LE016-R5

Full duplex amateur radio

QO-100 transverter system

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1. Introduction

The LE016-R5 transverter system allows licensed radio amateurs with a standard VHF and UHF radio to be able to communicate with the Qatar-Oscar 100 transponder onboards the geostationary Es'hail2 satellite. The Es'hail2 satellite is a Qatari satellite that has a linear transponder onboard that allows radio amateurs to do experiments and communicate with each other in narrowband and wideband modulations like SSB and DVB. The transponder has a 2400 MHz receiver and the downlink is done with a 10 GHz downlink transmitter.

These two frequency bands are in the microwave region, and is not commonly available with standard amateur radio's. Access to these higher microwave bands is normally done with upconverters and downconverters in combination with more standard available VHF and UHF radio's that are used as an Intermediate Frequency (IF).

In case of the QO-100 transponder a 2400 MHz upconverter is needed for the transmit section and a 10GHz downconverter is needed for the receiving section. For a complete full-duplex system several modules are needed which interact with each other in a correct way.

The reason that general amateur radio's do not cover the microwave frequencies higher than around 1 GHz is because the cable losses are very high. To overcome these losses it is possible to used power amplifiers and low-loss cables, but this will come at a high cost. A better solution is to use a general VHF or UHF radio and use these in combination with up- and downconverters that are close to the antenna.

The LE016-R5 transverter unit makes use of this concept. It combines a 435 MHz to 2400 MHz upconverter and a 10 GHz to 145 MHz downconverter in one single box. It is small enough to be mounted near the feed point of the dish antenna to minimize cable losses and in such a way having maximum power efficiency possible.

As the LE016-R5 is housing the upconverter as well the downconverter it is called a *transverter*. The LE016-R5 is a full-duplex transverter because it allows transmitting and receiving at the same time.

By having the transverter close to the antenna it must be able to withstand all weather conditions and operate at a wider temperature range than indoor equipment. The LE016-R5 transverter is a waterproof system specifically designed to work in an outdoor environment. Due to the integrated oven-controlled reference oscillator the LE016-R5 transverter has very low frequency drift over the wide temperature range.

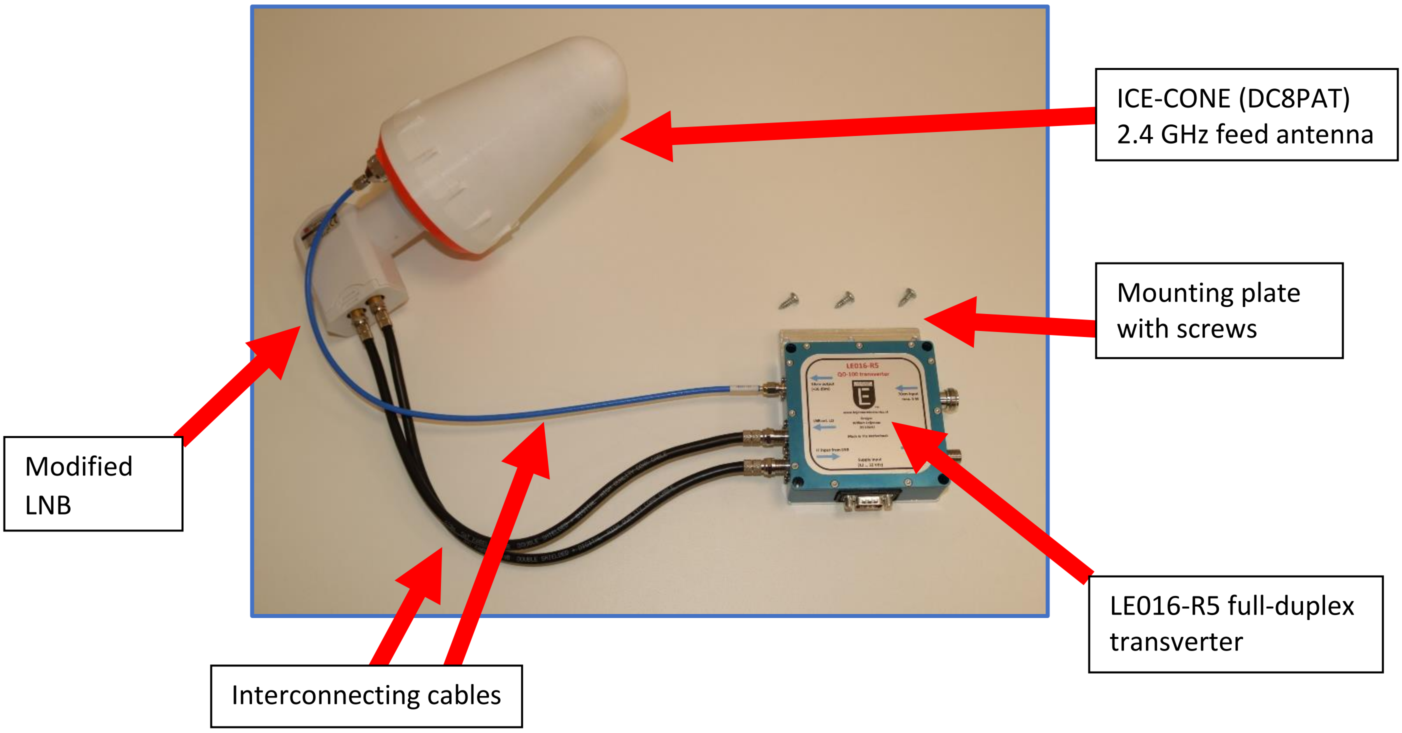
2. The full-duplex LE016-R5 transverter system

