Direct-Broadcast Satellite Tuners Overview

For SHARP Products: BSFH - BSFL Series

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OVERVIEW

This Application Note is intended to provide background material to anyone who is not familiar with SHARP's Single-Conversion Direct-Broadcast Satellite (DBS) Tuners. The concept and purpose for the tuner, and each of the major sections of the tuner block diagram (Figure 1) will be explained. Topics will start with basic concepts, advancing to more complex information where appropriate.

INTRODUCTION

The Direct Broadcast Satellite (DBS) Tuner is the first section of the satellite receiver system that receives the signal from the antenna Low-Noise-Block (LNB) converter. The LNB for this example, is mounted in the focal point of the parabolic receive antenna. The antenna focuses the received signal energy onto the LNB feedhorn, which then passes it into the LNB. The LNB will then convert the 11.7 ~ 12.5 GHz broadcast signal to a 950 ~ 1750 MHz Intermediate Frequency (IF), an 800 MHz bandwidth in this example. (LNBs are available in different types, with conversion bands of 950 ~ 1,450 MHz, 950 ~ 1,750 MHz, 950 ~ 2,000 MHz, and 950 ~ 2,050 MHz. The LNB for this example will convert the received energy to the 950 ~ 1,750 MHz band.) For more in-depth information on LNBs, refer to the BSCC - BSCH Series Application Note. The 950 ~ 1,450 MHz bandwidth is used primarily in the United States. The 950 ~ 1,750 MHz and 950 ~ 2,050 MHz bandwidths are primarily used in European and Asian satellite systems. After the broadcast signal has been converted by the LNB, the signal is sent to the tuner. The 800 MHz-wide broadcast signal now occupies a frequency region that is easier to process than the 12 GHz signal. The entire 800 MHz-wide band is provided to the tuner input. The tuner will then be instructed by the receiver system to select an individual channel from the 800 MHz band, for conversion and demodulation, to provide video and audio information for viewing. The tuner is the conversion module that allows user control and selection of the program material.

