Pad Setting Vs SFD Values

Executive Summary

Since the beginning of satellite communications, an earth station up-linking an analog video transmission to a satellite was a very simple and mature process. Even the nomenclature used to communicate between satellite customers and operators was very simple and straight forward. However with the transition from analog to digital video transmissions gaining momentum, plus the preference of using smaller uplink systems to deliver large full transponder HD video, brings about many challenges to both the customer and the satellite operator.

One objective of this white paper is to redefine the nomenclature from the current analog to the new digital world. Another objective is to highlight when a link analysis is needed to ensure a successful transmission.

For more information, we invite you to talk to our experts and discuss your specific requirements. Contact us by visiting **www.intelsat.com/network**.

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9/12/5913

Transponder Attenuation

Transponder attenuation is an important part of a satellite transmission. Attenuation ensures that signals received from earth are set at the proper operational level for the transponder High Power Amplifier (or HPA) to optimally transmit the signals back down to earth. The input of the transponder HPA is controlled by a set of attenuators that act like a RF "volume" control. We can set the attenuation relatively low and then send a weaker signal into the transponder HPA. Or, we can set the attenuation high and increase the carrier level accordingly to get the optimum signal to the transponder HPA. There are trade–offs to both types of operation. If we set the attenuation low, we also allow in more thermal and RF noise into the transponder HPA which then amplifies the noise as well as the intended carriers. This unwanted noise also consumes transponder power that cannot be used for amplifying the carriers we intend to amplify.

Ideally we want the HPA to amplify the carriers only. The best way to accomplish this is to block out all of the unwanted thermal and RF noise (before it can reach the transponder HPA) with increased attenuation. This also means we need to send a significantly stronger carrier signal to the satellite to overcome the attenuation, which requires a bigger (louder) carrier level sent from the earth. Sometimes the power requirements can exceed the earth station capabilities, or becomes cost prohibitive to the customer. Intelsat must carefully balance between the two extremes without compromising the quality of service.

We also use attenuators to help equalize the reception level across multiple transponders in the same and opposite polarity. This helps in reducing interference between adjacent transponders by setting the inputs to the transponder HPAs at the same relative level where possible.

In most early generation satellites there were three states of attenuation control; low, medium and high so keeping track of attenuation states was easy. Today's satellites are more sophisticated and can contain up to 15 or more steps of attenuation. This complexity is needed to fine tune the level of RF signal going into the transponder HPA. Because of this wide variance of attenuation states, it is important not to request attenuator or "pad" settings. When comparing satellites, a 3db pad on Galaxy 28 may not have the same impact as a 3db pad on Galaxy 16.

This variance is due to manufacturers using different satellite architectures, specifications and components. All satellite antenna contours, sensitivity (aka G/T), and starting and stopping of attenuation ranges differ by model and manufacturer. Instead of utilizing pad settings, the transponder value that all satellites have in common is known as Saturation Flux Density or SFD.

SFD is a reference point of power required to saturate a transponder from a given point on earth.

- When Intelsat refers to SFD @ Beam Peak (BP) it refers to the part of the uplink beam that is the most sensitive (highest G/T).
- The location on earth for Beam Peak varies from satellite to satellite.
- There are many factors such as manufacturer, antenna size, shape, and pointing which affect SFD and attenuation ranges.
- The range of SFD is determined and controlled by the attenuator.

Example

Satellite 1 may have an attenuation range of -100 dBW/m^2 to -70 dBW/m^2, Satellite 2 may have a range of -110 dBW/m^2 to -80 dBW/m^2.

In this example Satellite 1 with attenuation step 15 would have an SFD of -85 dBW/m^2 while the second satellite would need step 25 to reach the same state assuming each step was 1 dB.

Some satellites attenuation steps are smaller or not exactly 1 dB per step so it is best to refer to SFD when comparing uplink requirements.

An uplink saturating a transponder with the attenuation set to require SFD of -85 dBw/m^2 will require 50% less power if the attenuation was set to require SFD -88 dBW/m^2.

