Tektronix

Cable TV Measurements Using the 2714/2715 Spectrum Analyzers

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Introduction

Modern spectrum analyzers are the most powerful tools available for cable TV performance analysis. They provide the ability to measure a wide range of system parameters, from simple carrier level checks to in-depth analysis of system performance – including all of the RF proof-of-performance measurements. In addition, today's spectrum analyzers greatly simplify complicated test processes by automating many of the instrument setups and by logging the resulting data.

This application note will assist the engineer or technician in making and interpreting measurements made with the Tektronix 2714 and 2715 Cable TV Spectrum Analyzers. Covering 9 kHz to 1800 MHz, the 2714 and 2715 have the accuracy, resolution, and dynamic range to perform in-depth analysis of cable television systems. With a 2714 or 2715 and a little training, measurements that were previously difficult and time consuming can be performed quickly and with improved accuracy.

The primary difference between the 2714 and the 2715 is the 2715's enhanced ability to perform in-service measurements of carrier-to-noise ratio, in-channel response, and coherent disturbances. The specifications and operation of the two instruments is essentially the same in most other respects. In this document, they will be jointly referred to as the 2714/2715 except where the enhanced features of the 2715 are being discussed.

Several examples of measurement setups, procedures, and potential problems are presented to assist the user in becoming familiar with RF measurements on cable television systems using the 2714/2715. Although they automate many measurement processes, an understanding of the capabilities and limitations of the instruments is critical to making consistent, accurate measurements.

This application note assumes a basic understanding of spectrum analyzer applications and operations. For additional help with spectrum analyzer basics, refer to ***Spectrum Analyzer Fundamentals***, Tektronix Application Note 2EW-8380-1.

Additional information regarding the features and operation of the Tektronix 2714/2715 may be obtained from the following documents:

2714 Spectrum Analyzer User Manual, Tektronix P/N 070-8532-02

2714 Spectrum Analyzer Cable TV System Software Manual, Tektronix P/N 070-8536-01

2714 Spectrum Analyzer Programmer Manual, Tektronix P/N 070-8533-01

2715 Spectrum Analyzer User Manual, Tektronix P/N 070-9115-00

2715 Spectrum Analyzer Cable TV System Software Manual, Tektronix P/N 070-9095-00

2715 Spectrum Analyzer Programmer Manual, Tektronix P/N 070-8533-02

Conventions

In this application note, names of keys are enclosed in brackets ([ ]) and multiple key strokes are separated by slashes (/). For example, [INPUT] / [9] means "press the INPUT menu key, release it, then press the 9 key." Each procedure assumes that the instrument is in the factory-default power-up mode as you begin. You can put the 2714/2715 in the default mode by pressing [UTIL] / [1] / [1].

When instructed to use the keypad to change the channel number, frequency, span per division, or reference level, you may need to put the 2714/2715 in the proper immediate entry mode by pressing the CHAN/FREQ, SPAN/DIV, or REF LEVEL button first. The on-screen readout indicates which direct entry mode is active.

References to other sections of this application note are italicized. For example; "... refer to *Creating Custom Channel Tables*."

CAUTION: Protect Your Analyzer!

There are limitations on the maximum signal level that can be applied to a spectrum analyzer. DC voltages to 100 V and a total signal level of +70 dBmV can be applied to the 2714/2715 without damage. Refer to ***Distortion from Overdriving the Analyzer,*** *page 10 for details on calculating total signal level. Signal levels greater than +70 dBmV require external attenuation. Be certain that the power rating of external attenuators is adequate. The 65 VAC power commonly available on cable systems far exceeds the +70 dBmV rating of the 2714/2715 and will likely damage the instrument if connected.*

Be on the safe side! If in doubt about DC or low frequency AC levels on a cable, measure them with an appropriate meter before making connections to the analyzer. If in doubt about signal levels, use enough external attenuation to ensure that the input rating of the analyzer will not be exceeded.

