream RF signals are separated onto different signal lines. The upstream RF signal is then passed to the RF conditioner **808**, which performs gain adjustment and filtering on the upstream RF signal. Finally, the upstream RF signal is passed to frequency converter **806**, which frequency converts the upstream RF signal into an upstream IF signal using the upstream mixing frequency generated by the local oscillator generator **814**.

Each RF module **706** of example digital remote antenna unit **110** uses a separate antenna **720**. In other embodiments, RF diplexers are implemented downstream of multiple RF modules **706**, thereby allowing multiple RF bands to use a single antenna. In other embodiments, multiple antennas are used for each RF module **706**. For example, in other embodiments, the downstream signals are transmitted from one antenna and the upstream signals are received from another antenna. In embodiments with these type of alternative antenna configurations, the requirements and design of the RF duplexers and any necessary RF diplexers will vary to meet the requirements of the antenna configuration.

While the frequency conversion described above is a two step process between digital and an IF analog signal and then between the IF analog signal and an RF analog signal, in other embodiments, a direct conversion occurs between the digital signals received on communication link **718** and the RF signals output across antenna **720**. In such embodiments, the functionality of the DACU **802**, the IF conditioner **804**, and frequency converter **806** may be combined or replaced with other appropriate components.

The controller **816** uses control and management signals received over a communication link **816** to control and manage various components of the RF module **706**. In particular, the control and management signals are used by the controller **816** to control and manage the gain in the IF conditioner **804**. Adjustments may be made based on temperature changes and other dynamic factors. While communication link **816** is shown as a separate communication link, in some embodiments the communication link **816** is combined with the communication link **718** using a multi-conductor cable as described above with reference to FIG. **7**. In such embodiments, the multi-conductor cable couples the digital multiplexing unit **704** with each RF module **706** and the control and management messages are communicated over a pair of conductors in this cable. In other example embodiments, the multi-conductor cable is a generic communication link that combines the communication link **718**, the communication link **816**, and the communication link **722** into a single cable that interfaces each RF module **706** with the digital multiplexing unit **704**. The control signals are also used for the configuration of the subsequent frequency converter **806** and RF conditioner **808**. In example RF module **706**, all of the components of RF module **706** are powered by the power supply **712** of the digital remote antenna unit **110**. In other embodiments, a separate power supply is included in each RF module **706** and is used to power the various components of RF module **706**. In other embodiments, signal line power extraction is used to supply power to the RF module **706**.

FIGS. **9-11** and **13-14** are block diagrams of other embodiments of systems for providing wireless coverage into a substantially enclosed environment. The embodiments of FIGS. **9-11** and **13-14** show various topologies as described below. Because the operation of the components of the various topologies is similar to that described above, only the differences based on topologies is described below.

FIG. **9** is a block diagram of another embodiment of a system **900** for providing wireless coverage into a substantially enclosed environment. The system **900** includes the same components as system **100**, including at least one service provider interface **102**, at least one master host unit **104**, at least one hybrid expansion unit **106**, at least one analog remote antenna cluster **108**, and at least one digital remote antenna unit **110**. The differences between system **100** and system **900** are only in topology.

Example system **900** differs from example system **100** because it includes hybrid expansion unit **106-1**, analog remote antenna cluster **108-1**, analog remote antenna cluster **108-2**, digital remote antenna unit **110-1**, digital remote antenna unit **110-2**, and digital remote antenna unit **110-3**. Analog remote antenna cluster **108-2** operates in the same manner as analog remote antenna cluster **108-1**. Digital remote antenna unit **110-2** and digital remote antenna unit **110-3** operate in the same manner as digital remote antenna unit **110-1**. At least one DIOU **702** of digital remote antenna unit **110-2** is daisy chain connected to digital output line **716** of digital remote antenna unit **110-1** through a first digital remote antenna unit connection link **122-1**. Likewise, at least one DIOU **702** of digital remote antenna unit **110-3** is daisy chain connected to digital output line **716** of digital remote antenna unit **110-2** through a second digital remote antenna unit connection link **122-2**.

FIG. **10** is a block diagram of another embodiment of a system **1000** for providing wireless coverage into a substantially enclosed environment. The system **1000** includes the same components as system **100**, including a first service provider interface **102-1**, a second service provider interface **102-2**, a master host unit **104-1**, a master host unit **104-2**, a hybrid expansion unit **106-1**, an analog remote antenna cluster **108-1**, a digital remote antenna unit **110-1**, and an analog communication link **112-1**. The differences between system **100** and system **1000** are that system **1000** includes additional service provider interface **102-2**, master host unit **104-2**, and analog communication link **112-2**. Hybrid expansion unit **106-1** is connected to both the master host unit **104-1** and the master host unit **104-2**, through digital communication link **114-1** and digital communication link **114-3** respectively. In addition, hybrid expansion unit **106-1** includes DIOU **302-1** and DIOU **302-2** as shown in FIG. **3**. DIOU **302-1** is coupled with digital communication link **114-1** and DIOU **302-2** is coupled with digital communication link **114-3**. DIOU **302-1** and DIOU **302-2** are coupled to DMU **304**, which multiplexes and demultiplexes upstream and downstream signals together allowing various bands to be distributed from master host unit **104-1** and master host unit **104-2** through analog remote antenna cluster **108-1**. Other example systems include greater or fewer service provider interfaces **102**, master host units **104**, hybrid expansion units **106**, analog remote antenna clusters **108**, and digital remote antenna units **110**.

