PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04B 7/00

A2

(11) International Publication Number: WO 00/03494

(43) International Publication Date: 20 January 2000 (20.01.00)

(21) International Application Number: PCT/US99/15579

(22) International Filing Date: 9 July 1999 (09.07.99)

(30) Priority Data:
09/112,610 9 July 1998 (09.07.98) US

(71) Applicant: ACT WIRELESS [US/US]; Suite 14, 4710 East Elwood Street, Phoenix, AZ 85040 (US).

(72) Inventors: SCHUERMAN, Ken; Chandler, AZ (US). MEISS, James; Scottsdale, AZ (US). WEBBER, Mark; Chandler, AZ (US).

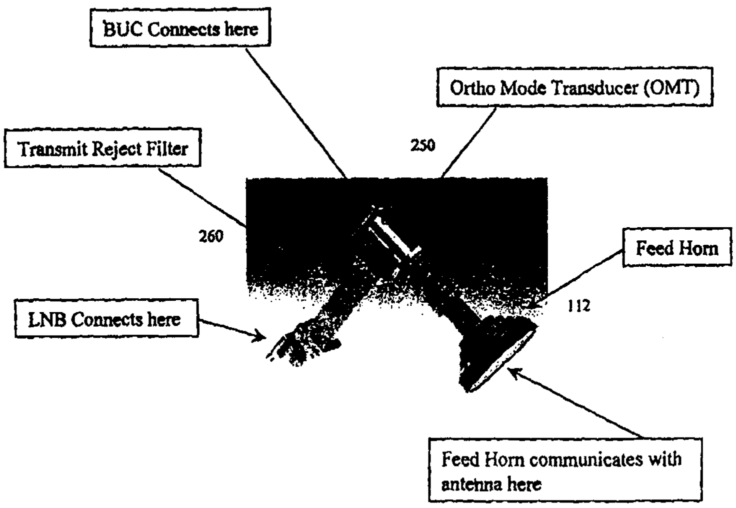
(74) Agent: SWERNOFSKY LAW GROUP; P.O. Box 390013, Mountain View, CA 94039-0013 (US).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: SATELLITE NETWORK TERMINAL

OMT / Tx Reject Filter / Feed Horn



(57) Abstract

The invention provides a method and system for simplified signal processing between the feed horn assembly and the frame relay equipment. Data is directly modulated from the frame relay equipment onto an L-band carrier and block up-converted for output at the feed horn. Block up-conversion is aided by adding a DC power signal and a 10.0 megahertz frequency reference signal to the L-band modulated signal (so as to protect the frequency reference against variations due to external elements), while maintaining spectral purity of the L-band modulated signal.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

Title of the Invention

Satellite Network Terminal

Background of the Invention

1. Field of the Invention

This invention relates to satellite network terminals.

2. Related Art

Signals received at a satellite network terminal are conventionally coupled from a feed horn at a satellite dish antenna, to an antenna transceiver (i.e. outdoor unit), to a signal up/down converter, to a modulator/demodulator for interpretation and routing. For example, when the satellite network terminal is used in a frame relay network, the modulator/demodulator is coupled to frame relay network equipment such as a frame relay receiver-filter and a frame relay switch. The feed horn is located at or near the focus of a dish antenna for the satellite network terminal, and is coupled to the antenna transceiver using a cable.

In known systems, the feed horn at the satellite dish antenna is disposed to receive and output signals modulated on a carrier in a first known frequency range such as C-band (about 11.7 to about 12.2 gigahertz) or Ku-band (about 14 to about 14.5 gigahertz). The antenna transceiver is disposed to receive those signals and output signals modulated on a carrier in a second frequency range such as L-band (about 950 to about 1450 megahertz). The signal up/down converter is disposed to receive those signals and output signals modulated on a carrier in a third known frequency range (about 70 megahertz ± 18 megahertz, or alternatively about 140 megahertz ± 36 megahertz).

A first problem known in the art is that the antenna transceiver and up/down converter are complex and expensive; it would be desirable to be able to modulate and demodulate the satellite signal directly between the feed horn at the satellite dish antenna and the modulator/demodulator. This would reduce required signal filtering. It would also greatly simplify, and reduce the expense of, producing the transmitted satellite signal.

A second problem known in the art is that the feed horn at the satellite dish antenna is exposed to external elements, such as weather, heat and cold. The cable coupling the feed horn to the antenna transceiver must be relatively short, because there is a substantial amount of power loss for signals transmitted through that cable with a carrier frequency at or above about the 1 gigahertz frequency range. The relatively short cable limits design options for placement of the modulator/demodulator, particularly if the antenna transceiver and up/down converter have been eliminated in response to the first problem noted above.

Accordingly, it would be advantageous to provide for greatly simplified signal processing between the feed horn and the frame relay equipment. This advantage is achieved in an embodiment of the invention in which data is directly modulated from the frame relay equipment onto an L-band carrier and block up-converted for output at the feed horn.

Summary of the Invention

The invention provides a method and system for simplified signal processing between the feed horn and the frame relay equipment. Data is directly modulated from the frame relay equipment onto an L-band carrier and block up-converted for output at the feed horn. Block up-conversion is aided by adding a DC power signal and a 10 megahertz frequency reference signal to the L-band modulated signal (so as to protect the frequency reference against variations due to external elements), while maintaining spectral purity of the 10 megahertz frequency and the L-band modulated signal. Additionally, a frequency reference is generated in the modulator synthesizer circuit by a phase locked loop (PLL) circuit using a numerically controlled oscillator (NCO) as a reference signal and a crystal filter to band-pass filter the output at 10.7-

megahertz. A noise floor for the NCO is set so that the output signal is clipped at the desired output frequency; this increases the signal/noise ratio at that desired output frequency.

Brief Description of the Drawings

Figure 1A shows a block diagram of a system for simplified signal processing between a satellite antenna and a set of frame relay equipment.

Figure 1B shows a diagram of a transmit reject filter, ortho mode transducer, and feed horn assembly.

Figure 2A shows a block diagram of a modulator and down converter coupled to a block up-converter.

Figure 2B shows a block diagram of a down converter including a commercial tuner module, a triplexer, a frequency reference, and a DC power supply.

Figure 2C shows a block diagram of a block up converter (BUC).

Figure 2D shows a block diagram of a low noise block down converter (LNB).

Figure 2E shows a block diagram of a modulator including a modulator element, a DC power supply, a frequency reference, and a triplexer.

Figure 3 shows a block diagram of the modulator synthesizer including the generation of an approximately 10.7 megahertz synthesizer frequency reference. This synthesizer generates the modulator L-Band carrier signal.

Figure 4 shows a triplex function element for combining an L-band modulated signal, a DC power signal, and a frequency reference signal.

