System Application Note

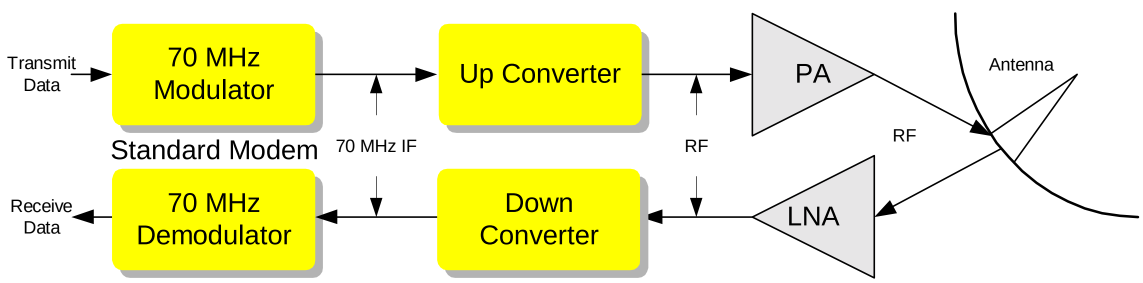
Build Robust Small Terminals Using Datum Systems "Hybrid" Modem

Introduction and Background:

The past 5 years have seen several attempts to simplify and lower the cost of small satellite earth stations. These stations are often called VSATs for Very Small Aperture Terminals, meaning literally that they use small antennas, but generally describing a small low cost station. This type station is often one of many that are all connected in a star network to a "Hub" site. Since there are many VSATs and only one or a few hubs then the obvious place to lower system cost is at the VSATs.

The small antenna is possibly the greatest lowering in costs and is made possible by improved, more powerful satellites, and the use of Ku-Band satellite frequencies. The ability to use small antennas not only reduces the cost of the antenna itself but also of the civil works, installation and mounting requirements.

A block diagram of the typical "Classic" satellite station components, whether in a hub or VSAT is shown below.

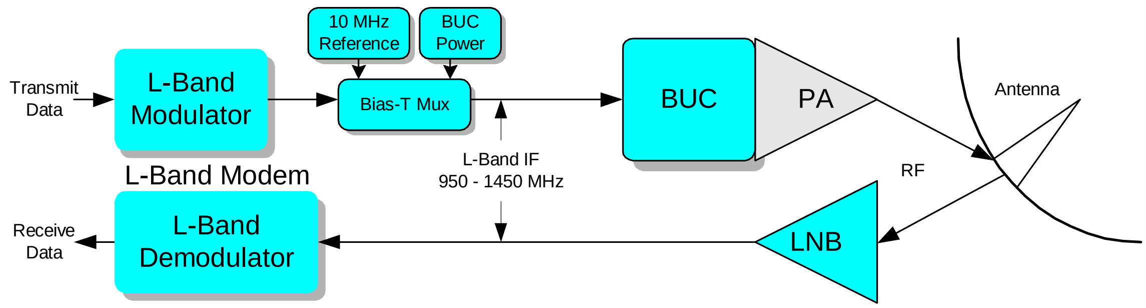


Classic Satellite Station Components

If these components were used in a hub site there would be splitters and combiners in the transmit and receive 70 MHz IF lines to allow connection of many modems sharing a single, or redundant, converter set.

Work on lowering the station equipment costs for VSAT use have centered on simplifying the up and down-conversion equipment and integrating functions into the modem. The first major change to ground station equipment design has been the use of readily available Low Noise Block Downconverters (LNBs) made popular in satellite television transmission. A companion change to the upconverter chain is being used now in the form of a Block Upconverter with integral Power Amplifier, commonly referred to as a BUC.

A block diagram of the revised full L-Band IF station is shown below.



Full L-Band IF Satellite Station Components

In this diagram note that the modem transmit and receive both operate at L-Band frequencies. This has transferred some of the cost of the converter equipment into the modem. Removing its high stability reference and power generation from AC line, and placing that equipment in or near the modem further reduce the converter equipment cost. Of course this cost still exists, but is shifted indoors, increasing the cost of the modem and associated equipment. But, there is the definite advantage of simplifying the outdoor equipment, and isolating the high stability reference from the rigors of an outdoor environment. It also means that typically no AC power is required at the antenna location unless de-icing is needed.

