Evaluating Co-site Mitigation for 2.7m Ku-band Terminal

2-29-15   Bit2Signal Communications

Introduction

A Ku-band auto-tracking mobile 2.7m terminal was installed for operation over commercial Ku-band satellites and was subsequently identified as a source of co-site interference. An effort aimed at finding a resolution resulted a proposal to incorporate a 'low noise" 100 Watt BUC/SSPA, taking the place of the existing BUC/TWTA. Bit2Signal was brought on board and asked to independently analyze and verify the effectiveness of the solution.

The proposed SSPA can produce a linear output of 100 watts, while the existing TWTA (linearized) is capable of producing 140-175 linear watts at the output flange. Both operate in the Ku-band frequency range 13.75-14.5 GHz. A satellite service provider (the provider) had previously estimated achievable data rates using the AMC-9 satellite, Bit2Signal was asked to evaluate the provider's estimates and verify the data rates that can be achieved with the lower power SSPA.

In the solution that was proposed prior to Bit2Signals involvement, a "Low Noise" SSPA would replace a linearized TWTA BUC/PA to eliminate reduce co-site interference to a manageable level. The TWTA specifies a maximum output noise of < -65 dBW/4 kHz in the transmit band up to 18.0 GHz.

The following preliminary high level requirements had been developed for the SSPA:

1. SSPA linear output power: 100 Watts
   Noise Emissions: In the band 13.0 – 15.0 GHz, no emissions outside of the fundamental channel shall exceed -43 dBm/MHz (threshold), -53 dBm/MHz (objective). The fundamental channel is defined as the carrier bandwidth +/- 25.

   The requirement of -43 dBm/MHz equates to a noise floor of -97 dBcw/4KHz. This represents a 33 dB improvement in noise emissions.

Link performance with 100 Watt PA
To evaluate the effect of lower power on link performance, one satellite service provider (the provider) was asked to evaluate the maximum data rate achieved under best (strong satellite) and worst (weak satellite) case link conditions incorporating either EBEM or SLM-5650A modems.

The Terminal EIRP expected for a 100 Watt output assuming 2 dB pointing loss and 1 dB filter loss is calculated as follows:

2.7m Terminal EIRP			
Power output HPA Flange Watts	100		
Power output HPA Flange dBW		20	
**Co-site filter loss		1	
Antenna Gain			
Net Gain	50.32		
Pedestal Filter Loss	0.35		
Radome Loss	0.33		
Total Gain		49.64	
Terminal Max EIRP dBw		68.64	
Pointing Loss dB		2	Estimate
Terminal Max EIRP toward Sat dBw		66.64	
Multi-carrier Backoff dB		1.2	
Per-carrier EIRP toward satellite dBw		62.4	Two carriers

Table 1. Terminal Parameters

Link Estimates
The provider provided analysis results for links using AMC-9 and assume links terminate into a 9.0m earth station.

Table 2 summarizes losses and margins used in the provider's link analysis for AMC-9 and also summarize results with parameters varied to develop a hypothetical best case and worst case with the following.

Hypothetical best case assumes minimal margins and losses, the carrier excess bandwidth selected is 1.2 vs. 1.35 used in the vendor evaluation (MIL-STD-188-165A requires a 1.2 roll-off).

Hypothetical worst (disadvantaged) case assumes terminals are moved more toward edge of coverage with a 20^0 look angle and accompanying contour adjustments of -4 dB for the uplink and –5.7 dB for the downlink. Also included in the worst case are uplink and downlink rain fades, 2 dB each link.

Note: The published EIRP contour variation for AMC-9 exceeds 10 dB, see figure 1, therefore the links presented here are not the absolute worst case that may be experienced within the AMC-9 footprint.

Figure 1. AMC-9 EIRP Contour

	Provider Parameters	Hypothetical Best Case	Hypothetical Worst Case
Tx Antenna elevation angle deg:	46.5		20
2.7m Terminal EIRP dBw	62.3	66.4	62.3
Transmit pointing loss dB:	0.25	0	0.25
Uplink path loss dB:	207.0	207.0	207.5
Uplink aspect correction dB:	0.62	0	4.0
Uplink atmospheric loss dB:	0.14	0.14	0.28
Uplink rain margin dB:	2.10*	0	2
Rcv Antenna elevation angle deg	24.4	24.4	24.4
Receive pointing loss dB	0.25	0	0.25
Downlink atmospheric loss dB	0.12	0.12	0.12
Downlink aspect correction dB	2.30	0	5.7
Downlink path loss dB	205.9	205.9	205.9
Downlink rain margin dB	10.39*	0	2
ASI dB	2.4	0.5	2.4
Implementation margin dB	1.0	0.5	1.0
Threshold margin dB	2.0	2.0	2.0
Total Margin dB	3.0	2.5	3.0
Satellite Parameters			
AMC-9(277 E)			
G/T bc	4.6	dB/K	
SFD bc	-89.3	dBw/m2	
IBO	5	dB	
OBO	2	dB	
EIRP bc	52.9	dBw	
BW	36	MHz	

***** Loss not included

Table 2. Link Parameters (Provider's, Hypothetical best case, Hypothetical worst case)

Link Analysis Results:
Link analysis provides estimates for the maximum data rates that can be expected using either EBEM or SLM-5650 modems employing turbo codes, results are summarized in table 3.

