Agile Modulator Characteristics and Their Effects on CATV Systems

William Woodward

Scientific Atlanta

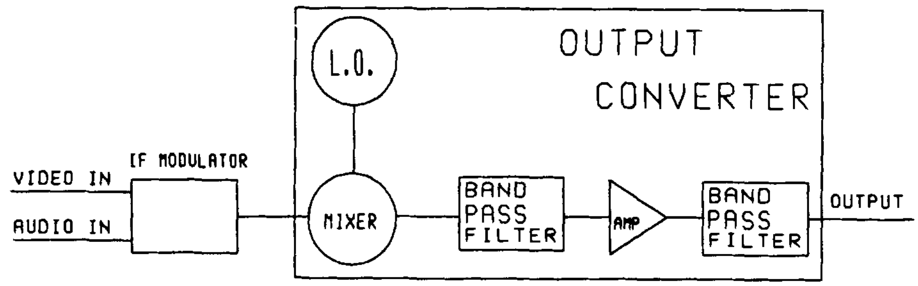
Over the past few years numerous video modulators which allow the user to select their output frequency have been introduced to the CATV market. Initially these frequency agile modulators were only used for back up of fixed channel modulators in CATV Headends, because they were significantly more expensive than fixed channel modulators. With increased interest in SMATV systems, numerous inexpensive frequency agile modulators have been introduced. Some of these "SMATV" modulators made their way into CATV applications, which precipitated the introduction of several cost effective "CATV Quality" frequency agile modulators intended for general Headend use. The CATV operator now has a large field of modulators to choose from. While frequency agile modulators offer numerous advantages, it is important to consider some additional performance parameters that have not historically been reflected in the specifications used to characterize fixed channel modulators. It is possible for two modulators to appear to have the same performance but actually have radically different performance. To understand the causes of these differences, it is necessary to understand how the fixed channel and frequency agile modulator differ in construction.

Basic Modulator Description

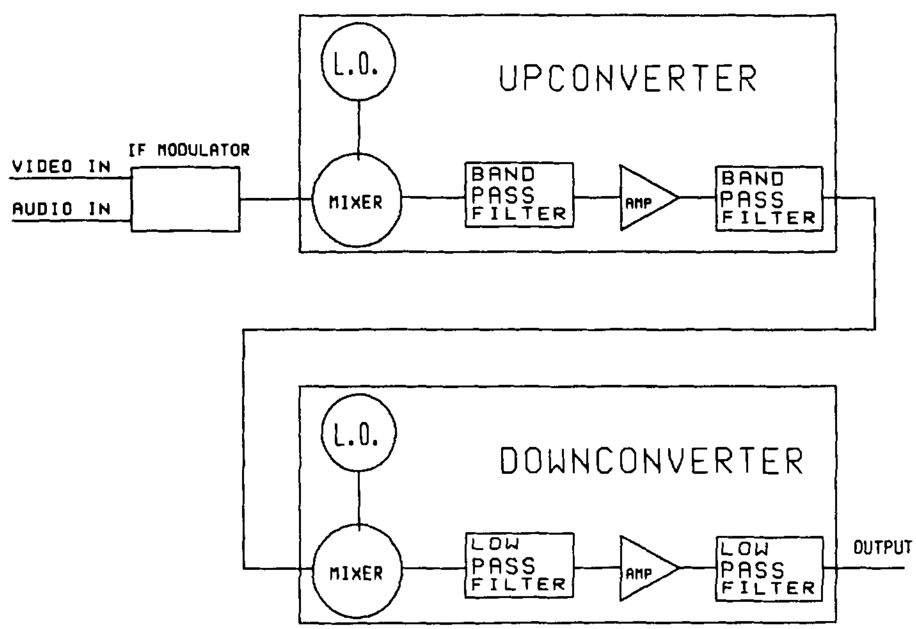
Most fixed channel modulators have a topology similar to that shown in Fig. 1. The baseband video signal is AM VSB modulated onto a 45.75Mhz carrier in the IF modulator block. This signal is typically run through a variable attenuator which ultimately provides the output level control. The 45.75Mhz IF signal is then processed in the output converter where it is hetrodyned in a mixer with a local oscillator which has a frequency 45.75Mhz above the desired output frequency. The output of the mixer is filtered and amplified to provide the final output signal.