> ***Sidebar – Speed vs. Cost***
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> One recurring misconception about transmission equipment is that a higher data rate or wider band signal requires more expensive equipment. One serious consideration is exactly the opposite – the phase noise contribution of every oscillator in the signal chain must improve at lower data rates in order to avoid affecting the Eb/No of the signal. Thus an inexpensive LNB used to receive a multi-megahertz analog or multi-megabit/second digital TV transmission is totally unsuitable for data reception at 2.4 to 256 kbps. A good quality data grade phase locked LNB is a necessity in data terminals. On the transmit side a very high quality, low phase noise reference oscillator is required which usually cost several hundred dollars itself.

The converter manufacturers also like the BUC concept because it makes their equipment look less expensive. And we have found that most BUC manufacturers do not have an assembly that provides needed support including Bias-T Mux, Power and Reference, assuming instead that these functions are automatically included in the modem.

Datum Systems has manufactured a full L-Band modem, the PSM-2100L, for several years. Datum’s modem design, which directly modulates and demodulates at the carrier frequency is ideal for this type system. No upconversion was required, just a wide band synthesizer in the 950 to 1650 MHz range. The 2100L can also be programmed with the BUC’s LO frequency and then automatically displays and works at RF frequencies, acting as if the modem/BUC combination were a single unit. Much of the money saved in the 70 MHz to L-Band upconversion however went into shielding to separate the transmit and receive.

Problems in Paradise.

Although this total design concept is very appealing because of the simplicity and reciprocity of the transmit and receive signal chains, there are several practical problems with a full L-Band IF approach.

First, the L-Band transmit IF cable run becomes critical.

- Because of the wide total band of frequency used (a full octave in some systems from 950 to 1900 MHz) the cable frequency response slope means that the transmitted power changes with frequency.
- At these L-Band frequencies the temperature variation of cable loss can be significant. In a desert environment where the day to night temperature difference may approach 30 degrees C the variation may be almost 2 dB.
- Since the transmit and receive are at similar frequencies, cross-talk between the transmit and receive cable runs becomes critical. Consider that the end of the cable run nearest the modem will have the highest transmit power, and the same point on the receive side will have the lowest receive signal level. The difference can easily be close to 90 dB.

Second, combining multiple modems at L-Band frequencies becomes a potential problem:

- All of the problems of a single modem are exacerbated when trying to add a combiner into the IF Link.
- The power supply and 10 MHz reference is normally part of the modem, but the Bias-T (power and reference insertion) logically belongs between the combiners and BUC and LNB.
- Connectors in a multi-modem station represent a more significant problem because they are a possible source of leakage between the transmit and receive IF links. This becomes worse again because of the typical type “F” connector used at L-Band, which are difficult to seal against RF leakage.

Datum Systems sought to alleviate the problem of different BUCs and possible multiple modems by separating the Bias-T Mux from the modem itself.

Gain variations can be taken care of by using an Automatic Level Control (ALC) loop between the modem and the transmit output, encompassing all common sources of level error. The problems with this approach are:

- Good quality RF level detectors are expensive and typically have frequency response slope themselves which can only be removed by calibration.
- The modem and BUC must now have a system to communicate and agreement on a standard set of protocols and controls. This is less of a problem when one manufacturer integrates all the equipment.
- A feedback loop is seriously compromised when multiple modems are desired at the station. Not only is there a question of who controls the level, but also the combiner circuitry must be able to pass the control protocol.
- Small terminals with one or multiple modems that “burst” information also causes significant problems for the leveling loop.