Another way to look at it is if the satellite SFD at a given point on earth is identical on two satellites the amount of power required to saturate will be the same.

Intelsat sets the attenuation on each adhoc transponder to accommodate the majority of our customer's transmission parameters, their uplink's antenna size and HPA capabilities. But Intelsat must also balance the adhoc needs with the needs of the adjacent transponder traffic as well. Therefore Intelsat may not be able to adjust the SFD sensitivity setting for just one adhoc service as it may introduce unwanted noise and interference into the adhoc transponder and cause interference.

Summary

1) The SFDs are expressed in negative numbers, so that -100 dBW/m^2 needs less power than an SFD of -85 dBw/m^2

   -100 dBW/m^2 means a low attenuator setting and hence lower uplink power [EIRP] is needed

   -85dBw/m^2 means a higher attenuator setting and hence higher uplink power [EIRP] is needed.

2) A down-side to having a low SFD and low attenuator setting is that it makes the transponder more susceptible to other RF interference – in layman's terms, if you are lowering the height of the barrier to get a signal into the transponder, then more unwanted signals can also penetrate. It is a careful balancing act to set transponder SFD levels – it has to be low enough that smaller power uplinks can use the transponder, while also keeping it high enough to keep unwanted interfering signals out.

Transponder Saturation versus Circuit Availability

Transponder Saturation

For a traditional full transponder analog video carrier to provide the best possible downlink signal, the uplink earth station must provide the necessary RF power to the receiver on the satellite to output the maximum downlink power from the transponder. This maximum transponder downlink power is called “transponder saturation.” Saturation is a delicate balance; the goal is to get the maximum power from the transponder, however providing more uplink transmit power, beyond saturation, will cause the transponder to actually compress the signal and degrade the carrier’s performance.

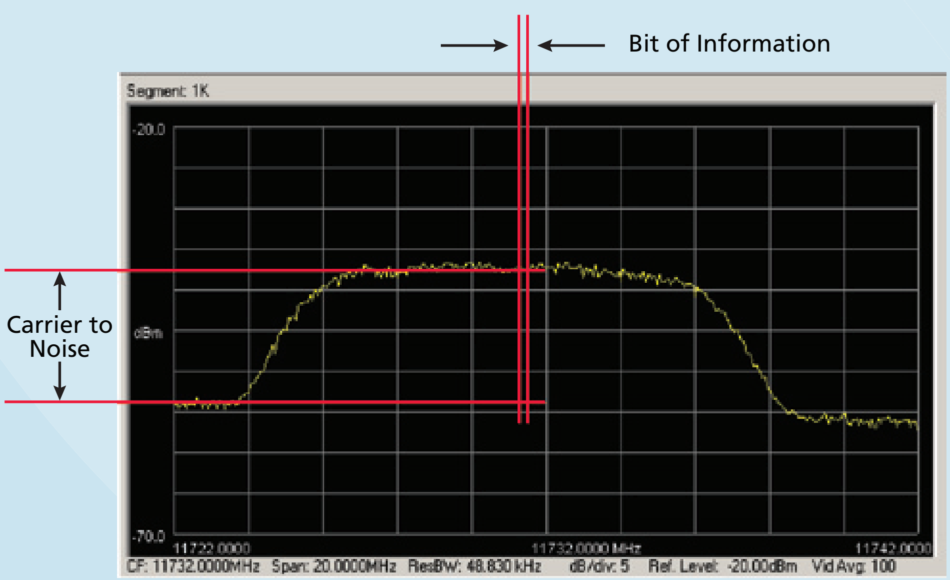
If an uplink earth station has limitations and/or challenges to achieving optimal saturation with the existing transponder settings, then a request is made to make the transponder more sensitive (higher Saturation Flux Density or, SFD) so the uplink earth station can saturate the transponder and provide the best service.