Additional Equipment

The versatility of the 2714/2715 can be enhanced by having additional equipment available. In particular, the following optional equipment may be useful.

External attenuators

If you anticipate high-level signals, you will need external attenuators of adequate power ratings.

Impedance-matching pads or transformers

Since the input impedance of the 2714/2715 is 75Ω, you can connect directly to the 2714/2715 for most cable TV measurements. You can also make measurements on other source impedances – 50Ω or 300Ω for example. For relative measurements, such as carrier-to-noise ratio or cross modulation, the impedance match between the spectrum analyzer and signal source is not critical. However, when measuring absolute amplitudes or when measuring over a frequency range of more than a few MHz, an impedance-matching device should be used.

Two common matching devices are minimum-loss pads and transformers. Minimum-loss pads to match between 50Ω and 75Ω impedances are readily available. Impedance-matching transformers are also available in a wide range of impedance ratios and have the advantage of not attenuating the signal. If you use an impedance-matching transformer, check its specifications to be certain it is designed for the frequencies over which you wish to use it. In either case, you can set up the 2714/2715 to account for losses in the matching device by pressing [INPUT] / [6] / [1] and entering the attenuation of the device. The 2714/2715 automatically includes the correction factor in its readouts and calculations.

If in doubt whether a matching device is needed, compare the same measurement with and without the pad or transformer. If there is no significant difference, you don't need to use the matching device.

Preselector filters

When evaluating your system, you must be certain that spurious signals generated within the spectrum analyzer do not degrade measurements. A bandpass filter (preselector) placed ahead of the spectrum analyzer minimizes analyzer-created distortions by limiting the number of carriers (and total power) applied to the analyzer. The filter should be wide enough to pass all signal components you want to measure and should have enough out-of-band rejection to ensure that the total signal level at the input to the analyzer is within its specification. Refer to *Distortion from overdriving the analyzer*, page 10 for additional information on using a preselector.

Appropriate filters are available from a number of sources.

If you want to record displays

Use a camera, printer, or plotter to record displays. The 2714/2715 comes with a choice of RS-232 or GPIB interface. Spectral displays can be documented by connecting the 2714/2715 to a printer or plotter with a matching interface. If an RS-232 interface is used, measurement results data can also be printed directly from the 2714/2715.

Camera: Tektronix C-9, C-30 or equivalent.

Printer: Any printer, with an RS-232 interface, that emulates the Epson FX-series or LQ-series printers.

Plotter: Tektronix HC100 or other HPGL compatible plotter with an interface that matches the one in the 2714/2715 (either RS-232 or GPIB).

If you want to use a computer with the 2714/2715

A computer allows you to create custom channel tables and measurement processes, retrieve and store test data from the 2714/2715, and generate reports using the test data. To use the software that is available for the 2714/2715, the computer must be an IBM™ PC, or compatible, and must have an interface port that matches your 2714/2715.

The 2714/2715 is available with either an RS-232 or a GPIB interface. RS-232 interfaces are commonly used for connecting a computer to a mouse, printer, or other peripheral device. The General Purpose Interface Bus (GPIB) is a parallel interface that is often used when multiple instruments are controlled by a single computer. GPIB is faster than RS-232 but less common. Most PC-compatible computers have one or more RS-232 interface ports available but require an additional interface card (e.g., Tektronix S3FG210) to provide GPIB capabilities.

Computer: IBM-PC-compatible computer with a hard disk, high-density floppy drive, color adapter and monitor, and either an RS-232 or a GPIB interface port – depending on the configuration of the 2714/2715.

Software: Two software packages are available for the 2714/2715. The **2714/15 CATV System Test Software** (included with the 2714/2715) and the optional Windows™-based **CSS 500 Software** for the Tektronix CMP 500 package. The **2714/15 CATV System Test Software** requires an IBM-PC compatible computer running MS-DOS Version 2.0 or higher. Minimum requirements for the **CSS 500 Software** are a 386-16 computer (a 486-33 or better is recommended), MS-DOS 5.0, and Windows 3.1.

