UNDERSTANDING MODULATORS

This article explains in simple terms, the basics of modulation as well as the different types of Modulators along with block diagrams and technical details of each Modulator topology.

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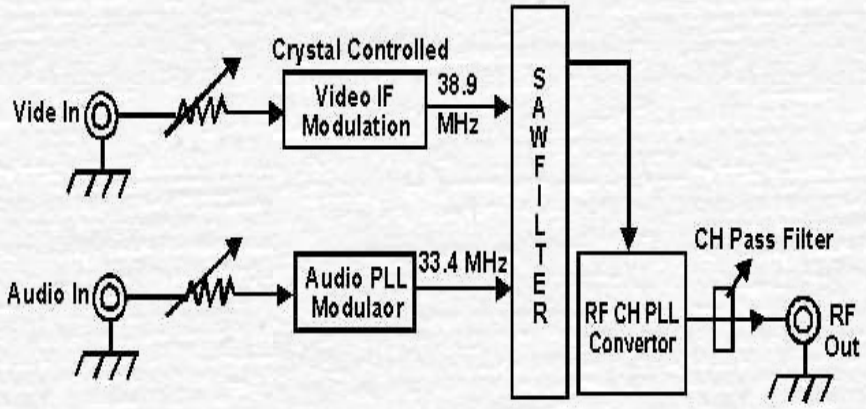
INTRODUCTION

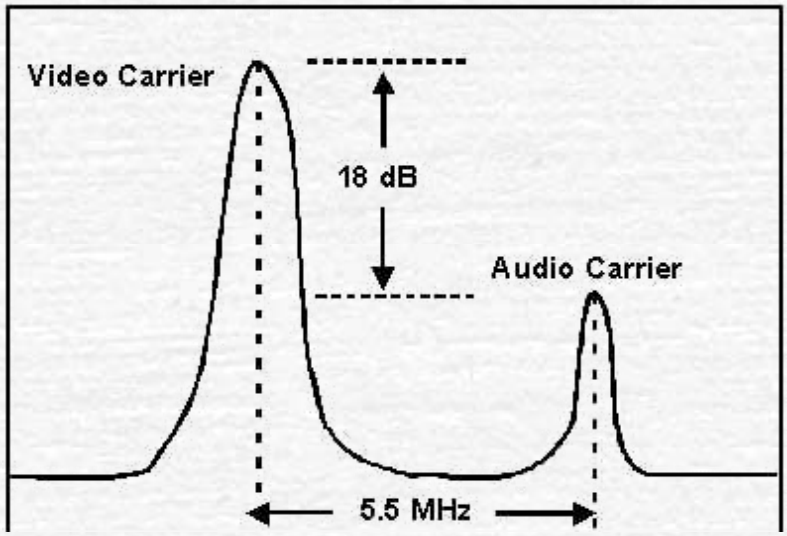
The Modulator is an indispensable part of any Headend or control room. Most CATV technicians accept the use of Modulators and the fact that each channel requires a Modulator at the Headend. However often, details of why modulation is necessary to begin with or the differences between various Modulators topology such as Saw Filter, single PLL, Double PLL and Frequency Agile Modulators, is often not fully understood.This article sets out to address these matters, in simple, easy to understand language.

MODULATION



Double PLL Sawfilter Modulator

While we all understand that a Modulator is required to modulate each channel at the CATV Headend, why do we need to modulate ? If we were to pass a single RF signal on a Cable TV network, the coaxial cable is well suited for the application. However, even one channel actually consists of two signals, in its simplest form the audio signal and the video signal. Therefore we would actually require two cables to carry a single television channel ! The situation would become completely unmanageable even for a modest number of channels say 36 channels..... Each subscriber would have to be provided 72 separate coaxial cables, 2 for each channel.