In today’s digital transmission world, the uplink earth station (depending on the receiving antenna size) does not necessarily have to saturate the transponder to provide useable and acceptable carrier performance. The carrier signal must have enough RF energy bit level (EB/No) to achieve acceptable circuit availability. Depending on the downlink antenna size, you may achieve the acceptable availability level using only 1/3 of the transponder power. The only way to really know for certain is to have an Intelsat Customer Solutions Engineer and/or Salesperson run a link analysis well before your service is scheduled/required to determine the amount of uplink earth station, and satellite downlink power, needed.

EB/No, Errors and Availability Threshold

For digital transmissions, the digital ones and zeros are modulated on the carrier frequency and uplink earth station Radio Frequency (RF) energy is used to lift the modulated information from the noise in the transponder – also called transponder noise floor. A digital signal level is measured by the distance from the modulation (where the information is carried) to the transponder noise floor. This measurement is called Energy Bit over Noise (or EB/No) and is measured in decibels. The higher the carrier from the transponder noise floor the higher the EB/No figure and the fewer number of errors that might be produced when un-modulating the carrier, or a simpler way to put it - the better the carrier performance.

Figure 1: EB/No Measurement



EB/No is the energy density per bit of information

There is another measurement term close to EB/No called Carrier-to-Noise or C/N. They are very similar but are calculated differently. For the purposes of this paper, and to simplify things, we will only use EB/No.

To set an acceptable performance (or availability) level, we use minimum EB/No figures that are dependent on the Forward Error Correction of the particular digital carrier being transmitted. The name for this minimum acceptable EB/No figure is called EB/No threshold. For example a customer uses standard DVB carrier parameters (QPSK, 3/4 FEC with Reed Solomon error correction 188/204), the minimum acceptable EB/No level (threshold) that we would not want to drop below is 5.6 dB above the noise floor.

Table 1: Examples of EB/No Thresholds and Related BER

(Any Data Rate) Modulation	FEC	Threshold C/N	Threshold Eb/No	BER
QPSK + Viterbi, C-Band				
	1/2	4.6	4.8	10-4
	3/4	7.8	6	10-4
	7/8	9.5	7.1	10-4
QPSK + Viterbi, Ku-Band				
	1/2	4.8	4.8	10-4
	3/4	7.8	6	10-4
	7/8	9.5	7.1	10-4
QPSK + Viterbi, Ku-Band				
	1/2	3.7	4.1	10-6
	3/4	7	5.6	10-6
	7/8	8.8	6.7	10-6

When the carrier top is close to the transponder noise floor, there is a greater chance of digital errors in the carrier data stream – measured in Bit Error Rate (or BER). The BER is measured in scientific notation. For example, a BER typical for threshold is 1 x 10(-6) or 1 error in 1,000,000 bits of information. To ensure expected performance we use a minimum acceptable Bit Error Rate (or BER) to establish a threshold – or a BER performance we do not want to go below (more on BER below). Using our prior example, the 5.6 dB minimum EB/No threshold produces a BER of 1 x 10-6 Bit Error Rate. For carrier parameters of 7/8 FEC, QPSK with Reed Solomon 188/204 the minimum EB/No to produce a BER of 1 x 10-6 is 6.7 dB. So as we change carrier parameters, we need to change the minimum EB/No value to maintain the BER threshold of 1 x 10-6.

Circuit Availability

Now that we have covered carrier parameters, EB/No, BER, and threshold, we need understand circuit availability or the availability of the digital circuit. This can be measured as the worst case month, or on an annual basis. The worst case month is the extreme of availability as we take into account all factors in a worst case month's time that could affect the circuit and base the circuit availability on it. For annual performance, we base availability on an overall yearly basis. Circuit availability is measured in percentage. For C-band, we normally try to set circuit availability to 99.96% (worst cast month or annual). And for Ku Band, we normally set circuit availability for 99.6% percent (worst case month or annual). Ku band is more susceptible to heavy atmospheric conditions (rain, snow, etc.) where a circuit availability of 99.96% would require too much transponder resource and is not feasible. Unless otherwise specified, Intelsat sets circuit availability on the annual basis and not on the worst case monthly basis.