Cables: RS-232 or GPIB interconnecting cables. Be certain to use cables that meet the requirements specified in Appendix A or B of the ***2714/15 Spectrum Analyzer Programmer Manual***. A simple three-wire cable will not work properly for the RS-232 interface. Refer to *Using a Computer with the 2714/2715*, page 32 for a wiring chart of the RS-232 cable.

Printer: Any printer that is compatible with an available PC interface port.

Refer to the ***2714/15 Spectrum Analyzer Cable TV System Software Manual*** for more detailed information.

Getting Started

Front-Panel Layout

The front panel of the 2714/2715 is divided into several functional areas. Take a few minutes to become familiar with the locations of the controls. The key parameters for spectrum analysis are center frequency, span per division, reference level, resolution bandwidth, and sweep rate. Those parameters are controlled by the CHAN/FREQ, SPAN/DIV, and REF LEVEL buttons located in the upper center area of the front panel and by the RES BW and SWEEP buttons in the lower right section of the front panel. For most measurements, the operator need only adjust CHAN/FREQ, SPAN/DIV, and REF LEVEL if the 2714/2715's automatic (AUTO) modes are used for RES BW and SWEEP.

The large knob and the buttons to its left are most often used to control on-screen markers for frequency and amplitude readouts. The VERT SCALE buttons are used to change the vertical scale from linear to logarithmic modes and to change the vertical scale factor when in the logarithmic mode. The DISPLAY STORAGE area provides control of four registers that are used in various combinations to display the current measurement, temporarily "hold" spectral displays, or to view displays previously stored in the 2714/2715's internal memory. The KEYPAD is used for direct numerical entry of setup and operating parameters such as vertical scale units, frequency, span per division, etc. The MENU area, in the center of the front panel provides access to a wide assortment of setup and measurement parameters.

When performing cable TV measurements, the most commonly used controls are channel selection – using either the CHAN/FREQ up/down buttons or keypad entry – and the submenus accessed via the CATV/APPL menu button.

On-Screen Readouts

The 2714/2715 is normally adjusted to display analyzer settings, measurement results, and operational messages on-screen. Analyzer settings are displayed in two columns in the top portion of the screen. Measurement results and messages are displayed in the middle and lower portions of the screen.

When a single marker is being used, the marker text (in the upper right corner) displays the frequency and amplitude values for that marker. When two markers are used, the difference in frequency and amplitude between the two markers is displayed. When the markers are disabled, the input attenuation and video filter values are displayed in that area of the screen. In addition, the channel table name and the channel number are displayed when in the (default) CATV test mode.

Additional messages, as appropriate, will appear elsewhere on the CRT.

Figures 1, 13, and 4 show typical on-screen readouts with single, double, and no markers, respectively.

Initial Procedures

The following procedure will enable and display the 2714/2715's internal calibration signal. It will help you become familiar with the operation of the 2714/2715, allow you to check that the instrument is operating properly, and will result in a setup that you may wish to store for later recall.