The vast majority of frequency agile modulators have a topology similar to that shown in Fig. 2. In this system the IF modulator block is very similar to the IF modulator block of the fixed channel system, with the exception that the level control has been moved to the output converter block. The reason for this will be discussed later. The output from the IF modulator block is then hetrodyned in a mixer with a high frequency local oscillator (typically 600Mhz to 900Mhz). The mixer product which is the sum of the two signals is filtered and amplified. This produces a high frequency second IF signal. From the output of the upconverter the signal goes to the downconverter block where it is hetrodyned with a high frequency local oscillator which has a tuning range equal to the modulator output tuning range. The difference product produced in the output mixer is the desired output frequency. Different channel frequencies are obtained by changing the downconverter local oscillator frequency. The signal from the mixer is lowpass filtered, sent through a variable attenuator and amplified to produce the modulator output. Both of these block diagrams are typical of their type of modulator and may not exactly describe any particular modulator on the market.

Since the IF modulator block of the fixed channel modulator and the frequency agile modulator are essentially the same, specifications which describe the functions of these blocks for a fixed channel modulator are generally quite adequate for both types of modulators. These include Differential Gain, Differential Phase and Tilt to name a few. The specifications which describe the converter portion of the modulator must be more detailed for frequency agile modulators.



FIXED FREQUENCY MODULATOR
FIGURE 1



FREQUENCY AGILE MODULATOR
FIGURE 2

The following output converter performance parameters will be considered:

1. Spurious Signals

2. Thermal Noise

3. Phase Noise

Spurious Signals

In the CATV industry it is generally accepted that all spurious signals at the output of a piece of Headend equipment should be at least 60 db below the desired video signal. The primary sources of spurious signals in fixed channel modulators are output converter local oscillator leakage and 2-tone intermodulation between the video and audio carriers. The primary reason that these are the only spurious signals which cause a problem in a fixed channel modulator is that the output converter mixer is filtered with a narrowband filter which removes all other spurious signals. Filtering these two signals, however, can be difficult because of the intermodulation product's close proximity to the desired signal and the high power level of the local oscillator leakage coming out of the mixer. It should be noted that these signals change frequency when the channel frequency changes and do not combine with the same spurious signals from other modulators.

In the case of the frequency agile modulator the above mentioned spurious signals are present (they are produced in the upconverter block of the output converter), however numerous others may also be present. Since the downconverter typically has an output passband from 50MHz to 550Mhz, any spurious signals produced in the downconverter mixer or output amplifier chain could be present at the output. This includes harmonics of the desired signal and numerous mixer products. Since all of these spurious signals change frequency as the output changes frequency, they generally do not fall on the same frequencies as the spurious signals from other modulators and should not cause a problem if they are 60db below the desired signal. It is possible, however, to have spurious signals in the output which don't change frequency as the output frequency changes. These fixed frequency signals might, for example, be produced by microprocessor and frequency synthesizer clocks and their harmonics, which fall into the 50Mhz to 550Mhz band. These signals can get into the output portion of the output converter if there is inadequate signal isolation and decoupling on the printed circuit boards and modules which make up the modulator. Since all of the modulators of a particular design will have these spurious signals (if they are present) at the same frequencies, they will add together at the headend combiner. These signals will combine on a power basis so the following equation will determine the spurious signal level at the Headend combiner output:

$$S=K+10\text{Log}(N)$$

where
- N=Total number of Agile Modulators
- K=Spurious rejection of one modulator (dBc)
- S=System spurious level (dBc)

As an example consider a modulator with a fixed frequency spurious signal which is -60dBc. If 50 of these modulators were used in the system the spurious output at the system output would be:

$$-60 +10 \log 50 = -43\text{db}$$

This demonstrates that spurious signals which do not change frequency when the output frequency of a frequency agile modulator changes, should be much less than -60dbc if multiple modulators are to be used. Furthermore, the acceptable level of these spurious signals depends on how many frequency agile modulators are to be used in the system.

Thermal Noise

The next area where the specifications which have historically been used to describe fixed channel modulators are not adequate is the carrier-to-noise specification. Before dealing with the specifications themselves let us first review the sources of thermal noise in both modulator types. All active devices add to the theoretical noise power of a resistive source which has equal noise energy at all frequencies. Ideally, passive filters limit the bandwidth of these noise sources without adding any noise of their own and thus reduce the overall noise output power of the system.

In the case of a fixed channel modulator the last circuit before the output is almost always a narrow bandpass filter. This filter will usually limit the bandwidth over which the modulator contributes noise to the system to between 12Mhz and 18Mhz. Because of this, the single channel modulator does not make a significant contribution to system noise in any channels other than its own output channel and its adjacent channels.

Unlike the single channel modulator, the frequency agile modulator has no narrowband filter in the output amplifier chain. All of the noise produced in the amplifiers will be present at the output. The only bandwidth limiting occurs in the upconverter. This causes the typical agile output converter to have a noise output spectrum similar to that in Fig. 3. There are some manufacturers who have several filters in their down converters, each of which is wide enough to pass several channels. A particular filter is automatically chosen for any given output channel. This will reduce the wideband noise output of the modulator, however this modulator topology will still have a wideband noise output which is greater than the wideband noise output of a single channel modulator.