Detailed Description of the Preferred Embodiment

In the following description, a preferred embodiment of the invention is described with regard to preferred process steps and data structures. Those skilled in the art would recognize after perusal of this application that embodiments of the invention can be implemented using circuits adapted to particular process steps and data structures described herein, and that implementation of the process steps and data structures described herein would not require undue experimentation or further invention.

Inventions described in this application can be used in conjunction with inventions described in the following patent documents:

- U.S. Application Serial No. 08/806,288, titled "Transmitting Multiplexed Frames on Communication Links", filed February 26, 1997, in the name of inventor Alain Gravel, assigned to ACT Networks, Inc., attorney docket number ANET-002; and o U.S. Application Serial No. 08/911,473, titled "Flexible Voice Shelf", filed August 14, 1997, in the name of inventors Kannan Rangarajan, David G. Stanfield, and Dan G. Wilson, and assigned to ACT Networks, Inc., attorney docket number ANET-004.

Each of these documents is hereby incorporated by reference as if fully set forth herein.

System Elements

Figure 1A shows a block diagram of a system for simplified signal processing between a satellite antenna and a set of frame relay equipment.

A system 100 includes a satellite dish antenna 110, including a parabolic dish reflector 111 and a feed horn 112. The feed horn 112 is disposed to receive and to transmit signals at a first set of known satellite transmission frequencies, such as those in C-band or Ku-band. Feed horns 112 for use with satellite dish antennas 110 are known in the art of satellite communication. An exemplar of a feed horn assembly including the feed horn, the mounts for the BUC (block up converter), LNB (low-noise block converter) and the transmit reject filter and the OMT (ortho mode transducer) is shown in Figure 1B.

In a preferred embodiment the feed horn 112 is coupled to an antenna transceiver 113, which is disposed to couple signals to and from the feed horn 112 at a second set of known frequencies, such as those in L-band. Note that in a conventional assembly the outdoor unit or antenna transceiver includes everything except the feed horn (i.e. the BUC, LNB, OMT and the transmit or Tx reject filter).

The antenna transceiver 113 is coupled to a hybrid modem including a modulator and down converter 120, which is disposed to couple signals to and from the antenna transceiver 113 at L-band frequencies.

The modulator and down converter 120 is coupled to a set of frame relay network equipment 130, which is disposed to transmit, receive and filter, and switch frames in a frame relay system.

In a preferred embodiment, the frame relay network equipment 130 includes the Skyframe™ 800-EM product, available from ACT Networks, Inc., of Camarillo, California. The Skyframe™ 800-EM product preferably includes a plurality of digital frame receiver/filters, such as the Skyframe™ DEF-01 product, also available from ACT Networks, Inc., of Camarillo, California, and at least one modulator/demodulator card, such as the Skyframe™ MOS-01-EM product, also available from ACT Networks, Inc., of Camarillo, California.

The modulator and down converter 120 is disposed to receive signals modulated on L-band frequencies, and to down convert those signals to a 70-megahertz carrier, to provide signals in the 70 megahertz ± 18 megahertz frequency range. Operation of the modulator and down converter 120 in this regard is further described with reference to figures 2A and 2B.

The modulator and down converter 120 is also disposed to receive digital data from the frame relay network equipment 130, and to directly modulate that data onto L-band frequencies. Optionally, a 70 megahertz demodulator is included in the modulator and down converter unit. This minimizes cost and is ideal for remotely located sites. Additionally including the 70 megahertz demodulator with the modulator down converter unit frees a slot in the frame relay equipment for other hardware. Operation of the modulator and down converter 120 in this regard is further described with reference to figure 2A and figure 2B.

Modulator and Down Converter

Figure 2A shows a block diagram of a modulator and down converter coupled to a block up-converter.

The modulator and down converter 120 includes a modulator 210 and a down converter 220.

Referring to figures 1A and 2A, the modulator 210(L-band modulator) is coupled to the frame relay network equipment 130 so as to receive digital data therefrom. The modulator 210 is also coupled to a BUC (block up converter) 230, so as to transmit signals on L-band frequencies for transmission by the satellite dish antenna 110.

The down converter 220 is coupled to the frame relay network equipment 130 so as to transmit signals thereto using a 70-megahertz carrier. The down converter 220 is also coupled to an LNB (low-noise block converter) 240, so as to receive signals on L-band frequencies for down conversion. Optionally, the demodulator 200 is coupled to the frame relay equipment

130 to transmit digital data thereto. Additionally, the demodulator 200 is coupled to the down converter 220 to receive signals using a 70 megahertz carrier as shown in Figure 2A. Figure 2B shows a block diagram of the elements of the down converter 220.

As shown in Figure 2A the BUC 230 is coupled to an OMT (ortho mode transducer) 250, so as to transmit signals to the feed horn 112. Figure 2C shows a block diagram of the elements of the block up converter (BUC).

As shown in Figure 2A the LNB 240 is coupled to a transmit-reject element 260, which is coupled to the OMT 250, so as to receive signals from the feed horn 112. Figure 2D shows a block diagram of the elements of the low noise block down converter (LNB). The transmit-reject element 260 is disposed to filter out frequency components of signals transmitted by the BUC 230 to the OMT 250, and to transmit signals received by the feed horn 112 to the LNB 240 for processing. Operation of transmit-reject elements 260 is known in the art of satellite communication.

The OMT 250 is coupled to the feed horn 112, so as to transmit and receive signals to and from the feed horn 112. Coupling between the OMT 250 and the feed horn 112 is known in the art of satellite communication.

As shown in Figure 2E the modulator 210 includes an input port 211, a modulator element 212 coupled to the input port 211, a DC power supply 223, a frequency reference 224, a triplex function element 225, and an output port 226.

The input port 211 is coupled to the frame relay network equipment 130, and is coupled to the modulator element 212. The modulator element 212 modulates incoming digital data from the frame relay network equipment 130 onto an L-band carrier frequency, to provide a modulated signal in the L-band frequency range. The modulator element 212 is coupled to the triplex function element 225.

The modulator element 212 includes an L-band reference frequency synthesizer element 213 and a quadrature modulator element 214. The modulator element 212 processes the incoming digital data from the frame relay network equipment 130, generates two quadrature signals (that is, I and Q data streams) and modulates those I and Q data streams onto the L-band reference frequency carrier in quadrature. In a preferred embodiment, the quadrature modulator element 214 includes an RF2422 circuit, available from R.F. Microdevices, of Greensboro, NC. Quadrature modulation is known in the art of signal processing.

The DC power supply 223 provides a constant DC power signal, and is coupled to the triplex function element 225.

The frequency reference 224 provides a constant 10.0 megahertz reference sine wave, and is coupled to the triplex function element 225.

The triplex function element 225 combines the output of the modulator element 212, the DC power supply 223, and the frequency reference 224, and provides a combined signal output at the output port 226. Operation of the triplex function element 225 is further described with reference to figure 4.