AMC-9 w EBEM or 5650A		
2.7m EIRP	62.3 dBw	66.4 dBw
Maximum Data Rate Mbps – per carrier		
Provider	46.7	63.0
Hypothetical Best Case	66.5	105.0
Hypothetical Worst Case	8.5	22

Table 3. Maximum data rate Scenarios

The satellite service provider's estimates trend toward best case conditions and perhaps illustrate a typical case. But, as shown in Table 3, conditions do exist within the satellite footprint that can support significantly higher data rates. Additionally, edge-of-beam conditions combined with rain can only support drastically lower data rates. In these cases the additional 1.2 to 2.3 dB terminal EIRP provided by the TWTA is highly beneficial.

HPA Noise Emissions
Incorporating an SSPA that exceeds the noise emission requirements may not provide a complete solution, noise contributions from other terminal components must also be considered.

The noise floor produced by the modem and then applied to the BUC/SSPA can be a significant contributor to the total output noise. For an EBEM modem, the output noise floor is required to meet MIL-STD-188-165A which specifies a maximum of -122 dBc/Hz in the frequency range +/- 10 to 100 MHz from the carrier center frequency.

With a modem output power of 0 dBm and 50 dB gain in the BUC/SSPA the noise floor would be amplified from -122 to -72 dbm/Hz. When comparing this to the requirement it equates to -12 dBm/MHz - well above the requirement of -43 dBm/MHz.

Additionally both the SLM-5650 and the EBEM specify a maximum output spurious of -51 dBc measured in any 10 KHz bandwidth. Spurious at this level can translate to -1 dBm at the output of the BUC, also well above the requirement.

In order to meet the requirement the satellite modem must exceed specifications, noise and spurious must not exceed -153 dBm/Hz outside of the fundamental channel. Since, satellite modems often exceed their design specifications it is possible that the modem can meet this noise level. It is recommended that the modem output noise be characterized.

The phase noise requirement from MIL-STD-188-165A is shown for reference.

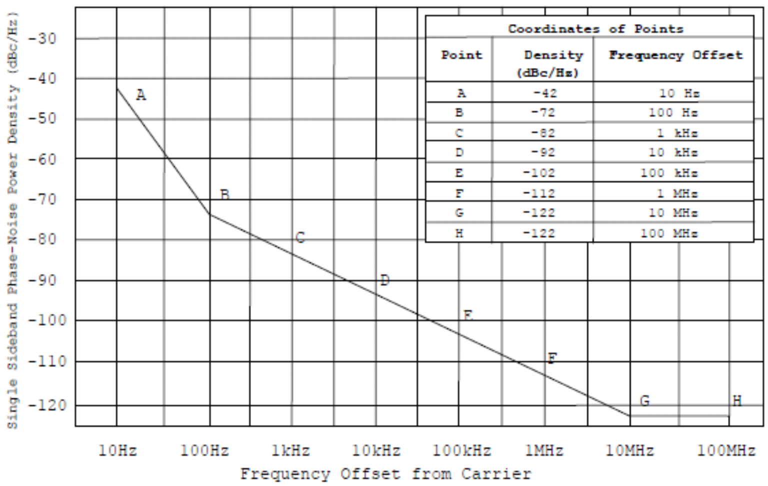

Figure 6. Phase noise of transmitted IF

5.1.6.7 Transmit output spurious emissions. The spurious emissions relative to the modulated carrier measured in a 10-kHz bandwidth shall be below the levels given in Table VII.

TABLE VII. Transmit output spurious emissions.

FREQUENCY OFFSET FROM CARRIER	DATA RATE	MAXIMUM SPURIOUS LEVEL
± (1.0 R_s to 500 MHz)	> 64 kbps	-51 dBc
± (1.0 R_s to 500 MHz)	≤ 64 kbps (optional)	-46 dBc

5.1.6.8 Transmit output harmonics. Harmonics of the modulated transmit carrier shall be at least -60 dBc. The frequency range for harmonics is up to the greater of the 12th harmonic or 4,000 MHz.

Figure 2. MIL-STD-188-165A Modem Output Noise & Spurious Specifications

CONCLUSIONS

1. The lower EIRP provided by the Low Noise SSPA is only a consideration when operating near edge of beam
2. The reduced noise emitted by the SSPA while helpful will not ultimately solve the co-site interference problem since amplified noise from the satellite modem will exceed the requirement. It is possible that the installed modem has better noise performance than specified so we recommend measuring the output of the modem prior to making a final decision.
3. Additional ideas for dealing with co-site interference:

   HPA Filters - A filter placed at the HPA output would produce the greatest effect and avoid modifying other components. Once the desired carrier frequency and bandwidth are known an appropriate filter is selected and manually installed from a set of filters.

   Constructing an electronically tuned filter or set of filters, capable of handling high power levels is possible but very difficult and may not fit in the space constraints.

   Modem add on filter – If the modem is determined to be a dominate noise source, an electronically tuned filter could be placed in line between the modem and HPA.