To demonstrate this point consider the following. The carrier to noise (C/N) specification is defined as the ratio of carrier power to noise power in a 4.2Mhz bandwidth occupied by the video modulation. In reality, the noise bandwidth of a typical modulator is more on the order of 18Mhz. The total noise contribution from a fixed channel modulator would be to the channel of interest and to the two adjacent channels. From this it can be seen that the system noise of a particular channel would be 3 times the noise of a single channel (The noise from the channel modulator plus the noise from the adjacent channel modulators). The combined Headend output C/N for a system made up of 50 single channel modulators with a 60db C/N would be:

$$C/N(sys)=C/N-10Log(3)$$

$$C/N(sys)=60-10log(3)=56db$$

If a similar system were built with 50 frequency agile modulators with the same C/N specification, and if the broadband noise level of these modulators were the same as their in-band noise level, the combined Headend output C/N would be:

$$C/N(sys)=60-10Log(50)=43dB$$

However, this is not necessarily the case, since a properly designed frequency agile modulator will contribute much less noise as the frequency spacing from the carrier increases. Note that such performance would not be indicated by the C/N specification which has historically been used. A simple carrier-to-noise specification is not adequate to characterize the noise performance of a frequency agile modulator. Frequency agile modulators require an in-band C/N specification and a wide-band specification which characterizes the out-of- channel noise performance of the modulator.

In addition to having a C/N specification, which usually implies a measurement with the output at its maximum level, it is important for the C/N specification not to decrease significantly as the modulator output level decreases. This is a function of where the output attenuator is placed in the modulator signal path. The closer the attenuator is to the output of the modulator the less the C/N decreases as the signal level decreases.

Phase Noise

The third area where fixed channel modulator specifications are not adequate to describe frequency agile modulators is in the phase noise specification. A phase noise specification has never been required in fixed channel modulators because the local oscillators are generally crystal oscillators which have very low phase noise. In the few cases where synthesized local oscillators are used, their tuning range is small enough and their operating frequency low enough that their phase noise is quite low. This might not be the case with frequency agile modulators.

Phase noise in frequency agile modulators can be broken into three categories, oscillator thermal noise, powerline related noise and reference sideband noise. Fortunately, the designs of most televisions make them tolerant to phase noise. Excessive phase noise can however decrease the video signal-to-noise ratio, create audio demodulation and stereo decoding problems, and make it impossible to use a synchronous video demodulator to demodulate the video signal. For these reasons the phase noise performance of a frequency agile modulator should be considered, with preference being given to units with the lowest phase noise.

Conclusions

As has been shown here, frequency agile modulators are a useful piece of equipment for the CATV Headend, however before choosing a modulator it is important to consider the additional characteristics discussed in this paper. It has been shown that frequency agile modulator performance with respect to these characteristics is especially important when multiple units are operating on the same system.

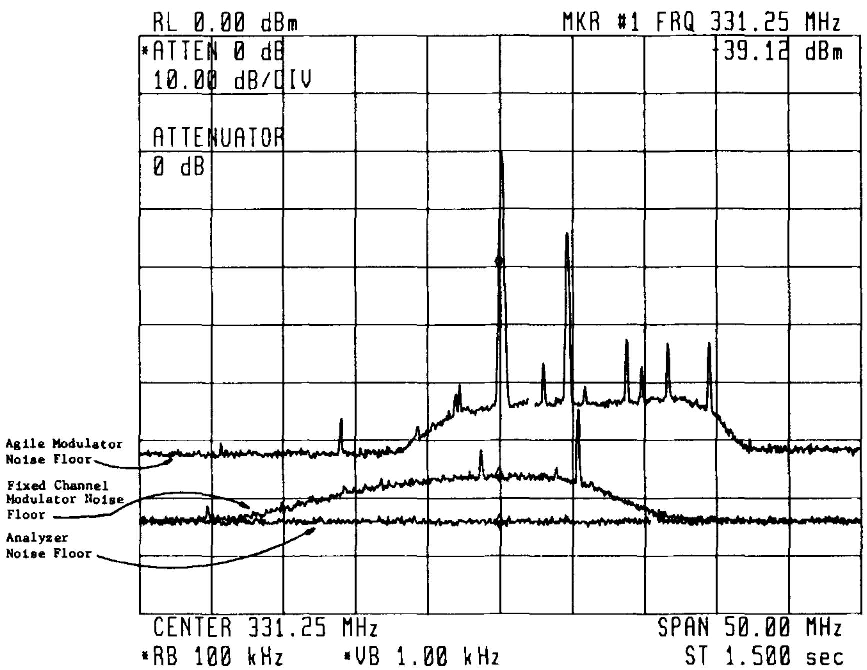


Figure 3