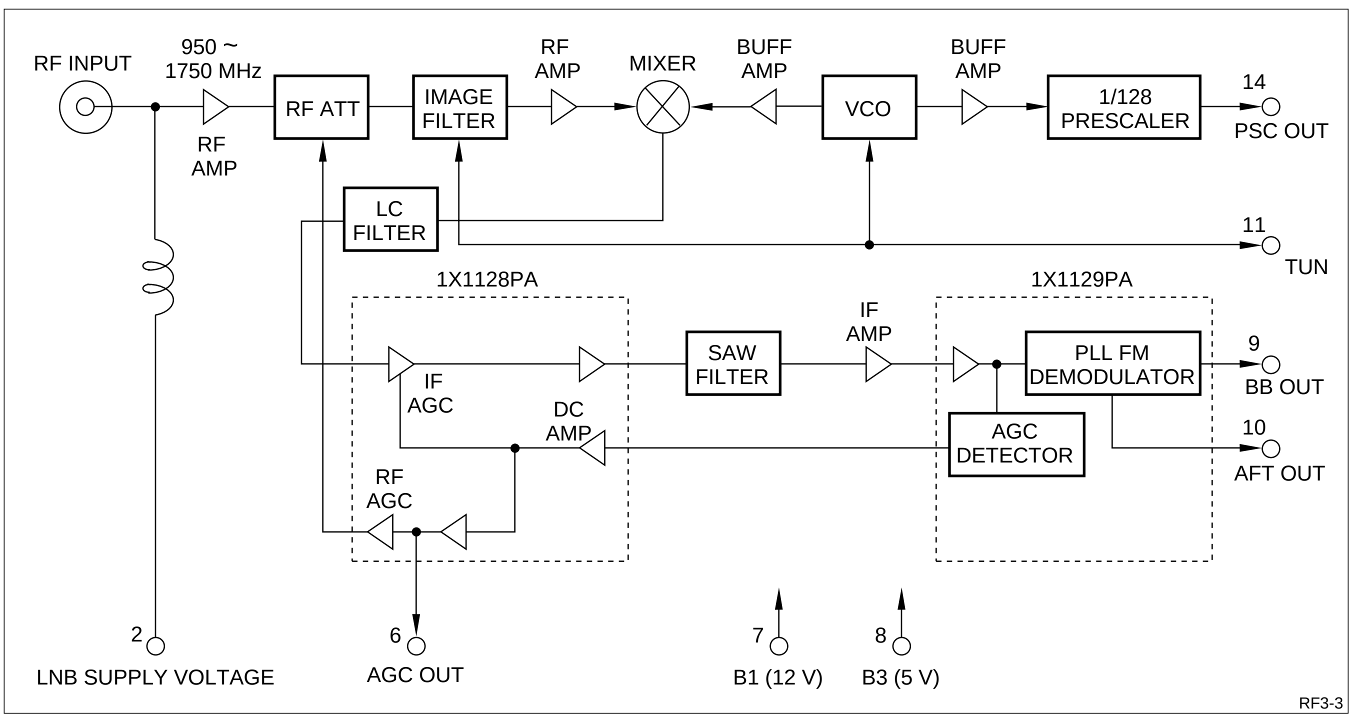

Figure 1. DBS Tuner Block Diagram

RF INPUT

The RF Input is the point of application for the received signal from the LNB. Refer to the tuner block diagram in Figure 1. The RF Input must be capable of handling the full bandwidth of the received signal energy without degradation. A 950 ~ 1,750 MHz signal would not be effectively handled by a 950 ~ 1,450 MHz tuner. This lower bandwidth tuner cannot tune the full band range, and the input is not configured to properly handle the wider input frequency range.

Input VSWR

The Input Voltage Standing-Wave Ratio (VSWR) is a specification that expresses how well the RF Input is electrically matched. The input electrical condition is stated to be a 75 Ω (Ohm, unit of resistance or complex impedance) environment. If the input is exactly 75 Ω in all respects, then the system is considered properly terminated, or matched, and all of the signal will be received by the tuner with no loss. In the real world, the electrical characteristics of the tuner input are not perfect and will change slightly. Some signal will always be lost, but the intent is to reduce the amount of loss whenever possible. VSWR is defined as a “ratio of standing-wave maximum amplitude to standing-wave minimum amplitude.” [1] The standing-wave minimum amplitude is generated by energy that is reflected from non-ideal characteristics in the RF Input, often expressed as a mis-match. A VSWR = 1 is ideal. As the input match becomes less ideal, the VSWR figure will increase. A VSWR = 2 is poorer than a VSWR = 1.5. In the tuner specification, a maximum value of VSWR = 2 indicates that the RF Input miss-match will be no worse than that given value. From this VSWR figure, an engineer can determine how much signal may be lost under worst-case conditions. For more information, refer to the Glossary/Appendix.

LNB Power

Electrical power for the LNB is provided on of the coaxial cable that connects the LNB to the tuner RF Input. The RF Input is AC-coupled to the tuner so that the signal energy is passed into the tuner assembly. The power for the LNB is a DC voltage, and will not be conducted to the tuner components. Any strong noise signals that are present on the DC power may be passed into the tuner input, or effect the operation of the LNB itself. For this reason, the LNB power source must be well-regulated and relatively noise-free to ensure the most efficient system operation.

RF AMPLIFIER

The RF Amplifier is used to raise the level of the incoming signal. Specific levels are required for proper operation of some components, such as the mixer. The RF amplifier at the input helps compensate for losses in the coaxial line from the antenna and LNB. The RF amplifier just prior to the mixer compensates for the loss associated with the Image Filter, ensuring that the mixer-drive level is correct for proper low-noise operation. A properly operated mixer will have a minimum number of spurious products in its output, and will perform in a predictable manner.

RF ATTENUATOR

The RF Attenuator is used to control the level of the signal entering the conversion chain. The input signal may change due to atmospheric conditions, or changes in the actual broadcast signal. The RF attenuator will be controlled by the AGC system to vary the input-signal level to maintain the proper operating conditions. It is part of a closed-loop system that will automatically track changes in the signal level so that the final output does not demonstrate any noticeable signs of the change.

IMAGE FILTER

The Image Filter is a tracking bandpass filter that is used to isolate the mixer section from the RF Input. Even though the block diagram shows signal flow from left to right, some of the energy from the VCO will migrate through the mixer and try to go out the RF Input port. Many regulatory agencies specify the level of signal energy that can be present at the RF Input due to the operation of the tuner itself. A well designed filter will provide a good impedance match between stages and attenuate reflected energy inside the tuner. Signal energy that tries to go from the mixer and through the filter will be reflected by the output of the RF input amplifier. This reflected signal will also be converted, generating spurious signals that will be delayed in time, and interfere with the original received signal. A good filter will minimize the amount of signal reflection and attenuate signals outside of the desired signal band. The tracking aspect of the filter is seen when the operating frequency of the tuner is changed. As the voltage on the TUN pin is adjusted to change the tune frequency of the VCO, the filter will also change its center frequency of operation. This change in bandpass frequency helps limit the number of individual channel frequencies that are fed to the mixer at one time. The mixer is not an ideal device and generates signal distortions based on the total number of signals and the level of each signal present. The amount of distortions indicate the degree by which the mixer is imperfect. Changing the filter center frequency during tuning limits the number of signals that are presented to and converted in the mixer, improving the inter-modulation performance of the mixer and the overall conversion process.