FIG. **11** is a block diagram of another embodiment of a system **1100** for providing wireless coverage into a substantially enclosed environment. The system **1100** includes the same components as system **100**, including a first service provider interface **102-1**, a master host unit **104-1**, a hybrid expansion unit **106-1**, an analog remote antenna cluster **108-1**, a digital remote antenna unit **110-1**, and an analog communication link **112-1**. The differences between system **100** and system **1100** are that system **1100** includes analog remote antenna cluster **108-2**, a digital expansion unit **124**, digital remote antenna unit **110-4**, digital remote antenna unit **110-5**, digital remote antenna unit **110-6**, and digital remote antenna unit **110-7**. Analog remote antenna cluster **108-1** is connected to hybrid expansion unit **106-1** through analog communication link **118-1** and analog remote antenna cluster **108-2** is connected to hybrid expansion unit **106-1** through analog communication link **118-2**. Digital expansion unit **124** is connected to master host unit **104-1** through digital communication link **114-4**. Digital remote antenna unit **110-4** is connected to digital expansion unit **124** through digital expansion communication link **126-1**. Digital remote antenna unit **110-5** is connected to digital expansion unit **124** through digital expansion communication link **126-2**. Digital remote antenna unit **110-6** is connected to digital expansion unit **124** through digital expansion communication link **126-3**. At least one DIOU **702** of digital remote antenna unit **110-7** is daisy chain connected to digital output line **716** of digital remote antenna unit **110-6** through a digital remote antenna unit connection link **122-3**.

FIG. **12** is a block diagram of one embodiment of a digital expansion unit **124** of system **1200**. Digital expansion unit **124** includes at least one digital input-output unit (DIOU) **1202**, at least one digital multiplexing unit (DMU) **1204**, at least one digital input-output unit (DIOU) **1206**, at least one central processing unit (CPU) **1208**, at least one digital expansion clock unit **1210**, and at least one power supply **1212**. It is understood that the DMU **1204** performs both multiplexing and demultiplexing functionality between the various upstream and downstream connections.

The digital expansion unit **124** communicates N-bit words of digitized spectrum between the master host unit **104** and at least one hybrid expansion unit **106**. Each DIOU **1202** (DIOU **1202-1** through DIOU **1202**-N) of the digital expansion unit **124** operates to convert between optical signals received across a digital expansion communication link **126** and electrical signals processed within the digital expansion unit **124**. In the downstream, the converted signals are passed from each DIOU **1202** to the DMU **1204**, where they are multiplexed together and output to at least one DIOU **1206** which converts the electrical signals to optical signals and outputs the optical signals to at least one hybrid expansion unit or another digital expansion unit for further distribution. In the upstream, each DIOU **1206** converts optical signals received from a downstream hybrid expansion unit or digital expansion unit into electrical signals, which are passed onto the DMU **1204**. The DMU **1204** takes the upstream signals and multiplexes them together and outputs them to at least one DIOU **1202**, which converts the electrical signals into optical signals and sends the optical signals across a digital expansion communication link **126** toward the master host unit. In other embodiments, multiple digital expansion units are daisy chained for expansion in the digital domain.

In the example embodiment shown in FIG. **12**, the CPU **1208** is used to control each DMU **1204**. An input/output (I/O) line **1214** coupled to CPU **1208** is used for network monitoring and maintenance. Typically, I/O line **1214** is an Ethernet port used for external communication with the system. The DMU **1204** extracts the digital master reference clock signal from any one digital data stream received at any one of the DIOU **1202** and DIOU **1206** and sends the digital master reference clock signal to the digital expansion clock unit **1210**. The digital expansion clock unit **1210** then provides the digital master reference clock signal to other functions in the DMU that require a clock signal. Power supply **1212** is used to power various components within digital expansion unit **124**.

In some embodiments, system **1100** further includes additional service provider interface **102-3** and master host unit **104-3**. Master host unit **104-3** is connected to service provider interface **102-3** with analog communication link **112-3**. Digital expansion unit **124** is connected to master host unit **104-3** through digital communication link **114-5**. In addition, digital expansion unit **124** includes DIOU **1202-1** and DIOU **1202-2** as shown in FIG. **12**. DIOU **1202-1** is coupled with digital communication link **114-4** and DIOU **1202-2** is coupled with digital communication link **114-5**. DIOU **1202-1** and DIOU **1202-2** are coupled to DMU **1204**, which multiplexes and demultiplexes upstream and downstream signals together allowing various bands to be distributed from master host unit **104-1** and master host unit **104-3** through the analog remote antenna clusters **108** and the digital remote antenna units **110**. Other example systems include greater or fewer service provider interfaces **102**, master host units **104**, hybrid expansion units **106**, analog remote antenna clusters **108**, digital remote antenna units **110**, and digital expansion units **124**.

FIG. **13** is a block diagram of another embodiment of a system **1300** for providing wireless coverage into a substantially enclosed environment. The system **1300** includes some of the same components as system **1100**, including a first service provider interface **102-1**, a master host unit **104-1**, a hybrid expansion unit **106-1**, an analog remote antenna cluster **108-1**, an analog remote antenna cluster **108-2**, a digital expansion unit **124**, a digital remote antenna unit **110-6**, and a digital remote antenna unit **110-7**. In addition, system **1100** also includes hybrid expansion unit **106-2** and analog remote antenna cluster **108-3** and **108-4**. Hybrid expansion unit **106-2** is coupled to digital expansion unit **124** through digital expansion communication link **126-4**. Analog remote antenna cluster **108-3** is connected to hybrid expansion unit **106-2** through analog communication link **118-3** and analog remote antenna cluster **108-4** is connected to hybrid expansion unit **106-2** through analog communication link **118-4**.

FIG. **14** is a block diagram of another embodiment of a system **1400** for providing wireless coverage into a substantially enclosed environment. The system **1400** includes all of the same components as system **1300** and some additional components from system **900**, including service provider interface **102-1**, master host unit **104-1**, hybrid expansion unit **106-1**, hybrid expansion unit **106-2**, analog remote antenna cluster **108-1**, analog remote antenna cluster **108-2**, analog remote antenna cluster **108-3**, analog remote antenna cluster **108-4**, digital expansion unit **124**, digital remote antenna unit **110-1**, digital remote antenna unit **110-2**, digital remote antenna unit **110-6**, and digital remote antenna unit **110-7**.

