5G INTERFERENCE IMMUNITY ON DEMAND

Introduction

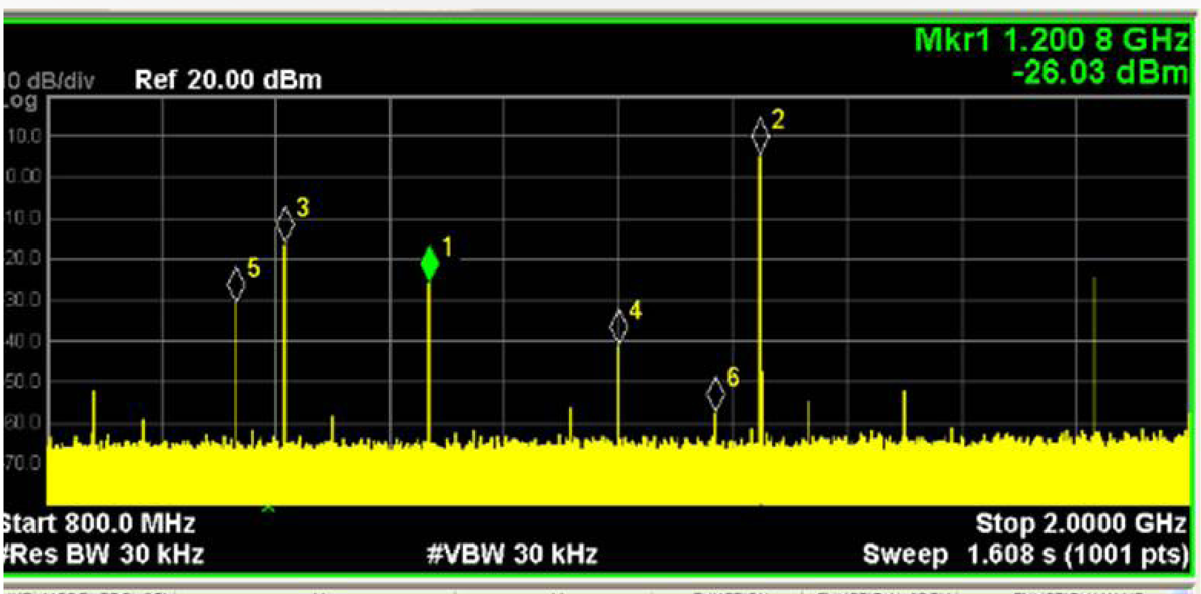
5G networks in the 3.4 to 4.0 GHz band are coming and will cause interference problems in the satellite C-band receive spectrum of 3.4 - 4.2 GHz. However, there are situations such as maritime communications where there is no 5G interference at sea, but there is interference close to land. In this case, the full satellite receive spectrum may be available at sea, but not close to shore where the receive spectrum is reduced due to 5G systems and where mitigation is thus required. The solution to this dilemma is to be able to switch on 5G mitigation on demand.

Impact of 5G Interference on LNBs

High power signals from 5G base stations, even out of band signals at the input of the LNB, will cause the following:

1) Reduced gain
2) Increase in noise temperature
3) Increased noise
4) Non-linear intermodulation products

This interference occurs because the high-power signal saturates the first amplifier stages or the mixer. By far, the worst degradation occurs due to intermodulation, resulting in reduced picture quality or degraded BER performance in data networks. Intermodulation is the generation of mixing products between the interference signals, the LNB LO and any in-band signals. The following figure of a standard LNB (3.7-4.2 GHz) output shows the in-band intermodulation products for a -34 dBm interfering signal at 3.6 GHz (Marker 2) with a desired signal at 3.95 GHz (Marker 1).



In addition to the in-band spurs, the interfering signal is saturating the LNB and appears at the IF output as a very strong signal. A typical modem requires the aggregate L-band input power to be no more than about -5 dBm. The interfering signal leaking through the LNB must be kept below this to ensure the modem performance is not impacted.