MIXER

The mixer is the device used to combine the received channel signals with the VCO signal, to produce an IF output with the desired channel signal. The VCO is operated at a frequency higher than the received channel spectrum. A general rule-of-thumb for mixers is that the signals present at the IF output are the sum, the difference, and the two original frequencies, or groups of frequencies. The mathematical expression for this operation is:

$$e(t) = m(t) \cos\omega_2 t + m(t) \cos (2\omega_1 \pm \omega_2)t$$

The input signal is represented by m(t) cos ω1(t) and the Local Oscillator (LO) is represented by cos ω2. The input signal has been translated to a new frequency, which is the LO plus or minus the input frequency. To work through the operation in general mathematics, the low end of the input range minus the LO is 11.7 GHz - 10.75 GHz = 0.95 GHz, which is 950 MHz. The upper end of the input range minus the LO is 12.5 GHz - 10.75 GHz = 1.75 GHz, or 1,750 MHz. In this manner, 11.7 to 12.5 GHz has been translated to 950 ~ 1,750 MHz. The sum of each of these signals is also present, though not desired or used in this type of application. To tune a channel that may be at 1,000 MHz, the VCO must be positioned at a frequency higher than the desired channel. The difference in frequency must be calculated to place the mixer IF output at the desired frequency. In this case, for an IF of 479.5 MHz, to tune a channel frequency of 1,000 MHz, the VCO would be positioned to 1,000 MHz + 479.5 MHz = 1,479.5 MHz. In the mixer, the combination of the 1,479.4 MHz VCO and the 1,000 MHz input signal will be combined to produce a 479.5 MHz output IF difference signal. In this manner, 1,000 MHz has been converted to 479.5 MHz. An input at 1,700 MHz could be converted to 479.5 MHz the same way. The other frequency components of the process are also present, but are undesired in the final output. The LC Filter block on the IF output of the mixer will be used to bandpass the desired signal, and reject the undesired components.

VOLTAGE CONTROLLED OSCILLATOR (LOCAL OSCILLATOR)

The Voltage Controlled Oscillator (VCO) is the signal reference used to select the desired channel signal for conversion. The VCO is tuned to a frequency above the channel of interest. The VCO must be tunable, yet stable at the selected signal frequency to ensure a quality conversion process. If the VCO is noisy in amplitude, or unstable in frequency, then the IF output will be poor. Amplitude variations will effect the quality of the recovered signal by causing variations in the amplitude of the IF signal. These variations directly influence the video content of the recovered signal. Frequency variations of the VCO, or jitter, are known as “Phase Noise.” The VCO is essentially tuned to a given frequency, but is experiencing small frequency variations. Poor system design will contribute to phase noise errors in the IF signal due to inserted error signals. Phase noise degrades the recovered signal because the IF will contain additional signal energy that was not part of the original signal. Frequency Modulation is used to transmit video information, so frequency errors directly become signal errors. Larger instability of the VCO will cause the IF to be affected to a greater degree and degrade the overall reception process. The VCO is tuned by the application of an external tuning voltage. The Phase-Locked-Loop (PLL) frequency synthesizer block will provide a DC voltage proportional to the frequency to be tuned. This tuning voltage must be noise-free and well controlled so as not to inject frequency related problems into the VCO. The tuning voltage is an easy entry point for frequency errors as the voltage directly effects the output of the VCO.

Buffer Amplifier

The VCO output is passed through two Buffer Amplifiers. These amplifiers isolate the VCO from the mixer and prescaler, respectively. Isolation prevents either the mixer or prescaler from affecting the VCO frequency or amplitude output, due to component variation, or changes in the environmental operating conditions. For example, if the input to the mixer is not a perfect impedance match, as described above, it will tend to load the VCO output by a different amount at different frequencies. The buffer amplifier can drive the changes in the mixer without affecting the output of the VCO.

Prescaler

The prescaler divides the VCO frequency, or prescales, for the frequency tuning system. Usually the frequency control system is a PLL device. The PLL loop will compare the scaled VCO signal with the PLL reference frequency to compensate for tuning errors. The prescaler, in this example, divides the VCO output frequency by the constant, 128. Some prescalers may be externally controlled to divide by different constants, as commanded by the PLL control system.