In the embodiments of the systems described above, the various components, including master host unit(s) **104**, hybrid expansion unit(s) **106**, analog remote antenna cluster(s) **108**, digital remote unit(s) **110**, and digital expansion unit(s) **124**, are shown as separate components. In some other example embodiments, some of these components can be combined into the same physical housing or structure and/or functionality can be ported from one component to another.

What is claimed is:

**1**. A communication system, comprising:

a first master host unit [adapted] *configured* to communicate analog signals with at least a first service provider interface using a first set of bands of analog spectrum[; a plurality of digital communication links coupled to the first master host unit], wherein the first master host unit is further [adapted] *configured* to communicate digitized spectrum in first N-bit words over at least a first digital communication link of [the] *a* plurality of digital communication links *coupled to the first master host unit* and second N-bit words over at least a second digital communication link of the plurality of digital communication links *coupled to the first master host unit*;

the first master host unit further [adapted] *configured* to convert between the first set of bands of analog spectrum and the first N-bit words of digitized spectrum, the first master host unit further [adapted] *configured* to convert between the first set of bands of analog spectrum and the second N-bit words of digitized spectrum;

a first hybrid expansion unit communicatively coupled to the first master host unit by the first digital communication link of the plurality of digital communication links and [adapted] *configured* to communicate the first N-bit words of digitized spectrum with the first master host unit across the first digital communication link, the first hybrid expansion unit further [adapted] *configured* to convert between the first N-bit words of digitized spectrum and a second set of bands of analog spectrum[; a first analog communication link coupled to the first hybrid expansion unit], wherein the first hybrid expansion unit is further [adapted] *configured* to communicate the second set of bands of analog spectrum across [the] *a* first analog communication link *coupled to the first hybrid expansion unit*;

a first analog remote antenna unit communicatively coupled to the first hybrid expansion unit by the first analog communication link and [adapted] *configured* to communicate the second set of bands of analog spectrum with the first hybrid expansion unit across the first analog communication link, the first analog remote antenna unit further [adapted] *configured* to transmit and receive first wireless signals over a first plurality of air interfaces;

a first digital remote antenna unit communicatively coupled to the first master host unit by the second digital communication link of the plurality of digital communication links and [adapted] *configured* to communicate the second N-bit words of digitized spectrum with the first master host unit across the second digital communication link, the first digital remote antenna unit further [adapted] *configured* to convert between the second N-bit words of digitized spectrum and a third set of bands of analog spectrum, the first digital remote antenna unit further [adapted] *configured* to transmit and receive second wireless signals over a second plurality of air interfaces; and

wherein the first master host unit, the first hybrid expansion unit, the first analog remote antenna unit, and the first digital remote antenna unit are synchronized in time and frequency.

**2**. The system of claim **1**, wherein the second set of bands of analog spectrum are at the same frequencies as the first set of bands of analog spectrum.

**3**. The system of claim **1**, wherein the first analog remote antenna unit is further [adapted] *configured* to frequency convert the second set of bands of analog spectrum to a fourth set of bands of analog spectrum.

**4**. The system of claim **3**, wherein the fourth set of bands of analog spectrum are at the same frequencies as the first set of bands of analog spectrum, and wherein at least a subset of the fourth set of bands of analog spectrum are transmitted and received by the first analog remote antenna unit over the first plurality of air interfaces.

**5**. The system of claim **1**, wherein the third set of bands of analog spectrum are at the same frequencies as the first set of bands of analog spectrum.

**6**. The system of claim **1**, wherein the first digital remote antenna unit is further [adapted] *configured* to frequency convert the third set of bands of analog spectrum to a fourth set of bands of analog spectrum, wherein the fourth set of bands of analog spectrum are at the same frequencies as the first set of bands of analog spectrum, and wherein at least a subset of the fourth set of bands of analog spectrum are transmitted and received by the first digital remote antenna unit over the second plurality of air interfaces.

**7**. The system of claim **1**, wherein the first analog remote antenna unit is part of a first analog remote antenna cluster that includes:

a master analog remote antenna unit [adapted] *configured* to communicate the second set of bands of analog spectrum with the first hybrid expansion unit across the first analog communication link;

a second analog remote antenna unit [adapted] *configured* to transmit and receive third wireless signals over a third plurality of air interfaces; and

wherein the master analog remote antenna unit distributes a first subset of the second set of bands of analog spectrum to the first analog remote antenna unit and a second subset of the second set of bands of analog spectrum to the second analog remote antenna unit.



**8**. The system of claim **1**, wherein the first digital remote antenna unit includes:

at least one module [adapted] *configured* to convert between at least a portion of the second N-bit words of digitized spectrum and a third set of bands of analog spectrum.

**9**. The system of claim **1**, further comprising:

a first digital expansion unit communicatively coupled to the first master host unit by a third digital communication link of the plurality of digital communication links and [adapted] *configured* to communicate third N-bit words of digitized spectrum with the first master host unit across the third digital communication link;

a first digital expansion communication link coupled to the first digital expansion unit, wherein the first digital expansion unit is further [adapted] *configured* to communicate at least a portion of the third N-bit words of digitized spectrum across the first digital expansion communication link; and

a second digital remote antenna unit communicatively coupled to the first digital expansion unit by the first digital expansion communication link and [adapted] *configured* to communicate the at least a portion of the third N-bit words of digitized spectrum with the first digital expansion unit across the first digital expansion communication link, the second digital remote antenna unit further [adapted] *configured* to convert between the at least a portion of the third N-bit words of digitized spectrum and a fourth set of bands of analog spectrum, the second digital remote antenna unit further [adapted] *configured* to transmit and receive third wireless signals over a third plurality of air interfaces.

