TELEDYNE PARADISE DATACOM, Ltd.
A Teledyne Technologies Company

PARADISE DATACOM APPLICATION NOTE

Satellite Terminal System Planning using L Band Modems.

AN_032
Issue 2

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INTRODUCTION

Teledyne Paradise Datacom L Band Satellite Modems are designed to be operated with suitable RF equipment and a Satellite Antenna to create a cost effective Satellite Terminal. This document guides the System Integrator through the hardware selection and planning process involved in the integration of the L Band Modem and RF equipment in the Satellite Terminal.

SATELLITE TERMINAL EQUIPMENT

A typical Satellite Terminal system comprises an L Band Modem, Inter Facilities Link (IFL) or Cross Site cabling, RF Block Upconverter and SSPA (BUC), Low Noise Block converter (LNB) with optional Tx reject filter and antenna system.

Satellite Terminal system block diagram

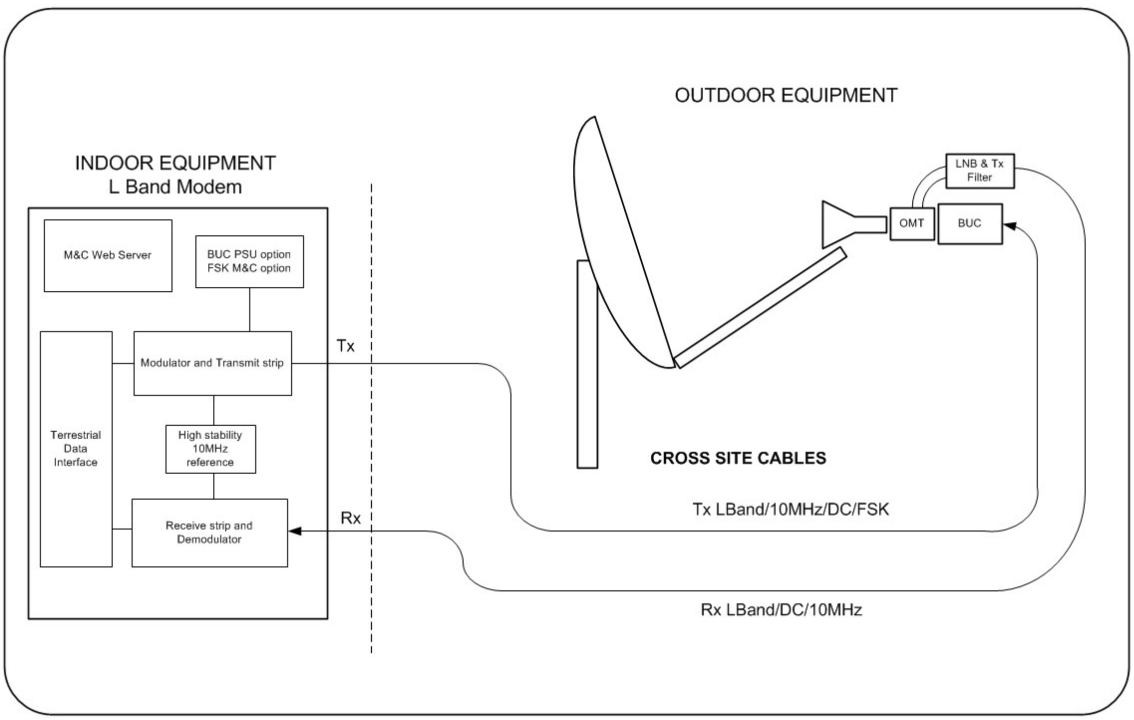


Figure 1

Teledyne Paradise Datacom L Band Satellite Modems and RF equipment can be easily configured to provide the services and M&C necessary to integrate these components together into a Satellite Terminal package.

The basic decisions when planning the terminal are as follows;

- Frequency band: What band will the terminal be operating within the C, Ku and Ka Satellite frequency range? This is important to know as it affects the range and availability of the RF products.
- Symbol rate: Dependent on the system link budget a particular modulation and FEC scheme will have been chosen to provide specific symbol rate over the satellite (transponder bandwidth). This will have a direct bearing on the choice of LNB.

- Terminal performance. The transmit EIRP is a function of the antenna size, losses and BUC output power. The BUC output power requirements will determine the BUC type; is it a vBUC (typically up to 70W) or a Compact Outdoor amplifier (up to 400W).
- BUC services: Once the BUC type is selected the BUC services need to be considered. Does the BUC need an external 10MHz reference, can the BUC be DC powered from the L Band modem via the IFL or will it require an external AC power supply?
- Terminal performance: The receive G/T is a function of the antenna size, losses and LNB noise figure. The antennas size (linked in to the EIRP requirements) will determine the LNB noise figure.
- Indoor and outdoor equipment position: The distance between the indoor and outdoor unit dictates the type of IFL used; copper or fibre? If copper is used what are the IFL losses and will the System have a 20 dB transmit output power range?
- Monitor & Control requirements: What are the M&C requirements of the Satellite Terminal – can the BUC FSK M&C system be used?

INTER FACITLITIES LINK

The goal when designing the IFL is to ensure that for the required cross site length the system has the ability to provide a 20 dB gain adjustment range from the maximum output power of the terminal.

The variables when considering the IFL design are;

- RF cable losses: The frequency band requirements of the BUC plus the IFL cable losses need to be considered. Typically longer IFL lengths will need a better (lower loss) cable. Using good quality coaxial cable it is possible to run IFL links up to 100 metres, above this the system planner needs to consider using Heliax cables or a Fibre system.
- DC cable losses: As the IFL length increases the cable copper losses start to become an issue for the higher power BUCs. The system planner needs to look at the operational DC input voltage range for the BUC and the predicted IFL copper loss.
- Output power range of the Satellite Terminal. Teledyne Paradise L Band modems have a 30 dB control range from 0 to -30 dBm. Teledyne Paradise Datacom BUCs require either -20 dBm or -30 dBm input power to achieve P1dB compression at SHF. Taking the IFL losses into account will this allow the system to drive the BUC to the wanted SHF output power and also provide a 20 dB output power adjustment range?
- BUC gain adjustment: Teledyne Paradise Datacom BUCs have a 15 dB input attenuator, which can be set during system installation to ensure P1dB output is achievable. Does the input attenuator need to be adjusted during Satellite Terminal commissioning?

IFL RF loss calculation

To help analyse the impact of changing IFL length, cable type, BUC gain and attenuation Teledyne Paradise Datacom can provide the System Planner with a simple Excel spreadsheet allowing all variables to be adjusted. An example of this is shown below in Fig 2 and 3.

Fig 2 shows that for a system with a low gain BUC set to 5 db attenuation and Belden 9914 cable type, 20 dB gain variation is achievable with an IFL length of between 30 and 40 meters. This is shown in the Output Range cells where the 30 and 40 metre length cells are clear and all other cells have ***** indicating that the gain range adjustment is less than 20 dB.

Fig 3 shows the effect of changing the BUC input attenuation to 10 dB. For a wanted 20 dB gain adjustment the IFL length has changed from 30 to 40 metres to 0 to 30 metres.