The LE016-R5 transverter makes use of a modified external LNB that handles the 1st down conversion off the 10 GHz satellite downlink signal. Because off this configuration the total system performance is dependent on it. The same is true for the uplink feed antenna, which needs to be a right match for the used parabolic dish antenna. The same also is true for the interconnection cables, that need to be of good quality.

For the above reasons the LE016-R5 transverter will be only available as a complete system which includes the LE016-R5 transverter, the modified LNB, the ICE-CONE feed antenna and all the needed interconnecting cables. The picture below shows a complete QO-100 transverter system.

Before the system can be used it first needs to be installed on a parabolic dish antenna, which can be a general TV offset dish available from any TV satellite shop. In the next chapter this will be further explained.

In the picture below the complete LE016-R5 transverter system can be seen.



3. Which offset dish antenna to use ?

The system is designed to work with a parabolic dish reflector of F/d = 0.6, like most standard TV offset dishes available in Europe. For SSB communication a smaller diameter dish can be used compared to when receiving DVB signals. SSB communication works well with a dish diameter in the range of 60 cm to 80 cm, while DVB needs a dish size of at least 80 cm when using the Ice-Cone feed.

In the table below you can see possible antenna configurations that can be used:

Mode	Offset dish diameter	Remarks
SSB full-duplex only	60 cm up to 80 cm	
SSB full-duplex and DVB receive	80 cm up to 120 cm	! Reduce power with SSB uplink
DVB receive only	Down to 60 cm (LNB only)	Ice-Cone helical feed removed*
DVB full-duplex**	More than 150 cm	Need additional PA

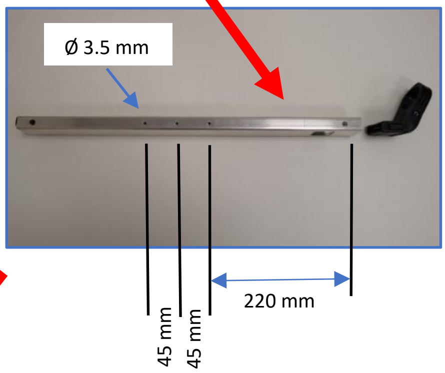
*   The Ice-Cone feed degrades 10 GHz reception, which has more impact on smaller dish sizes.
** This mode has not been tested yet.

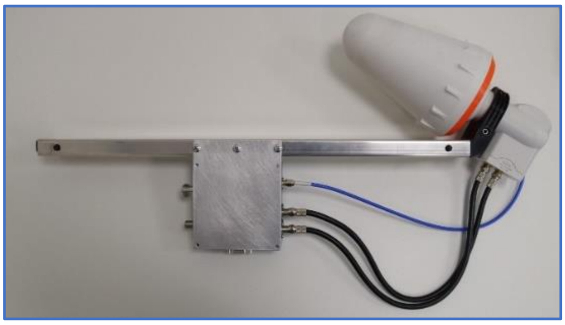
4. Installing the transverter system on an offset dish

To make installation easier the transverter system comes with a mounting plate that works as an interface between the transverter and the feed arm of the offset dish. In case the feed arm can not be disconnected from the dish antenna it is possible to separate the transverter from the mounting plate, making it easier to work with. The transverter can be separated by unscrewing the four socket head screws in each corner of the transverter enclosure.