To determine whether a circuit will work properly, a link analysis (also called link budget) is needed. We first set the downlink antenna size and, if known, the transmit antenna size and HPA size. Then using the carrier and transponder parameters we determine how many Watts are needed to provide the minimum availability of 1 x 10-6 BER on a yearly basis. For instance if the circuit is C-band, the circuit availability used is 99.96% at a BER of 1 x 10-6. Depending on the receive antenna size, the transponder will not necessarily have to be saturated to provide that availability.

Example

A 2.4m earth station uplinks a 51 MBps carrier using the following parameters; 3/5 FEC, 8PSK and an EB/No threshold of 5.6 dB (for 1 x 10-6 Minimum BER performance) using Galaxy 28, transponder C124. The SFD setting is currently set at -87.9 dBW/m^2 at Beam Peak.

The downlink antenna is also a 2.4m earth station. The circuit availability is set for 99.96% annual availability (the standard for C Band). The link analysis shows that only 12.65 MHz of transponder Power Equivalent Bandwidth (power) is needed. The uplink earth station will need approximately 210 Watts of uplink HPA power to achieve this.

Figure 2: Link Analysis Screen

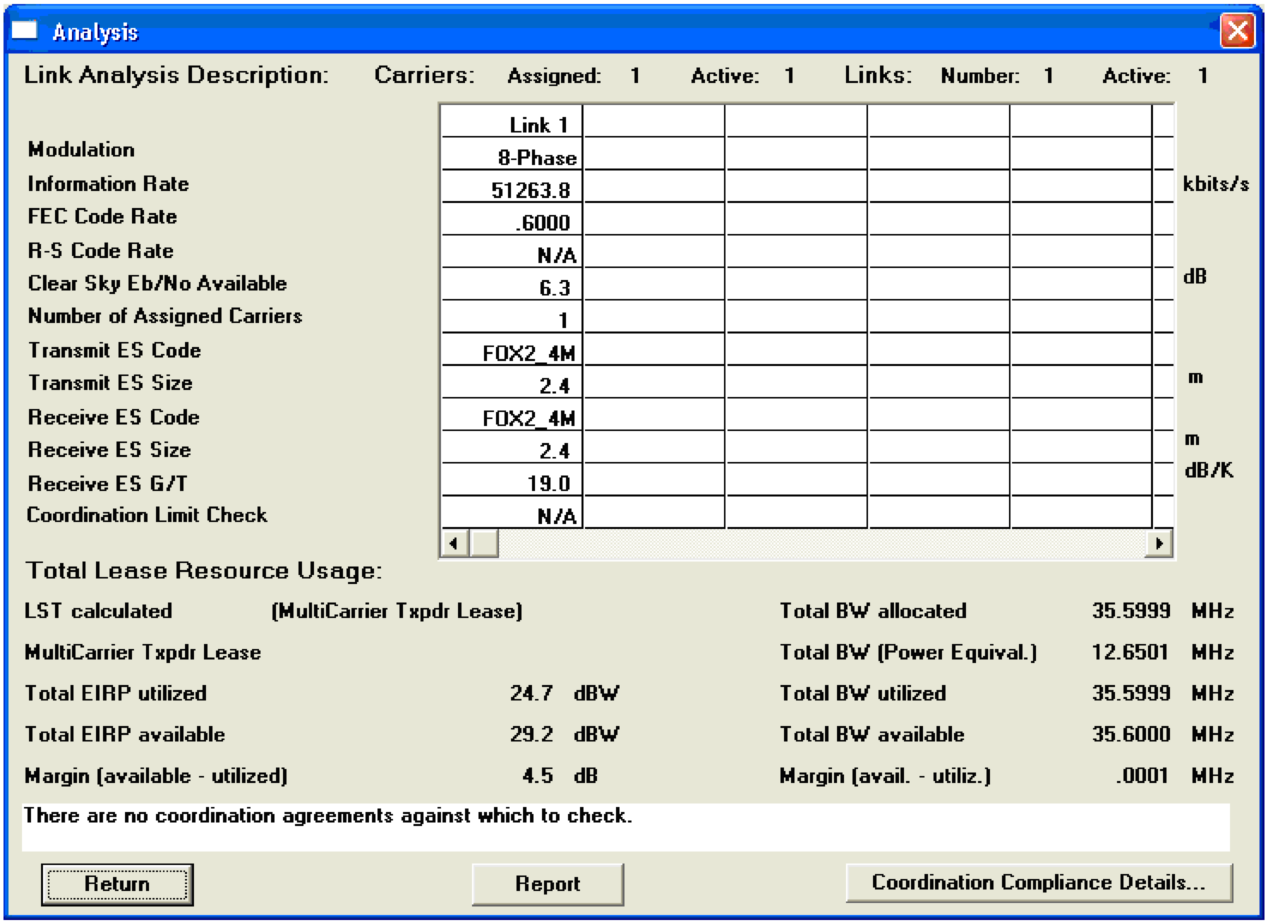
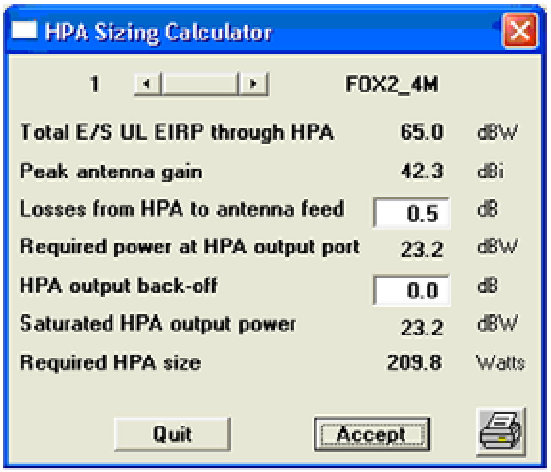