PLL SYSTEM

A Phase-Locked-Loop (PLL) system is generally used as the frequency control for DBS tuners. As the name implies, phase information is actually used to track the operation of the VCO. The PLL device is clocked by a high-stability fixed-reference frequency, usually provided by a crystal. The PLL is sent tuning data by the system microprocessor for each frequency that the system will tune. Using this information, the PLL looks at the phase difference between the reference and the VCO input from the prescaler. Phase errors correspond to frequency errors in the loop. Phase differences between the reference and the prescaled VCO output indicate a difference in frequency, as frequency is the rate of change of phase. When the phase difference between the reference and the VCO sample indicates that phase errors are at a minimum, or zero, the VCO is at the correct frequency. This comparison is performed in the PLL device. The data sent by the microprocessor is a count value that is proportional to the difference between the reference frequency and the desired prescaled VCO input. The prescaled VCO frequency input will be higher in frequency than the reference frequency. The count value provided by the microprocessor will be loaded into counter-registers internal to the PLL. As each cycle of the prescaled VCO input reaches the PLL chip, the counter, or counters if more than one, will be decremented in a predetermined fashion. The output signal from the counter-registers will be compared to the reference frequency. The PLL chip will then make a phase comparison and provide output signals that may be used to correct the VCO tune frequency to place the tuner on channel. For each channel that the tuner is programmed to receive, there will be a unique count value for the PLL to use as comparison data. This ability allows the PLL to tune and lock to a wide range of channel frequencies, while still maintaining close control over the frequency of the VCO. The flexibility offered by PLL circuits has led to a new generation of lower cost, high quality tuners and other devices across the RF industry.

External PLL

Some DBS tuners generally do not have an internal PLL. A prescaler or VCO output is provided for connection with a PLL system. This allows the receiver system engineer to design the PLL system, choosing amplifier circuits, filters, and the VCO driver. Some applications may have special requirements that would not be adequately addressed by a pre-designed PLL system. Also, by not including the PLL circuits, the tuner is generally lower in cost to the customer. However, additional work is required on the part of the system designer to complete the tuning system.

Internal PLL

Most DBS tuners are available with an internal PLL system. The tuner module is interfaced with the receiver system microprocessor for the loading of tuning data. Internal PLL systems are designed by the factory engineer to provide accurate and stable frequency control for the tuner. In many cases, the receiver system designer has no need for special tuning requirements, and the modular design fits all requirements. Internal PLL tuners may have a somewhat higher price than non-PLL tuners, depending on production volume.

IF SYSTEM

The Intermediate Frequency (IF) system amplifies and filters the channel signal of interest. The unwanted channel signals will be suppressed to eliminate any source of interfering signals. The first IF amplifier is controlled by the AGC circuits to adjust the signal level after the LC filter and prior to the SAW filter. The SAW filter output will then be amplified to provide the correct level into the demodulator assembly.

Filter

The primary bandwidth filter is a Surface-Acoustic-Wave (SAW) filter that has a well defined frequency response. The out-of-band rejection by the SAW filter eliminates most of the signal energy not associated with the selected channel. SAW filters are used for their well defined characteristics, and stability over changes in operating environment.

Multiple Filters

Capability for incorporation of multiple IF SAW filters is designed into some tuner products. Filter selection is provided by an RF switch that connects one filter or the other into the IF signal path. In some models an external pin(s) is provided on the tuner assembly to allow for receiver system control over the bandwidth selection. Other models use internal software control to select the desired filter. Current tuner models provide either one or two bandwidth filters.

AGC

Automatic Gain Control (AGC) is incorporated into the tuner to maintain optimum internal signal levels over a defined range of signal levels at the RF Input. The AGC system monitors the IF signal applied to the demodulator and develops a DC voltage proportional to the signal level. This AGC voltage is then amplified and sent to the IF AGC amplifier and the RF Attenuator. As the input signal level increases, the RF Attenuator will decrease the signal level and the IF amplifier may decrease its amount of amplification, depending on the AGC level. The AGC system works in the opposite manner for decreasing input signal levels. If tuner components change over time and operating conditions, the AGC system will help to compensate.