The Modulator actually receives the video and audio signals of a TV channel and modulates them or makes them change either the frequency or amplitude of an external, unrelated high frequency signal. This high frequency signal is the "Carrier" which carries with it the video or audio signal. If the video signal alters the amplitude (or strength) of the carrier signal, the modulation is referred to as Amplitude

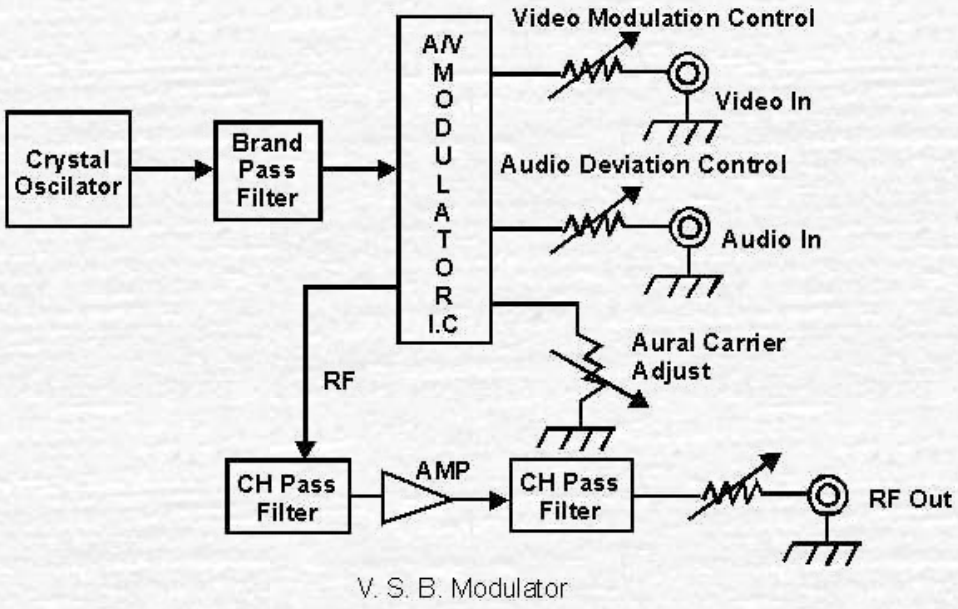
Modulation (AM). If the sound or audio signal alters the frequency of the carrier, it is referred to as Frequency Modulation (FM).

PAL-B/G MODULATORS

PAL-B/G Modulators provides for amplitude modulation of the video carrier and frequency modulation of the sound carrier. The PAL-B system dictates that the audio carrier is at a frequency of 5.5 MHz above the video carrier. It also allocates 7 MHz per channel in which both the audio and video carriers are accommodated. The PAL-B frequency plan is applied for carriers upto 300 MHz.

The UHF frequency band starts at 300 MHz. It would become increasingly difficult for TV tuners to accurately tune into a 7 MHz channel. Therefore, for frequencies above 300 MHz, the PAL-G frequency plan is used. PAL-G is identical to PAL-B in all respects except that 8 MHz is allocated per channel. Note that the spacing between the audio and video carriers remains at 5.5 MHz for both PAL-B and PAL-G.