XSITE CABLE LOSS AND BUC GAIN SELECTOR

BUC GAIN	L	H = -30 dBm I/P, L = -20 dBm I/P
BUC I/P ATTEN	5	
CABLE TYPE	C	See X Site cable data table below for selection

L BAND MODEM O/P POWER VS CROSS SITE LENGTH

LENGTH (m)	0.1	10	20	30	40	50	60	70	80	90	100
LOSS (dB)	0.02	2.14	4.28	6.42	8.56	10.70	12.84	14.98	17.12	19.26	21.40
POWER (dBm)	-14.98	-12.86	-10.72	-8.58	-6.44	-4.30	-2.16	-0.02	2.12	4.26	6.40
O/P RANGE	*****	*****	*****			*****	*****	*****	*****	*****	*****

X SITE CABLE DATA

X SITE CABLE TYPE	**LOSSES/100m @ 1.5 GHz**
A=RG214	36.6
B=CABLE EXPERT CXP1318	28.3
C=BELDEN 9914	21.4
D=LMR400	16.8
E=CUSTOM	5.6

Figure 2

XSITE CABLE LOSS AND BUC GAIN SELECTOR

BUC GAIN	L	H = -30 dBm I/P, L = -20 dBm I/P
BUC I/P ATTEN	10	
CABLE TYPE	C	See X Site cable data table below for selection

L BAND MODEM O/P POWER VS CROSS SITE LENGTH

LENGTH (m)	0.1	10	20	30	40	50	60	70	80	90	100
LOSS (dB)	0.02	2.14	4.28	6.42	8.56	10.70	12.84	14.98	17.12	19.26	21.40
POWER (dBm)	-9.98	-7.86	-5.72	-3.58	-1.44	0.70	2.84	4.98	7.12	9.26	11.40
O/P RANGE				*****	*****	*****	*****	*****	*****	*****	*****

X SITE CABLE DATA

X SITE CABLE TYPE	**LOSSES/100m @ 1.5 GHz**
A=RG214	36.6
B=CABLE EXPERT CXP1318	28.3
C=BELDEN 9914	21.4
D=LMR400	16.8
E=CUSTOM	5.6

Figure 3

This spreadsheet allows the System Planner to quickly determine the correct cable type for the IFL.

For a more accurate calculation of the IFL requirements the input frequency of the BUC also needs to be considered along with the L Band cable losses at the wanted frequency. Fig 4 provides the input frequency range for Paradise Teledyne BUCs and Fig 5 shows cable losses and gain frequency slope for a range of cable types.

Teledyne Paradise BUC type vs. input frequency range

BUC type	Input frequency range (MHz)
Standard C Band	950 - 1525
Extended C Band	950 - 1825
Palapa C Band	950 - 11250
Insat C Band	950 -1250
Extended C Band 2	950 - 1675
Standard X Band	950 - 1450
Standard Ku Band	950 - 1450
Extended Ku Band	950 - 1700
Ka Band	1000 - 2000

Figure 4

Coaxial cable characteristics

Cable type	Centre conductor DC resistance (Ohms per 1000ft / 300m)	Outer diameter (inches/mm)	Attenuation at 950 MHz (dB per 100 ft / 30m)	Attenuation at 1450 MHz (dB per 100 ft / 30m)	Slope across band for 100 ft / 30m cable (dB)	Slope across band for 300 ft / 90 m cable (dB)
RG-214	1.7	0.45/11.3	7.8	11.3	3.5	10.5
Belden 8214	1.2	0.403/10.24	6.8	9.2	2.4	7.2
Belden 7733	0.9	0.355/9.02	5.8	8.3	2.5	7.5
Belden 9914	1.2	0.403/10.24	4.5	6.3	1.8	5.4
Belden 9913	0.9	0.403/10.24	4.2	5.6	1.4	4.2

Figure 5

BUC / LNB Services

All Teledyne Paradise L Band Satellite Modems have fitted as standard a 10 MHz reference out to the BUC and LNB on the IFL cable. The modem receive port also provides 15 or 24 volts DC at 0.5 A on the IFL cable to power the LNB.

The BUC and LNB services running across the IFL also need to be taken into consideration. The DC power, 10 MHz reference and FSK M&C signalling need to reach the BUC at a suitable drive level.

Teledyne Paradise Datacom L Band Modems provide as standard a 10 MHz reference: +3 dBm on the transmit port, 10 MHz at 0 dBm on the receive port and transmit FSK signalling at -10 dBm.

Teledyne Paradise Datacom BUCs have a 10 MHz input level range of +5 to -10 dBm and a FSK input level range of -5 to -15 dBm.

IFL Modem Services loss calculation

The cable type with the greatest loss, RG214, has a loss of 2dB per 100 meters at 10 MHz. Therefore unless an extremely long IFL is chosen, the 10 MHz reference and FSK signals will always be within specification. However care must be taken when introducing combiners and splitters into the IFL run as these will introduce extra loss, which needs to be accounted for.

The DC cable losses of the IFL also need to be taken into account. Looking at the power requirements for the Teledyne Paradise Datacom BUCs in Fig 7 it can be seen that the 24V DC input BUCs have the highest input current requirements. The DC cable losses (copper loss) will be worse for the 24V system compared to the 48V system as the 24V BUC has a DC input operating window of 20 to 54V whilst the 48V BUC has a 36 to 70V DC operating window.

The DC loss in 30 meters of RG214 cable for the 25W C Band BUC operating at 24V @ 7.2 A is 1.224V. Looking at the voltage present at the BUC (24 – 1.224V) this is within the BUCs input specification. However with a 100m IFL link the copper losses are 4.04V. This is a problem as it is just on the 20V BUC operating limit and over time will almost certainly cause problems.

The solution to the problem for longer IFL runs is to use a lower loss cable; Belden 7733 or 9913 would be the obvious choice with a lower copper loss of 0.9 Ω per 300m compared to 1.7 Ω for the RG214.

MODEM BUC PSU HARDWARE OPTIONS

The system planner needs to consider the DC power requirements of the BUC and the system requirements for greater BUC monitor and control from the modem.

The BUC power supply options available are shown in fig 6

Paradise BUC PSU options

Part Number	BUC PSU	Type
P3531	100W 48V output	A.C. in/D.C. out
P3535	180W 48V output	A.C. in/D.C. out
P3532	100W 24V output	A.C. in/D.C. out
P3536	180W 24V output	A.C. in/D.C. out
P3537	+/-48V input, 180W 48V output	D.C. in/D.C. out
P3538	+/-48V input, 180W 24V output	D.C. in/D.C. out
P3539	+48V input, 180W 48V output	D.C. in/D.C. out

Figure 6

The Teledyne Paradise Datacom BUC power supply consumption figures are shown below in fig 7 along with the suggested modem BUC PSU.

Paradise BUC power supply requirements

Manufacturer & BUC Type	PSU Required Voltage	PSU Required Wattage	PSU Required Current	Paradise BUC PSU 24V	Paradise BUC PSU 48V
Paradise 10W C-band VSAT BUC	24V	120	5A	**P3536**	**-**
	48V	120	2.5A	**-**	**P3535**
Paradise 20W C-band VSAT BUC	24V	144	6A	**P3536**	**-**
	48V	144	3A	**-**	**P3535**
Paradise 25W C-band vBUC	24V	173	7.2A	**P3536**	**-**
	48V	173	3.6A	**-**	**P3535**
Paradise 10W X-band vBUC	24V	100W	4.2A	**P3532**	**-**
	48V	96W	2.0A	**-**	**P3531**
Paradise 10W Ku-band vBUC	24V	149W	6.2A	**P3536**	
	48V	144W	3.0A	**-**	**P3535**
Paradise 10W Ka-band vBUC	24V	-	-	**-**	**-**
	48V	192	4.0A	**-**	**P3535**

Figure 7

Fig 8 shows the power supply requirements for other BUC manufacturers.

OEM BUC power supply requirements

Manufacturer & BUC Type	PSU Required			Paradise ODU PSU	
	Voltage	Wattage	Current	24V	48V
Terrasat 5W C-band IBUC	24V	72	3A	**P3532**	**-**
	48V	72	1.5A	**-**	**P3531**
Terrasat 10W C-band IBUC	24V	108	4.5A	**P3536**	**-**
	48V	96	2A	**-**	**P3535**
Terrasat 4W Ku-band IBUC	24V	72	3A	**P3532**	**-**
	48V	72	1.5A	**-**	**P3531**
Terrasat 8W Ku-band IBUC	24V	120	5A	**P3536**	**-**
	48V	120	2.5A	**-**	**P3535**
NJR 1W C-band 5665 & 5666	24V	30W	-	**P3532**	**-**
NJR 2W C-band 5667 & 5668	24V	37.5W	-	**P3532**	**-**
NJR 5W C-band 5669 & 5670	24V	55W	-	**P3532**	**-**
NJR 10W C-band 5662 & 5663	24V	130W	-	**P3536**	**-**
	48V	130W	-	**-**	**P3535**
NJR 1W Ku-band 5015	24V	25W	-	**P3532**	**-**
NJR 1W Ku-band 5075	24V	18W	-	**P3532**	**-**
NJR 1.5W Ku-band 5035	24V	24W	-	**P3532**	**-**
NJR 2W Ku-band 5076 & 5016	24V	37.5W	-	**P3532**	**-**
NJR 3W Ku-band 5037	24V	30W	-	**P3532**	**-**
NJR 4W Ku-band 5077 & 5017	24V	48W	-	**P3532**	**-**
NJR 8W Ku-band 5018	24V	170W	-	**P3536**	**-**
	48V	170W	-	**-**	**P3535**
Codan 5W C-band 6705	24V	60W	-	**P3532**	**-**
	48V	60W	-	**-**	**P3531**
Codan 10W C-band 6710	48V	105W	-	**-**	**P3535**
Codan 20W C-band 6720	48V	130W	-	**-**	**P3535**
Codan 4W Ku-band 6904	24V	80W	-	**P3532**	**-**
	48V	80W	-	**-**	**P3531**
Codan 8W Ku-band 6908	48V	115W	-	**-**	**P3535**

Figure 8

The BUC power supply is switched using a separate option card, which is supplied as part of the BUC PSU kit. The option card is available either as a DC switch (P3509) or as a FSK signalling and DC switching option card (P3503).