DEMODULATOR

Existing satellite broadcasts for video transmission use Frequency Modulation (FM) as opposed to terrestrial broadcast using Amplitude Modulation (AM). The demodulator also uses a PLL to recover the video signal. In preparation for satellite uplink, the amplitude-varying video signal is converted to a frequency-varying modulated signal. The demodulator PLL in the receiver tries to track the frequency-varying modulated signal, producing an error signal that is proportional to the amount of frequency change. This error signal is then processed as the recovered baseband video signal. Another signal is added at the transmission facility to help prevent damage to the satellite components. A 30 Hz triangle wave is superimposed on the FM video signal to keep the signal moving, with respect to frequency, in the satellite's electronic components. This prevents the satellite's power amplifiers from remaining stationary at a single frequency for any period of time, which could damage those components. This is a protection feature insuring the operational capability of the satellite.

Digital Demodulation

Newer Digital broadcast techniques use a Quadrature Phase-Shift Keying (QPSK) process to transmit digital data. The RF section of the tuner operates in a similar manner as for FM signals. However the demodulator uses a digital process to extract the data and is not included in the tuner. Tuners that provide an IF output are used in this type of reception system and are not covered herein.

AGC Detector

The Automatic Gain Control (AGC) detector monitors the level of the IF signal at the input to the demodulator. The AGC detector output will be a DC voltage that is proportional to the IF signal level. The detector input is monitored, as the detector needs a steady input level for consistent recovery of the video signal. The AGC output will be amplified and used to control the RF Attenuator and the IF AGC amplifier, maintaining the level at the detector relatively constant at all times.

OUTPUTS

Video

Baseband (demodulated) video is provided as one of the outputs from the demodulator section of the tuner. Baseband video is different from a modulated carrier such as broadcast by a local television station. This is the composite video signal that includes all of the information required by a monitor to present an image. Baseband video corresponds to the video signal that is provided from video recorders and players directly to a monitor. The video output occupies a 4.5 MHz bandwidth when the program source material has been deviated with 17 MHz p-p FM modulation at the transmit site, as shown in Figure 2. The 4.5 MHz bandwidth includes all of the signals in the baseband video to provide a color television picture for North American NTSC-M format systems. For this example, 17 MHz represents a fully deviated signal from the uplink facility. The use of a wide bandwidth allows for greater signal recovery at the receiver site.