**10**. The system of claim **1**, further comprising:

a first digital expansion unit communicatively coupled to the first master host unit by a third digital communication link of the plurality of digital communication links and [adapted] *configured* to communicate third N-bit words of digitized spectrum with the first master host unit across the third digital communication link;

a first digital expansion communication link coupled to the first digital expansion unit, wherein the first digital expansion unit is further [adapted] *configured* to communicate at least a portion of the third N-bit words of digitized spectrum across the first digital expansion communication link;

a second hybrid expansion unit communicatively coupled to the first digital expansion unit by the first digital expansion communication link and [adapted] *configured* to communicate the at least a portion of the third N-bit words of digitized spectrum with the first digital expansion unit across the first digital expansion communication link, the second hybrid expansion unit further [adapted] *configured* to convert between the at least a portion of the third N-bit words of digitized spectrum and a fourth set of bands of analog spectrum;

a second analog communication link coupled to the second hybrid expansion unit, wherein the second hybrid expansion unit is further [adapted] *configured* to communicate the fourth set of bands of analog spectrum across the second analog communication link; and

a second analog remote antenna unit communicatively coupled to the second hybrid expansion unit by the second analog communication link and [adapted] *configured* to communicate the fourth set of bands of analog spectrum with the second hybrid expansion unit across the second analog communication link, the second analog remote antenna unit further [adapted] *configured* to transmit and receive third wireless signals over a third plurality of air interfaces.

11. The system of claim **1**, further comprising:

a second master host unit [adapted] *configured* to communicate analog signals with at least a second service provider interface using a fourth set of bands of analog spectrum;

a second plurality of digital communication links coupled to the second master host unit, wherein the second master host unit is further [adapted] *configured* to communicate digitized spectrum in third N-bit words of digitized spectrum over the second plurality of digital communication links;

the second master host unit further [adapted] *configured* to convert between the fourth set of bands of analog spectrum and the third N-bit words of digitized spectrum;

wherein the first hybrid expansion unit is communicatively coupled to the second master host unit by one of the second plurality of digital communication links and [adapted] *configured* to communicate the third N-bit words of digitized spectrum with the second master host unit across the one of the second plurality of digital communication links; and

wherein the first hybrid expansion unit multiplexes the third N-bit words of digitized spectrum into the first N-bit words of digitized spectrum before converting between the first N-bit words of digitized spectrum and the second set of bands of analog spectrum.

12. The system of claim **1**, further comprising:

a first digital expansion unit communicatively coupled to the first master host unit by a third digital communication link of the plurality of digital communication links and [adapted] *configured* to communicate third N-bit words of digitized spectrum with the first master host unit across the third digital communication link;

a second master host unit [adapted] *configured* to communicate analog signals with at least a second service provider interface using a fourth set of bands of analog spectrum;

a second plurality of digital communication links coupled to the second master host unit, wherein the second master host unit is further [adapted] *configured* to communicate digitized spectrum in fourth N-bit words of digitized spectrum over the second plurality of digital communication links;

the second master host unit further [adapted] *configured* to convert between the fourth set of bands of analog spectrum and the fourth N-bit words of digitized spectrum;

wherein the first digital expansion unit is communicatively coupled to the second master host unit by one of the second plurality of digital communication links and [adapted] *configured* to communicate the fourth N-bit words of digitized spectrum with the second master host unit across the one of the second plurality of digital communication links;

wherein the first digital expansion unit multiplexes the third N-bit words of digitized spectrum and the fourth N-bit words of digitized spectrum into fifth N-bit words of digitized spectrum; and

a first digital expansion communication link coupled to the first digital expansion unit, wherein the first digital expansion unit is further [adapted] *configured* to communicate the fifth N-bit words of digitized spectrum across the first digital expansion communication link.

13. The system of claim **12**, further comprising:

a second digital remote antenna unit communicatively coupled to the first digital expansion unit by the first digital expansion communication link and [adapted] *configured* to communicate the fifth N-bit words of digitized spectrum with the first digital expansion unit across the first digital expansion communication link, the second digital remote antenna unit further [adapted] *configured* to convert between the fifth N-bit words of digitized spectrum and a fifth set of bands of analog spectrum, the second digital remote antenna unit further [adapted] *configured* to transmit and receive third wireless signals over a third plurality of air interfaces.

14. The system of claim **1**, further comprising:

wherein the first hybrid expansion unit is further [adapted] *configured* to convert between the first N-bit words of digitized spectrum and a fourth set of bands of analog spectrum;

a second analog communication link coupled to the first hybrid expansion unit, wherein the first hybrid expansion unit is further [adapted] *configured* to communicate the fourth set of bands of analog spectrum across the second analog communication link; and

a second analog remote antenna unit communicatively coupled to the first hybrid expansion unit by the second analog communication link and [adapted] *configured* to communicate the fourth set of bands of analog spectrum with the first hybrid expansion unit across the second analog communication link, the second analog remote antenna unit further [adapted] *configured* to transmit and receive third wireless signals over a third plurality of air interfaces.

15. The system of claim **14**, wherein at least a portion of the fourth set of bands of analog spectrum is the same as at least a portion of the second set of bands of analog spectrum.

16. The system of claim **14**, wherein the second analog remote antenna unit is further [adapted] *configured* to frequency convert the second set of bands of analog spectrum to a fifth set of bands of analog spectrum, wherein the fifth set of bands of analog spectrum are at the same frequencies as the first set of bands of analog spectrum, and wherein at least a subset of the fifth set of bands of analog spectrum are transmitted and received by the second analog remote antenna unit over the third plurality of air interfaces.

17. The system of claim **1**, further comprising:

a first digital remote antenna unit connection link coupled to the first digital remote antenna unit;

a second digital remote antenna unit communicatively coupled to the first digital remote antenna unit by the first digital remote antenna unit connection link and [adapted] *configured* to communicate third N-bit words of digitized spectrum with the first digital remote antenna unit across the first digital remote antenna unit connection link, the second digital remote antenna unit further [adapted] *configured* to convert between the third N-bit words of digitized spectrum and a fourth set of bands of analog spectrum, the second digital remote antenna unit further [adapted] *configured* to transmit and receive third wireless signals over a third plurality of air interfaces.

18. The system of claim **17**, wherein at least a portion of the second N-bit words of digitized spectrum is the same as at least a portion of the third N-bit words of digitized spectrum.

