EXPANDED BANDWIDTH REQUIREMENTS IN CATV APPLICATIONS

DANIEL M. MOLONEY
DIRECTOR, SUBSCRIBER MARKETING

JOHN SCHILLING
DIRECTOR, RESIDENTIAL EQUIPMENT ENGINEERING

DANIEL MARZ
SENIOR STAFF ENGINEER

JERROLD COMMUNICATIONS

Converters have played an important role in the cable industry for years. As system bandwidth requirements have grown, so have the tuning capability in converters. During the 1980's, the introduction of "cable-ready" TV's and VCR's raised serious questions as to the benefits of converters. Unfortunately, however, most cable-ready tuners selected by consumer electronics companies are not acceptable in a direct cable environment. This paper presents an analysis of TV versus CATV tuners and the measureable benefit of converters in ensuring high quality, distortion minimized pictures are delivered to the viewing screen. It also touches upon the future challenges in tuner designs to achieve extended bandwidths beyond 550 MHz.

Bandwidth expansion in Cable Television has been a routine occurrence since the early days of cable. In the beginning of CATV, bandwidth requirements were limited to only the re-transmission of local programming in areas which could not access any off-air programming. Since these simple days, bandwidth has continued to double every 12 - 15 years due to the increased availability of diverse programming. Today, state-of-the-art system designs include 550 MHz or 750 MHz spaced plant with the plans to use the added capacity to offer new services such as Cable On Demand or multichannel Pay Per View. Time-Warner Cable has taken these designs even further with the 1 GHz plant in Queens, New York.

As bandwidth requirements have grown, so has the need to provide expanded bandwidth converters to allow subscribers access to these programs. Over the past several years, however, much has been written regarding the availability of "Cable-Ready" televisions and the related desire to remove the converter as a tuning device from the home. This argument has been based upon the perception that cable-ready TV's offer all the tuning capability required and converters simple duplicate this functionality in a less than consumer friendly fashion. As this paper will clearly demonstrate, however, even with only the current standard of 550 MHz bandwidth requirements, converters play a key role to ensure high quality, distortion minimized pictures are delivered to the viewing screen. Beyond 550 MHz, converters will play an even greater role as the tuner performance requirements exceed the capability of any TV tuner design. In moving beyond 550 MHz, a new technology is being investigated (GaAs) to provide these enhanced bandwidth capabilities.

Before analyzing the performance of TV tuners relative to CATV tuners, a brief review of the bandwidth expansion growth is in order. In the early 1960's, channel capacity on the cable plant exceeded the tuning capability of TV's for the first time. To add additional services, operators were required to deploy an 8 channel mid-band tuner. By 1967, the first 20 channel electro-mechanical cable converters were available. TV tuners were still limited to the VHF and UHF bands, so all homes receiving the expanded service needed to take a converter. 1973 brought about the need to expand the cable converter bandwidth to 300 MHz (36 channels) and by 1979 this had expanded to 400 MHz. During the 1980's, bandwidth continued to expand, first to 450 MHz and then to the current standard level of 550 MHz.

It was also during the 1980's, however, when TV manufacturers set out to solve the TV tuner limitation by adding "cable-ready" performance. Basically, this meant a TV was capable of tuning the entire cable band, first to 300 MHz, then to 450 MHz and over the past few years to 550 MHz and 806 MHz. What many TV manufacturers have failed to take into account, though, is the added tuner performance requirements necessary to survive in the cable environment without a cable converter. To fully understand this issue, it is necessary to review the technology employed in TV tuners as compared to that in CATV tuners.

SINGLE CONVERSION TUNERS

TV tuners utilize an approach commonly known as single-conversion tuning (Figure 1). In this implementation, all signals are first fed through an input tracking filter, and then are received by a mixer and the proper channel selected. A local oscillator (L.O.) is used to select the proper frequency under the control of the tuning system. The resultant single channel intermediate frequency (I.F.) signal is then made available to the TV demodulator for conversion to a baseband signal for viewing by the consumer. This approach to tuning is very cost effective and thus the preferred approach in the very cost competitive consumer market.