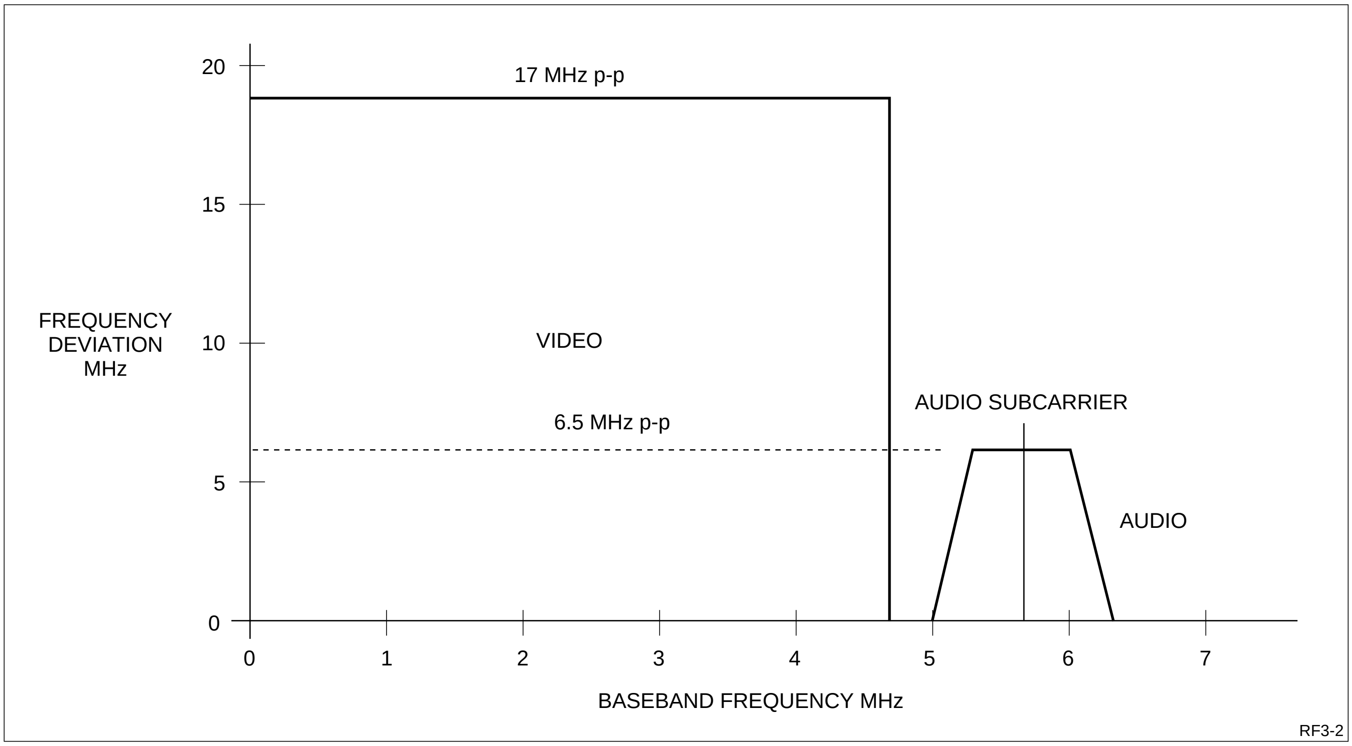

Figure 2. Combined Video and Audio Outputs

Coupling

The video output on many tuners is AC coupled with a capacitor to the video circuits. This means that there is an AC signal path from the tuner output to the video circuits, but no DC path. In applications where a tuner module is being used to replace an earlier model, this point needs to be considered. Some earlier version tuners had DC coupled outputs. If a tuner requiring AC coupling is inserted in a circuit designed for a DC coupled tuner, the output signal will be incorrect. Addition of an appropriate coupling capacitor between the new tuner and the original video circuits will generally solve this problem (Figure 3).

Video AFT

The Video Automatic Fine Tuning (AFT) output provides a method for the demodulator to indicate how precisely the tuner is on channel. The PLL in the demodulator expects the IF input to be at a particular frequency. If for some reason the tuner is tuned below the desired frequency, the AFT output will provide a DC level that is shifted away from its normal level. The polarity of the DC change in voltage indicates whether the tuner is above or below the correct frequency. Usually the AFT output will be summed in with the VCO control voltage to automatically correct for small tuning errors.

The tuning errors may be due to the satellite broadcast system, or to slight changes in the components of the receiver system. AFT generally compensates for small errors. The input to the demodulator is able to compensate for reasonable errors without correction, however for best operation it is best to center the received signal frequency as close as possible in the IF bandpass filter. Large tuning errors should be corrected by the microprocessor adjusting the main frequency control PLL.

Analog AFT

Two types of AFT circuits are used in FM Demodulator tuners: Analog and Digital AFT. Analog AFT is a DC voltage derived from the demodulator in the tuner. The demodulator is a Phase-Locked Loop configured as a tracking demodulator. It can track and demodulate combined video and audio up to 40 MHz in width. However, to properly recover the signal content, the IF needs to be centered in the bandpass filter. The demodulator provides a DC output voltage that is proportional to the amount of IF tuning error that the demodulator sees. In analog AFT systems, this voltage is provided on a tuner pin for connection to external circuits. In these systems, a set of window comparators or an Analog to Digital Converter (ADC) is used to sample the AFT voltage and then use the system Microprocessor make

