RF MODEM SPECIFICATIONS
. . . testing between the lines

Kenneth C. Crandall
Program Manager, RF Modems

Zeta Laboratories, Inc., a subsidiary of CCTC
3265 Scott Blvd., Santa Clara, California 95051

Abstract

The RF modem, used for both voice and data communications on CATV systems, is becoming an important tool for increasing cable operators' revenues. However, any new device added to the network must be tested to see that it meets its specifications. It also must meet certain unwritten specifications that guarantee that it reliably operate under a variety of real world impairments known to exist; such as mechanical shock, frequency translator drift, and intermodulation distortion. Simple tests are presented that help identify a potentially poor performing device and keep it from eroding into those higher revenues gained by offering voice and data communications services.

Introduction

Until recently the primary application of RF modems for voice and data communication over coaxial cable broadband systems has been on private industrial and government cable systems or specialized office automation systems for centralized computer data bases. This technology is now spreading to metropolitan CATV systems where more stringent requirements must be observed. A cable operator can only add data and voice capability to his system if it does not interfere with existing services. The RF modem hardware must also be reliable and inexpensive to install and maintain.

Rigorous testing is necessary --but what are the crital parameters to test? How do you know when a modem works but is on the brink of erratic behavior or catastrophic failure?

RF Modem, What is it?

Before exploring the details of RF modem testing and answering the questions raised, a general definition of the term RF modem is necessary and consideration of its place in the CATV system.

The term "RF modem" is a series of contractions. RF stands for "Radio Frequency" and means simply that its channel of communication is in the radio frequency spectrum. For CATV that usually means from about 5 MHz to 500 MHz. The term modem is a contraction of "modulator-demodulator" and is synonymous with "transmitter-receiver" or "transceiver".

The RF modem sends and receives voice and/or data over CATV facilities. The bandwidth required is dependent on data rate in the case of data transmission and fidelity in the case of voice or music transmission. Higher data rates or better fidelity require greater bandwidth.

The modulation technique also has a bearing on spectral usage and efficiency. Frequency modulation is both noise immune and inexpensive to receive. It is also one of the least bandwidth efficient modulation techniques. Amplitude modulation is more efficient spectrally but is more likely to be impaired by noise. Phase modulation is spectrally efficient and more noise immune but is more expensive to implement.

Various forms of modulation coding are also used to achieve higher bandwidth efficiencies. QPSK (quadraphase shift keying) is a good example. The increased efficiency is gained at the expense of less noise immunity and increased hardware cost.

The RF modem is usually used in conjuction with a block frequency translator at the head end of the cable system. The translator, due to its central location in the network topology, can receive all reverse channel signals. The reverse channel usually occupies the lower frequency portion of the cable frequency spectrum for signals travelling upstream to the head end.

The translator retransmits a block of spectrum back downstream on the cable system on a forward channel. The forward channel usually occupies the higher portion of the frequency spectrum. Because the retransmission takes place at the central head end, all RF modems on the system receive the translated spectrum signal. This allows any RF modem to communicate with any other RF modem on the system. In effect, the translator serves the same function as a satellite transponder in microwave communications systems.

Although RF modems can be configured to operate without a translator, the translator is preferred for large tree topologies where single coax two way transmission is used. The translator gives the added advantage of allowing any location visibility to the reverse channel frequency spectrum. This allows maintenance facilities to be located anywhere on the cable system.

The Published Specifications

The typical specifications that RF modem manufactures publish fall into five main categories:

1. Interface (digital or analog)
2. Modulator
3. Demodulator
4. Environmental
5. General

1. Interface

The interface specifications deal with the connection to the terminal equipment. In the case of voice RF modems the specifications are mostly analog and deal with signal levels, frequency response, group delay, impedance levels, and connector types.

The omission of specification in voice modem interface usually involves voice quality and overmodulation characteristics. The tests for these are usually subjective and involve human ear judgement. Background hum or hiss are frequent problems in addition to adjacent channel cross-talk. The overmodulation is usually caused by a loud talker or the touch tone pad if a telephone set is used. Amplitude compression is often used to overcome these difficulties.

The digital RF modem interface is most often a generic type and typically cites an industry standard such as the E.I.A RS-232C interface. The standard gives most of the details of the interface. The data rates of the interface are not usually covered by the standard and must be specified for the particular modem. Also, the RTS/CTS delay must be specified. Synchronous as well as asynchronous capabilities often must be called out separately.

The omissions of note in data interface specifications are of various kinds. The transmit clock frequency accuracy for synchronous modems is usually omitted. The ability to provide external transmit clock or derive clock on data is often not mentioned in the specifications. The response of the modem to a prolonged break (space state) in asynchronous mode should be checked. The loop-back capabilities should be tested to see that terminal echo as well as data regeneration (retransmitting what is received) work for both synchronous and asynchronous if that is required. Also, some multiplexers require a single system clock from the modem pair. This capability should be investigated if needed.

It should be noted that the interface omissions are done intentionally in the interest of brevity. The installation manual often answers these questions. Be aware that interfaces are a frequent source of problems during installation. Wiring errors in cables that connect terminal equipment to modems are common.