19. The system of claim 1, further comprising:

a second hybrid expansion unit communicatively coupled to the first master host unit by a third digital communication link of the plurality of digital communication links and [adapted] *configured* to communicate third N-bit words of digitized spectrum with the first master host unit across the third digital communication link, the second hybrid expansion unit further [adapted] *configured* to convert between the third N-bit words of digitized spectrum and a fourth set of bands of analog spectrum;

a second analog communication link coupled to the second hybrid expansion unit, wherein the second hybrid expansion unit is further [adapted] *configured* to communicate the fourth set of bands of analog spectrum across the second analog communication link;

a second analog remote antenna unit communicatively coupled to the second hybrid expansion unit by the second analog communication link and [adapted] *configured* to communicate the fourth set of bands of analog spectrum with the second hybrid expansion unit across the second analog communication link, the second analog remote antenna unit [adapted] *configured* to transmit and receive third wireless signals over a third plurality of air interfaces.

20. The system of claim 19, wherein the second analog remote antenna unit is further [adapted] *configured* to frequency convert the fourth set of bands of analog spectrum to a fifth set of bands of analog spectrum.

21. The system of claim 20, wherein the fifth set of bands of analog spectrum are at the same frequencies as the first set of bands of analog spectrum, and wherein at least a subset of the fifth set of bands of analog spectrum are transmitted and received by the second analog remote antenna unit over the third plurality of air interfaces.

22. A method comprising:

converting first wireless spectrum for a first wireless service between a first band of analog spectrum and a first stream of N-bit words of digitized spectrum at a first master host unit;

converting second wireless spectrum for a second wireless service between a second band of analog spectrum and a second stream of N-bit words of digitized spectrum at the first master host unit;

in the downstream direction,

multiplexing at least the first stream of N-bit words of digitized spectrum with the second stream of N-bit words of digitized spectrum into a first multiplexed stream at the first master host unit; and

multiplexing at least the first stream of N-bit words of digitized spectrum with the second stream of N-bit words of digitized spectrum into a second multiplexed stream at the first master host unit;

transporting the first multiplexed stream of wireless spectrum on a first digital communication link between the first master host unit and a hybrid expansion unit;

converting the first multiplexed stream of wireless spectrum between N-bit words of digitized spectrum and a third set of bands of analog spectrum at the hybrid expansion unit;

transporting the third set of bands of analog spectrum on a first analog communication link between the hybrid expansion unit and a first analog remote antenna unit;

communicating at least a portion of one of the first wireless spectrum and the second wireless spectrum across at least a first air interface at the first analog remote antenna unit;

transporting the second multiplexed stream of wireless spectrum on a second digital communication link between the first master host unit and a first digital remote antenna unit;

converting the second multiplexed stream of wireless spectrum between N-bit words of digitized spectrum and a fourth set of bands of analog spectrum at the first digital remote antenna unit;

communicating at least a portion of one of the first wireless spectrum and the second wireless spectrum across at least a second air interface at the first digital remote antenna unit; and

synchronizing the first master host unit, the [first] hybrid expansion unit, the first analog remote antenna unit, and the first digital remote antenna unit in time and frequency.

23. The method of claim 22, further comprising:

in the upstream direction,

demultiplexing the first multiplexed stream into at least the first stream of N-bit words of digitized spectrum and the second stream of N-bit words of digitized spectrum at the first master host unit; and

demultiplexing the second multiplexed stream into at least the first stream of N-bit words of digitized spectrum and the second stream of N-bit words of digitized spectrum at the first master host unit.

24. The method of claim 22, further comprising:

in the downstream direction,

multiplexing at least the first stream of N-bit words of digitized spectrum with the second stream of N-bit words of digitized spectrum into a third multiplexed stream at the first master host unit;

transporting the third multiplexed stream of wireless spectrum on a third digital communication link between the first master host unit and a first digital expansion unit;

transporting the third multiplexed stream of wireless spectrum on a first digital expansion communication link between the first digital expansion unit and a second digital remote antenna unit;

converting the third multiplexed stream of wireless spectrum between N-bit words of digitized spectrum and a fifth set of bands of analog spectrum at the second digital remote antenna unit; and

communicating at least a portion of one of the first wireless spectrum and the second wireless spectrum across at least a third air interface at the second digital remote antenna unit.

25. The method of claim 24, further comprising:

in the upstream direction,

demultiplexing the third multiplexed stream into at least the first stream of N-bit words of digitized spectrum and the second stream of N-bit words of digitized spectrum at the first master host unit.

26. The method of claim 22, wherein converting the first multiplexed stream of wireless spectrum between N-bit words of digitized spectrum and a third set of bands of analog spectrum at the hybrid expansion unit includes at least one of:

in the downstream,

demultiplexing the first multiplexed stream of wireless spectrum into first component parts;

converting the demultiplexed first component parts from N-bit words of digitized spectrum to analog spectrum; and

multiplexing the first component parts together into the third set of bands of analog spectrum; and in the upstream,

demultiplexing the third set of bands of analog spectrum into second component parts;

converting the demultiplexed second component parts from analog spectrum to N-bit words of digitized spectrum and

multiplexing the second component parts together into the first multiplexed stream of wireless spectrum.

**27**. The method of claim **22**, wherein converting the second multiplexed stream of wireless spectrum between N-bit words of digitized spectrum and fourth set of bands of analog spectrum at the first digital remote antenna unit includes at least one of:

in the downstream,

demultiplexing the second multiplexed stream of wireless spectrum into first component parts;

converting the demultiplexed first component parts from N-bit words of digitized spectrum to analog spectrum and

multiplexing the first component parts together into the fourth set of bands of analog spectrum and

in the upstream,

demultiplexing the fourth set of bands of analog spectrum into second component parts;

converting the demultiplexed second component parts from analog spectrum to N-bit words of digitized spectrum; and

multiplexing the second component parts together into the second multiplexed stream of wireless spectrum.