The P3503 option card allows remote monitoring and control of any compatible BUC via a modulated FSK signal on the IFL cable to the BUC. This allows the modem to monitor and control the performance of the BUC, which simplifies the Satellite Terminal M&C requirements as the modem is the single point of communication. The modem provides several control modes for the Terminal output power, allowing either separate control of modem transmit output power and BUC attenuation or a closed loop system where the modem monitors and controls the Satellite Terminal output power automatically adjusting modem output power and BUC attenuation. These are discussed in greater detail in a later section.

SATELLITE TERMINAL FREQUENCY UNCERTAINTY

The Teledyne Paradise Datacom L Band satellite modems are equipped with a Very High Stability 10 MHz reference. This is used internally within the modem as the master frequency reference and can also be supplied to the BUC and LNB, via the IFL cable, to phase lock the Super High Frequency (SHF) local oscillators. The Teledyne Paradise Datacom BUCs have the ability to sense the presence of a 5, 10, 20, 25 or 50 MHz reference and automatically lock onto it. The BUCs also have the option to fit an internal 10 MHz reference with similar performance to the modems 10MHz reference.

The Very High Stability 10 MHz oscillator performance is shown in figure 9.

	Parameter	**Conditions**	**Typical value**	**Unit**
Stability				
	Temperature	-40 to +90 C	± 0.010	ppm
	vs. supply	5% change	± 0.0025	ppm
	vs. load	5% change	± 0.0025	ppm
	Allen variance	1 sec	5.0e-11	
	Aging	per day @ 30 days	± 0.001	ppm
		per year (after 30 days of operation)	± 0.05	ppm
	Warm up time	5 minutes @ 25C ref to 24 hour frequency	0.10	ppm
Phase Noise	SSB offset			
	10Hz		-120	dBc/Hz
	100Hz		-140	dBc/Hz
	1kHz		-145	dBc/Hz
	10kHz		-152	dBc/Hz
	100kHz		-155	dBc/Hz

Figure 9

The Satellite Terminal frequency uncertainty can be calculated by analysing each component within the Terminal. The frequency uncertainty is directly related to the 10 MHz reference stability. Most BUCs will require a 10 MHz reference on the transmit path. The System Planner has the choice of selecting an external or internal reference LNB. If an internal reference LNB is chosen (due to cost) then the frequency error is specified as a specific ± kHz or parts per million (ppm) value.

The System Planner must be certain that the Terminal frequency stability is suitable for the symbol rate of the service running over the Satellite. Examples of two frequency uncertainty budgets are shown over-page. The Satellite frequency uncertainty has been specified as ± 25 kHz for yearly stability and ±2.5 kHz for monthly stability.

The first example is for a Ku band Terminal using an external referenced BUC and LNB, showing yearly and monthly frequency uncertainty (Fig 10). This shows that the monthly stability for the Terminal transmit chain is ± 14.55 Hz and the overall link frequency uncertainty is ± 2.526 kHz.

The IESS 308 specification for frequency stability of the Satellite Terminal is ± 0.025 R Hz, where R is the transmission data rate in bits per second with an upper limit of ± 3.5 kHz. For a 9.6 kbps carrier with ½ rate FEC this is ± 480 Hz. This result also shows that the Terminal using external reference BUC and LNB with the 10 MHz sourced from the modem is suitable for transmission of 9.6 Kbps data.

The second example is for a Ku Band Terminal using an external reference BUC and an internal reference LNB (Fig 11). The LNB stability has been specified as ± 25 KHz (2.5 ppm) for yearly and monthly calculations. As expected that the Terminal receive path stability is much worse, with a monthly link frequency uncertainty of ± 25 kHz. This result would be acceptable for a terminal with a data rate of 256 ksps or higher but would obviously not be suitable if running a 9.6 ksps link.

Terminal frequency uncertainty for external reference BUC and LNB

	YEARLY STABILITY				MONTLY STABILITY		
Description		Value	Units			Value	Units
10 MHz ref stability		0.050	ppm			0.001	ppm
L Band Modem frequency		1500.00	MHz			1500.00	MHz
BUC LO frequency		13.05	GHz			13.05	GHz
LNB LO frequency		10.00	GHz			10.00	GHz
Satellite frequency uncertainty	+/-	25.00	kHz		+/-	2.50	kHz
Modulator frequency uncertainty	+/-	75.00	Hz		+/-	1.50	Hz
BUC frequency uncertainty	+/-	652.50	Hz		+/-	13.05	Hz
Satellite frequency uncertainty	+/-	25000.00	Hz		+/-	2500.00	Hz
LNB frequency uncertainty	+/-	500.00	Hz		+/-	10.00	Hz
Demodulator frequency uncertainty	+/-	75.00	Hz		+/-	1.50	Hz
Total frequency uncertainty for Satellite terminal Tx path	+/-	727.50	Hz		+/-	14.55	Hz
Total frequency uncertainty for Satellite terminal Rx path	+/-	575.00	Hz		+/-	11.50	Hz
Total frequency uncertainty single satellite hop: Tx + Rx +Satellite error	+/-	26302.50	Hz		+/-	2526.05	Hz

Figure 10

Terminal frequency uncertainty for ext ref BUC and int ref LNB

	YEARLY STABILITY				MONTLY STABILITY		
Description		Value	Units			Value	Units
10 MHz ref stability		0.050	ppm			0.001	ppm
L Band Modem frequency		1500.00	MHz			1500.00	MHz
BUC LO frequency		13.05	GHz			13.05	GHz
LNB frequencystability	+/-	25.00	kHz		+/-	25.00	kHz
Satellite frequency uncertainty	+/-	25.00	kHz		+/-	2.50	kHz
Modulator frequency uncertainty	+/-	75.00	Hz		+/-	1.50	Hz
BUC frequency uncertainty	+/-	652.50	Hz		+/-	13.05	Hz
Satellite frequency uncertainty	+/-	25000.00	Hz		+/-	2500.00	Hz
LNB frequency uncertainty	+/-	25000.00	kHz		+/-	25000.00	Hz
Demodulator frequency uncertainty	+/-	75.00	Hz		+/-	1.50	Hz
Total frequency uncertainty for Satelite terminal Tx path	+/-	727.50	Hz		+/-	14.55	Hz
Total frequency uncertainty for Satelite terminal Rx path	+/-	25075.00	Hz		+/-	25001.50	Hz
Total frequency uncertainty single satellite hop: Tx + Rx +Satellite error	+/-	50802.50	Hz		+/-	27516.05	Hz

Figure 11

SATELLITE TERMINAL COMMISIONING

All Teledyne Paradise Datacom L Band Satellite Modems have a range of user selectable features which allow the modem to act as the master monitor and control point for the Terminal. This section describes the available choices when connecting the L Band modem to BUC and LNB.

The L Band Modem is the main provider of services within the Satellite Terminal. As well the transmit and receive L Band signals it also provides the following services on the two IFL cables;

- 24 or 48V DC to the BUC.
- FSK BUC monitor and control signal.
- 24/15 V DC @ 0.5A to the LNB.
- 10 MHz reference signal to the BUC and LNB.