CARRIER STABILITY

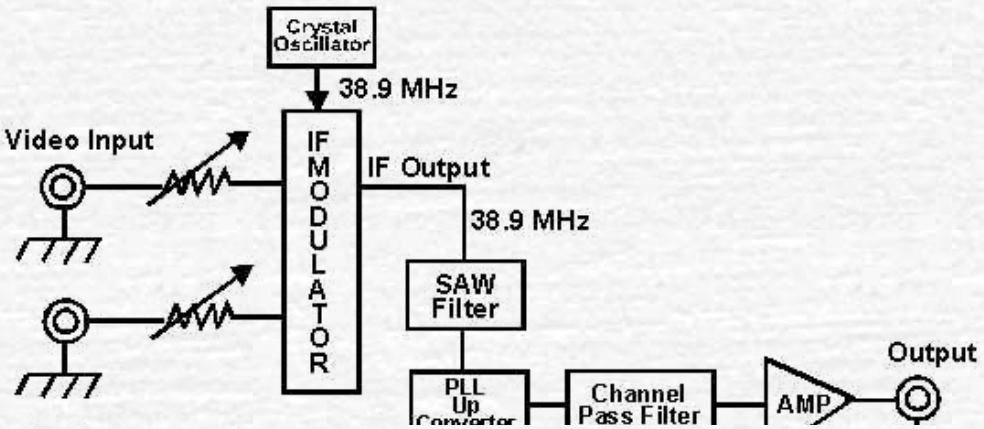


V. S. B. Modulator

If a large number of channels are to be closely packed together, it is very important to ensure that the carrier (video and audio) frequencies must be very well defined. Further the exact frequency should also not drift or change over a period of time. If the carrier frequency of 1 channel drifts, it could over lap with or cause disturbance to the adjacent channel. To ensure stable carrier frequencies, most modulators utilise a crystal oscillator. Crystal oscillators are low cost and provide excellent stability. Infact, we all know the accuracy of a digital watch or clock, which is driven by a crystal oscillator.

SAW & L/C FILTERS

The signal generated by a modulator has certain unwanted components. Simple Modulators also referred to as VSB or Vestigial Side Band Modulators include an output for about 1.25 MHz before the video carrier. This "lower side band" (lower because it is lower in frequency than the video carrier) will interfere with the sound carrier of the previous channel.



This implies that a VSB

Fig 3 : Block Diagram of a SAW Filter Modulator

Modulator is an alternate channel modulator. If a VSB Modulator is used for channel 4, Channel 3 will have to be kept unutilised on the system. Considering the large demand for channels on a Cable TV network, VSB Modulators are almost never used, even though they are much cheaper. The lower side band can be removed or filtered by using a combination of Inductors (L) and Capacitors (C). These L/C filters use low cost components but do not provide perfect filteration or suppression of the side band. Further, the value of the inductor, which is a coil of wire, can change significantly with temperature, humidity and even bump and vibration during transportation.

Some years ago a new technology emerged - the SAW Filter. The SAW Filter is a Piezo electric crystal which is cut in a particular fashion so as to permit the passage of only a pre-defined frequency between its input and output. The SAW filter provides near perfect side band filteration. As a result they have been widely adopted in all modern day Adjacent Channel Modulators.

THE INTERMEDIATE FREQUENCY (IF)

More than a 100 channels can be accommodated over the frequency span of 48 MHz to 900 MHz. It would be difficult to manufacture separate SAW filters for each of these channels. Maintaining stocks and other practical logistics would make the situation extremely difficult. As a solution, most modern day modulators adopt a system design that is indicated in the figure below. The video and audio signals are modulated, using a 38.9 MHz crystal oscillator. The modulated video and audio signals are produced at an "intermediate" frequency of 38.9 MHz for the video and 33.4 MHz for the sound. Note that the video carrier is above the audio carrier by 5.5 MHz. The 38.9 MHz / 33.4 MHz frequencies are referred to as intermediate frequencies since they are not the final output frequencies for the modulator but intermediate frequencies used inside the modulator which will then be transformed or UpConverter to the required RF output frequency. Also observed that the IF frequencies are lower than the lowest channel frequency of 48.25 MHz (PAL-B). The video and sound IF are then fed into a SAW Filter. This filter removes the side band and passes the filtered signal to the next stage.

DOUBLE SAW FILTER MODULATORS

A single SAW filter can be used or alternatively separate SAW filters for the video (38.9 MHz) and audio (33.4 MHz) IF frequencies can be employed for even better performance. If 2 separate SAW filters are employed, the Modulators are referred to as Double SAW Filter Modulators.