**28**. The method of claim **22**, wherein transporting the first multiplexed stream of wireless spectrum on a first digital communication link between the first master host unit and a hybrid expansion unit includes:

converting the first multiplexed stream of wireless spectrum between an electrical signal and an optical signal; and

wherein the first digital communication link includes at least one optical communication medium.

**29**. The method of claim **22**, wherein transporting the second multiplexed stream of wireless spectrum on a second digital communication link between the first master host unit and the first digital remote antenna unit includes:

converting the second multiplexed stream of wireless spectrum between an electrical signal and an optical signal; and

wherein the second digital communication link includes at least one optical communication medium.

**30**. A communication system, comprising:

a first master host unit [adapted] *configured* to communicate analog signals with at least a first service provider interface using a first set of bands of analog spectrum[; a plurality of digital communication links coupled to the first master host unit], wherein the first master host unit is further [adapted] *configured* to communicate digitized spectrum in first N-bit words over [the] *a* plurality of digital communication links *coupled to the first master host unit*;

the first master host unit further [adapted] *configured* to convert between the first set of bands of analog spectrum and the first N-bit words of digitized spectrum;

a first hybrid expansion unit communicatively coupled to the first master host unit by a first digital communication link of the plurality of digital communication links and [adapted] *configured* to communicate the first N-bit words of digitized spectrum with the first master host unit across the first digital communication link, the first hybrid expansion unit further [adapted] *configured* to convert between the first N-bit words of digitized spectrum and a second set of bands of analog spectrum[; a first analog communication link coupled to the first hybrid expansion unit], wherein the first hybrid expansion unit is further [adapted] *configured* to communicate the second set of bands of analog spectrum across [the] *a* first analog communication link *coupled to the first hybrid expansion unit*;

a first analog remote antenna unit communicatively coupled to the first hybrid expansion unit by the first analog communication link and [adapted] *configured* to communicate the second set of bands of analog spectrum with the first hybrid expansion unit across the first analog communication link, the first analog remote antenna unit further [adapted] *configured* to transmit and receive first wireless signals over a first plurality of air interfaces;

a first digital expansion unit communicatively coupled to the first master host unit by a second digital communication link of the plurality of digital communication links and [adapted] *configured* to communicate second N-bit words of digitized spectrum with the first master host unit across the second digital communication link;

a first digital expansion communication link coupled to the first digital expansion unit, wherein the first digital expansion unit is further [adapted] *configured* to communicate the second N-bit words of digitized spectrum across the first digital expansion communication link;

a first digital remote antenna unit communicatively coupled to the first digital expansion unit by the first digital expansion communication link and [adapted] *configured* to convert between the second N-bit words of digitized spectrum and a third set of bands of analog spectrum, the first digital remote antenna unit [adapted] *configured* to transmit and receive second wireless signals over a second plurality of air interfaces; and

wherein the first master host unit, the first hybrid expansion unit, the first analog remote antenna unit, the first digital expansion unit, and the first digital remote antenna unit are synchronized in time and frequency.

**31**. The system of claim **30**, wherein the second set of bands of analog spectrum are at the same frequencies as the first set of bands of analog spectrum.

**32**. The system of claim **30**, wherein the first analog remote antenna unit is further [adapted] *configured* to frequency convert the second set of bands of analog spectrum to a fourth set of bands of analog spectrum.

**33**. The system of claim **32**, wherein the fourth set of bands of analog spectrum are at the same frequencies as the first set of bands of analog spectrum, and wherein at least a subset of the fourth set of bands of analog spectrum are transmitted and received by the first analog remote antenna unit over the first plurality of air interfaces.

**34**. The system of claim **30**, wherein the third set of bands of analog spectrum are at the same frequencies as the first set of bands of analog spectrum.

**35**. The system of claim **30**, wherein the first digital remote antenna unit is further [adapted] *configured* to frequency convert the third set of bands of analog spectrum to a fourth set of bands of analog spectrum, wherein the fourth set of bands of analog spectrum are at the same frequencies as the first set of bands of analog spectrum, and wherein at least a subset of the fourth set of bands of analog spectrum are transmitted and received by the first digital remote antenna unit over the second plurality of air interfaces.

36. The system of claim 30, wherein the first analog remote antenna unit is part of a first analog remote antenna cluster that includes:

a master analog remote antenna unit [adapted] *configured* to communicate the second set of bands of analog spectrum with the first hybrid expansion unit across the first analog communication link;

a second analog remote antenna unit [adapted] *configured* to transmit and receive third wireless signals over a third plurality of air interfaces; and

wherein the master analog remote antenna unit distributes a first subset of the second set of bands of analog spectrum to the first analog remote antenna unit and a second subset of the second set of bands of analog spectrum to the second analog remote antenna unit.

37. The system of claim 30, wherein the first digital remote antenna unit further includes:

at least one module [adapted] *configured* to convert between at least a portion of the second N-bit words of digitized spectrum and a third set of bands of analog spectrum.

38. The system of claim 30, further comprising:

a second master host unit [adapted] *configured* to communicate analog signals with at least a second service provider interface using a fourth set of bands of analog spectrum;

a second plurality of digital communication links coupled to the second master host unit, wherein the second master host unit is further [adapted] *configured* to communicate digitized spectrum in third N-bit words of digitized spectrum over the second plurality of digital communication links;

the second master host unit further [adapted] *configured* to convert between the fourth set of bands of analog spectrum and the third N-bit words of digitized spectrum; and

wherein the first digital expansion unit is communicatively coupled to the second master host unit by one of the second plurality of digital communication links and [adapted] *configured* to communicate the third N-bit words of digitized spectrum with the first master host unit across the one of the second plurality of digital communication links; and

wherein the first digital expansion unit multiplexes the second N-bit words of digitized spectrum and the third N-bit words of digitized spectrum into fourth N-bit words of digitized spectrum; and

a first digital expansion communication link coupled to the first digital expansion unit, wherein the first digital expansion unit is further [adapted] *configured* to communicate the fourth N-bit words of digitized spectrum across the first digital expansion communication link.