The L Band Modem can be configured to allow the user to operate the terminal at SHF frequencies, report the transmit output power in dBm or dBW and apply a gain correction to the transmit path to allow the user to see the transmit EIRP.

Transmit path: BUC selection

From the main menu of the Local User Interface (LUI) or from the Web User Interface (WUI) it is possible to select the BUC type from a range of standard products or to specify a set of custom BUC parameters, either of which will allow the modem to display the Terminal SHF frequency and power.

From the LUI the BUC selection menu is accessible from;

- Main
- Edit (2).
- Tx (2)
- Carrier (7)
- Advanced (6)
- BUC (2)
- BUC type (2)

At this point the user will be prompted for the BUC M&C type, either RS485 or FSK. The user must select between one of these options even if there is no M&C used in the system. The available BUC types will be shown to the user along with three other choices; None, Other and User.

> None: This switches the BUC frequency offset off, switches the DC and 10 MHz off and re-sets the modem frequency to 950 MHz.
>
> Other: This is used for BUCs which have no M&C capabilities. The 10 MHz and DC services are available but the FSK/RS485 signalling is switched off.
>
> The user is asked to specify the BUC LO frequency in MHz and also specify whether it is a low side or high side LO (non-inverting / inverting). To do this the user must modify the "+" or "-"sign of the LO frequency using the up and down arrows on the keypad.
>
> A "+" sign before the LO frequency indicates that the BUC uses low side frequency conversion. The Modem will report the Terminal SHF frequency as the BUC LO frequency added to the L Band modem frequency.

A "-"sign before the LO frequency indicates that the BUC is using a high side LO. The modem will report the Terminal SHF frequency as the BUC LO frequency minus the modem L Band frequency.

The BUC LO frequencies for Teledyne Paradise Datacom BUCs are shown in Fig 12.

Teledyne Paradise Datacom BUC frequency band and LO data

Band	Frequency Plan*	IF Input	LO Frequency	RF Output
C	Standard C-Band	950 - 1525 MHz	4.900 GHz	5.850 - 6.425 GHz
C	Extended C-Band	950 - 1825 MHz	4.900 GHz	5.850 - 6.725 GHz
C	Palapa Band	950 - 1250 MHz	5.475 GHz	6.425 - 6.725 GHz
C	Insat Band	950 - 1250 MHz	5.775 GHz	6.725 - 7.025 GHz
X	Standard X-Band	950 - 1450 MHz	6.950 GHz	7.900 - 8.400 GHz
Ku	Standard Ku-Band	950 - 1450 MHz	13.050 GHz	14.00 - 14.50 GHz
Ku	Extended Ku-Band	950 - 1700 MHz	12.800 GHz	13.75 - 14.50 GHz

Figure 12

To enable the user to monitor and control the Satellite Terminal SHF output power the user is able to enter a Power Offset. This is available from the BUC (2) menu; the user selects Power Offset (1) and enters the gain/loss of the system followed by the power display selection in dBm or dBW. When the user then selects the modem output power this will be displayed with the offset adjustment added.

<u>Standard BUCs</u>: If the user is selecting a standard BUC with M&C capability then the L Band modem will pre-program the modem with the correct SHF frequency band and the BUCs power class. The current range of supported BUCs is shown in Fig 13 for FSK and RS485 M&C.

FSK BUCs RS485 BUCs

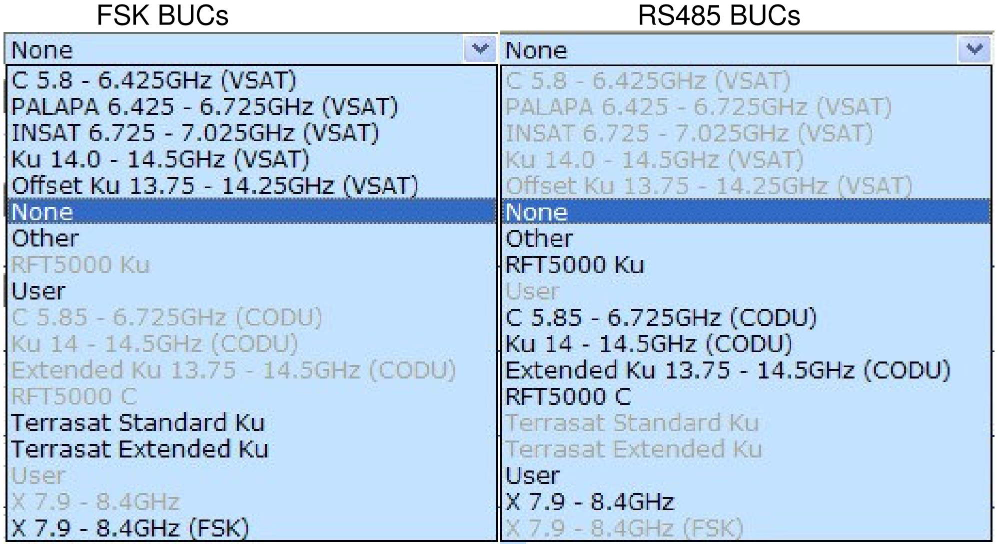


Figure 13

After selecting the BUC type the user will be asked if they want to operate the Satellite Terminal in "Independent" or "Terminal" mode. These are described in detail in the next section. "Independent" mode allows control of the modem L Band output power and BUC input attenuation to achieve the wanted Satellite Terminal SHF output power. "Terminal" mode automatically sets the modems L

Band output power and BUC input attenuator to achieve the wanted Satellite Terminal SHF output power.

The final selection in the “BUC type” menu is the power class. The BUC software protocol allows for automatic detection of BUC power up to 170W. If the BUC SHF output power is above 170W, which is possible in the case of the Compact Outdoor range of BUCs, the user can enter the correct value within the range 170 to 999W. The BUC power class detection system is described in the following sections.

User: This allows the user to enter custom values for the BUC Local Oscillator (LO) frequency and power class of the BUC. The user selects the Local Oscillator frequency (see “Other” mode) and is then asked to select either “Terminal” or “Independent” mode for the Satellite Terminal SHF power control. These are described in detail in the next section. Finally the user has to provide the power class of the BUC if it is above 170W SHF output power. The BUC power class detection system is described in the following sections.

Satellite Terminal output power control, Terminal and Independent modes

All Teledyne Paradise Datacom BUCs have a calibrated SHF output power monitor with a 20 dB or greater dynamic range from P1dB. This information is fed back to the L Band modem; via FSK on the IFL or via an RS485 M&C link. This information allows the user to be able to easily set the SHF output power from the L Band modem and also monitor this on the modem LUI or WUI screens.

In “Independent” mode the user sets both the L Band modem transmit output power and the BUC input attenuation to suitable values to achieve the wanted transmit output power, taking into account the IFL losses. The BUC status screen on the LUI (Fig 14) shows the Terminal output power. This is accessed from Main, Status (1), and BUC (9) menus.

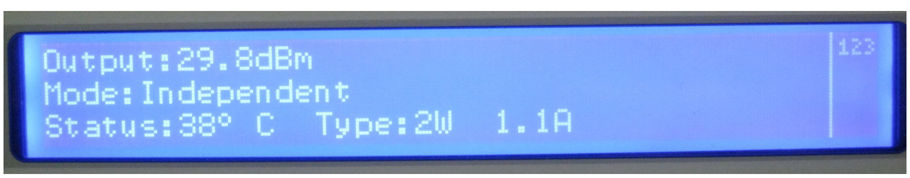


Figure 14

In “Terminal” mode the user sets the Satellite Terminal transmit SHF output power. The modem automatically sets the L Band transmit power and the BUC input attenuation to achieve the wanted Satellite Terminal SHF output power. If the modem cannot achieve the wanted BUC output power in this mode a warning will be placed in the Traffic log. The most common cause of this warning is when the IFL losses are to great for the modem to be able to set the wanted BUC output power, the solution is to reduce the IFL losses either by replacing the cable with a lower loss type, or by removing any excess cable which may have been coiled up, rather than cutting and re-terminating the cable to the correct length.