Verifying correct operation

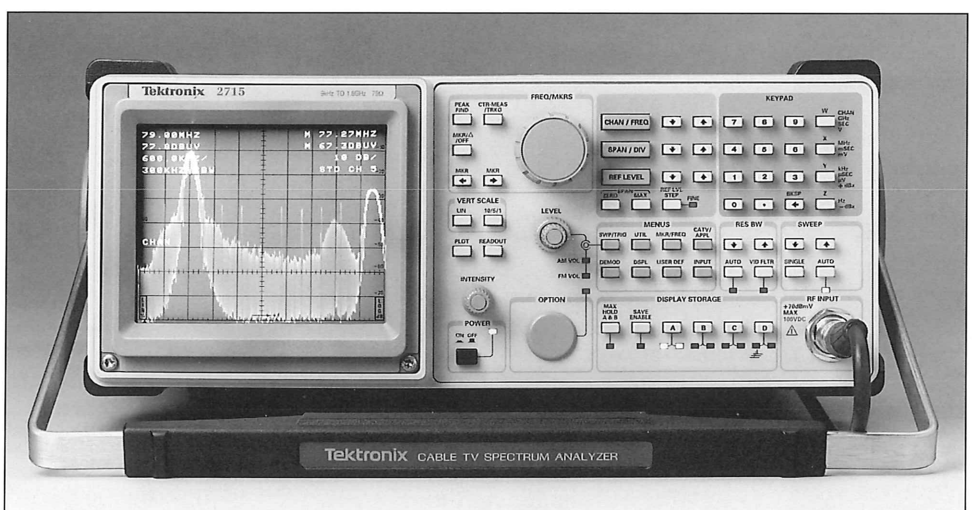
Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Procedure

This procedure will help you become familiar with basic operation of the 2714/2715. It uses the internal calibrator signal to confirm that the instrument is operating properly.

1. Disconnect all signals from the RF INPUT. The internal calibration signal is used for this procedure.
2. Connect the 2714/2715 to the power source and turn it on. Measurements and preliminary checks can be carried out almost immediately, but a 15-minute warm-up ensures that the 2714/2715 is operating within its specifications. You may see a NORMALIZATION SUGGESTED message during the warm-up time. If the message does not disappear within 15 minutes, consult the ***2714/15 Spectrum Analyzer User's Manual***.
3. Adjust the trace intensity as desired. If you would like to enable the graticule illumination, press [DSPL] / [6].
4. Press [CATV/APPL] / [8] / [0] to exit the CATV mode. Notice that the channel table and number readout disappeared and the letters CHAN near the left center



The Tektronix 2715 Cable TV Spectrum Analyzer.

of the display changed to FREQ.

5. Press the AUTO buttons located in the RES BW and SWEEP areas to enable the AUTO RES BW and AUTO SWEEP modes (both AUTO indicator LEDs should be on).
6. Press [INPUT] / [9] to enable the internal calibrator.
7. Press [100] / [X] on the keypad to set the center frequency to 100 MHz.
8. Press [SPAN/DIV] to change the keypad function from frequency to span per division. Notice that the readout changes to SPAN.
9. Press [500] / [Y] on the keypad to set the span per division to 500 kHz.
10. Press [REF LEVEL] to change the keypad function to reference level. Notice that the readout changes to REFL.
11. Press [28.8] / [Y] on the keypad to change the reference level to 28.8 dBmV.
12. Press [PEAK FIND]. The resulting display should look like Figure 1. The frequency, span per division, and reference levels can also be changed by pressing the up/down arrows adjacent to their corresponding (CHAN/FREQ, SPAN/DIV, and REF LEVEL) buttons. Try changing the frequency, span per division, and reference level using the arrows. Return the settings to 100 MHz, 500 kHz, and 28.8 dBmV when finished.

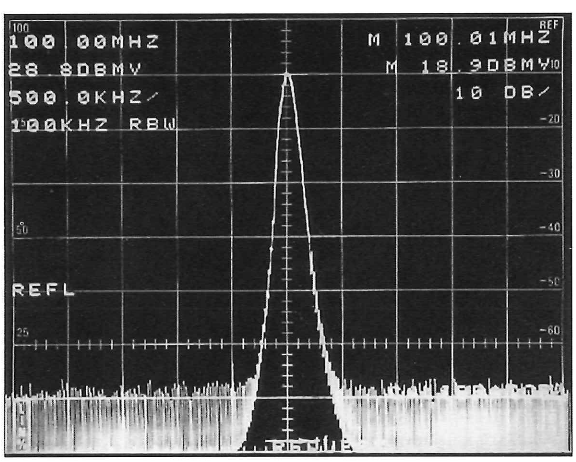


Figure 1. 100 MHz calibration signal.