39. The communication system of claim 30, further comprising:

a second digital expansion communication link coupled to the first digital expansion unit, wherein the first digital expansion unit is further [adapted] *configured* to communicate third N-bit words of digitized spectrum across the second digital expansion communication link;

a second hybrid expansion unit communicatively coupled to the first digital expansion unit by the second digital expansion communication link and [adapted] *configured* to communicate the third N-bit words of digitized spectrum with the first digital expansion unit across the second digital expansion communication link, the second hybrid expansion unit further [adapted] *configured* to convert between the third N-bit words of digitized spectrum and a fourth set of bands of analog spectrum; and

a second analog communication link coupled to the second hybrid expansion unit, wherein the second hybrid expansion unit is further [adapted] *configured* to communicate the fourth set of bands of analog spectrum across the second analog communication link.

40. The communication system of claim 39, further comprising:

a second analog remote antenna unit communicatively coupled to the second hybrid expansion unit by the second analog communication link and [adapted] *configured* to communicate the fourth set of bands of analog spectrum with the second hybrid expansion unit across the second analog communication link, the second analog remote antenna unit further [adapted] *configured* to transmit and receive third wireless signals over a third plurality of air interfaces.

41. A communication system, comprising:

a first master host unit [adapted] *configured* to communicate analog signals with at least a first service provider interface using a first set of bands of analog spectrum[; a first digital communication link coupled to the first master host unit], wherein the first master host unit is further [adapted] *configured* to communicate digitized spectrum in first N-bit words over [the] *a* first digital communication link *coupled to the first master host unit*;

the first master host unit further [adapted] *configured* to convert between the first set of bands of analog spectrum and the first N-bit words of digitized spectrum;

a first digital expansion unit communicatively coupled to the first master host unit by the first digital communication link and [adapted] *configured* to communicate the first N-bit words of digitized spectrum with the first master host unit across the first digital communication link[; a first digital expansion communication link coupled to the first digital expansion unit], wherein the first digital expansion unit is further [adapted] *configured* to communicate digitized spectrum in second N-bit words across [the] *a* first digital expansion communication link *coupled to the first digital expansion unit*;

a first hybrid expansion unit communicatively coupled to the first digital expansion unit by the first digital expansion communication link [of the plurality of digital expansion communication links] and [adapted] *configured* to communicate the second N-bit words of digitized spectrum with the first digital expansion unit across the first digital expansion communication link, the first hybrid expansion unit [adapted] *configured* to convert between the second N-bit words of digitized spectrum and a second set of bands of analog spectrum[;

a first analog communication link coupled to the first hybrid expansion unit], wherein the first hybrid expansion unit is further [adapted] *configured* to communicate the second set of bands of analog spectrum across [the] *a* first analog communication link *coupled to the first hybrid expansion unit*;

a first analog remote antenna unit communicatively coupled to the first hybrid expansion unit by the first analog communication link and [adapted] *configured* to communicate the second set of bands of analog spectrum with the first hybrid expansion unit across the first analog communication link, the first analog remote antenna unit further [adapted] *configured* to transmit and receive first wireless signals over a first plurality of air interfaces; and

wherein the first master host unit, the first digital expansion unit, the first hybrid expansion unit, *and* the first analog remote antenna unit[, and the first digital remote antenna unit] are synchronized in time and frequency.

**42**. The system of claim **41**, wherein at least a portion of the first N-bit words is the same as at least a portion of the second N-bit words.

**43**. The system of claim **41**, further comprising:

a second digital expansion communication link coupled to the first digital expansion unit, wherein the first digital expansion unit is further [adapted] *configured* to communicate digitized spectrum in third N-bit words across the second digital expansion communication link; [and]

a first digital remote antenna unit communicatively coupled to the first digital expansion unit by the second digital expansion communication link [of the plurality of digital expansion communication links] and [adapted] *configured* to convert between the third N-bit words of digitized spectrum and a third set of bands of analog spectrum, the first digital remote antenna unit [adapted] *configured* to transmit and receive second wireless signals over a second plurality of air interfaces*; and*

*wherein the first master host unit, the first digital expansion unit, the first hybrid expansion unit, the first analog remote antenna unit, and the first digital remote antenna unit are synchronized in time and frequency.*

**44**. The system of claim **43**, wherein at least a portion of the first N-bit words is the same as at least a portion of the third N-bit words.

**45**. The system of claim **1**, wherein at least a portion of the second N-bit words is the same as at least a portion of the first N-bit words.

**46**. The system of claim **1**, wherein the first analog communication link includes a wired analog communication medium.

**47**. The system of claim **1**, wherein the first digital communication link includes a wired digital communication medium.

**48**. The system of claim **1**, wherein the second digital communication link includes a wired digital communication medium.

**49**. The system of claim **1**, further comprising:

a second master host unit [adapted] *configured* to communicate analog signals with at least a second service provider interface using a fourth set of bands of analog spectrum;

a second plurality of digital communication links coupled to the second master host unit, wherein the second master host unit is further [adapted] *configured* to communicate digitized spectrum in third N-bit words of digitized spectrum over the second plurality of digital communication links;

the second master host unit further [adapted] *configured* to convert between the fourth set of bands of analog spectrum and the third N-bit words of digitized spectrum;

wherein the first hybrid expansion unit is communicatively coupled to the second master host unit by one of the second plurality of digital communication links and [adapted] *configured* to communicate the third N-bit words of digitized spectrum with the second master host unit across the one of the second plurality of digital communication links; and

wherein the first hybrid expansion unit multiplexes the third N-bit words of digitized spectrum into the first N-bit words of digitized spectrum before converting between the first N-bit words of digitized spectrum and the second set of bands of analog spectrum.