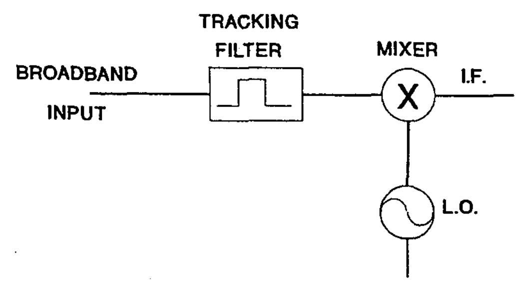

FIGURE 1: SINGLE CONVERSION TUNER

Single-conversion TV tuners were designed to operate in a broadcast environment where the tuning dynamic range is large, but the actual number of channels being tuned is limited and adjacent channel reception is seldom found. In this scenario, the power loading on the mixer due to the input channels is somewhat limited, thereby not overloading its capability which would result in distortion. When these same tuners are utilized in a cable environment, the channel loading is much greater and thus the power loading on the mixer is greater. The result of such loading is a reduction in the overall distortion performance of the tuners above a given bandwidth. In addition, TV's used in the broadcast environment are generally not coupled to one another within a home and therefore are not susceptible to L.O. leakage from another TV's tuner. Even when multiple sets are connected to the same antenna, leakage from the L.O. does not fall into the frequency of another channel. When these devices are linked in the cable system, however, L.O. leakage will inevitably fall within another channel and thus result in distortion.

To determine the actual performance of TV tuners in various channel loading scenarios, 21 TV's and VCR's ranging in date of manufacture from 1981 to 1990 were obtained. These devices were selected at random from the variety of equipment available within Jerrold. The bandwidth on the TV's and VCR's ranged from 300 MHz to 806 MHz, representing a cross section of all tuners manufactured over the past ten years. Measurements were made on the various devices on four basic criteria:
(1) L.O. leakage out the input connector,
(2) composite second order beats (CSO),
(3) cross modulation (adjacent channel),
and (4) image rejection.

L.O. leakage is a measurement worthy of further discussion in the cable market. The basic design of tuners uses an L.O. mixed with the input signal to select the proper channel. In a single conversion tuner, the L.O. frequency is set 45.75 MHz above the tuned channel. With an unbalanced mixer and high input power, it is difficult to prevent the L.O. frequency from leaking out in both directions from the mixer. The result is signal leaking out the input connector and into the input signal of a connected TV of VCR (Figure 2). In a single TV household, at least 25 dB of isolation is provided by the tap. Between sets in the same household, however, commercially available splitters provide less than 20 dB of isolation. Because a minimum of 60 dB of isolation is required to eliminate interference, the frequency of the leakage from the TV tuner L.O. becomes critical.

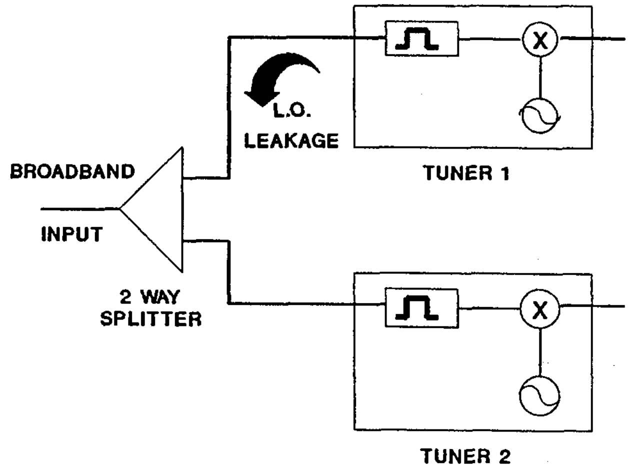

FIGURE 2: L.O. LEAKAGE SITUATION

Image rejection is also more critical in a cable environment than in the broadcast environment. The image frequency is 90 MHz above the channel being tuned. While TV and VCR tuners do employ filtering techniques, 60 dB of rejection is required in a cable environment. Because an image is seldom present in the broadcast environment, TV and VCR tuners are only designed for a maximum of 45 dB of rejection. Therefore, image rejection will cause problems with TV's and VCR's in a direct cable environment.