The BUC 230 includes a signal separator element 231, a phase-locked multiplier element 232, a mixer 233, and an amplifier 234. The signal separator element 231 is disposed for coupling to the modulator element 212, using a high-quality signal transmission cable to prevent signal degradation. The signal separator element 231 isolates the 10.0 megahertz reference sine wave and provides that reference frequency to the carrier synthesizer element 232. The signal separator element 231 isolates the DC power and provides that power as required throughout the BUC 230.

The carrier synthesizer element 232 is coupled to the 10.0-megahertz reference sine wave and provides an output carrier signal to mixer 233. In a preferred embodiment, the output carrier signal is about 14.0 to 14.5 gigahertz (for Ku-band). Carrier synthesizers are known in the art of signal processing.

The signal separator element 231 also isolates the L-band modulated digital data and provides that signal to the mixer 233. The mixer 233 translates the L-Band modulated carrier to a Ku-band carrier frequency for transmission. Mixers are known in the art of signal processing.

The amplifier 234 is coupled to the mixer 233, to receive the modulated Ku-band signal and to amplify it by about 50 decibels, for coupling to the feed horn 112 and transmission by the satellite dish antenna 110. Amplifiers are known in the art of signal processing.

Modulating Digital Data onto an L-Band Carrier

Figure 3 shows a means for providing a numerically controlled 10.7-megahertz ± 7.5 kilohertz reference sine wave. This sine wave is used as the reference input to a single loop synthesizer 360.

The frequency reference 224 includes a first frequency reference 310(part of 224), an NCO (numerically controlled oscillator) 320 and a DAC (digital to analog converter) 330, a band-pass filter 340, a frequency divider 350, a PLL (phase locked loop) 360, and a low-pass filter 370, coupled as shown in the figure. The PLL 360 includes a phase detector 361, a loop filter 362, a VCO (voltage controlled oscillator) 363, and a programmable frequency divider 364, coupled in a feedback configuration as shown in the figure.

The first frequency reference 310 includes a 40-megahertz sine wave signal. In a preferred embodiment, a temperature controlled quartz crystal oscillator generates this signal. Crystal oscillators are known in the art of signal processing.

The NCO 320 is coupled to an output of the first frequency reference 310, and includes a digital input port 321, so as to receive a 32-bit digital value specifying the frequency multiplier the NCO 320 applies to its input. The frequency multiplier is less than one, so that the output signal from the NCO 320 and the DAC 330 comprises a 10.7-megahertz ± 7.5 kHz sine wave.

In a preferred embodiment, the NCO 320 and the DAC 330 are embodied in a single circuit, such as the AD9830 product, available from Analog Devices Corporation of Norwood MA. Numerically controlled oscillators and digital to analog converters are known in the art of signal processing.

The DAC 330 is coupled to an output of the NCO 320, and is disposed to convert a digital signal output from the NCO 320 to an analog signal. The DAC 330 includes a resistor 331 coupled to adjust the output level of the DAC 330. In a preferred embodiment, the resistor 331 is set so as to cause the 10.7-megahertz component of the output signal to clip at the maximum amplitude reachable by the DAC 330. This causes the signal-to-noise ratio of the DAC 330 to be maximized for the 10.7-megahertz component of the output signal.

The band-pass filter 340 is coupled to an output of the DAC 330. The band-pass filter 340 has a center frequency of 10.7-megahertz and a 3-decibel roll-off loss for a ± 7.5 kilohertz of difference from that center frequency. The design of band-pass filters is known in the art of signal processing, as is the design of band-pass filters with selected roll-off loss. The band-pass filter 340 imposes about an 80-decibel loss for frequencies greater than ± 40 kilohertz deviation from the nominal 10.7 megahertz NCO output frequency.

The frequency divider 350 is coupled to an output of the band-pass filter 340. The frequency divider 350 divides the signal output by the band-pass filter 340 (intended to be a substantially pure sine wave at about 10.7 megahertz) by 12, to generate a square wave 890 kilohertz signal.

The PLL 360 includes a digital input port 365 and an output port 366. The PLL 360 includes the phase detector 361, the loop filter 362, the VCO 363, and the programmable frequency divider 364, coupled in a feedback configuration. The digital input port 365 receives a digital value specifying the frequency divider the PLL 360 applies to its input signal. The programmable frequency divider 364 is responsive to the input signal so as to divide a signal appearing at the output port 366 and couple a resultant to the phase detector 361. The output port 366 provides the output of the PLL 360. Phase-locked loops are known in the art of signal processing.

The attenuator / amplifier 367 is coupled to the output port 366 of the PLL. The attenuator / amplifier combination is coupled to the low pass filter 370. The attenuator / amplifier 367 provides greater than 55 decibels of isolation between the modulator 214 and the synthesizer VCO 363. Without this isolation, digital data signals present in the modulator 214 would feed backwards into the VCO 363 corrupting its spectral purity and seriously degrading the integrity of the modulator output signal. When an input digital data signal is modulated onto the carrier in quadrature (that is, having I and Q components), the signal output from the PLL 360 includes extraneous components at two times the desired output frequency. The low-pass filter 370 removes these extraneous components.

Triplex Function Element

Figure 4 shows a triplex function element for combining an L-band modulated signal, a DC power signal, and a frequency reference signal.

The triplex function element 225 includes a signal input port 410, a high-pass filter 420, a reference input port 430, a band-pass filter 440, a power input port 450, a low pass filter, a first summing element 460, a second summing element 470, and an output port 480.

The signal input port 410 is disposed for coupling to an incoming L-band signal, which includes digital data that has been modulated onto a carrier in the L-band frequency range of about 950 megahertz to about 1450 megahertz. The signal input port 410 is coupled to the high-pass filter 420, which prevents frequency components of the other two inputs 430 and 450 from feeding back into the L-Band signal path.

The reference input port 430 is disposed for coupling to an incoming reference signal at 10.0 megahertz. The reference input port 430 is coupled to the band-pass filter 440, which removes frequency components other than the desired reference frequency component at 10.0 megahertz, and prevents frequency components from the other two inputs 410 and 450 from feeding back into the 10.0 megahertz signal path.

The power input port 450 is disposed for coupling to DC power signal, for example +24 V. The power input port is coupled to the low pass filter which remove unwanted frequency components from the power input signal. The band-pass filter 440 and the low pass filter are coupled to the first summing element 460, which includes a set of first filter elements 461 and a first summing node 462, to sum the reference frequency component at 10.0 megahertz with the DC power signal. The high-pass filter 420 and the first summing element 460 are coupled to the second summing element 470, which includes a set of second filter elements 471 and a second summing node 472, to sum the L-band modulated digital data with the signal provided by the first summing element 460.

