Interference, Modems and Satellite Links (rev 1)

1 Introduction

Digital carriers are susceptible to interference that causes degradation and increases the number of errors received at the distant end of a satellite link. Wideband carriers are sometimes particularly vulnerable to interference that is difficult to detect and eliminate, and may consume a great deal of time to cure. A particular case is examined with the CDM-700, but the principles are the same for any satellite modem or satellite link.

Tests were conducted with CDM-700 modem operating at 100 Mbps with 16-QAM 7/8 in the presence of an interfering signal to simulate field conditions that degraded performance (high packet loss), while the E_b/N_o, BER and IQ constellation looked quite good.

To provide a starting point for investigating the causes that impair links, a number of reported cases of degradation due interference are summarized here.

2 A Specific Example – Symptoms and Results

A link carrying Ethernet traffic has two sites transmitting 100 Mbps in one direction and 25 Mbps in the other. The following symptoms are present:

- A site with a small antenna receives 100 Mbps (29.5 Msps) with 16-QAM 7/8 (20/23 actual)
    - CDM-700 reports E_b/N_o = 9.5 dB (BER < 10^{-10})
    - I-Q constellation is normal
    - No evidence of interference viewing the active carrier
        - [1] Testing was not possible with the carrier OFF
    - [2] FPGA link errors occur continually
    - This modem functions properly at the other site
- The site with the larger antenna receives 25 Mbps (8.5 Msps) with 16-QAM 3/4
    - This link is OK

With an operating E_b/N_o of 9.5 dB, no bit errors and no FPGA link errors are expected over a short observation period. Normally, in this configuration, the modem threshold where FPGA link errors appear continually is about 7.9 dB (BER = 4.6×10^{-7}).

Initial lab tests were attempted to duplicate the symptoms at the troubled site. Conducted at E_b/N_o = 9.5 dB, duplication of the symptoms did not succeed. This effort included tests using Smart Bits test equipment to send and receive known packets. The modem was tested with the Ethernet data cable attached and then removed to look for modem problems and none were found. At this point, an alternate approach is needed to duplicate the field results.

3 Lab Interference Tests

In some instances, difficult problems arise that are challenging to detect and sometimes tough to correct. This includes interferers (or jammers) that hide beneath the desired carrier. The jammer degrades the desired carrier, but is not obvious because it is masked by the desired carrier.

[1] The link was operational. It is often necessary turn OFF the active carrier and monitor with a spectrum analyzer in the Max Hold mode to catch bursty jammers to detect an interferer.

[2] FPGA link errors are counted (2^{16} bit counter) whenever a defect in the HDLC stream is detected. HDLC is the wrapper used to send the bursty Ethernet packets over the link by the CDM-700 Modem.

A test setup was constructed to model a link with an interferer that produced the symptoms described in the previous section. **Figure 1** simulates a link with two CDM-700s, and then adds an interfering source to create the symptoms. The setup was run in both directions at 100 Mbps with 7/8 16-QAM, because this is the configuration experiencing degraded performance.

The jammer uses a CDM-600L modem transmitting a 4 Msps carrier. The CDM-600L transmitter is turned ON/OFF using a pulse generator to activate the EXT carrier control available on the Alarm Connector at the rear of the unit. Transmitting the Tx IF interfering carrier with a 10% duty factor (DF) allows the CDM-700 to report the E_b/N_o = 9.5 dB, and FPGA link errors occur regularly.