Figure 3: HPA Sizing Calculator



Conversely, a link analysis also indicates the uplink station would need approximately 596.8 Watts of uplink HPA power to saturate the transponder.

Figure 4: Link Analysis Screen

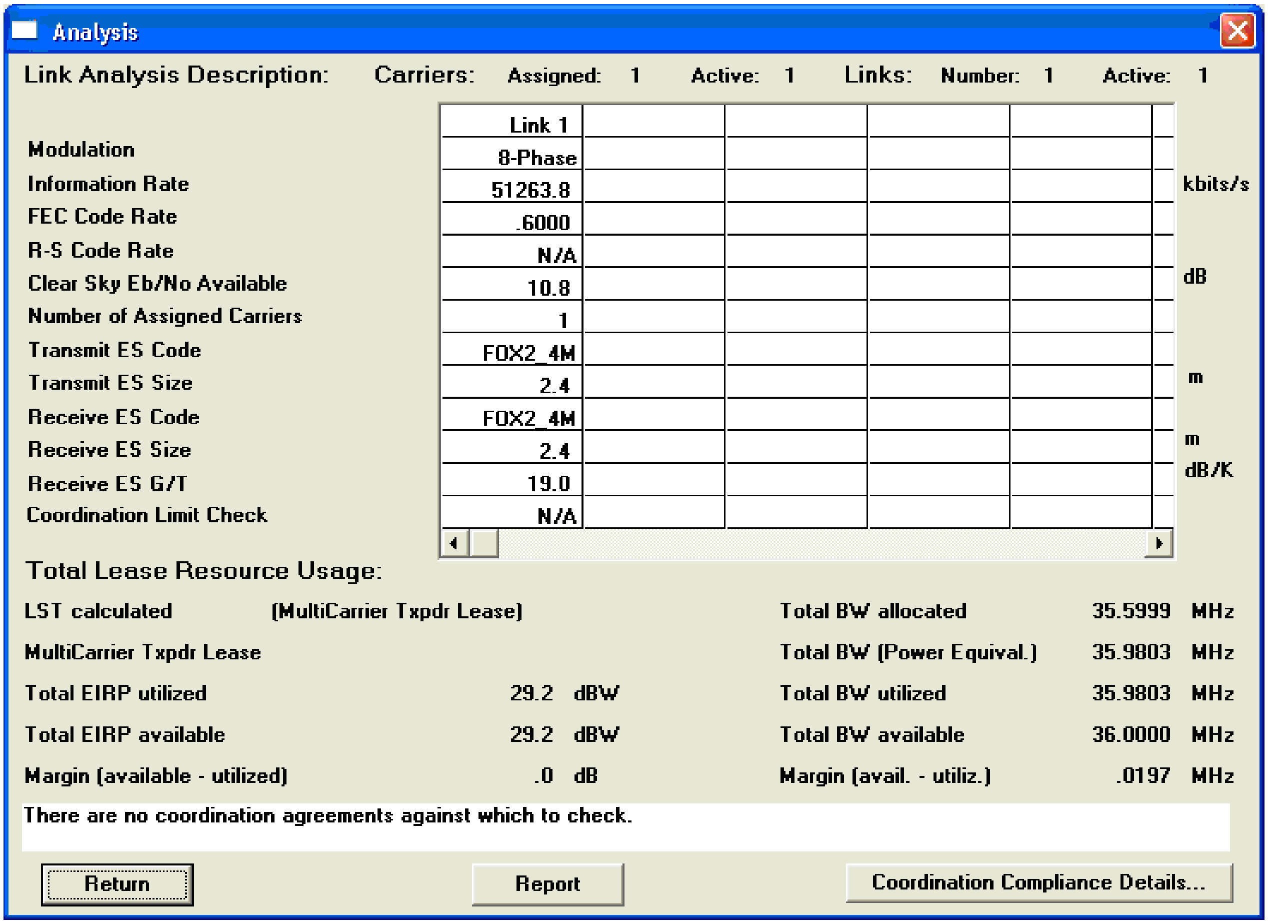
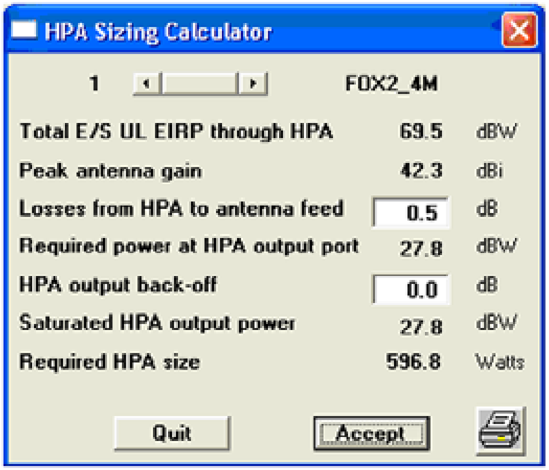


Figure 5: HPA Sizing Calculator



Conditions Where a Link Analyses Might Be Needed

Recent history has shown that a link analysis is recommended for digital transportable and SNG uplink earth stations with small antennas and/or HPAs limitations that need to uplink large MCPC or HD type or carriers to a full transponder. A link budget analysis is recommended for C-band antenna sizes 2.4m or smaller and for Ku-band antennas 1.8m and smaller. Intelsat will perform a link analysis to determine if a circuit will work without a transponder SFD change.

Information we need to provide a meaningful link analysis:

- Requested satellite and transponder
- Downlink antenna size, and location
- Uplink antenna and HPA size, and location

Carrier parameters including;

- Data Information Rate
- Modulation – QPSK, 8PSK, 16QAM, etc.
- Forward Error Correction (FEC) - 1/2, 2/3, 3/4, 5/6, 7/8, etc.
- Reed Solomon or other outer coding schemes – DVB or DVB-S2
- **Acceptable EB/No Threshold

**This is key as it sets the circuit availability target.

Summary

For large digital MCPC type circuits, the transponder does not necessarily need to be saturated to achieve an acceptable level of performance at the receive earth station. Small earth stations transmitting to big full transponder carriers, a link analysis should be requested to determine if the uplink earth station can achieve acceptable circuit availability at the current SFD setting without changing the transponder sensitivity.

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