Many of the spurs are in-band, so L-Band or IF filters placed between the LNB and modem will not be effective. Equally, LNBs with integrated L-band filters will not provide immunity. Appropriate L-band filters could mitigate the IF interfering signal.

5G Interference Mitigation on Demand

To provide immunity to 5G interference requires:

a) Waveguide Filter in front of LNB
b) LNB with integrated filtering and designed to handle higher power
c) Combination of an external filter and LNB with integrated filter

To provide 5G interference mitigation on demand requires that the external filters be switchable, the LNB integrated filters be switchable or both be switchable.

Switchable Bandpass Filters (BPF)

To provide 5G interference on demand with external filters requires that the system be able to switch the external filters or LNB protection on or off. This essentially provides one receive path for normal operation and a second receive path with 5G interference protection. Switching external filters while maintaining low loss requires a waveguide switch, additional waveguide components and a couple of bandpass filters with LNBs. Low loss is important to maintain a high system G/T and system performance. Losses between the antenna feed and the LNB have a 2x multiplier effect on the G/T, so for every 0.1 dB increase in insertion loss between the antenna and LNB results in approximately a 0.2 dB degradation in G/T. The additional components make this solution more costly and larger – WR-229 waveguide is not exactly compact. It may be challenging to install these additional components on a maritime terminal as space is usually limited. The following figure shows a simplified switchable external filter assembly. The full spectrum path includes a standard transmit reject filter (TRF) and standard LNB. The 5G interference mitigation path includes a BPF and LNB with integrated BPF.

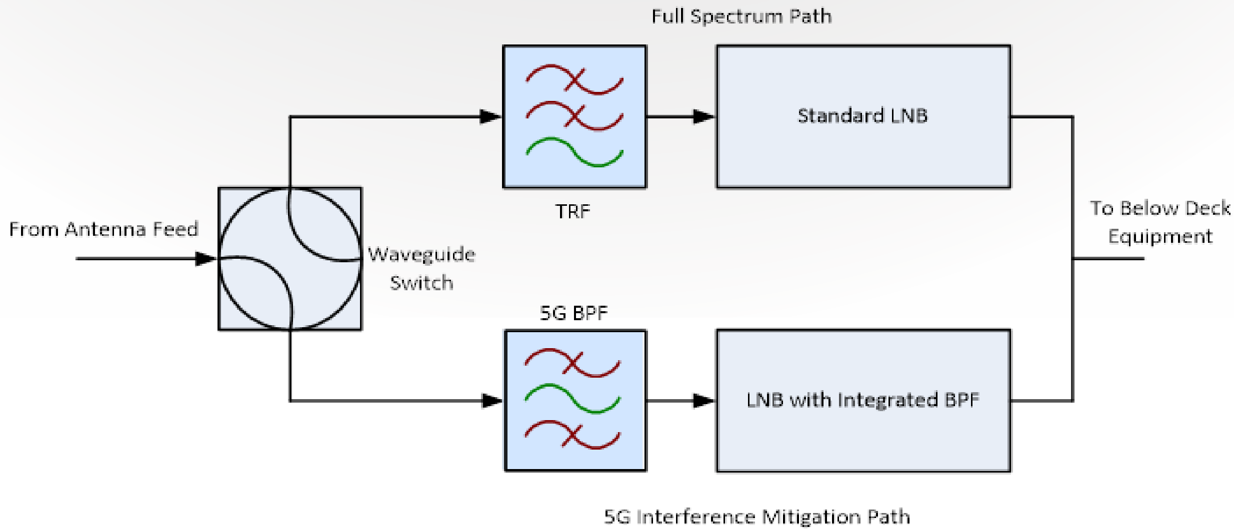


Figure 1: Switchable Path Configuration

Filters alone may not provide sufficient mitigation and it may be necessary to use a specially designed LNB such as the Norsat 3200-BPF LNB to handle the interference signals getting through the filter.