The second summing element 470 is coupled to the output port 480, to provide an output which is the sum of the three inputs: (1) the L-band modulated digital data, (2) the 10.0 megahertz reference frequency component, and (3) the DC power signal.

Alternative Embodiments

Although preferred embodiments are disclosed herein, many variations are possible which remain within the concept, scope, and spirit of the invention, and these variations would become clear to those skilled in the art after perusal of this application.

Claims

1. A method for satellite communication, including steps for

receiving digital data from digital communications equipment and directly modulating said digital data onto a first carrier signal to provide a first modulated signal, and up-converting said first modulated signal for output at a satellite terminal;

receiving modulated satellite signals at said satellite terminal, down-converting said modulated satellite signals, providing said down converted modulated satellite signals to said digital communications equipment for demodulation, and demodulating down-converted satellite signals for output to said digital communications equipment.

2. A method as in claim 1, wherein said digital communications equipment includes a frame relay.

3. A method as in claim 1, wherein said first carrier signal includes an L-band carrier frequency.

4. A method as in claim 1, wherein said down-converted satellite signals are demodulated by a 70 MHz demodulator before said step of providing said down-converted satellite signals to said digital communications equipment.

5. A method as in claim 1, wherein said steps for up-converting include steps for combining said first modulated signal with a power signal prior to up-converting, while maintaining spectral purity of said first modulated signal.

6. A method as in claim 1, wherein said steps for up-converting include steps for combining said first modulated signal with a frequency reference signal prior to up-converting, while maintaining spectral purity of the reference signal and said first modulated signal.

7. A method for generating a frequency reference signal to a PLL for synthesizing an L-Band carrier signal that includes steps for

providing a first reference signal to a numerically controlled oscillator;

providing an output of said numerically controlled oscillator to a digital to analog converter; providing an output of said digital to analog converter to a crystal band-pass filter; and

providing an output of said band-pass filter to a phase-locked loop.

8. A method as in claim 5, including steps for setting a noise floor for said digital to analog converter so said output of said digital to analog converter clips at a selected output level for said frequency reference signal.

9. A method as in claim 5, including steps for setting a noise floor for said digital to analog converter so said output of said digital to analog converter has a maximum signal to noise ratio at a selected output frequency for said frequency reference signal.