PHASE LOCKED LOOP (PLL)

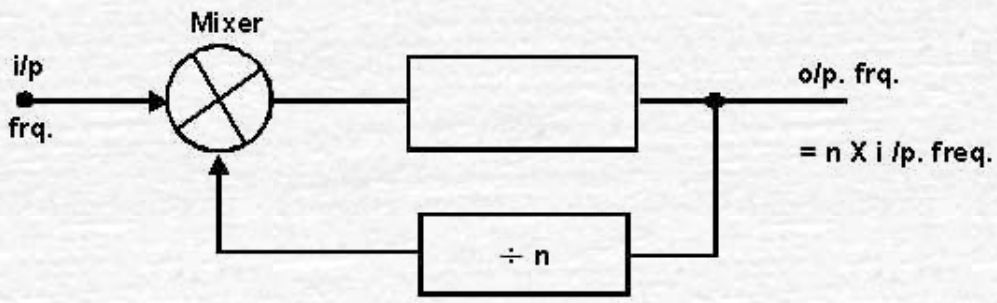


Fig. 4: PLL Block Diagram

The Phase Locked Loop is an electronic circuit which provides and output frequency which is a direct multiple of the input frequency. The factor by which the input frequency is multiplied to produce the output frequency can be very easily set. As an example, a simple PLL can produce an output frequency which is twice the input frequency. This multiplying factor of 2 can be altered very simply and this fact is used to design a Frequency Agile Modulator, as we will see later in the article.

THE PLL CONVERTER

Referring again to the block diagram of the Modulator, the output from the SAW filter(3) is fed to a PLL UpConverter. The multiplication factor of the PLL is set so that the input video and sound IF frequencies produce the required output video and audio carriers. In the up conversion process, the IF sound carrier actually emerges at a frequency 5.5 MHz above

the video carrier.

Using this simple method of up converting standard IF frequencies, the entire modulator block diagram and components upto the SAW Filter section are exactly the same for modulators of any channel. This facilitates manufacturer as well as lowers inventory cost.

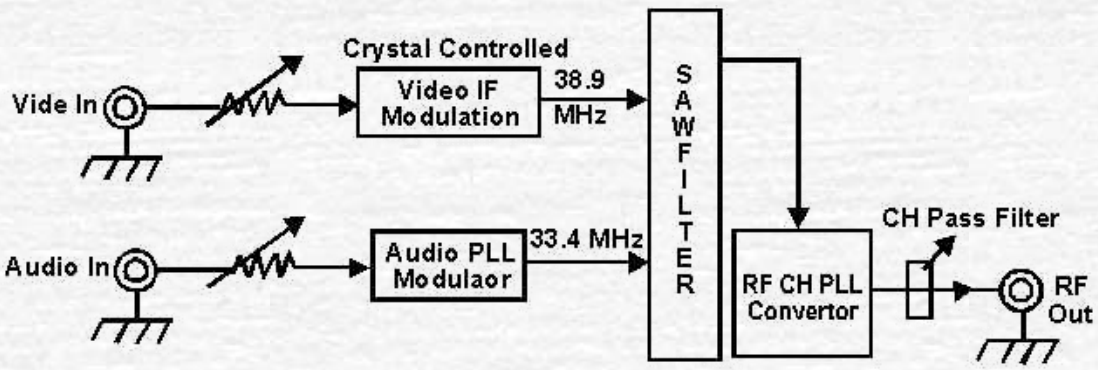
CHANNEL OUTPUT FILTER

The output of the PLL converter is usually fed to an L/C filter which suppresses unnecessary distortion and noise produced, outside the channel frequencies of interest. The channel pass filter is different for each channel and needs to be carefully tuned by the manufacturer.

Frequency Agile Modulators have an output that varies over a large frequency span. Hence they cannot employ fixed channel filters. In practice these modulators either do not employ any filter at all, which leads to poor output quality but lower cost. Alternatively, 2 or 3 band pass filters may be employed. A micro processor selects the appropriate band pass filter, depending on the selected output frequency. As an example, a modulator that is frequency agile from 48 to 860 MHz may actually employ 3 different band pass filter sections viz 48 to 300 MHz, 301 to 550 MHz and 550 MHz to 860 MHz. These band pass filters can easily add upto 30% to the cost of the product.