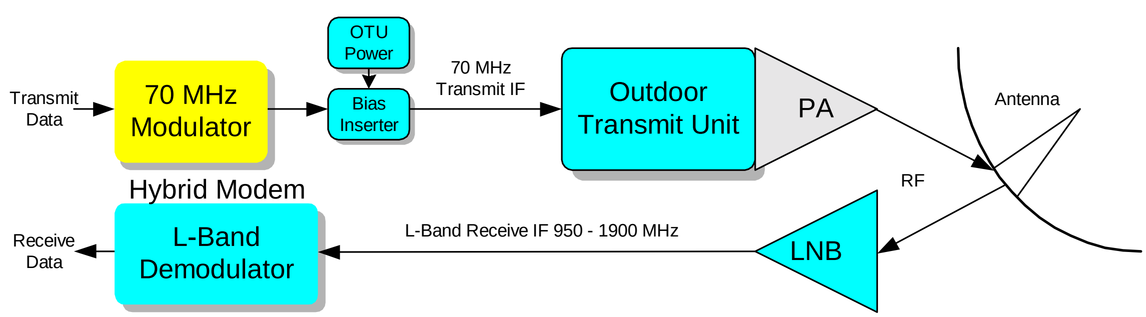
The issue of a standard set of controls and design agreement is another problem when dealing with the different manufactures of L-Band modems available and of BUCs available In virtually all cases the BUC manufacturer believes that the “Bias-T” is not their responsibility, even though 100% of the function is meant to support the BUC. The function of the Bias-T includes multiplexing the power and reference signals onto the transmit IF cable.

A “Hybrid” Solution

Datum Systems is now producing a new modem design intended to solve the issues and problems mentioned above. The new design in our PSM-4900H Satellite Modem is called a “Hybrid” modem and incorporates an L-Band Receive IF and a more standard 70 MHz transmit IF. This is a step back from a full L-Band station design, but we believe that the advantages of this design far outweigh the disadvantages. We also believe that in addition to creating a more robust station it actually lowers the cost of building the station. Here is how it breaks out.

- Transmit level stability, frequency response and variation are greatly reduced, even over longer distances. The 70MHz IF is not only extremely stable with temperature, but the total 40 MHz band has very little slope compared to the approximate 700 MHz of an L-Band IF.
- IF link transmit to receive cross-talk is eliminated due to the vastly different frequencies and the better shielding performance of cables at 70MHz.
- Connectors performance of the normal BNC and type N connectors is far superior to that of type F, and exactly where its needed on the transmit chain.

The modem internal design is simplified - especially considering the reduced shielding requirements. This results in a lower cost modem. A block diagram of a “Hybrid” system is shown below.



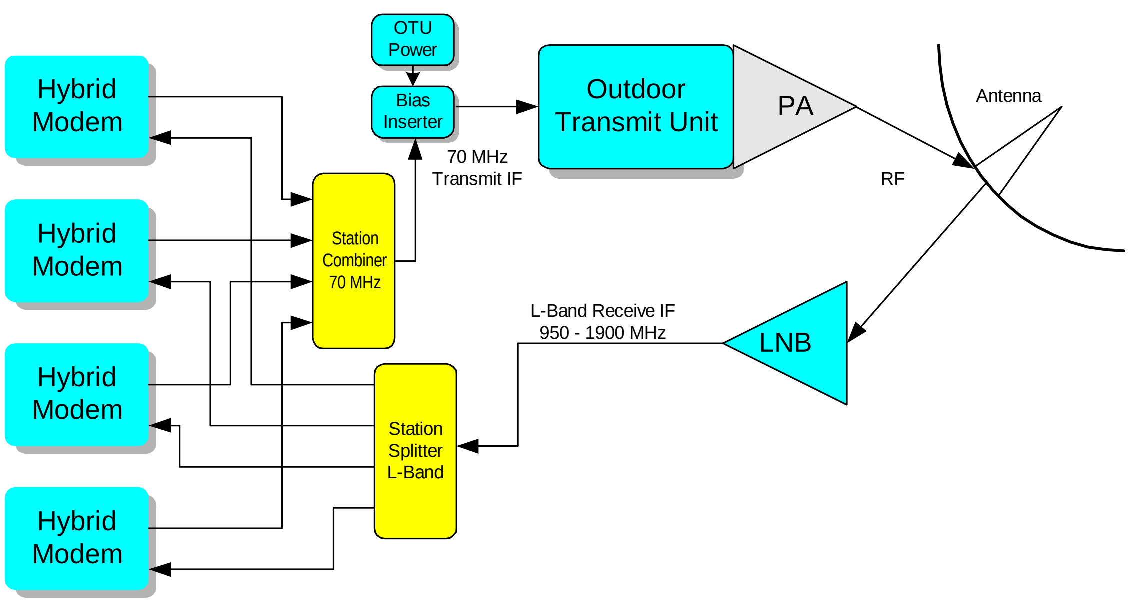
Hybrid 70 MHz / L-Band IF Satellite Station Components

In this hybrid station design the Outdoor Transmit Unit, or OTU, typically contains the high stability reference oscillator, but still uses the transmit cable to bring its DC power in. The OTU cost compared to a BUC with an L-Band transmit IF is increased because of an added tunable up-conversion from 70 MHz and the inclusion of the reference, but these functions had to be done somewhere in any event. That cost is now shifted from the modem back to the converter. The lower transmit cable cost and the simplified Bias-T recover some of the higher OTU cost though.