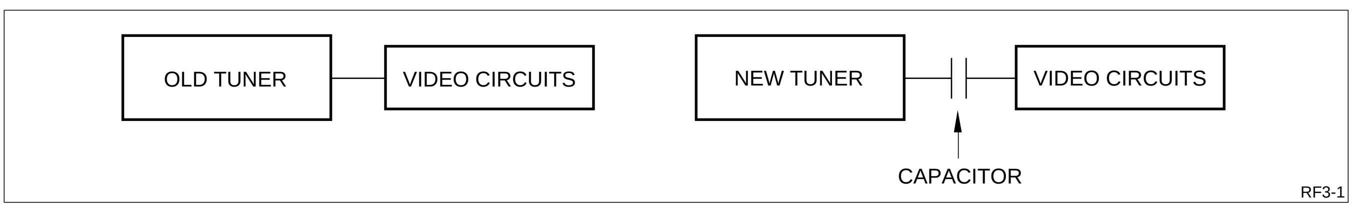

Figure 3. Inserting New Tuner in Old Tuner Circuit

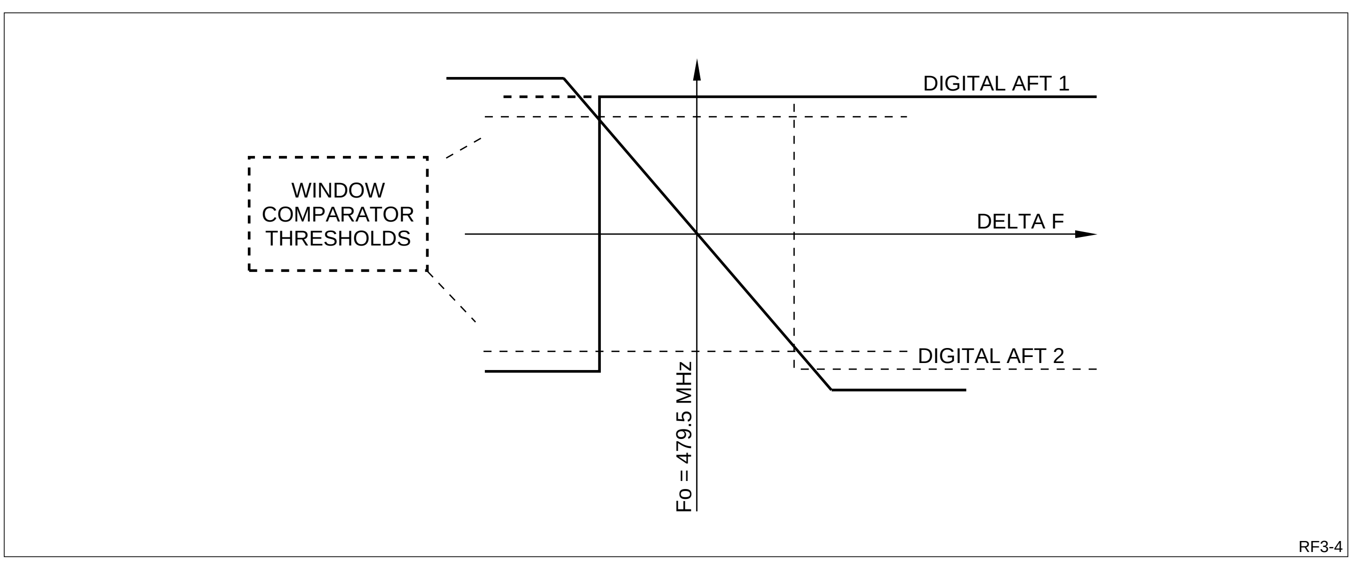

Figure 4. AFT

appropriate PLL tuning adjustments. Use of analog AFT has required additional external circuits to determine the receiver tuning accuracy. Consideration of changes in these components over temperature is important to the overall system tuning accuracy.ers, a Digital AFT process has been incorporated. The same process as described in the section on Analog AFT is used to derive the DC voltage that indicates tuning accuracy. However, in the case of Digital AFT, the window comparator is provided as part of the demodulator IC. Two AFT bits are provided as outputs, Digital AFT 1 and Digital AFT 2. Since the window comparator is included on the demodulator IC, all of the circuit errors track together over temperature. The system designer does not need to add external circuits to check the AFT condition. The system Microprocessor can simply read the condition of the two AFT bits provided on tuner pins to determine the AFT condition. A diagram of the AFT slope, the window comparator thresholds and the condition of the AFT bits is shown in Figure 4. The center section where both AFT bits are high is about 400 kHz in width. The horizontal axis is delta F, the change in frequency from the center of the IF passband. For most systems, the PLL is able to step and keep the IF within the 400 kHz window, which will provide optimum operation.

Video Measurements

The recovered video signal includes all of the information that is required to produce a television picture, and is known as composite video. There is no guarantee that all components of the signal are correct in all respects. After a tuner is installed in a receiver system, the engineer must make certain measurements to insure that the video signal is not being affected by either the tuner or the supporting video circuits. Care must be taken by the engineer so that the process of making the measurements does not skew the test results. Poorly performed measurements will give the impression that the tuner or video circuits have a problem, when in fact the measurement practice is at fault. A few of the more common measurements will be touched on here. Frequency Response “Frequency-response measurements evaluate a system’s ability to uniformly transfer signal components of different frequencies without affecting their amplitudes. This parameter, which is also known as gain/frequency distortion or amplitude versus frequency response, evaluates the system’s amplitude response over the entire video spectrum.” [2] Frequency response problems can cause a wide variety of picture problems. The picture quality may be poor and the specific cause difficult to ascertain. Differential Gain is present if chrominance gain is affected by the luminance level. [3] Luminance is the portion of the video signal that carries the information describing how bright an individual pixel in the television image will be. Chrominance carries the information about which color and how much color is in each pixel. The combination of luminance and chrominance are used in a television receiver to properly reconstruct the picture image with the correct colors and intensity. [4] Differential Phase distortion is present if a signal’s chrominance phase is affected by luminance level. [5] This type of distortion can cause changes in picture hue when the picture brightness changes, or colors may not be properly reproduced in high-brightness areas. [6] This is because the chrominance signal carries the image color information, and if this signal changes, so will the colors in the displayed image. The chrominance phase is measured relative the color subcarrier signal, which is also part of the composite video signal. There are a wide variety of other video tests that should be performed on a video recovery system to ensure correct video delivery. The three tests outlined above only provide a little insight into the complexity of the video signal and the need to ensure that all portions of it are correct for a television picture that provides comfortable viewing. Refer to the Appendix for additional information on television measurements and informational references.