Below the mounting of the transverter system is explained without separating the transverter from the mounting plate.

Take the feed arm of the dish antenna and drill the mounting holes





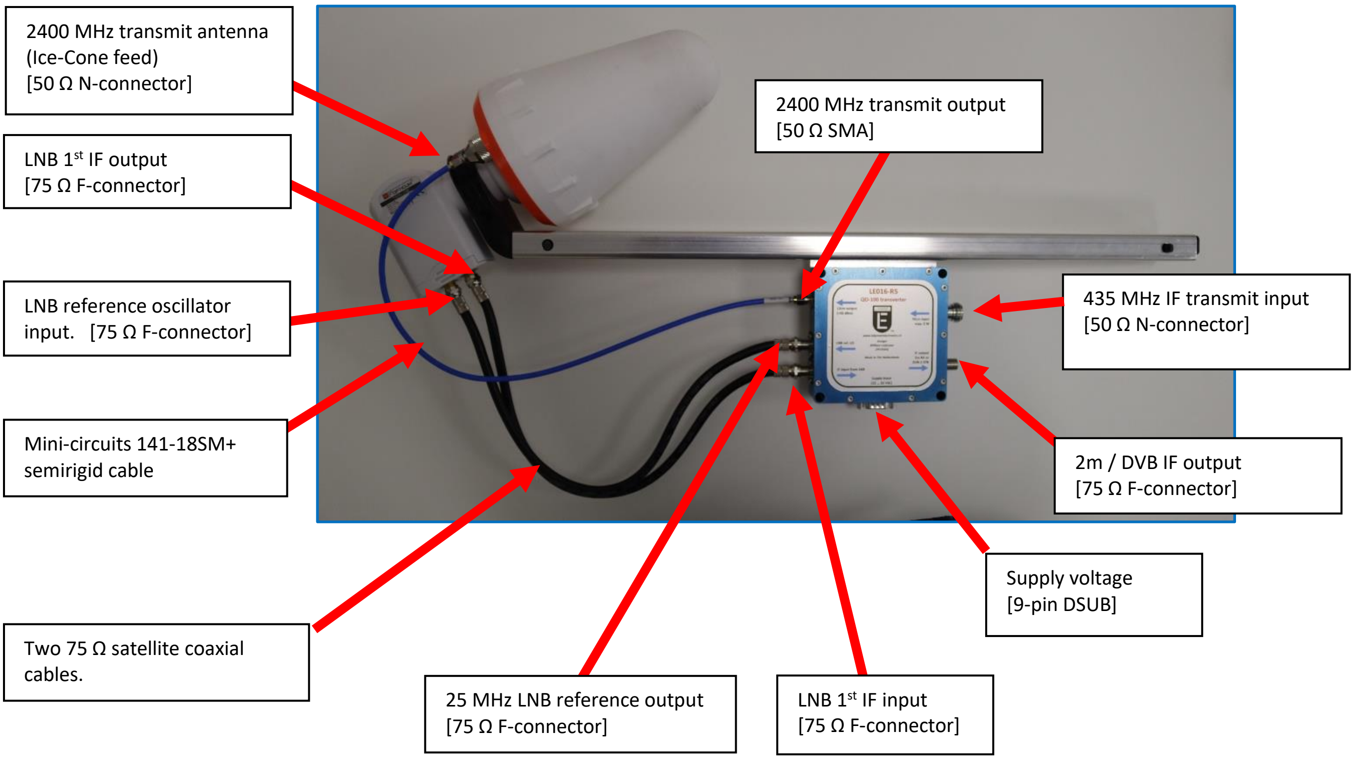
Connect the LE016-R5 transverter and the Ice-Cone feed antenna to the feed arm.

Put the whole system back on the offset dish.

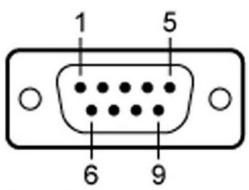
Connect the VHF and UHF IF cables and DC supply cable.

5. Connecting the interconnecting cables

The cables between the LE016-R5 transverter, modified LNB and Ice-Cone feed antenna have to be connected as shown in the picture below.