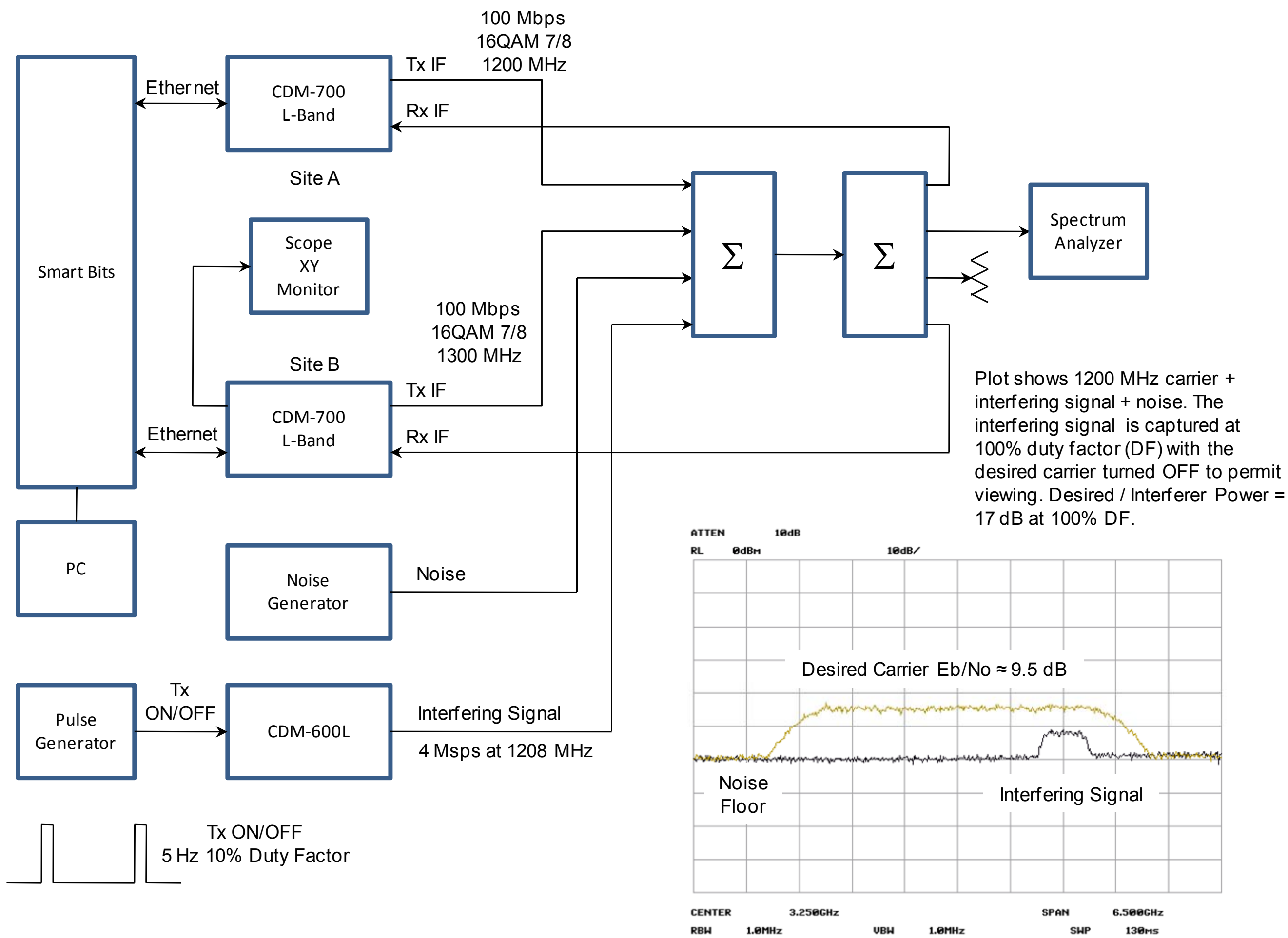


Figure 1 Test Setup for Interference Testing

The desired carrier is centered at 1200 MHz and the jammer is placed at 1208 MHz. The jammer is far enough below the desired carrier that it is not visible when viewed with a spectrum analyzer. A duty factor of 10% results in insignificant degradation of E_b/N_o and a barely noticeable impairment to the IQ constellation display. The FPGA link error counter increments because the bursts from the interfering signal corrupt the HDLC wrapper carrying the Ethernet packets over the link.

The Desired / Interferer ratio is 17 dB when the duty factor is 100%. The average power is 10 dB less when the duty factor is 10%, so the jammer is 27 dB below the desired carrier. Clearly, the instantaneous bursts are enough to corrupt the packets transported by the desired carrier.