Audio

The recovered Audio signal is provided on the same output pin as the video information. The audio is carried on a 5.727 MHz subcarrier that positions it above the recovered video signal (Figure 2). When the audio signal at the transmit site is deviated 3.25 MHz, a 727 kHz signal will be recovered from the IF demodulator. An audio demodulator integrated circuit will then be used to remove the audio subcarrier and provide an audio output. The Audio output should also be tested for audio frequency response and amplitude distortions. These distortions may be created at the broadcast facility or at the DBS receiver. Recovery of audio signals, including stereo processing, must be done external to all SHARP tuners. Most manufacturers of Integrated Receiver/ Descrambler (IRD) units want control of audio processing in order to be able to offer audio quality commensurate with the cost of the receiver. Stereo, or other extra audio information will be provided on the audio subcarrier along with the regular audio information.

GLOSSARY/APPENDIX

Ohm (Ω) Unit of electrical resistance. In complex circuits such as those seen in RF transmission lines and circuits, the unit of Ohms is used to define complex impedance in addition to electrical resistance. In the impedance plane, both resistive and reactive elements exist. If the reactive element is zero, then the real component (resistance) remains. Reactive components of impedance are due to inductive and capacitive components as seen by the circuit.

Video Measurements

The performance of correct video measurements is a specialty and an industry all to itself. These measurements should be approached only after reviewing the correct procedures and methodologies for each test. Incorrect procedures and methods will create erroneous readings and lead to poor conclusions about the operating capability of the equipment under test.

Books and application notes covering television measurements are available from several vendors. Source material for this document was drawn from publications obtained from Tektronix, Inc., a manufacturer of television measurement systems. Use of these source materials does not imply endorsement of any kind by SHARP Electronics Corporation. Tektronix contact point: P. O. Box 1700, Beaverton, Oregon, 800-835-9433, Fax: 503-641-7245. Voltage Standing Wave Ratio (VSWR), defined as:

$$VSWR = \frac{|V(\times)|max.}{|V(\times)|min.} = \frac{1+|\Gamma_0|}{1-|\Gamma_0|}$$

where $\Gamma 0$ is the reflection coefficient of the load, or terminating input in the case of this discussion. [7] The VSWR is a ratio expressing the incident energy compared to the reflected energy at a fixed reference point or plane. In this discussion, the reference point (or plane) is the RF Input of the tuner. An ideal match with VSWR = 1 implies that all of the incident, or incoming energy is perfectly coupled into the RF Input with no loss. If the RF Input has any imperfections (real world) then some amount of energy will be reflected. VSWR is an indicator of how well the RF Input of this tuner matches its expected characteristics. This argument holds for any reference point or plane in an RF transmission line system. Bear in mind that transmission line theory operates in the complex impedance plane and has many attributes that are not discussed here. Any good text on transmission line theory will explain this topic in greater depth.

REFERENCES

[1] Illustrated encyclopedic Dictionary of Electronics, John Douglas-Young, 1981, Parker Publishing Co.

[2]Television Measurements, NTSC Systems, Margaret Craig, p. 37, Tektronix, Inc., Beaverton, OR

[3] ibid, Craig, p. 52

[4] Solving the Component Puzzle, John Horn, p.2, Tektronix, Inc., Beaverton, OR

[5] ibid, Craig, p.48

[6] ibid, Craig, p.48

[7] Microwave Transistor Amplifiers, Guillermo Gonzalez, 1984, p. 4 - 8, Prentice Hall

ADDITIONAL REFERENCES

RF/IF Designer's Handbook, 1992, Mini-Circuits Division of Scientific Components.

Principles of Communications, Ziemer/Tranter, 1985, Houghton Mifflin Company.

Telecommunication Transmission Handbook, Roger L. Freeman, 1991, Wiley & Sons.

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