The summary results of the tests are shown in Tables 1 to 3. Table 1 reflects the number of tuning devices which passed the test in a 300 MHz loaded system, while table 2 assumes 450 MHz loading and table 3 assumes 550 MHz loading. Throughout the testing, live video feeds were used on all channels to simulate a real headend. The criteria used to determine acceptability was visible distortion which from years of experience would result in the following distortion numbers: (1) L.O. leakage > 40 dB with a 0 dBmV input level, (2) CSO >53 dB, (3) cross mod >57 dB, and (4) image rejection < 0 dB.

As can be seen from the results, only 4 of 21 tuners were able to perform within acceptable levels in all four categories with 300 MHz loading, with the number of acceptable sets dropping to 1 at 450 MHz and 550 MHz. While many people have proposed the use of cable-ready TV's along with some form of broadband technology to secure basic and/or premium services in cable systems in the future, these results clearly demonstrate the fallacy of such beliefs, even in 300 MHz analog systems, due to performance considerations. As system channel expansion grows, the use of broadband security approaches with "cable-ready" TV's and VCR's will result in the deterioration of performance. For reference purposes, table 4 provides the actual measured performance of the best and worst device tested in the study at 550MHz loading. The best TV was a 806 MHz model manufactured in the late 1980's which is only indicative of tuners sold into the market over the past few years. As the lifespan of TV's far exceeds ten years, the "cable-ready" sets which cannot truly survive in this environment without degrading picture quality will dominate the market for at least another ten years.

While no testing was performed with digital signals, the impact of L.O. leakage upon QAM modulated signals in sets connected through splitters becomes even more critical. Unlike analog signals, digital signals interfered with by L.O. leakage are not forgiving. Therefore, if one TV in the household is connected to the broadband signal in a cable-ready capacity and a second set is connected via a splitter and a QAM demodulator, the digital signals are likely to be overloaded by the L.O. leakage of the cable-ready TV. The final result may be either the loss of digital signal(s) or a very long time acquiring the channels due to the limitation of the adaptive equalizer. The implication of such a result is conclusive: direct connections to a cable-ready set for analog signals along with the connection to a digital demodulator for another TV or VCR will create problems. Therefore, the need for cable converters to maintain picture quality, in either analog or mixed analog/digital applications, will continue to grow.

DUAL CONVERSION TUNERS

Dual conversion tuners were available in the satellite industry long before their application in cable television became known. The first recorded use within cable was the introduction of a 260 MHz tuner in the early 1970's. In a dual conversion tuner, broadband signal are first converted to a high IF by mixing the input with the first L.O. and then downconverting it to the proper L.O. by mixing with the second L.O. (Figure 3). The first L.O. frequency is selected such that the leakage frequency falls outside the input video spectrum and thus eliminates the L.O. leakage concern. The first IF is then filtered before being subjected to the second L.O. and converted to either the proper TV frequency in a heterodyne converter or to the proper IF frequency for demodulation in baseband converters.

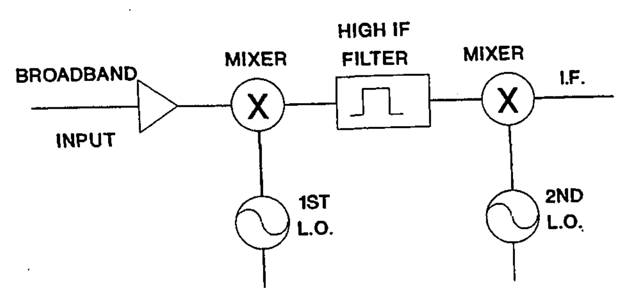

FIGURE 3: DUAL CONVERSION TUNER

TUNER B.W.	TOTAL TESTED	L.O. LEAKAGE	CSO	X-MOD	IMAGE	OVERALL
300 MHZ	4	0	4	1	3	0
400 MHZ	3	3	3	1	2	0
450 MHZ	2	0	2	0	2	0
806 MHZ	10	4	10	8	8	4
SP-650	2	0	2	2	0	0