In Terminal mode, the modem will attempt to achieve the wanted SHF output power by initially setting the L Band output power. If it cannot achieve the target SHF output power it will then adjust the BUC input attenuation. The Terminal mode control algorithm has an initial acquisition phase followed by a tracking phase. During the acquisition phase the modem adjusts the SHF output power, up or down, by 66% of the previously measured value. When the Terminal SHF output power is within 0.5 db of the target value the algorithm then changes to the tracking phase. The tracking phase looks at the

SHF output power and nudges the value in 0.1 dB steps until it reaches the wanted SHF output power.

The tracking phase has an output power window of ± 0.25 dB of the target value. When the SHF output power is being reported within this value it will not adjust the output power. If the SHF output power falls outside the ± 0.25 dB window it will then start the 0.1 dB nudge process. If the output power falls outside a ± 0.75 dB window the modem drops back into acquisition phase. The BUC status screen on the LUI (Fig 15) shows the wanted SHF output power, the modem L Band output and the BUC input attenuation setting.

Figure 15

BUC Power class

All Teledyne Paradise Datacom BUCs are assigned a power class value. This is shown in Fig 16.

Value	Power
0x1	2 watt
0x2	4 watt
0x3	5 watt
0x4	8 watt
0x5	10 watt
0x6	16 watt
0x7	20 watt
0x8	25 watt
0x9	40 watt
0xA	55/60 watt
0xB	30 watt
0xC	125 watt
0xD	80 watt
0xE	100 watt
0xF	170 watt

Figure 16

When the BUC type is selected the modem automatically sets the BUC frequency range from LO data held in the modem and then interrogates the BUC to determine the power class. If the BUC responds back with a value from 1 to 15 (1 to F in hex) then the modem will use this value and select the power output from corresponding power output range shown in the table. If the BUC responds back with a 0 then the modem knows that the BUCs SHF output power is outside of the standard range and asks the user to enter a value in Watts from 0 to 999.
Note this value will only be used when the BUC responds back with a 0 in the power class. It will ignore values entered by the user if it has a valid power class value from 1 to 15

BUC Services

Before the Satellite terminal can start transmitting the user needs to select the correct services for the BUC and switch the SHF output on. Dependent on the BUC type it may require DC and 10 MHz from the modem. Both of these services are available from the;

Main, Edit (2), Tx (3), Carrier (7), Advanced (6), BUC (2) menu.

DC power is selected from The PSU (3) menu and the 10 MHz reference is selected from the Reference (3) menu.

When the Satellite terminal is first being commissioned with a BUC using FSK or RS485 M&C the BUC output will need to be switched ON. This is available from the Output (5) menu.

Receive path: LNB selection

From the main menu of the Local User Interface (LUI) or from the Web User Interface (WUI) it is possible to select a standard LNB product, or to specify a User LNB, which will allow the modem to display the Terminal receive SHF frequency.

From the LUI the BUC selection menu is accessible from;

- Main
- Edit (2).
- Rx (2)
- Carrier (7)
- Advanced (4)
- LNB (1)
- LNB type (1)

At this point the user will be prompted with a range of LNB types will be shown to the user along with two other choices; None and User.

None: This switches the LNB frequency offset off, re-sets the modem frequency to 950 MHz but leaves the DC and 10 MHz ON.

Other: This is used for LNBs which have a non standard Local Oscillator (LO) frequency. The user specifies the LNB Local Oscillator frequency in MHz and also specifies if it is a high or low side LO by selecting the "+" for low side frequency conversion and "-" for a high side frequency conversion.

Standard LNBs: If the user is selecting a standard LNB with a known frequency range then the L Band modem will pre-program the modem with the correct SHF frequency band. The current range of supported LNBs is shown in Fig 17.

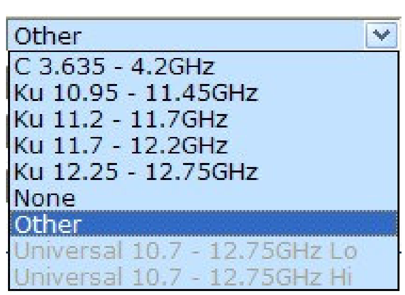


Figure 17

Universal LNB: The Universal LNB type can only be selected when the Multiswitch option has been specified in the LNB DC power menu. The Multiswitch hardware option is mounted in-line on the receive IFL and is also connected to the modem via an RS 485 link. With the Multiswitch option selected the modem can control a Universal LNB. This LNB type allows operation over the entire Ku frequency band by switching the LO from 9.75 to 10.6 GHz. The LO selection is achieved by sending a 22.5 kHz tone at 0.5V pk-pk to from the Multiswitch to the LNB. This changes the LO from the low band, 9.75 GHz to the high band,10.6 GHz. Polarisation control is also possible using the Multiswitch option. Vertical polarisation is obtained when the Multiswitch provides 13V DC to the LNB, horizontal polarisation is selected when the Multiswitch provides 18V DC to the LNB.

Universal LNB selection form the WUI is shown in Fig 18

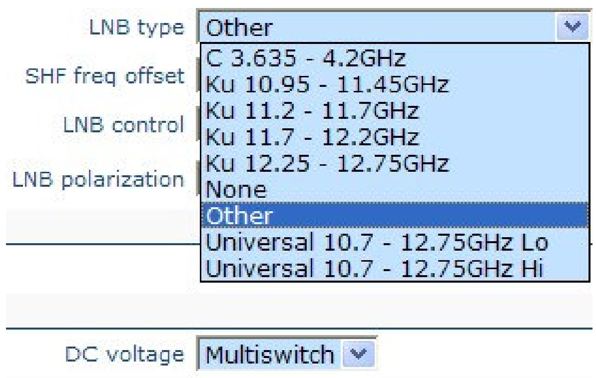


Figure 18

LNB services

Before the Satellite terminal can receive a signal from the satellite the user needs to select the correct services for the LNB.

Dependent on the LNB type it may require DC and 10 MHz from the modem. Both of these services are available from the;

Main, Edit (2), Rx (3), Carrier (7), Advanced (4), LNB (1) menu.

DC power is selected from The PSU (2) menu. The user has the option of 15 or 24V DC at 0.5 A or Multiswitch (see Universal LNB option).

The 10 MHz reference is selected from the Reference (3) menu.

LNB frequency stability selection

The Satellite Terminal Frequency Uncertainty section provides a detailed analysis of the transmit and receive path frequency uncertainties. The system planner needs to take into account the receive frequency uncertainty when considering the frequency stability of the LNB and also the demodulator sweep width setting.

The LNB frequency stability should also be chosen with the receive symbol rate in mind. The system planner has the choice of a variety of different LNB types ranging from the external reference type, with the highest stability and highest cost to the internal reference DRO LNB, which will have poor frequency stability but is the cheapest option.

The main factor in choosing the LNB type is the receive symbol rate. At low receive symbol rates (< 16 ksps) it is recommended to use an external reference LNB. For symbol rates above this the system planner must choose the appropriate stability LNB. The internal reference LNB stability should be chosen to be much less than the symbol rate multiplied by the transponder frequency spacing (typically 1.3 x symbol rate). If this is not taken into account the modem has the possibility of locking to the wrong carrier. Fig 19 shows the effect that a 25 kHz stability LNB has when used in a terminal receiving a 64 kbps, 8PSK, Turbo rate 7/8 service. This has a symbol rate of 24.381 kHz and an occupied bandwidth of 26.819 kHz. The signals are spaced at 1.3 x symbol rate, which equals 31.7 kHz. The upper diagram shows the wanted carrier with adjacent carriers running a similar service. The lower diagram shows the effect of an LNB LO downward frequency drift of 25 kHz. In this instance the upper adjacent carrier is now almost at the wanted frequency and the modem will tune to this signal rather than the wanted. This figure of 25 kHz is conservative as the previous frequency uncertainty calculation in Fig 11 showed that the overall link had an uncertainty of 27.516 kHz per month.