5.1 The 9-pin DSUB power supply pinning is shown below:



Pin 1,6 : GND
Pin 5,9 : +Vdd (12 V ... 32 Vdc)

6. Important note before we start to connect our VHF and UHF radio's

Before you connect any 2m radio or 70cm radio to the transverter please make sure you set BOTH RX and TX radio's at their lowest transmitting power setting. This should be no more than 5W to avoid internal damage to the transverter.

In case you use a 2m transceiver at the 2m IF receive side, please make sure the transmit power setting is no more than 2 Watts. It avoids internal damage to the transverter in case you grab the wrong microphone. The LE016-R5 transverter has an internal overload protection at the IF output port that can handle 2 Watt RF input power for a short moment of time.

7. Connecting the 2m and 70cm radio's

After we set both radio's to their lowest power setting they can be connected to the transverter. The 70 cm transmit radio needs to be connected via a 50 Ω coaxial cable having a male N-connecter at the transverter side. The 2m IF downlink need to be connected with standard 75 Ω satellite coaxial cable having at both ends an F-connector. The 75 Ω satellite cable can be connected to the 2m radio with the supplied F to BNC connector.

Note: Because the same IF output can be used to receive DVB signals on a set top box 75 Ω satellite coax is used. The impedance mismatch for the 50 Ω VHF radio is for receive mode not an issue.

The power supply to the transverter is done via the 9-pin DSUB connector. The pinning can be found in chapter 5.1. Please make sure and double check the right voltage polarity at your power supply.

In the pictures below the connection of the radio's (FT-847) to the transverter can be seen.

70 cm IF input
[50 Ω coax cable]

2 m / DVB IF output
[75 Ω satellite coax cable]

DC power supply
[9-pin DSUB with Blank/Red DC cable]

70 cm transmitter IF output
[50 Ω coax cable]

2 m IF input
[75 Ω satellite coax cable]
! Note: Using adapters F → BNC → PL

NOTE:
The FT-847 radio in the picture has both the UHF transmitter and VHF receiver build in and is the most compact way to do full-duplex satellite communication. In most cases two separate radios have to be use which doesn't diminish functionality.

8. The supply voltage

Before switching on the power supply to the transverter make sure your power supply can deliver enough current. In the table below the minimum current rating is shown.

Power supply voltage	Minimum current rating
12 Vdc	3.0 A
24 Vdc	1.5 A
32 Vdc	0.8 A

Note: Make sure you are using low voltage drop cables, especially at 12 V supply voltage where currents are higher and therefor the voltage drop is more when using thin and/or long cables. When using too thin and/or too long cables the voltage level at the transponder will go below the operating voltage. This will then cause instability and in the extreme case this can cause permanent damage to the transverter.

When operating the transverter in close proximity to shortwave antenna's interference might be experienced from the radiated high power shortwave energy. Although the transverter is fully shielded and its supply circuit has RF absorbing capacitors, it is not tested under these conditions, and no guaranty can be given to its behaviour.

8.1 After powering up the transverter

A few seconds after switching on the power supply there should be a noticeable increase in noise at the 2m receiver. This is completely normal as the receiver system has a lot of gain.

Additionally, for frequency stability the transverter has an internal oven controlled oscillator that keeps the crystal reference oscillator at a very constant elevated temperature. This guaranties that the uplink and downlink frequencies having ultra-low drift and will not be affected by thermal variations from outside.

After applying supply voltage the oven-controlled-oscillator will first need to warm up to its operating temperature. This warming-up time will take around 1 minute and is depending on the outside temperature.

During the warming-up time the transverter will draw some more current, and over time when the oscillator is approaching its operating temperature the current will slowly drop to its nominal value.

9. Optimizing antenna direction

Depending on the location on the earth you have to figure out what direction the satellite is standing at. The actual polarisation is also depending on your position related to the satellite.

The easiest way to find the last few degrees off pointing accuracy is by tuning the 2m receiver at the CW beacon frequency (144.500 MHz) and listen for the maximum possible downlink signal coming from the satellite.

After the best satellite pointing position has been found the horizontal/vertical angle can be optimised by slightly rotating the LNB to the left or right. For stations in Europe this is only for a small degree, but in other locations in the world you might also have to optimize your LNB horizontal/vertical angle. On request the transverter can be set in inverse LNB mode.