4 Miscellaneous Examples – Other Interference and Jammers

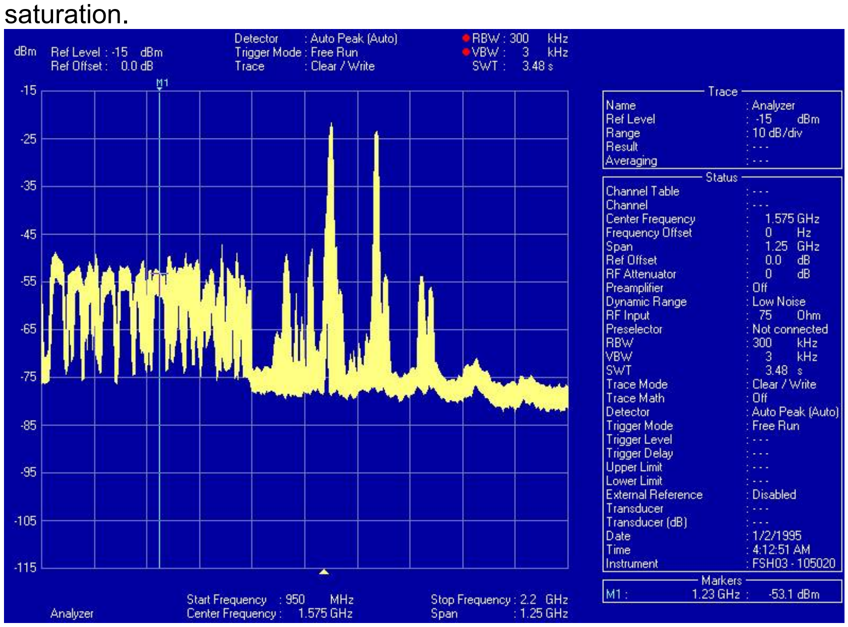
This section is a loose collection of interference scenarios that caused problems in the past. These were collected from customers who have lived the agony of a link that *should* work, because all the reported parameters look normal; but it doesn't quite work as expected:

- More bit errors than seems reasonable
- Blocks of errors occur for a time and then cease for hours or days
    - Errors appear to repeat nearly on a schedule
- The link performs very poorly for a time (minutes to hours) and is then normal for days to weeks

The tough problems are difficult to detect and other sources are blamed until the real culprits are identified.

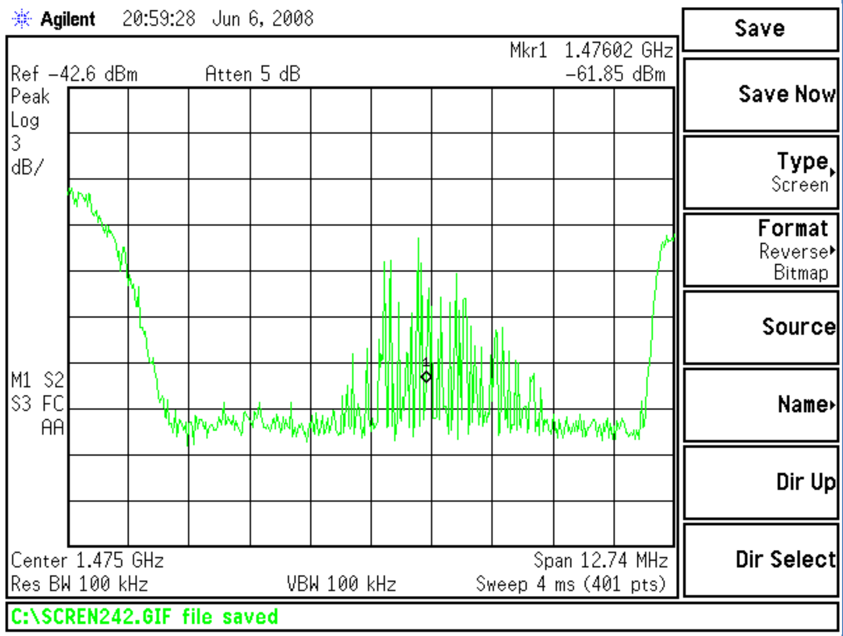
<table>
<tr><th>Cause</th><th>Comment</th></tr>
<tr><td>Operation at low-look angles</td><td>C-Band links may experience degradation that seems like a fade, but the impairment is due to an increase in the noise temperature. The result is the same: the C/N decreases. There is additional vulnerability to electrical ground clutter and terrestrial sources.</td></tr>
<tr><td>Auto and engine ignition noise.</td><td>Problems with certain auto models and motor cycles were reported. Snowmobiles are also in this category.</td></tr>
<tr><td>Radar systems</td><td>Old ones..? There are no recent reports.</td></tr>
<tr><td>Radar detectors</td><td>This occurred every time an employee drove to the earth station. There are several radar detector reports.</td></tr>
<tr><td>WiMax – potential for interference