External filters work by reducing the power of the 5G interference while passing the desired signals. All filters have a transition region between the stopband and the passband and the rejection in this transition region is much less than in the stopband. The effectiveness of the filter on mitigating the 5G interference depends on how close to the passband the 5G interference is. The Norsat BPF-C bandpass filters provide about 58 dB, 28 dB and 3 dB rejection at 100 MHz, 50 MHz and 20 MHz from the passband, respectively. It is quite possible that this filter will not provide immunity to 5G interference if the interferer is close to the passband and is high power.

Norsat also offers a set of extreme bandpass filters that provide more rejection closer to the passband. For example, the eBPF provides 70 dB, 65 dB and 60 dB rejection at 100 MHz, 50 MHz and 20 MHz offsets, respectively. However, the insertion loss of these filters is about 0.8 dB more than the standard filter, and this will impact the system G/T and the received Eb/No.

LNB with Switchable Integrated filtering

The Norsat 3200-sBPF series LNBs are designed to provide both a normal full spectrum receive chain and an alternate 5G interference protected chain. The following diagram shows a simplified block diagram of the 3200-sBPR-5, where the 5G interference mitigation path utilizes spectrum from 3.9 GHz to 4.2 GHz.

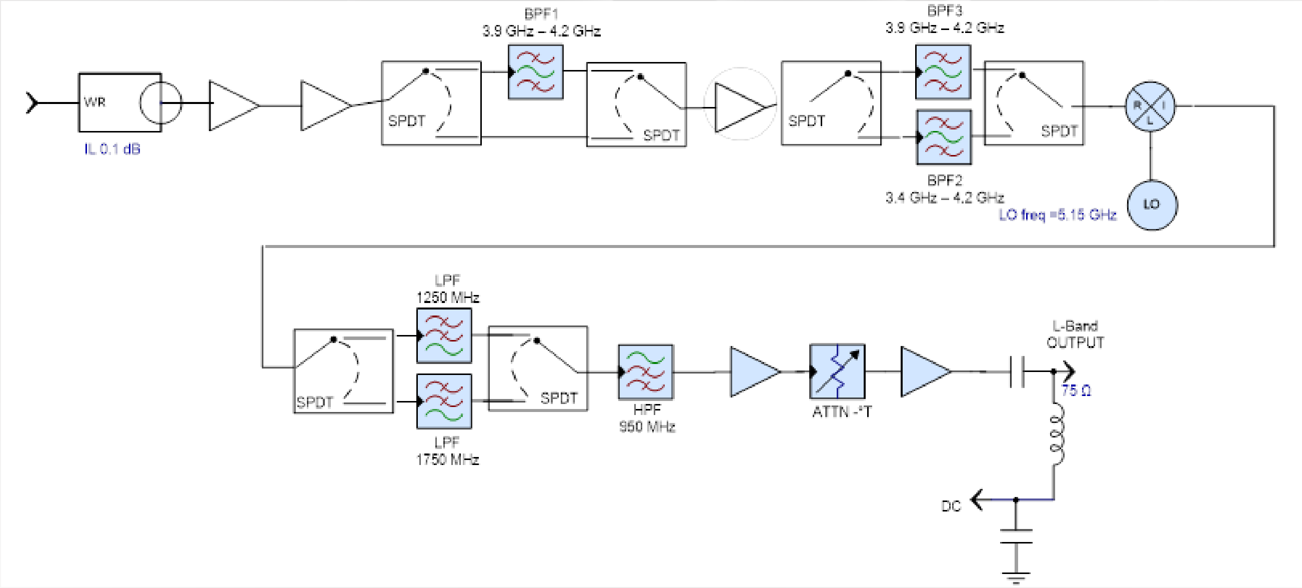


Figure 2: Norsat 3200-sBPF Simplified Block Diagram

Besides the filters shown in the block diagram, the mixer is chosen to be able to handle higher power signals without creating intermodulation. The Norsat 3200-sBPF filter can successfully mitigate the effects of interference signals up to about -25 dBm 100 MHz from the passband. The following figure shows the 3200-sBPF-5 with an interfering signal of -25 dBm at 3.8 GHz (Marker 3). The desired signal is about -70 dBm at the input (Marker 2). The output spectrum is unaffected by the interfering signal; however, the interfering signal is still present at the L-band output of the LNB and is high enough in power to cause degradation in modem performance.