2. Modulator

The modulator specification is the easiest of all to test. Most often the spectrum analyzer tells all! Look for various spurious signals (spurs) around the carrier frequency as well as at harmonic multiples. Close-in signals when the carrier is not modulated indicate phase noise and are often sidebands spaced at the power line frequency. A good transmitter should deliver a clean signal with spurs down 50 dB from the carrier regardless of power setting.

If the modem is frequency agile, try different frequencies, including different receiver frequencies to see if the receiver local oscillators are leaking out to the cable.

Another modulator specification to check is the carrier disable leakage. When Request to Send is dropped the carrier should be down at least 50 dB. High leakage causes problems in single frequency multi-drop applications where the leakage signals can add up to a detectable signal level.

The frequency accuracy is associated with the temperature specification. This specification becomes more critical the closer the carrier frequencies are spaced. Transmitters usually hold tighter at low frequencies so plan your spectrum to have the narrow spaced RF modems in the lower channels if this is possible. Avoid spacing carriers any closer than 20 kHz, regardless of modulating bandwidth.

3. Demodulator

The demodulator performance is more difficult to test. Carrier detect threshold should be checked on a variety of frequencies if the modem is frequency agile. Certain subchannels may be unusable due to mixing products.

Two tone tests should be performed to check the receiver's front end for intermodulation products. A good way to do this is to generate two adjacent signals both at the maximum rated receiver input level. Apply these signals to the receiver input and see if the receiver detects the next adjacent channel which is the $2f_1-f_2$ third order intermodulation product. A measure of quality is to exceed the maximum level rating until the third order is detected. More is not better in the case of RF modem received signal strength. Third order intermods are a serious consequence of receiver overloading that can degrade modem performance dramatically.

Image rejection is another important specification to test. The manufacturer probably has not volunteered the IF frequencies in the specifications. Find out and apply a signal at the image and determine if it can be detected. The image rejection should be 50 dB in a good receiver design.

The receiver dynamic range is important. Make sure the modem can operate error free (data modems) or distortion free (voice modems) over the full range of rated signal strengths. Check with the manufacturer for the preferred receiver input level. Typical narrow band RF modems operate in the range of -20 dBmV to +10 dBmV and should normally see signal levels of around -10 dBmV.

A specification most often not specified for RF modems is tolerance to frequency translation errors. It is a very real impairment and gives a good measure of the quality of the RF modem. What happens in a system is that the head end frequency translator drifts so that the retransmitted forward channel signals are off frequency. A simulation of this will allow a measure of how many kHz a translator may be mistuned before the modems begin to operate erratically. Temperature affects frequency drift so test translation margins over temperature for a really rigorous test. A good headend frequency translator should be expected to hold within 750 Hz. RF modems should tolerate at least 2 kHz of translator drift with more margin very desirable.

Bit error rate under poor signal to noise conditions can also be tested. However, it should be noted that RF modems are not normally subject to the same kinds of noise that telephone modems experience. A properly maintained cable system has carrier to noise ratios well in excess of 30 dB. The bigger source of noise to the modem may well be the phase noise of the headend frequency translator! So beware not of amplitude related noise sources but the frequency/phase types of distortion. They are more subtle and have a far greater effect on the performance of the RF modem.

4. Environmental

Most RF modems are specified for a rather benign commercial temperature range. The biggest effect temperature has is causing the local osillators to drift in frequency. This can cause poor performance if the margin of frequency translation is narrow.

Low temperature can create problems with oscillator start-up. Test the modem for cold start. You may be surprised!

FM frequency discriminators sometimes become nonlinear under temperature extremes. This may cause distortion in voice modems or bit errors in data modems.

An environmental specification that is almost never specified in commercial equipment is mechanical shock. Your RF modems may not be flying in a high G force aircraft, but vibration is a very definite impairment to proper operation. The best test is the "slam test". Some modems, particularily those with poorly designed frequency synthesizers, are so sensitive to microphonics that the slightest tap of a pencil will cause a string of bit errors. Make sure the modem is slammed and keeps on working without errors. Of course, keep those slams reasonable or you may be slammed yourself!

5. General

The general specifications group are concerned with left over details such as power, size, and weight. The power specification usually gives a tolerance to line voltage variations. This should be checked with a variac while observing transmitted frequency and bit error performance.

The Unpublished Specifications

What you don't know may either hurt you or help you. There is often a fine line drawn between important specifications and trivial detail. Experience is usually the best judge. Below is a summary of important specifications that are often found "between the lines" of the specification sheet:

1. User test points.
2. User adjustments.
3. Intermodulation products
4. Frequency translation margin.
5. Mechanical shock tolerance.

Be certain to check these details. A good RF modem needs test points to support field testing and adjustments for various parameters such as transmitter power, receiver carrier detect level, and RTS/CTS delay.

Give every modem a frequency translation and shock test before installing at the user's location. Most problems show up with just these two simple tests. It takes ten seconds and could save days!

Don't forget to test the frequency translator for the same kinds of impairments. Frequency drift and third order intermodulation products are a real problem with poor translators. And of course, give it a good slam test too!

Conclusion

RF modems for CATV are here today. Test the specifications, written and unwritten, and participate in the booming data and voice communications business now happening on metropolitan cable television systems.