Note: [3] WARC ruled to reserve the 3.4 to 4.2 GHz band for satellite only use in Nov 2007</td><td>There was a WiMax proposal to extend operation into a 3.4 to 4.2 GHz band. A macro base station will transmit up to 46 dBm/MHz (micro base station: up to 22 dBm/MHz) and accommodate distances of 30 km or more. There is an international effort to recommend against use of this band. For more information see www.no-change.info</td></tr>
<tr><td>WiMax – actual problem at 3400 MHz.

This is a serious problem even though the interference is located outside the satellite band, because the level is so high and the RF front end is broadband.</td><td>The two interfering signals are 25+ dB above the desired carriers and are terrestrially-based. They reached a sufficient level to pass through the antenna and LNB at 3400 MHz and drive the LNB nearly to saturation.


This problem was solved with a low-loss filter between the antenna and LNB to reject the out-of-band energy.</td></tr>
</table>

[3] This is no help for satellite links in regions where WiMax is already installed.

Cause	Comment
In-band jammer on transponder – actual problem	Interfering jammer detected using Max Hold. The jammer is a low duty cycle waveform occurring ~Nx1 sec (N= 1 to 7) with a duration of 5 to 7 ms that was totally OFF for hours at a time making it difficult to catch. The low duty cycle of the jammer assures the average power is well below the desired carrier and not visible when both are present. This emphasizes the need for Max Hold testing in the absence of the desired carrier. 
Terrestrial microwave in the satellite band	This problem appears in Phoenix and other cities where older microwave sites are “grandfathered” and may interfere with satellite reception (C-Band). They are not always documented.
Waveguide leakage within the earth station	The mechanism is not clear, but leakage was reported in the waveguide system where unwanted energy is present inside the desired band and not coming from the satellite or from external terrestrial sources.
Co-pol interference	This includes terrestrial and interference from the satellite link.
Cross-pol interference	DSNG and other occasional services with misaligned polarization leak energy into services located on the opposite polarization. These are often occasional-use carriers, so the degradation appears for a time and then vanishes. Long term, Max-Hold tests with a spectrum analyzer monitoring the empty slot are often the only way to detect this.
Cross-pol from an FM TV carrier	Serious interference from this source is less of a problem today, as the FM carriers are being replaced by digital ones.
Adjacent satellite interference	There are reports of C-Band interference with 3.8 and 4.5 meter antenna. This worsens at low-look angles. It was necessary to increase the size of the antenna.
L-Band interference	There were instances where L-Band signals penetrated the cabling system with L-Band modems and caused interference.
FM signals	FM signals have entered IF cables at a site with grounding problems.
Mobile Phones	Normally not a problem. There is a potential for 2x (824 to 849 MHz), 2x (GSM 850 and GSM 900 frequencies) or 1x (DCS 1800 or 1900).

5 Conclusions

It is convenient to hypothesize scenarios that produce the symptoms, but it is always necessary to confirm the interference in the field. In fact, the lab testing duplicated the symptoms, but they were not the cause, just another way of producing the same problem signature. There are usually multiple ways to cause degradation. Also, there are often multiple sources of interference that allow engineers to work long hours to sort out and get the links operating properly.

The best method of locating in-band interference is searching the desired band when the desired carrier is turned OFF. Of course, there is no service during the test period, unless an alternate slot is available or some other way is devised. During these tests, the spectrum analyzer is operated in the Peak Hold or Max Hold mode to catch bursty jammers or occasional use transmitters that appear as co-polar, cross-polar interferers, adjacent satellite or terrestrial jammers. In some cases, tests lasting longer than 24 hours were required to detect the problem.

There are many other ways and sources of interference that can degrade a link, as shown in the table. The process of determining the symptoms and isolating the causes is sometimes very time consuming and requires a good deal of perseverance and patience.

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