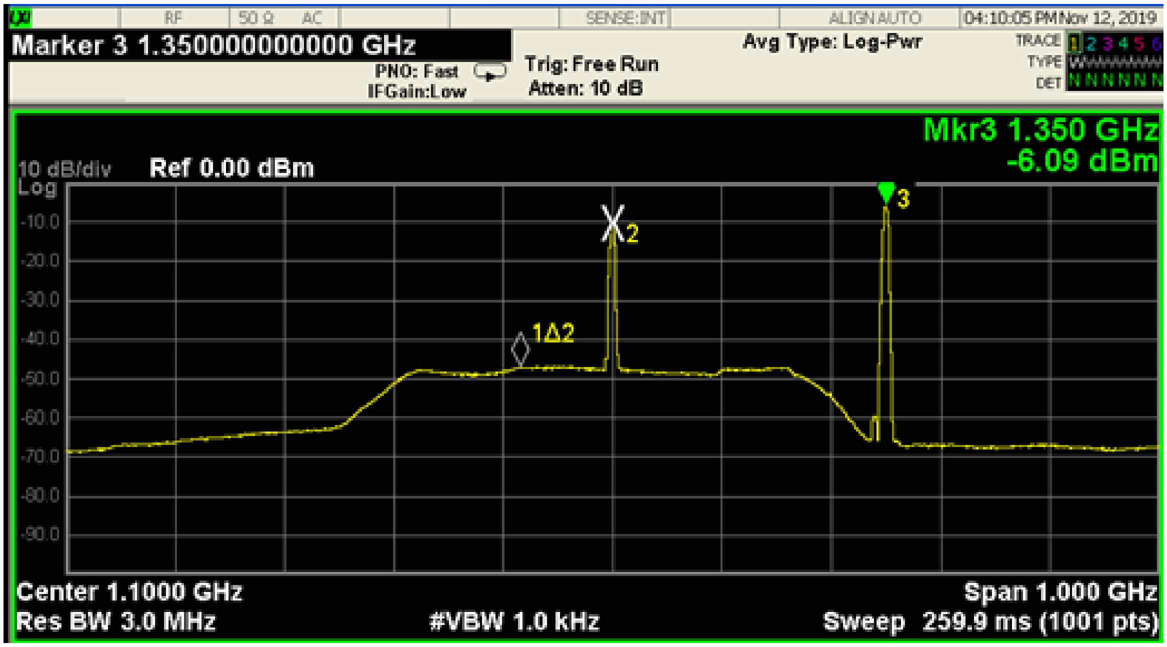


Figure 3: Output Spectrum of Norsat 3200-sBPF With Interfering Signal

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The 3200-sBPF LNB with an integrated filter is much different than the typical WiMAX or radar tolerant LNBs. These LNBs usually only have filtering at IF. They cannot mitigate in-band interference, which will cause intermodulation products in the RF and mixer stages of the LNB. The 3200-sBPF includes filtering at RF to mitigate this.

The Norsat 3200-sBPF LNB is the same size and weight as a standard 3000 series LNB. The receive path is switched by changing the input DC voltage: 14V for full-spectrum (normal) and 18V for the 5G interference mitigation path.

The noise temperature of the 3200-sBPF is slightly degraded over both a standard 3000 series LNB and a 3200-BPF due to the additional losses introduced by the internal switches. The 3200-sBPF noise temperature is less than 60 oK while the 3200 BPF and standard LNB are 40 oK and 30 oK, respectively.

Figure 4: Norsat 3200-sBPF

Combination of an external filter and LNB with integrated filter

In cases where the 5G signal is high, and the guard band between the 5G network and the satellite receive spectrum is less than 100 MHz, a combination of a switchable external filter and LNB with switchable integrated filter is required. If the guard band is 20 MHz, we will need to use a bandpass filter with a steep transition, such as the Norsat eBPF series.