10. Quick operating procedure

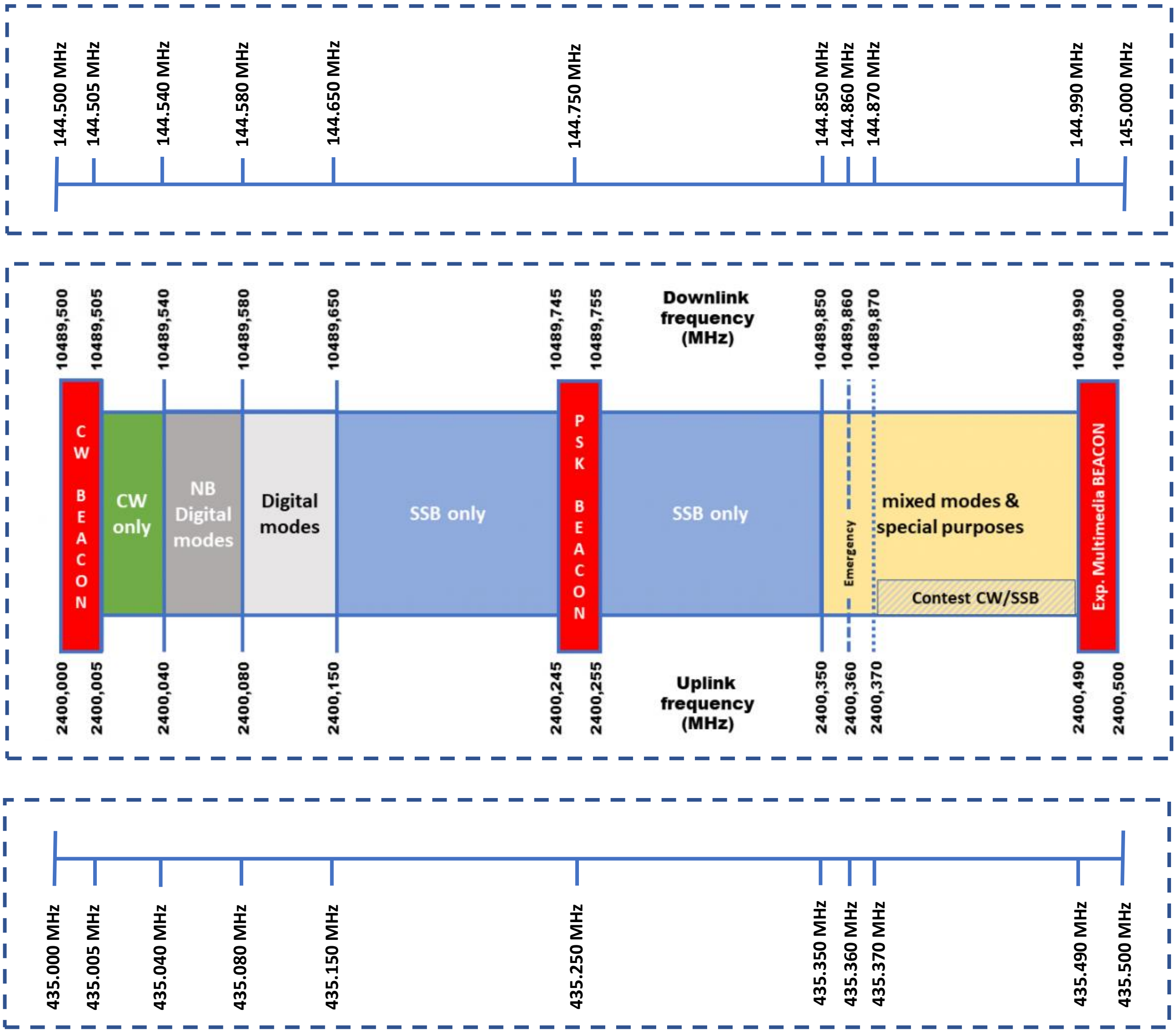
Please follow the following steps each time you want to work the QO-100 transponder:

A) Set your 70 cm transmitter to minimum output power (no more than 5W)
B) Set your 2 m receiver to minimum output power (in case you use a transceiver)
   - Preferable remove the 2m microphone to avoid mistakenly using it.
C) Tune your 2m receiver radio to the CW beacon, which is at 144.500 MHz in USB mode
D) Tune your 70cm transmitter radio to 435.000 MHz in USB mode. (! Do not transmit)
E) Power up the LE016-R5 transverter system
   - An increase of the noise floor will be noticeable on the 2m receiver
F) We need to wait for about 1 minute for the oven-controlled-crystal to warm up.
   - After a while the CW beacon can be heard moving in on frequency.
G) Tune your 2m receiver to the transponder area you like to work on. (E.g. 144.670 MHz)
   - Make a note of the frequency difference compared to the CW beacon
      - (144.670 MHz – 144.500 kHz = 0.150 MHz in this example)
H) Tune your 70cm transmit frequency the same amount as with the 2m receive radio
      - 435.000 MHz + 0.150 MHz = 435.150 MHz in this example)
I) You can now start to transmit.
   - ***!! Make sure you have reduced the TX power like mentioned in section A !!***
J) While transmitting you can slightly tune your 70cm transmitter to get a better uplink/downlink frequency match, and increase uplink power (no more than 5 W at 70cm)

11. Transverter frequency translation diagram

The table below shows in the middle the actual transponder frequencies with their corresponding uplink vs downlink frequencies. On the top side the corresponding downconverter VHF frequencies are shown, while on the bottom side the corresponding upconverter UHF input frequencies are shown.

LE016-R5 down-converter part



LE016-R5 up-converter part

12. LE016-R5 characteristics (preliminary)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Vcc	Supply voltage		12.0	-	32.0	V
Idc_rx	Supply current in rx mode	Vsupply = 12.0 Vdc	344	356	364	mA
		Vsupply = 24.0 Vdc	200	206	211	mA
Idc_tx	Supply current in tx mode	Vsupply = 12 Vdc, fin = 435 MHz Pin = 37 dBm	1.75	1.86	1.96	A
		Vsupply = 24 Vdc, fin = 435 MHz Pin = 37 dBm	0.89	0.94	0.98	A
Pin_avg	70 cm maximum average RF input power	Continues wave mode			37	dBm
Pin_peak	70 cm maximum peak RF input power	Maximum 50 % duty-cycle pulsed			40	dBm
Pout	2400 MHz	2 W input power at 435 MHz	34	35		dBm
OP1dB	Output P1dB point	2400 MHz output		38		dBm
OIP3	Output IP3 point	F1 = 2399.900 MHz, P1 = +30 dBm F2 = 2400.100 MHz, P2 = +30 dBm		40		dBm
VOX (RF power activating TX switch)	PTT activation	435 MHz input power	23			dBm
	PTT de-activate	435 MHz input power			20	dBm
	Activation time			0.5		sec
	Deactivation time			3		sec
Prev_avg	Maximum RF power injected at the 2m IF output port	Tested with 5 m long satellite coaxial cable, for a duration of 30 seconds			33	dBm
G_rx_ssb	SSB transverter downconverter gain	Fin = 739.50 MHz, Pin = -60 dBm Fout = 144.50 MHz Mode = SSB		5.5		dB
G_rx_DVB	DVB transverter downconverter gain	Fin = 740.00 MHz, Pin = -80 dBm Fout = 1580.00 MHz Mode = DVB		28.0		dB
G_tx_SSB	SSB upconverter gain in the linear range	Fin = 435.00 MHz, Pin = 33 dBm Vsupply = 12 … 32 Vdc	2.23	2.89	3.35	dB
V_lnb_vert	LE016-R5 LNB supply output	Vertical mode		13.30		Vdc
V_lnb_hor	LE016-R5 LNB supply output	Horizontal mode		18.75		Vdc
I_LNB_prot	LNB supply current protection	Both vertical and horizontal mode		600		mA
LNBrefLvl	LNB reference level	25 MHz reference freq. selected		1.5		Vpp
LNBref2nd	LNB reference harmonics suppression	Measured at 50 MHz relative to the 25 MHz LNB reference level	-60			dBc
LNB_Freq	LNB reference frequency	Measured with GPS locked analyzer	-3.3	- 1.0	0.5	ΔHz
LNB_RefPN	LNB reference phase noise			t.b.d		dBc/Hz
Fref_stab	Reference oscillator stability	Factory reference stability		± 300		ppb
Fref_drift	Reference oscillator drift	After 5 minutes warming-up time		± 10		ppb
T_op	Operating temperature range		-20		+70	°C