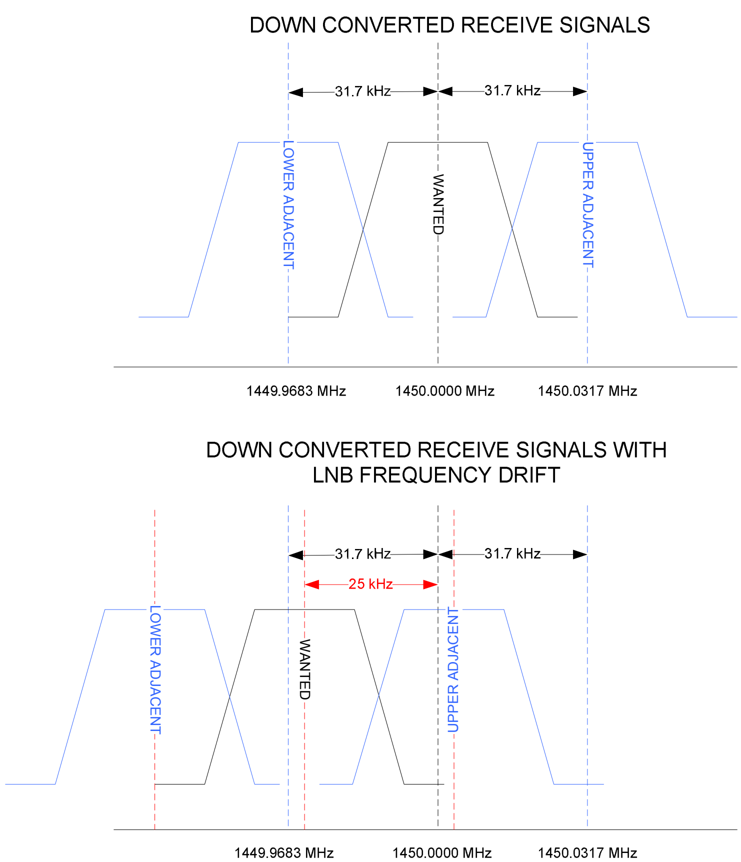


Figure 19

To ensure that this event does not happen, the System planner needs to select a higher stability LNB (± 5 kHz) and also ensure that the demodulator sweep range is changed from the standard ± 32 kHz to a more sensible ± 6 kHz (1/4 of symbol rate) to allow for LNB and Satellite frequency stability. In practice this figure of ± 6 kHz may be too small as the satellite frequency uncertainty of ± 2.5 kHz also needs to be considered. Taking this into account a value of ± 10 kHz is a more realistic figure to set the demodulator sweep width to for this service.

10 MHz reference frequency adjustment

The accuracy of the 10 MHz high stability oscillator is important as it is used as the reference oscillator for the local oscillators of the L Band Modem , BUC and if required the LNB. The 10 MHz oscillator frequency is set in the factory as part of the normal test process and will slowly increase in frequency over time. At 14 GHz the typical frequency shift will be 625 Hz per year, 13 Hz per month, see fig 10. The frequency stability specification for the transmit terminal in IESS 308 /309 requires the frequency drift to be ± 3.5 kHz per month, which is easily met by this performance.

Maintenance on the satellite terminal to adjust the output frequency can only be achieved from the LUI and should be planed as part of the typical annual maintenance for the terminal.

From the LUI the 10 MHz reference is adjusted from the Edit (2), Unit (4), Advanced (7), Adj Ref (7). The user is shown a value from 0 to 255; typically this value will be pre set during factory testing at around 90. The 10 MHz reference has a typical adjustment range of ± 1.0 ppm. At 14 GHz this is a tuning range of ± 13.05 kHz, with a step size of 101 Hz.

Satellite Terminal Monitor and Control options

The L Band Satellite Modem has a variety of Monitor and Control options, which allow the System Integrator to link the modem into existing Earth Station M&C systems, or use the modem as a stand alone data collection source. The modem handbook deals with the standard M&C features of the modem. This section explains how the modem can easily be configured to provide BUC monitor and control via the FSK or RS485 M&C signalling. It also explains the receive composite power indication and shows how this can be used by the System Integrator to determine if the modem is operating in its correct receive level range.

BUC monitor and control

If the BUC FSK option is selected then an FSK messaging signal will be multiplexed onto the IFL link along with the DC power supply and 10 MHz reference to the BUC. The messaging protocol used is the same for FSK and RS485, the two systems are interchangeable as far as the BUC M&C is concerned. The application note will concentrate on the FSK option but the same M&C can be obtained with an RS485 link from L Band Modem to BUC.

The Frequency Shift Keying signal consists of a 650 kHz ± 60 kHz tone, which is used to send and receive an industry standard protocol message to and from the BUC (see Teledyne Paradise document 20140 for full details).

The FSK messaging can also be used to communicate with Other Equipment Manufacturers (OEM) BUCs. OEM equipment which have been tested for compatibility with the Teledyne Paradise Datacom L Band Modem are; Codan, Terrasat, AnaCom and NJR. The compatibility is limited to the common commands and functionality between the OEM manufacturers BUCs and the Teledyne Paradise Datacom product.

Operation of the FSK system requires as a minimum the modem to be equipped with the FSK and DC switching card P3503, and also to have the FSK SAF selected. The modem does not require the BUC power supply option P35XX (see page 7) to be fitted, the BUC may be powered separately. Teledyne Paradise vBUCs can be equipped with an AC power supply module, which fits onto the vBUC and provides 48V DC power. Note: A common problem when commissioning the Satellite Terminal is to forget to switch the 10 MHz reference on to the BUC, this will inhibit the BUC and stop it from transmitting.

With the FSK signalling link between the L Band modem and the BUC operational the modem is capable of supplying the following BUC / Terminal status information;

- BUC output power in dBm or dBW.
- BUC output status, on or off.
- Operational mode: Terminal or Independent.
- L Band Modem Tx output power in dBm (dependent on mode set).
- BUC input attenuation in dB.
- BUC Temperature in degrees centigrade.
- Maximum BUC output power in Watts (see power class table fig 16).
- BUC current consumption in amps.

The following BUC alarms are reported into the modem Traffic log;

- BUC temperature out of range.
- BUC PLL out of lock.
- Unable to achieve required BUC output power (Terminal mode only).

The only user selectable BUC control is the BUC input attenuation, which is available when the modem is set to Independent mode.

BUC Status

The BUC status information is available from the LUI under Status (1) and BUC (9). The same information is shown on the WUI BUC Status screen, shown below in fig 20.

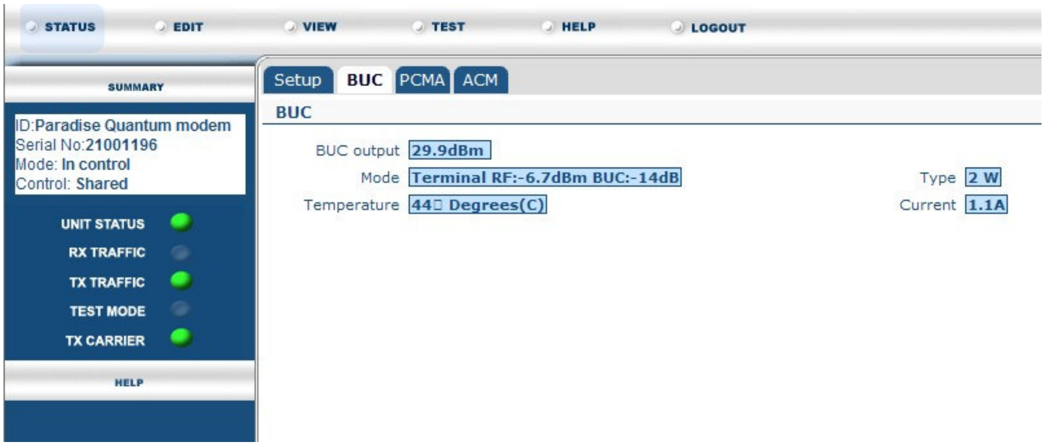


Figure 20

If the System Integrator is planning to use a simple BUC with no FSK messaging the M&C options are limited to monitoring the BUC current. In this instance the System Integrator should choose to use the P3509 DC switching option card. With this fitted only the BUC current will be displayed on the LUI and WUI. Fig 21 shows the effect on the WUI BUC status screen of moving the BUC type to "Other" mode. The BUC output, mode, temperature and power class have reverted to default with only the BUC current display showing relevant data.