OUTPUT AMPLIFIER

The



Double PLL Sawfilter Modulator

output from the PLL UpConverter and subsequent channel filter is usually 80 dBU to 90 dBU. Most modulators now add an output hybrid IC which would provide and output level of upto 115 dBU for the modulator. Technically inclined readers will recall that the typical hybrid IC output level is maintained at approximately 100 dBU in amplifiers. In amplifiers, the IC is called on to amplify upto 67 channels (for a 550 MHz system) in the modulator, the IC needs to amplify a single channel and hence can provide a much higher output without significant distortion.

DOUBLE PLL SAW FILTER MODULATORS

The block diagram below illustrates a double PLL SAW Filter Modulator.As the name suggest, 2 PLLs are employed in the Modulator. The first PLL locks the audio IF carrier to 5.5 MHz below the video IF carrier. The video IF carrier frequency is determined by their crystal oscillator. A second PLL is used for the final up-conversion of the IF output from the SAW filter. The Double PLL circuit, can ensure that the audio carrier drifts less than 1 KHz from its specified frequency. This is excellent performance and would permit the modulator to be classified as Grade I equipment as per the BIS specifications.

FREQUENCY AGILE MODULATOR

The frequency agile modulator is usually similar to the Double PLL Modulator. The main difference is that the output up converter frequency can be changed by the user. A built in micro processor is typically prog-rammed with all RF carrier frequencies associated with specific channels. The user simply selects the channel number and the micro processor adjusts the PLL multiplication factor to obtain the necessary output carriers. As indicated earlier, either no output channel filter is used or a bank of band pass filters are employed which substantially add to the product cost.

MODULATOR ADJUSTMENTS

Manufacturers often provide user adjustments on the Modulators. Given below are a list of the various controls offered, usually on the front panel. We have also listed the effect of altering these and their optimum setting. It is generally recommended that besides the RF

output level, other controls on the Modulator be retained as per factory settings. Any meaningful changes in the factory settings can be done only with the use of the spectrum analyser or other specialised test equipment. The general recommendation is that "if all's well, DONT TOUCH !".

RF OUTPUT LEVEL

The RF output level from the Modulator can be adjusted usually over a range of 10 to 15 dB. The exact setting depends on the output level of other modulators as well as the mixing loss and whether a separate output amplifier is used after mixing. Full details on this have been covered in our April 2000 issue, in the article "Setting up the Headend".

AURAL LEVEL CONTROL

This adjust the amplitude of the audio / aural carrier, relative to the video carrier. Ideally, the audio carrier is factory pre-set 16 to 18 dB below the video carrier. If the audio carrier is too high, it will cause interference with the video of the next channel e.g. if the audio carrier of the channel 8 modulator is too high, it will cause interference with and distort the channel 9 picture.

Setting the audio carrier level too low results in a very low level of audio output on the TV set. Audio signal to noise ratio will be poor and a background hiss will be heard along with the audio.

AUDIO DEVIATION

The sound carrier is frequency modulated in a PAL-B/G system. This implies that the frequency of the audio carrier changes in response to level changes in the audio input to the modulator. Ideally, the audio deviation should be set to +/- 25 KHz. In effect this adjust the loudness or dynamic of the modulated audio signal. If set too low, it will lead to a poor signal to noise ratio and a background hiss on the channel. If set too high, it will cause bars on the picture of the same channel.

VIDEO MODULATION

The video carrier is amplitude modulated i.e. the amplitude of the video carrier changes with the video signal input to the video modulator. Proper adjustment calls for a 87.5% modulation depth. Reduced modulation depth will yield a dull picture with poor contrast. An excessive modulation depth will cause picture tearing and rolling.

CONCLUSION

This article seeks to cover practically all aspects of a CATV modulator's set up as well as the key technologies involved. It is hoped that readers will find the article helpful in selecting the best modulator for their needs, as well as evaluating the implications of advertised specifications and modulator configurations such as VSB, SAW Filter, Double SAW Filter, Single & Double PLL as well as Frequency Agile Modulators.

ACKNOWLEDGEMENTS

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