5G Immunity Solutions

The following tables summarize the immunity to 5G signals for various combinations of LNB and filter for guard bands of 100 MHz, 50 MHz and 20 MHz below the band edge and are sorted from lowest to highest immunity. The values in the table indicate the highest level of interference that the LNB/Filter combination can handle without impacting the LNB performance. The tables below assume a received signal of about -70 dBm. The immunity on the upper band edge is less, but this is not critical for interference mitigation.

Solution	Signal Level @ 100 MHz causing Interference (dBm)
3000 LNB (Standard LNB)	-65
3200-sBPF	-25
BPF-C + 3000 LNB	-9
eBPF-C + 3000 LNB	5
BPF-C + 3200-sBPF	31
eBPF-C + 3200-sBPF	45

Solution	Signal Level @ 50 MHz Causing Interference (dBm)
3000 LNB (Standard LNB)	-65
3200-sBPF	-55
BPF-C + 3000 LNB	-37
BPF-C + 3200-sBPF	-27
eBPF-C + 3000 LNB	0
eBPF-C + 3200-sBPF	10

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Solution	Signal Level @ 20 MHz Causing Interference (dBm)
3000 LNB (Standard LNB)	-65
3200-sBPF	-63
BPF-C + 3000 LNB	-62
BPF-C + 3200-sBPF	-60
eBPF-C + 3000 LNB	-5
eBPF-C + 3200-sBPF	-3

The various combinations of LNB and filters have different insertion losses and noise figures, and as such, will affect system performance differently. The following table provides some guidance on the impact on system G/T of the various combinations

Solution	Description	WG Losses	Filter Insertion Loss (dB)	LNB Noise Figure (dB)	G/T dB/K (2.4m Antenna)	Change in G/T (dB)
TRF+3000 LNB	Standard single path configuration	0	0.4	< 0.4	16.8	
TRF+3200-sBPF LNB	Single path configuration with switchable LNB	0	0.4	< 0.8	15.7	-1.2
TRF + 3000 LNB	Switchable path configuration, full spectrum path	0.3	0.4	< 0.4	16.0	0.8
BPF-C + 3000 LNB	Switchable path configuration, 5G Mitigation Path	0.3	0.5	< 0.4	15.7	-1.1
TRF + 3200-sBPF LNB	Switchable path configuration, 5G Mitigation Path	0.3	0.4	< 0.8	15.0	-1.8
BPF-C + 3200-sBPF LNB	Switchable path configuration, 5G Mitigation Path	0.3	0.5	< 0.8	14.7	-2.1
eBPF+3000 LNB	Switchable path configuration, 5G Mitigation Path	0.3	1.3	< 0.4	13.9	-2.9
eBPF-C + 3200-sBPF LNB	Switchable path configuration, 5G Mitigation Path	0.3	1.3	< 0.8	13.1	-3.7

The first row represents a standard single path configuration with a TRF and standard LNB that is typical on most maritime terminals. The second row indicates a standard single path configuration with a TRF and the Norsat 3200-sBPF switchable LNB. The remaining rows represent a switchable path configuration, as shown in Figure 1. The table shows the more extreme solutions have a more negative impact on system performance. Thus, it is important to balance the immunity solution with system performance.

Conclusion

In situations where a satellite terminal operates in both a clear area and a 5G compromised area, such as a maritime terminal, it may be beneficial to be able to turn on 5G interference mitigation at will. This will allow the use of the full spectrum while at sea and possibly enjoying less expensive airtime while still being able to use the system close to shore in a constrained way. On-demand 5G interference immunity can be achieved using switchable bandpass filter assemblies using the Norsat BPF-C and eBPF-C filters, a switchable LNB such as the 3200-sBPF series of LNBs or a combination of both. Switchable filters require a waveguide switch and additional waveguide components making them large and costly. The additional losses introduced negatively impact system performance. While not providing the ultimate in 5G interference mitigation, replacing a standard LNB with a Norsat 3200-sBPF provides reasonable mitigation with minimal expense and impact on system performance. Usually, you would not even need to rebalance the antenna system.