The receive chain remains the same as the full L-Band station design, so the costs remain low or could be slightly lower because the sensitive receive is relieved of having to deal with wayward in-band transmit signals. In this new hybrid station diagram notice that the receive L-Band frequency range is 950 to 1900 MHz. The PSM-4900H is designed to tune over a full octave allowing one modem to work with current and future LNBs that cover expanded ranges.

Hybrid Modem Station Designs are Flexible

Consider now that we might want to add more modems at this hybrid station. Just as in the hub station where we share the cost of the converter equipment among all of the modems, that advantage is available here, because each modem is less expensive. The more modems at this small station the more savings are realized. A block diagram of a multi-modem small station is shown below.



Multiple Hybrid Modems in a Small Station

Notice where the transmit power bias inserter is located in a multi-modem station. This configuration would represent a problem in the typical L-Band Modem that includes the BUC power and reference within the modem itself. How do you get the power and reference through the combiner? A "Wilkinson" type combiner could possibly couple the power through, although the current is normally Amps. The combiner may however have trouble with the 10 MHz reference. The hybrid design is vastly superior in this case.

The same situation could exist in the receive direction. The Datum Systems' PSM-4900H is capable of inserting power and reference on the receive cable under electronic control via the front panel or remote control. The typical LNB current of less than 1/3 Amp would be no problem for either a Wilkinson design splitter or special splitters with one DC pass thru port. See the sidebar on "*Redundant LNB Power*". The reference for most common data grade phase locked LNBs is located in the LNB itself, relieving the splitter of passing the reference signal through.

Not all Roses

If all of this sounds too good there are some lost advantages compared to an L-Band modulator and BUC. First is that obviously the upconverter is more expensive than a BUC, mainly because it now requires double conversion and a flexible LO to allow tuning. The BUC uses just a single fixed LO.

Since the upconverter must be tuned we have potentially lost the single point transmit frequency setting. In reality the upconverter is normally used to tune to a specific satellite transponder, so the tuning is rarely changed.

At Datum Systems we have been working to help reduce both disadvantages. First, working with upconverter manufacturers to reduce the cost and present new methods of setting the upconverter tuning. For most upconverters the majority of the cost is the power amplifier, casting and the high stability reference, both of which are not affected by whether the design is a BUC or a true upconverter.

Several unique possibilities are also becoming available. One new OTU design allows tuning of the outdoor upconverter using a Palm Pilot type IrDA interface. This should work fine in the majority of cases where a single transponder is used and rarely changed. A control link between the modem and OTU will permit single point control and RF frequency setting, but requires 'smarts' in the modem and a common protocol to be established.

Sidebar – Redundant LNB Power

The PSM-4900H Modem has a current limited power output on the receive input connector used to send either 13 or 18 VDC up the receive cable to power the LNB. This power can be turned on or off. If a Wilkinson splitter is employed in the station and if multiple modems all supply power then the supply becomes redundant. If one modem is turned off or removed, the other modem(s) take over the supply.

Caution! – Multiple modems should never be set to supply the 10 MHz reference. A "beat" frequency would be generated by the small difference between the 10 MHz sources causing severe LNB performance problems.

Sidebar – LNB Reference

In most commercial LNBs the cost of a unit with an integral reference providing approximately 10 ~ 15 kHz accuracy is actually less than the same unit that accepts an external reference sent up the IF cable. Apparently this results from the cost of the added circuitry required to accept an external reference. The LNB power consumption also seems to rise along with the price of a unit accepting an external reference.

One disadvantage we have noticed with some internal LNB references is a tendency to be "microphonic". This could be an issue at low data rates when, for example, a hailstorm causes heavy pelting of the antenna, LNB assembly.

New Technology for a New Generation of Low Cost VSATs.