BUC current alarms

In this configuration the System Integrator has the option of selecting a BUC power supply alarm to show when the BUC has lost lock. In almost all simple BUCs the loss of the 10 MHz reference, or the failure of the BUC LO circuitry, will result in the BUC output being muted and the DC power to the final output stages of the BUC being switched off. The effect of this failure mode is that the BUC current consumption will change.

The L Band Modem allows the System Integrator to set a high/low current window as an optional BUC power supply alarm. This is available on the LUI under; Edit (2), Unit (4), Advanced (7), Alarms (1) and Thresholds (1). The user will then be asked to set a maximum and minimum operating window for the BUC current monitor. To switch this alarm on the user must move back to the Alarms menu and then select the Actions (2) menu followed by BUC PSU (4).

This will provide the System Integrator with an entry in the L Band modem traffic log, to display that the BUC has failed or the 10 MHz reference / BUC power supply in the modem has a problem.

Receive Wanted signal and Composite power level indicator

The Teledyne Paradise Datacom L Band Modem is equipped with a broadband receive input power meter for the Composite signal as well as a Wanted signal level indication.

This is shown on the LUI and WUI under the Status (1), Demodulator (3) menu. On the LUI the receive levels in dBm are displayed as the wanted signal first, followed by the composite signal level.

The composite level indication is important as it shows if the receive path of the modem is being overdriven and ensures that the demodulator is operating in its correct range for optimum performance.

The L Band modem specifications for the wanted receive level and wanted to composite level are both directly related to the receive symbol rate. The specifications are;

- Minimum receive level = -130 + 10 $\log_{10}$ (symbol rate), to a max of -10 dBm.
- Maximum receive level = -80 + 10 $\log_{10}$ (symbol rate), to a max of -10 dBm
- Maximum wanted to composite = 102 – 10 $\log_{10}$ (symbol rate), to a max of +10 dBm

Considering a 2048 ksps service; the minimum signal level is -66 dBm, the maximum signal level is -16 dBm and the maximum wanted to composite is +38.8 dB.

This means that for the minimum 2048 ksps signal level of -66 dBm, the wanted to composite cannot exceed +38.8 dB, giving a maximum composite level of -66 dBm + 38.8 dB = -27.1 dBm.

For the maximum signal level the specification is not as simple. The wanted to composite level is 38.8 dBm and the maximum composite level is +10 dBm, which means that for the maximum composite level into the modem, the maximum receive signal level is +10dBm -38.8dB = -28.8 dBm, which is considerably lower than the -16 dBm maximum signal level specification for the 2048 kbps service.

On an L Band Satellite Terminal the composite signal level is determined primarily by the output power of the LNB. The LNB provides an L Band signal from 950 to 2150 MHz, comprising all of the downconverted signals from all of the transponders on the satellite (on that polarisation). This will be a much higher level than the wanted signal and the ratio of these two needs to be controlled to ensure that the demodulator performance is not degraded. This becomes more important when operating with larger antennas, where the gain is high and the composite levels can easily exceed the wanted to composite specification. For this reason the System Planner needs to consider carefully the expected composite levels when considering the service they are planning to run.

Satellite Terminal Redundancy options

The Teledyne Paradise Datacom L Band Modem and RF equipment are both able to operate in a stand alone 1:1 redundancy mode. This means that when the System Integrator is planning the Satellite Terminal there are a variety of redundancy protection modes to choose from. The diagrams below show the most commonly chosen Satellite Terminal redundancy configurations, with comments on the suitability of each type.

Basic Terminal no redundancy

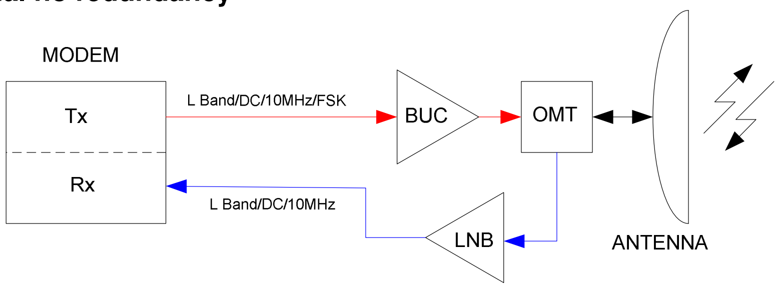


Figure 21

The Basic Terminal block diagram Fig 21 shows the component parts of the Satellite Terminal. Some components have not been shown for clarity, Tx reject filter for example.

Option A: 1 for 1 redundant modems, no RF redundancy

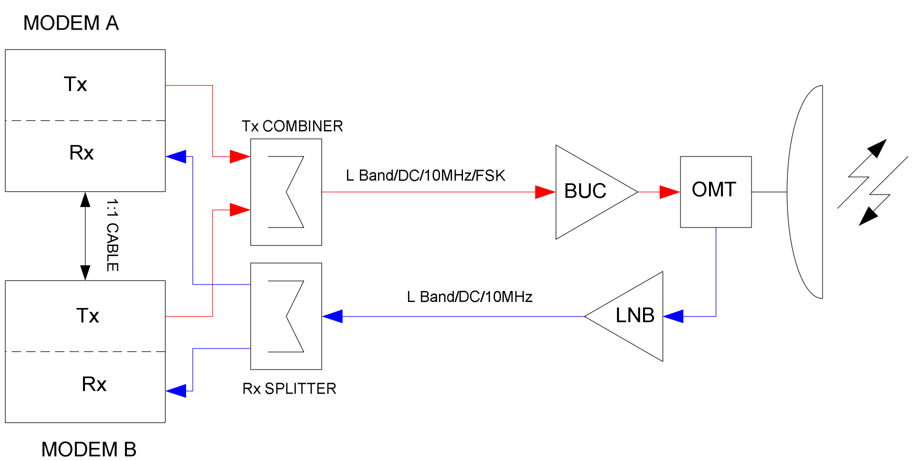


Figure 22

The diagram for Option A shows a redundant modem service with a non redundant RF system. The modems are joined together using the 1:1 redundancy cable and both configured for identical transmit and receive services. The online modem supplies the DC power, 10 MHz reference and FSK signals (if required) to the BUC and LNB, via an L Band splitter combiner. Note the splitter/combiners must be able to pass the L Band signal, plus the services to the BUC. A redundancy changeover will occur when there is a fault on either transmit or receive path of the on-line modem. The changeover moves the traffic on both transmit and receive path to the other modem. In this system it is not possible to have transmit of modem A, and the receive of modem B passing traffic. When the modem redundancy change over takes place the services to the BUC follow the on-line modem and the standby modem will have its services muted. To ensure that the modem is set correctly the System Integrator should configure the modems for “Mute services in standby” mode. This is available on the LUI in the BUC and LNB menus under the 1:1 option and on the WUI it is under the Edit, Tx-Rx, BUC – LNB menu.

The main advantage of this system is that it is fairly simple to configure and maintain. The disadvantage of this system is that it is only provides redundancy for the modems. The RF equipment, which will be fitted to the antenna and will be exposed to the environment, has no redundancy protection.