OMT / Tx Reject Filter / Feed Horn

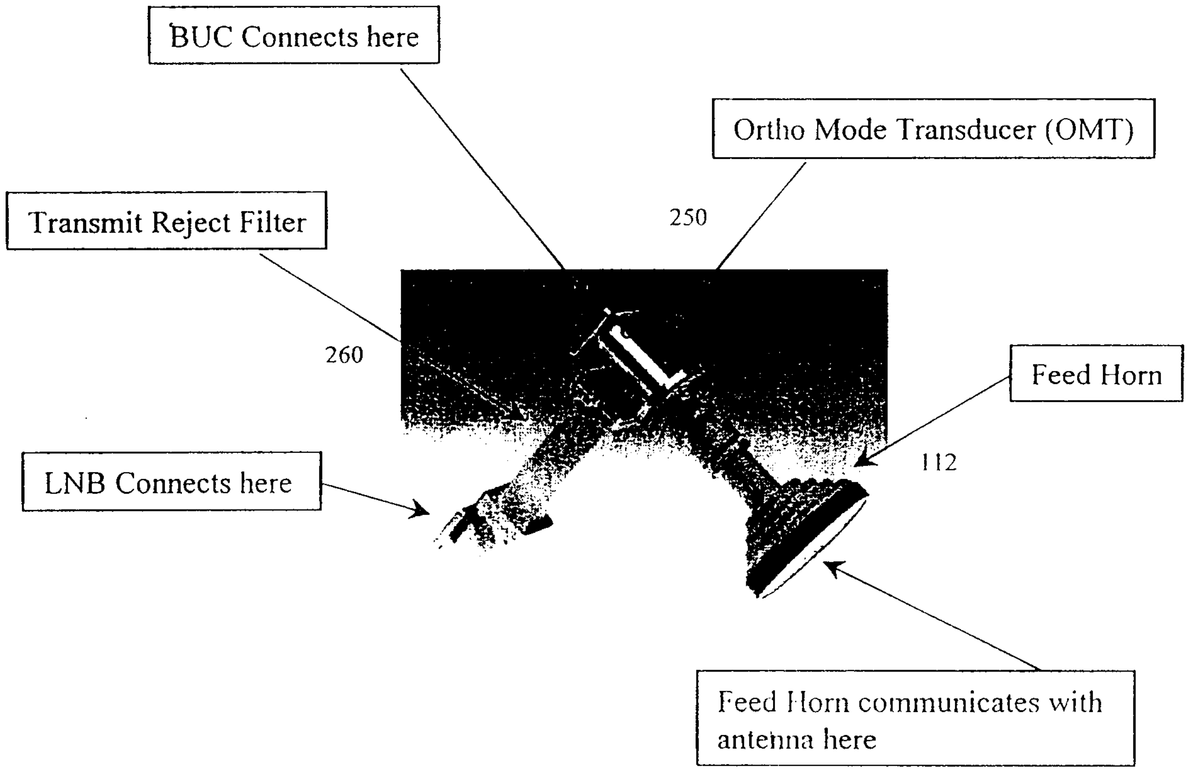


Figure 1B

SL-512V, Hybrid Modem coupled to a BUC and LNB

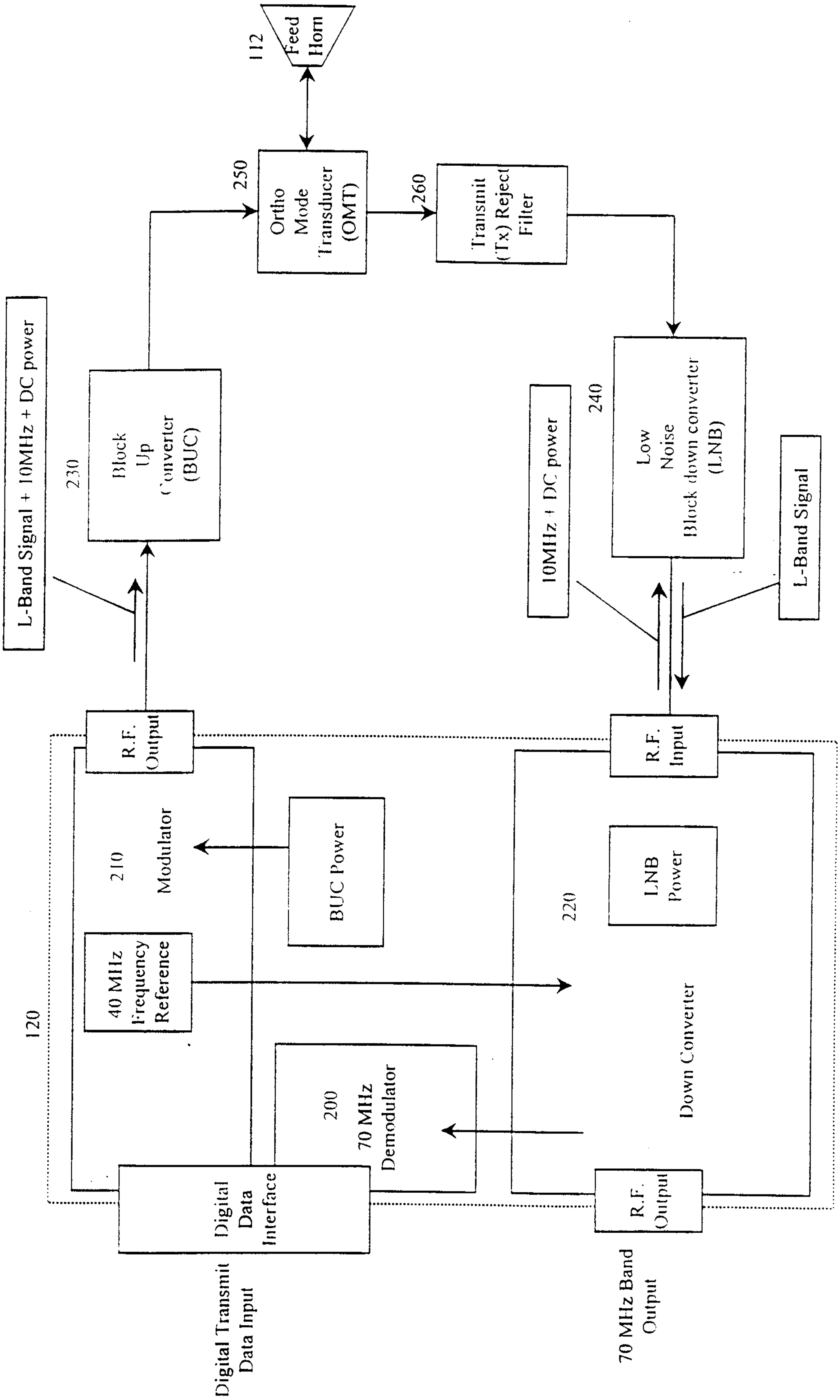


Figure 2A

SL-512V Down Converter

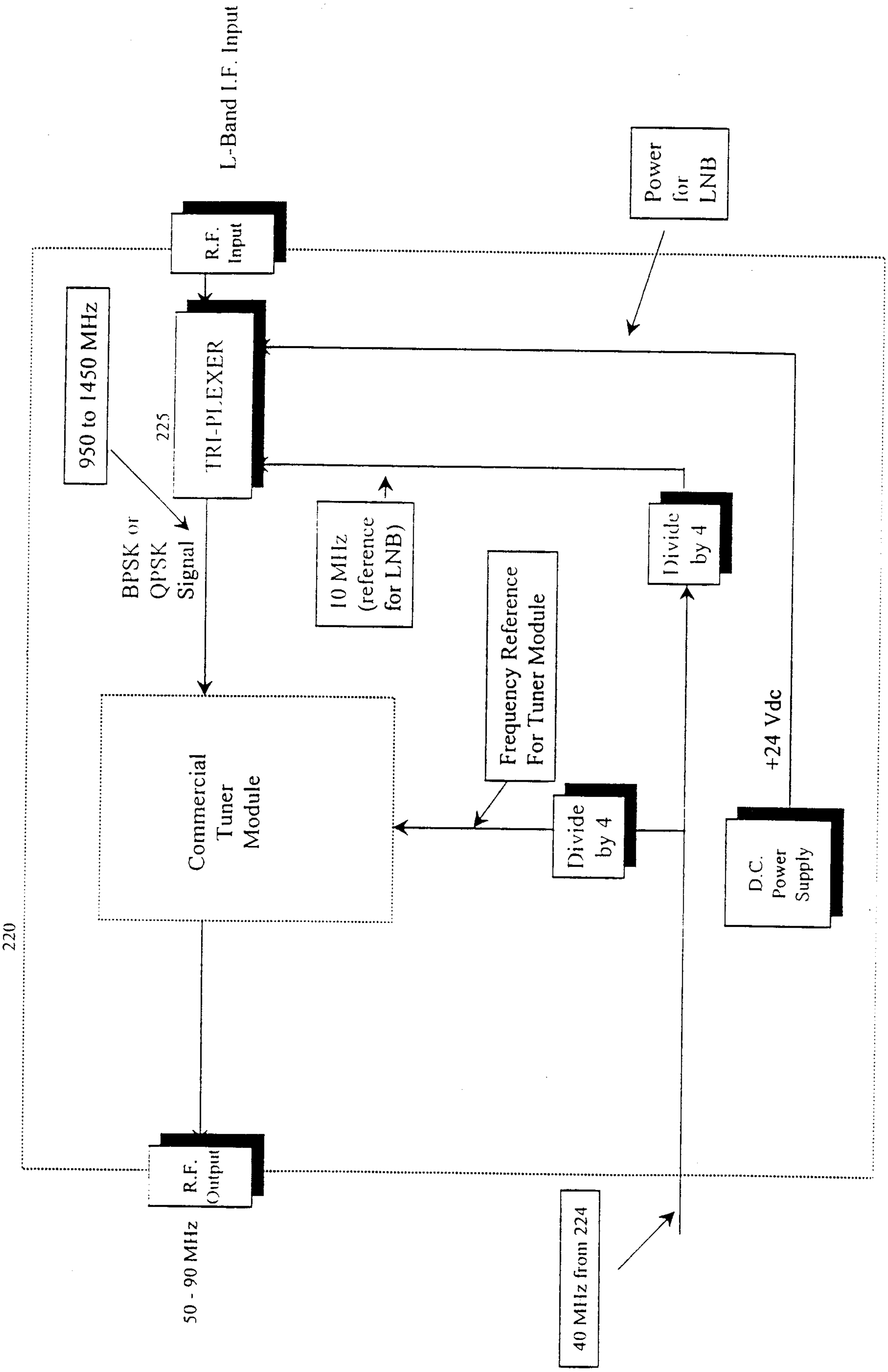


Figure 2B

Block Up Converter (BUC)