TABLE 1: 300 MHZ LOADING

TUNER B.W.	TOTAL TESTED	L.O. LEAKAGE	CSO	X-MOD	IMAGE	OVERALL
450MHZ	2	0	1	0	2	0
806MHZ	10	4	8	1	5	1
SP-650	2	0	2	0	1	0

TABLE 2: 450 MHZ LOADING

TUNER B.W.	TOTAL TESTED	L.O. LEAKAGE	CSO	X-MOD	IMAGE	OVERALL
806MHZ	10	1	5	1	4	1
SP-650	2	0	2	0	1	0

TABLE 3: 550MHZ LOADING

	L.O. LEAKAGE	X-MOD	IMAGE REJECTION
BEST DEVICE	-2dBmV @129MHZ	-7dB CH 86	-24dB CH 70
WORST DEVICE	-26dBmV @485MHZ	+10dB CH 16	>+15dB CH 16

TABLE 4: PERFORMANCE AT 550MHZ

To determine the performance of cable tuners in various power loading situations, published specifications for converters from each of the major converter manufacturers were compared. The results of this comparison clearly indicate the superiority of the dual tuner approach in all situations, including 550 MHz loading. Therefore, dual conversion tuners must be utilized to provide the best picture quality possible in the cable environment.

EXPANDED BANDWIDTH CHALLENGES

As the cable industry moves beyond 550 MHz bandwidth, whether it be 750 MHz, 860 MHz, or 1 GHz analog and/or digital signals, the complexity of the dual conversion tuner design will grow. Due to the need to up-convert to such high IF's (up to 2 GHz in a 1 GHz tuner), the basic discrete design utilized to date presents several problems. One solution to this problem is to utilize a tracking filter on the front end of the tuner to limit the power to the first mixer. The downsides to such an approach, however, are the additional cost involved, the precision of the required alignments, and a decrease in noise performance. Another critical concern is the applicability of such an approach to digital signals due to phase noise considerations. With such overwhelming concerns, the need to discover a better approach is clear.

The most promising approach to solve the expanded bandwidth challenges involves the use of compound semiconductors. Silicon devices have been utilized in high precision microwave applications for a number of years. GaAs MESFET devices have demonstrated their superiority in low noise, wideband capability, and high frequency amplification. New generations of devices based on band gap engineering with the use of heterojunction structures have been explored. With improvements in material processing, lithographic techniques, and handling capability, yields have increased significantly with four inch wafers, reducing costs to the point that GaAs is extremely competitive with silicon. As a result, GaAs technology has become available in the high volume, low cost commercial applications such as cellular communications and automotive radar systems.

GaAs MMIC technology will shortly become available and cost effective for such applications as cable tuners as well. When used in this application, GaAs technology allows for the integration of low noise, low distortion amplifiers, low distortion mixers, wide dynamic range voltage controlled oscillators (VCO), and the attenuators required for AGC. Integration of these IC's in tuner designs requires extremely close coordination between the IC design house and the tuner manufacturer due to the total system implications of the IC performance. The long-term benefits of such an approach are high quality and consistency in manufacturing due to the component reduction and the elimination of several manual alignments.

The initial implementations of GaAs IC's at 550 MHz have recently been completed with performance equalling and in some cases exceeding discrete tuner designs. Tuners utilizing such technology are currently incorporated in one cable vendors product. Development is also far along on the use of GaAs IC's in 1 GHz applications. The results of such products will not be known for several months, although initial testing has proven quite successful. Long-term, the use of IC tuners in extended bandwidth applications will enable cable to achieve significantly enhanced performance relative to existing TV tuners, independent of the bandwidth or the composition of analog and digital signals.

CONCLUSIONS

"Cable-Ready" TV's and VCR's are truly an oxymoron. In today's cable environment, these devices are not capable of handling the system performance requirements. The use of an alternate access control mechanism to enable broadband signals to enter the home will ultimately result in a picture quality which is inferior to that which is provided through cable converters and thus will be judged unacceptable by most subscribers. This phenomena will be exacerbated over the next several years as bandwidth expansion takes most systems to at least 450 MHz of analog channels. With the introduction of digital signals on the plant and the potential expansion to 750 MHz/ 1GHz, the need for high quality extended bandwidth tuners is critical. TV and VCR manufacturers have recently begun to utilize dual conversion tuners in their more expensive products as the result of strong encouragement from the cable industry. Unfortunately, the window of opportunity has all but passed as cable bandwidth expansion will occur significantly faster than the replacement TV/VCR market. Therefore, converters will continue to play an important and beneficial role in the consumer's home for many years to come.