Option B: No modem redundancy, 1:1 BUC redundancy

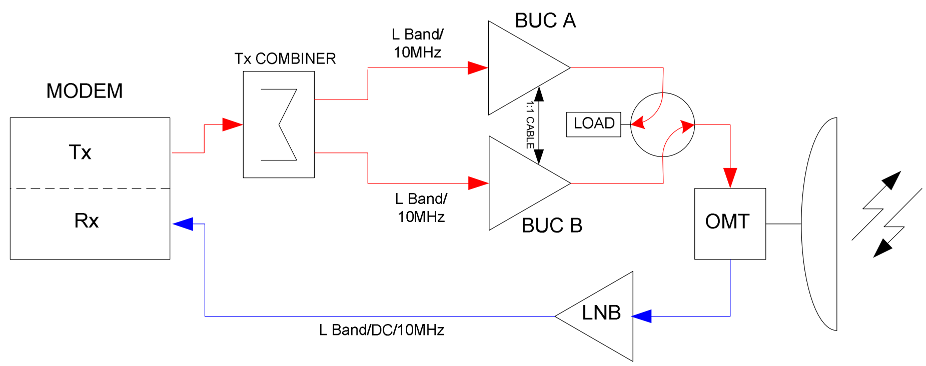


Figure 23

Option B provides a non redundant modem service linked to a 1:1 redundant transmit system. In this configuration the modem does not supply DC power to the BUCs, as it cannot power both of the BUCs at the same time. The solution to this problem is to either use the AC power supply option for each of the BUCs, or supply the DC power to the BUCs from a separate power supply. The BUCs are connected together via a 1:1 redundancy cable, no further configuration is necessary. Changeover will take place when either BUC senses a fault. In this scheme the modem should be configured so that the DC power to the BUC is switched off, The 10 MHz reference is optional and the LNB supply is permanently on.
The advantage of this system is that it is providing redundancy for the BUCs, which are fitted to the antenna and are subject to extremes of the weather. The disadvantage of this system is that it is not possible to use the FSK signalling to monitor the BUC status. This is because both the BUCs will respond to the modem FSK status request and send messages at the same time causing a M&C message collision.

Option C: Redundant Modem and BUC system

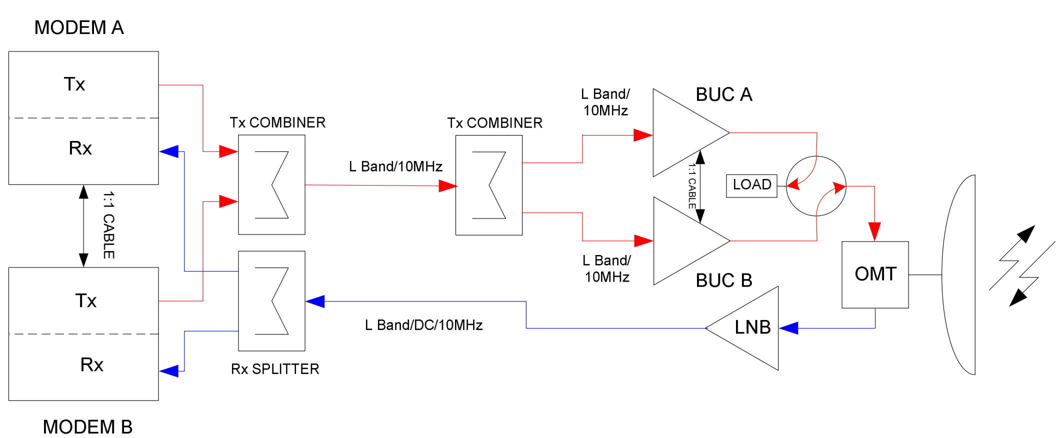
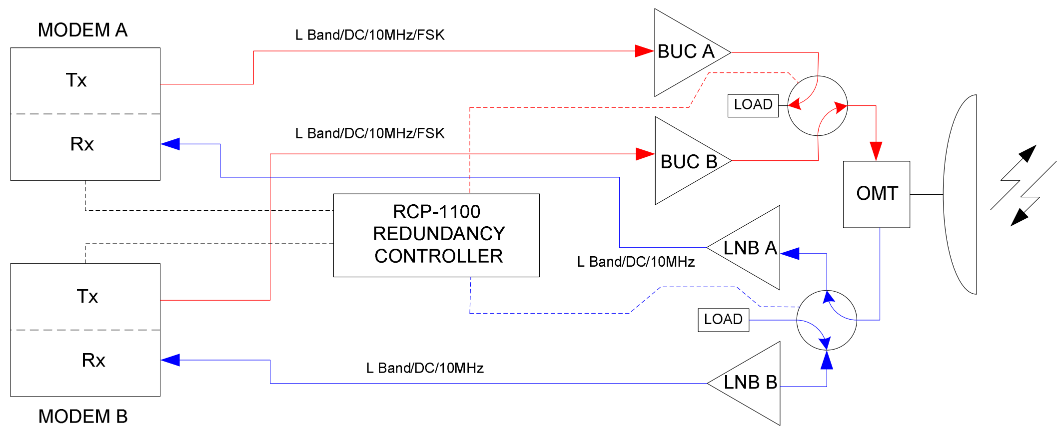


Figure 24

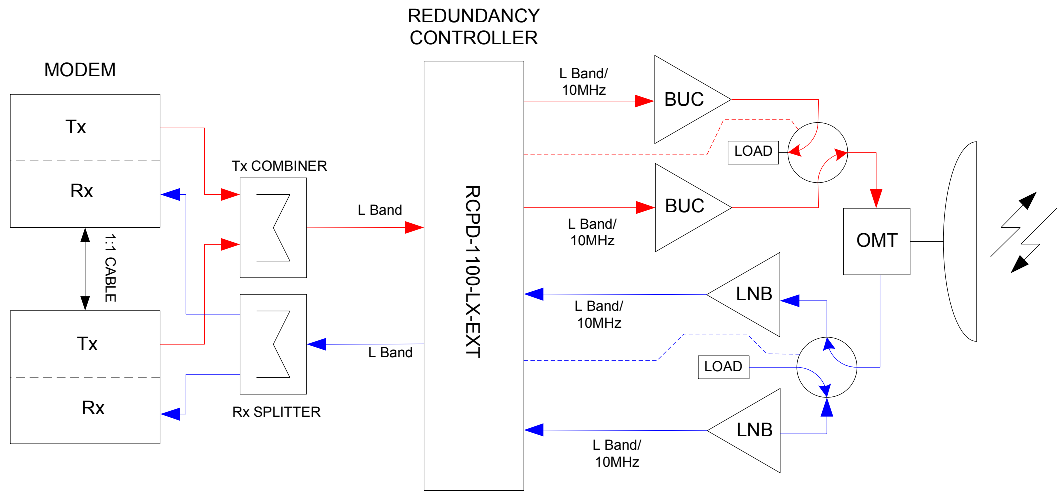
Option C combines the features of options A and B to provide a fully redundant transmit chain with a non redundant receive chain. This is an improvement on options A and B as it provides protection for both the Modems and the BUCs. As in option B the BUCs must have a separate DC power supply as the modem is unable to power both BUCs at the same time. The Modem and BUC redundancy sub-systems will change-over independently from each other. The modems should be configured so that the transmit and receive services are muted on the standby modem. The main disadvantage of this system is that it is not providing any redundancy protection for the LNBs. The other problem is that similar to Option B it is not possible to use FSK to monitor the BUC status.

Option D: Chain redundancy



In option D the transmit and receive path equipment is linked in a "chain" to provide a higher level of equipment redundancy protection. The control for the two equipment chains (A & B) is provided by the RCP-100 redundancy controller. This monitors the equipment status and provides changeover switching controls. If a fault occurs in either the transmit or receive of the online path the system will switch over to the standby path. This an improvement in the level of redundancy protection compared to the previous options but it is not perfect. The main issue with this system is that it is complex for the level of redundancy offered. A failure of two components, one in chain A and the other in chain B will cause the system to shut down. Option E provides a higher level of redundancy protection for an identical similar level of complexity. Wherever possible this system should be replaced with Option E. The only significant advantage of this system over Option E is that it resolves the issues of FSK messaging seen in the previous designs, allowing the modems to report the BUC status.

Option E: Fully redundant terminal



Option E provides the highest level of redundancy protection. All major components within the system operate in 1:1 pairs and can switch independently of each other. The system will continue to operate with one failed component in each subsystem. The RCPD-1100 controller configures the waveguide switches and provides the 10 MHz to the BUCs and LNBs if required. The RCPD-1100 can also provide the DC power to the LNBs and can also be configured to monitor the current consumption of the LNBs. This allows the controller to monitor LNB status and force a switchover if the LNB current falls outside a user configurable current window. In this configuration the modems do not need to provide any services to the RF equipment and should be configured with all services off. The only disadvantage of this system is that it is not possible to use the FSK link to monitor the BUC status.

CONCLUSION

The Teledyne Paradise Datacom L Band Modem and RF equipment have been shown to be easily integrated into an L Band Satellite Terminal system, providing a high level of flexibility for the System Integrator.

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