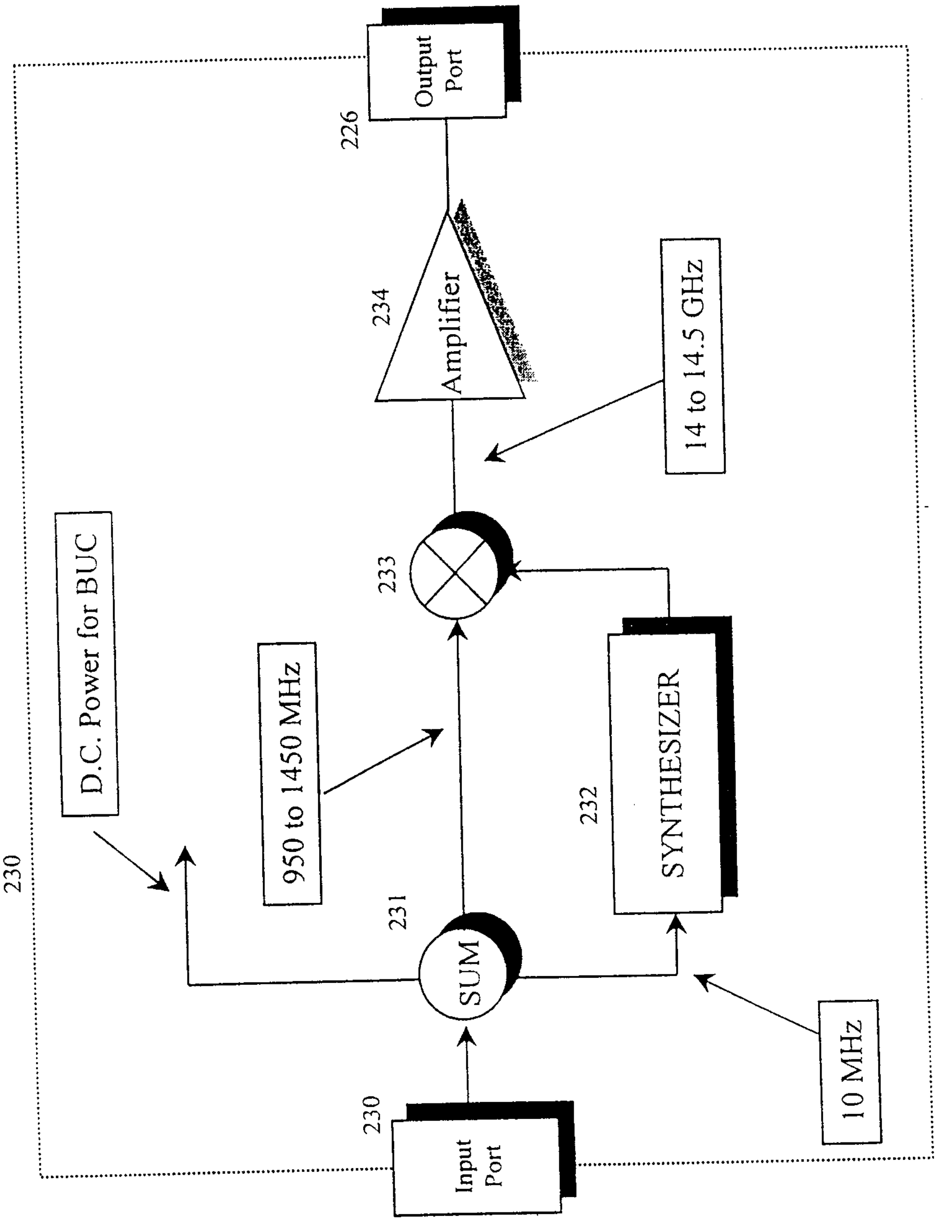


Figure 2C

Low Noise Block down converter (LNB)