**50**. The system of claim **1**, further comprising:

a second master host unit [adapted] *configured* to communicate analog signals with at least a second service provider interface using a fourth set of bands of analog spectrum;

a second plurality of digital communication links coupled to the second master host unit, wherein the second master host unit is further [adapted] *configured* to communicate digitized spectrum in third N-bit words of digitized spectrum over the second plurality of digital communication links;

the second master host unit further [adapted] *configured* to convert between the fourth set of bands of analog spectrum and the third N-bit words of digitized spectrum; and

wherein the first digital remote antenna unit is communicatively coupled to the second master host unit by one of the second plurality of digital communication links and [adapted] *configured* to communicate the third N-bit words of digitized spectrum with the second master host unit across the one of the second plurality of digital communication links.

**51**. The method of claim **22**, wherein at least a portion of the second stream of N-bit words is the same as at least a portion of the first stream of N-bit words.

**52**. The method of claim **22**, wherein the first analog communication link includes a wired analog communication medium.

**53**. The system of claim **30**, wherein at least a portion of the second N-bit words is the same as at least a portion of the first N-bit words.

**54**. The system of claim **30**, wherein the first analog communication link includes a wired analog communication medium.

**55**. The system of claim **30**, wherein the first digital communication link includes a first wired digital communication medium;

wherein the second digital communication link includes a second wired digital communication medium; and

wherein the first digital expansion communication link includes a wired digital communication medium.

**56**. The system of claim **41**, wherein at least a portion of the second N-bit words is the same as at least a portion of the first N-bit words.

**57**. The system of claim **41**, wherein the first analog communication link includes a wired analog communication medium.

**58**. The system of claim **41**, wherein the first digital communication link includes a first wired digital communication medium;

wherein the second digital communication link includes a second wired digital communication medium; and

wherein the first digital expansion communication link includes a wired digital communication medium.

**59**. A communication system, comprising:

a first master host unit [adapted] *configured* to communicate analog signals with at least a first service provider interface using a first set of bands of analog spectrum[; a plurality of digital communication links coupled to the first master host unit], wherein the first master host unit is further [adapted] *configured* to communicate digitized spectrum in first N-bit words over at least a first digital communication link of [the] *a* plurality of digital communication links *coupled to the first master host unit* and second N-bit words over at least a second digital communication link of the plurality of digital communication links *coupled to the first master host unit*;

the first master host unit further [adapted] *configured* to convert between the first set of bands of analog spectrum and the first N-bit words of digitized spectrum, the first master host unit further [adapted] *configured* to convert between the first set of bands of analog spectrum and the second N-bit words of digitized spectrum;

a first hybrid expansion unit communicatively coupled to the first master host unit by the first digital communication link of the plurality of digital communication links and [adapted] *configured* to communicate the first N-bit words of digitized spectrum with the first master host unit across the first digital communication link, the first hybrid expansion unit further [adapted] *configured* to convert between the first N-bit words of digitized spectrum and a second set of bands of analog spectrum[; a first analog communication link coupled to the first hybrid expansion unit], wherein the first hybrid expansion unit is further [adapted] *configured* to communicate the second set of bands of analog spectrum across [the] *a* first analog communication link *coupled to the first hybrid expansion unit*;

a first analog remote antenna unit communicatively coupled to the first hybrid expansion unit by the first analog communication link and [adapted] *configured* to communicate the second set of bands of analog spectrum with the first hybrid expansion unit across the first analog communication link, the first analog remote antenna unit further [adapted] *configured* to transmit and receive first wireless signals over a first plurality of air interfaces;

a first digital remote antenna unit communicatively coupled to the first master host unit by the second digital communication link of the plurality of digital communication links and [adapted] *configured* to communicate the second N-bit words of digitized spectrum with the first master host unit across the second digital communication link, the first digital remote antenna unit further [adapted] *configured* to convert between the second N-bit words of digitized spectrum and a third set of bands of analog spectrum, the first digital remote antenna unit further [adapted] *configured* to transmit and receive second wireless signals over a second plurality of air interfaces; and

wherein a common reference clock is distributed to [wherein] the first master host unit, the first hybrid expansion unit, the first analog remote antenna unit, and the first digital remote antenna unit.

**60**. The system of claim **59**, wherein at least a portion of the second N-bit words is the same as at least a portion of the first N-bit words.

**61**. A method comprising:

converting first wireless spectrum for a first wireless service between a first band of analog spectrum and a first stream of N-bit words of digitized spectrum at a first master host unit;

converting second wireless spectrum for a second wireless service between a second band of analog spectrum and a second stream of N-bit words of digitized spectrum at the first master host unit;

in the downstream direction,

multiplexing at least the first stream of N-bit words of digitized spectrum with the second stream of N-bit words of digitized spectrum into a first multiplexed stream at the first master host unit; and

multiplexing at least the first stream of N-bit words of digitized spectrum with the second stream of N-bit words of digitized spectrum into a second multiplexed stream at the first master host unit;

transporting the first multiplexed stream of wireless spectrum on a first digital communication link between the first master host unit and a hybrid expansion unit;

converting the first multiplexed stream of wireless spectrum between N-bit words of digitized spectrum and a third set of bands of analog spectrum at the hybrid expansion unit;

transporting the third set of bands of analog spectrum on a first analog communication link between the hybrid expansion unit and a first analog remote antenna unit;

communicating at least a portion of one of the first wireless spectrum and the second wireless spectrum across at least a first air interface at the first analog remote antenna unit;

transporting the second multiplexed stream of wireless spectrum on a second digital communication link between the first master host unit and a first digital remote antenna unit;

converting the second multiplexed stream of wireless spectrum between N-bit words of digitized spectrum and a fourth set of bands of analog spectrum at the first digital remote antenna unit;

communicating at least a portion of one of the first wireless spectrum and the second wireless spectrum across at least a second air interface at the first digital remote antenna unit; and

distributing a common reference clock to the first master host unit, the [first] hybrid expansion unit, the first analog remote antenna unit, and the first digital remote antenna unit.

**62**. The method of claim **61**, wherein at least a portion of the second N-bit words is the same as at least a portion of the first N-bit words.

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