An exciting new addition now available in the PSM-4900 standard and Hybrid modems is the incredible Turbo Product Codes FEC. This FEC offers improved performance over even a concatenated Reed-Solomon and Viterbi FEC. The improved performance allows a smaller antenna/power amplifier combination in addition to less satellite bandwidth.

This new Turbo Product Codes, or “TPC” technology improvement can attack the costs of three constant and expensive components in all of the previous designs discussed – the power amplifier, the antenna and the satellite usage costs. Once the power output required gets above approximately 1 or 2 Watts the PA cost goes up very quickly. It could easily override the costs of the other station equipment. If the antenna cost size/cost is reduced this represents a significant potential savings in installation and civil works in addition to the cost of the antenna itself. Lastly, the satellite usage charges can be reduced by less bandwidth or power required to operate the system.

In the case of satellite resources, TPC lends itself well to Automatic Uplink Power Control (AUPC, also available in the PSM-4900 series modems), even in C-Band systems. This is true because TPC can operate at such a low Eb/No that little margin would be left in a system. By lowering the operating Eb/No and allowing AUPC to handle the margin with many VSATs means that the average power can be significantly reduced. This option does however have potential complications and may not be usable in ‘burst’ type systems without sophisticated system control software.

The TPC type FEC represents a real 2~3 dB improvement over a Viterbi FEC. It also represents a real 0.5~2 dB improvement over even a concatenated Reed-Solomon/Viterbi type FEC. Datum Systems’ new TPC FEC is also low cost, and fully selectable for either Rate ½, ¾ or 7/8 allowing a tradeoff between power and bandwidth usage. This tradeoff can be used to select which components of the system are cost reduced by inclusion of TPC.

Specific examples of using TPC are:

- Use ½ Rate TPC instead of ½ Rate Viterbi to reduce power required by approximately 3 dB.
- Use 7/8 Rate TPC instead of ½ Rate Viterbi to reduce bandwidth required by over 40%.
- Use 3/4 Rate TPC instead of ½ Rate Viterbi concatenated with Reed-Solomon to reduce bandwidth required by approximately 40%.

Many other possibilities exist, but in all cases TPC technology can reduce the cost of building a VSAT or a hub station. As of the time of this document the Datum Systems TPC performed significantly better than any other manufacturer’s published data.

A Comparative Analysis of Low Cost VSATs.

Let's look at some real numbers to show comparisons of popular Standard, Full L-Band and Hybrid systems approaches. This comparison is based on a hypothetical small station that will operate with approximately 256 kbps QPSK. Prices are relative only and presented in 1000s of dollars.

VSAT Cost Comparison				
Comparison Component	**Standard 70 MHz**	**Full L-Band**	**Hybrid with Viterbi FEC**	**Hybrid with Turbo FEC**
Modem Cost	3.5	4.5 (note 1)	2.8	3.0
Converter/BUC Cost	9	2 ~ 6	2.5 ~ 8 (note 2)	2 ~ 8 (note 2)
Antenna Size	1	1	1	.7
Antenna Cost	1.5	1.5	1.5	1 ~ 1.5
Bandwidth	1	1	1	.6
Power Amplifier Output Power	4 Watts	4 Watts	4 Watts	2 ~ 3 Watts
Total Cost	14	8 ~ 12	6.8 ~ 12.3	6 ~ 10
Operating Cost/Year	4	4	4	3

Notes:

1. *Bias-T/Mux plus 10 MHz reference and power supply costs are included with the modem in the full L-Band system,*
2. *Bias-T and power supply costs are included with the converter for Hybrid systems.*

A word of warning about the costs is in order. This is not a quote for equipment. The numbers are mainly relative and any specific configuration can be found that costs more or less than the numbers stated above. The point is that a full L-Band system is about 30% less than a classic standard configuration. The addition of a well-designed hybrid modem with Turbo Product Codes FEC results in an even lower equipment costs and lower operating costs. Another important point to be derived here is that as the bandwidth and power requirements increase the operating costs can overtake the equipment costs in a short period of time. Here the Turbo Product Codes advantage is significant.

Conclusion.

The result of Datum Systems' latest work in "Hybrid" modem design and implementation of low cost, high performance Turbo Product Codes FEC can result in significant VSAT station and system cost reduction. This equipment will also definitely produce a more robust, reliable and flexible small satellite station design.

See our web site at www.datumsystems.com for more information and breaking news on these and other modem innovations.