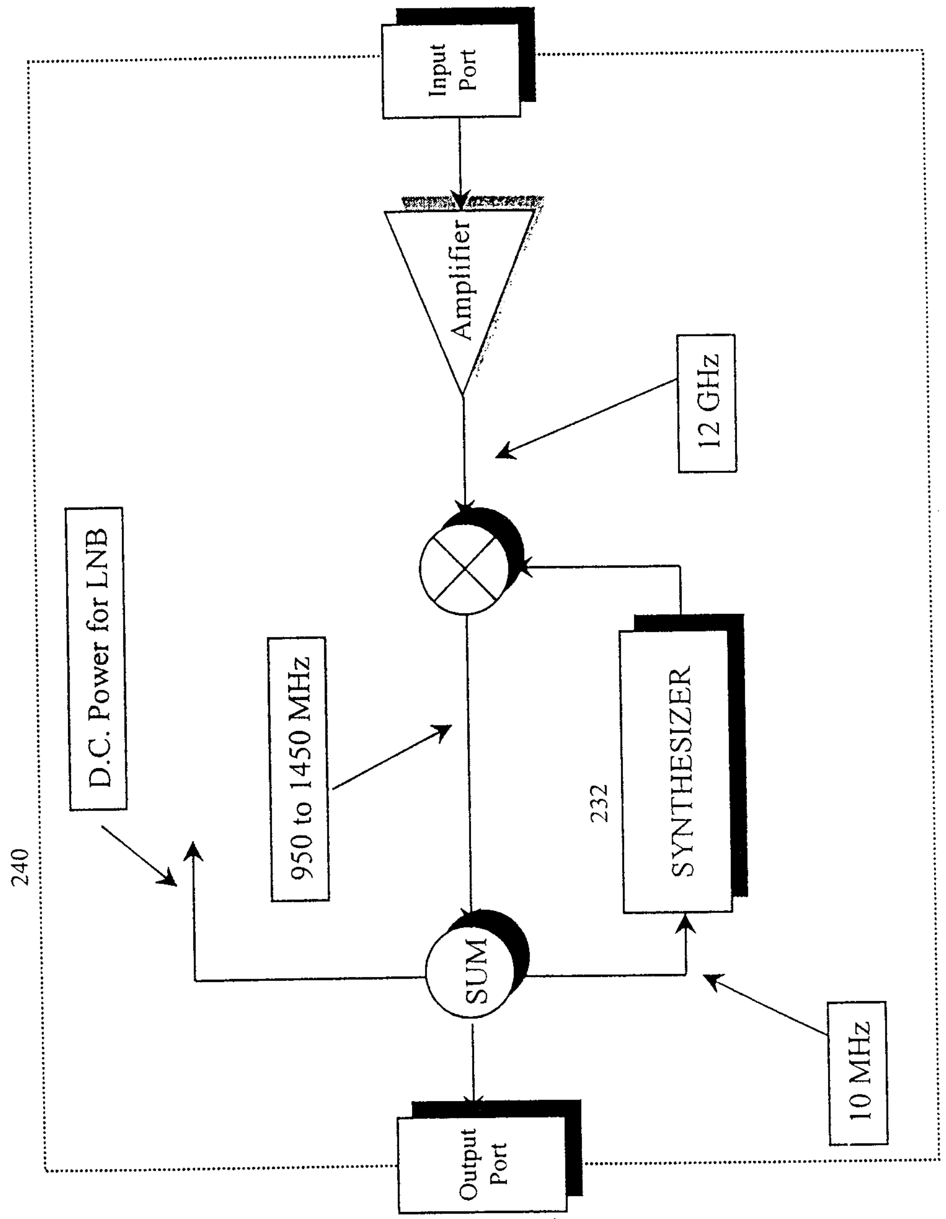


Figure 2D

SL-512V Modulator

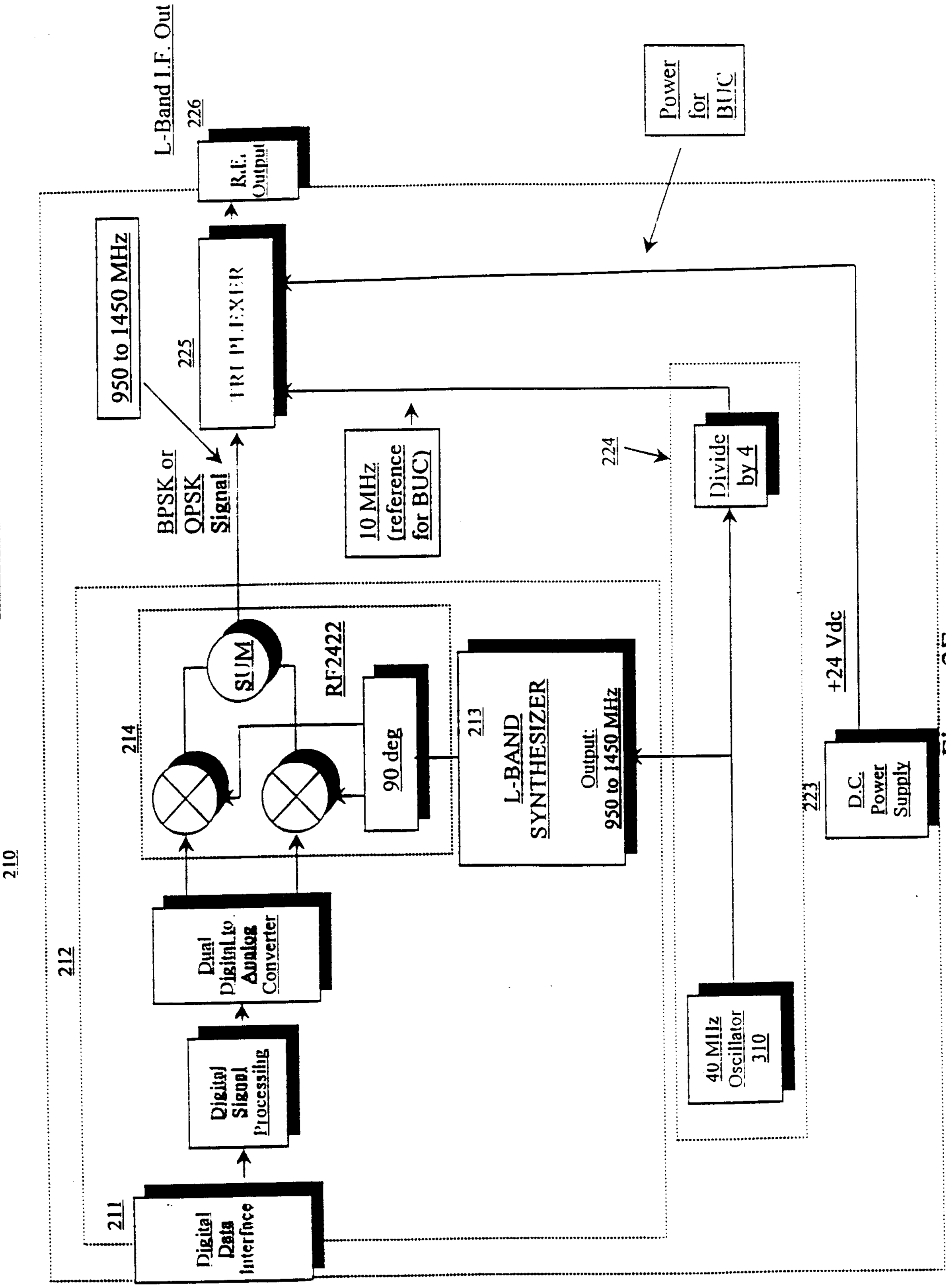


Figure 2E

L-Band Synthesizer Block Diagram

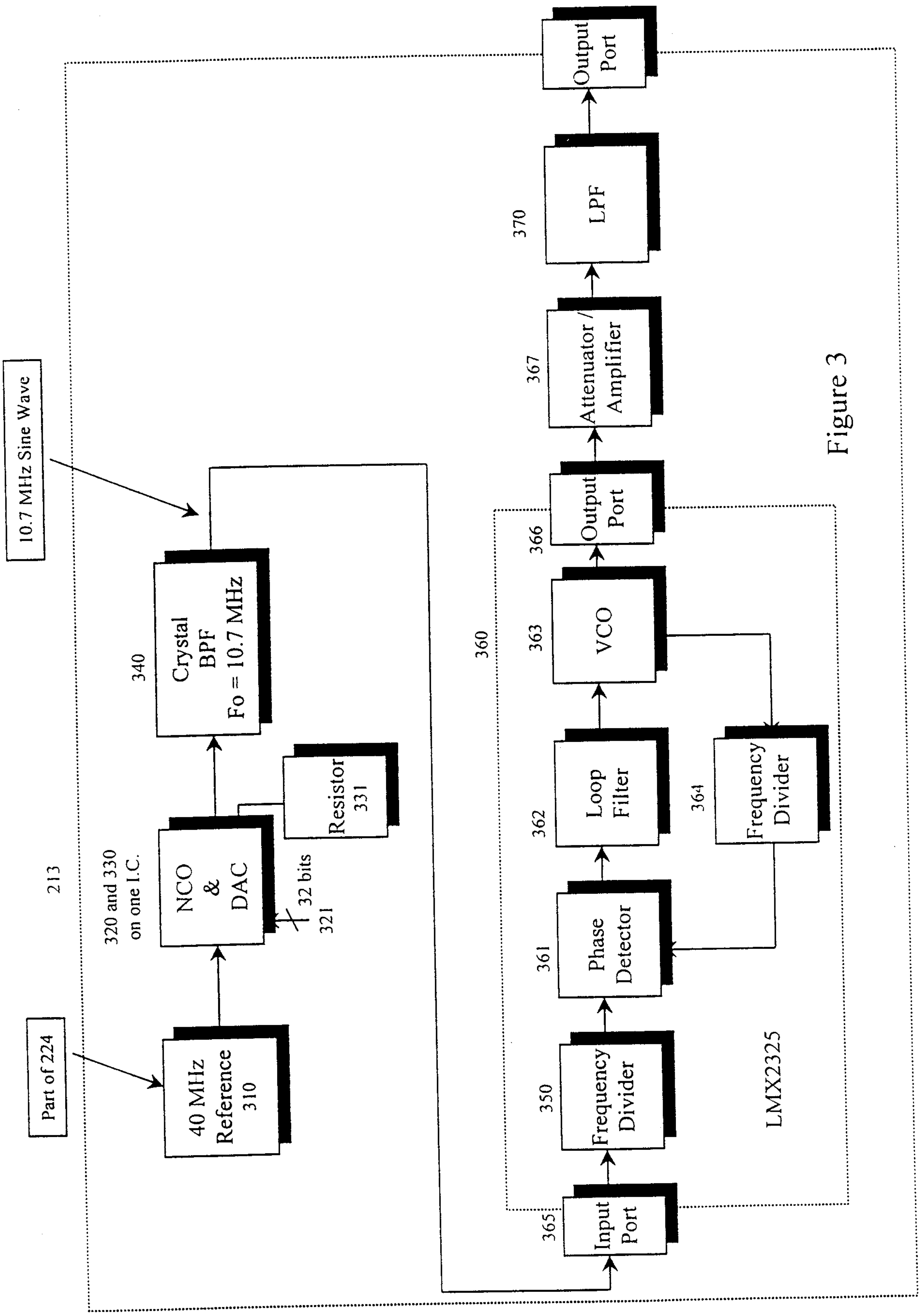


Figure 3

Triplex Function Block Diagram

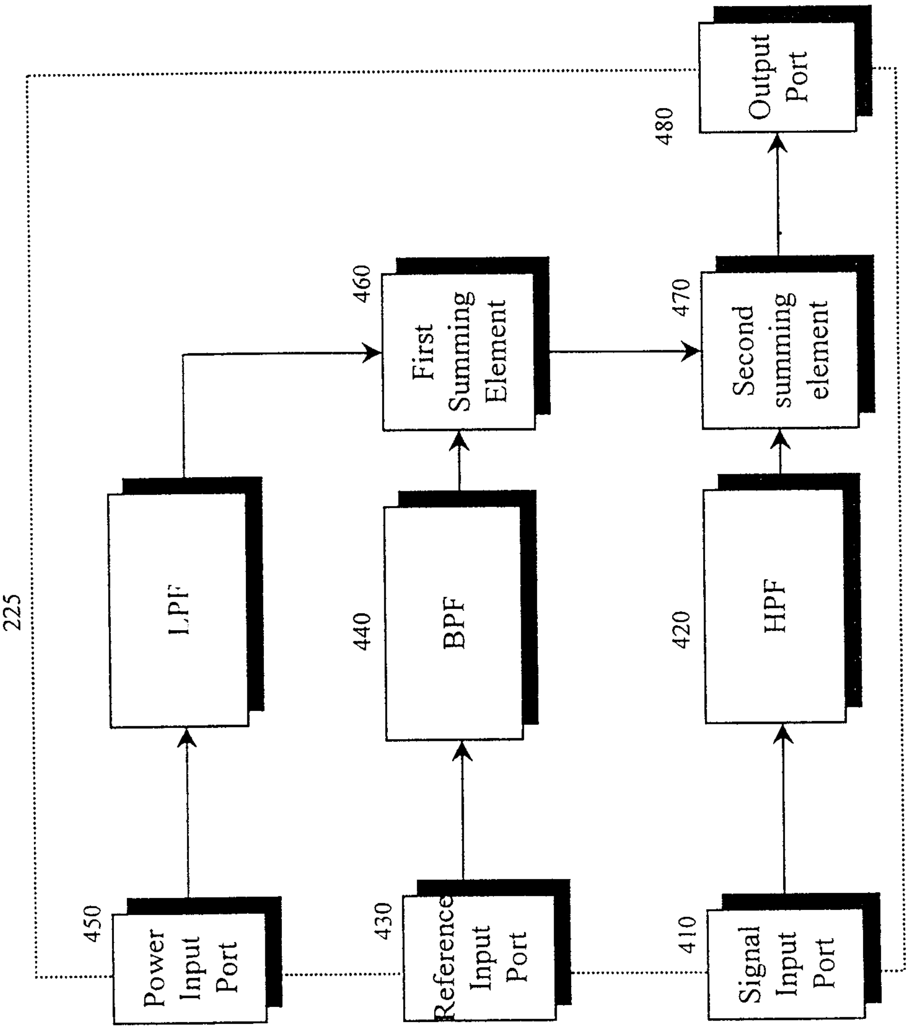


Figure 4

Summing Elements Block Diagram

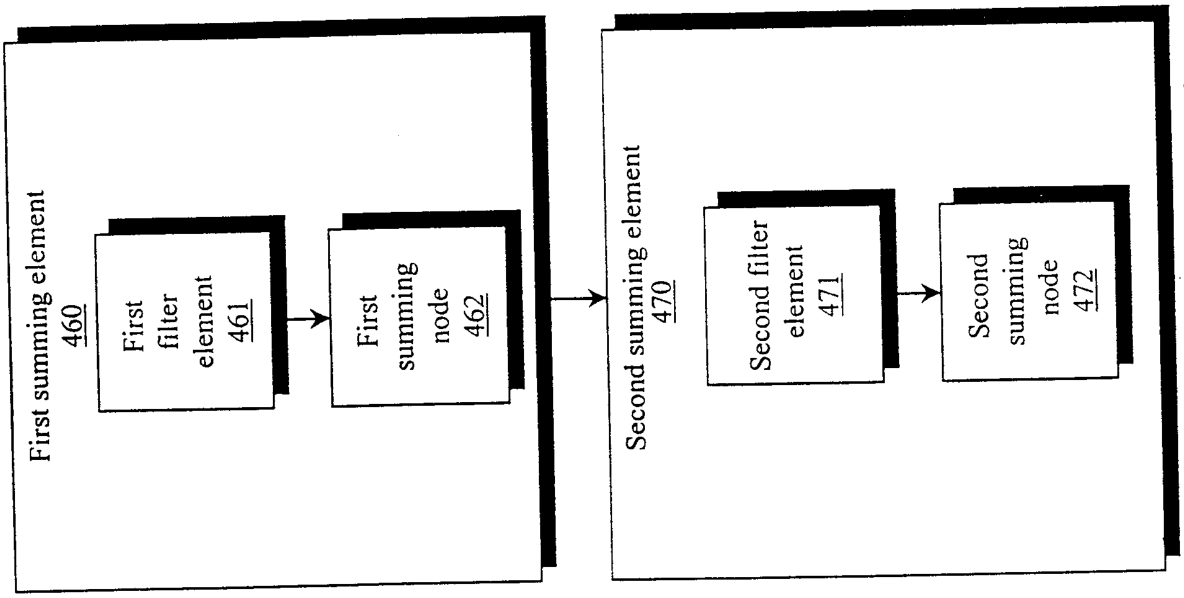


Figure 5