13. Press [CTR-MEAS/TRKG] to measure the amplitude and frequency of the calibrator signal. Check that the calibrator signal measures 100 MHz ±2 kHz and 18.8 dBmV ±0.3 dB.

If you would like to store this setup so you can quickly and easily perform calibration checks in the future, press [UTIL] / [1] to access the STORED SETTINGS/DISPLAYS menu. Select an unused memory location and press [*the memory number you wish to use*] / [X] to store.

NOTE: If you store this setup in memory location 2, it will become the power-up operating mode.

To return to the factory default power-up setting, press [UTIL] / [1] / [1].

Understanding The Menus

Most of the 2714/2715's setup and measurement functions are accessed via the menus. For the purpose of this application note, you need a basic understanding of the menu structure. A detailed description of each menu item can be found in the ***2714/15 Spectrum Analyzer User Manual***.

Each of the main menu items provides the ability to select a setup or operation to be performed, or access to another menu. For example, press the INPUT menu button. An INPUT MENU screen appears with several options. Selecting item 1 (PREAMP) will enable the internal preamplifier and return to the spectral display. The next time PREAMP is selected from the INPUT menu, the preamp will be turned off. Similarly, selecting item 9 (CAL SIG) will toggle the internal calibrator on and off each time it is selected. Selecting items 3, 4, 5, or 6 results in an additional menu with appropriate selections for that function. Menus can be exited by pressing any menu key or by pressing the BKSP key on the keypad.

When in the CATV MEASUREMENTS mode, many of the menu items select measurements to be performed. Since you will likely want to perform the same measurement on multiple channels, the 2714/2715 retains the menu setup until specifically told to leave that particular measurement mode. Because the menu structure is retained, you can conduct a given test on multiple channels by simply entering the channel number and pressing [CATV/APPL] / [0].

Display Modes

The 2714/2715 has both digital and analog display capabilities.

Digital: Probably the display mode you will use most frequently. This mode provides a flicker-free display by digitizing the signal spectrum and placing it in the selected display storage register (A, B, C, or D). The contents of the display register is normally updated each sweep or it can be saved by pressing [SAVE ENABLE] / [A, B, or C]. Register D is used only for displaying the current sweep; it cannot be used for saving traces.

When using the digital display mode, you can select either PEAK or MAX/MIN displays. In PEAK display mode, only the maximum levels of the signal spectrum are displayed during the analyzer's sweep. In MAX/MIN mode, both the maximum and minimum levels are displayed – which more closely resembles an analog display.

A powerful feature of digital storage is the ability to subtract a saved waveform from a stored one and display the difference. The contents of the B and C registers can be displayed relative to the contents of the A register by pressing [DISP] / [2]. This feature is especially useful for comparing the output of a device to its input and for detecting spectral shifts in frequency or amplitude.

Digital storage also provides the ability to display the maximum level of the signal over a series of sweeps (MAX HOLD mode). The MAX HOLD mode is particularly useful for capturing the peak level of signals that occur randomly or infrequently – such as the peak level of the visual carrier on encrypted channels.

Analog: Usually, the visibility of fine details is better using the analog mode. The human eye is capable of picking out subtle differences in areas of the analog display that are not visible using digital display techniques. The advantages of the analog display mode are most apparent when searching for low-level signals and beats.

The display mode is automatically controlled by the status of the display storage registers. If any of the display registers are selected, the digital display mode is enabled. If no display registers are selected, the analog display mode is enabled. Alternatively, the display mode can be changed by pressing [DISP] / [0].

Connecting a Signal to the 2714/2715

Refer to *CAUTION: Protect Your Analyzer!*, page 3. Even if you think signal amplitudes are acceptable, it's good practice to begin each measurement session by setting the reference level and span per division to maximum before connecting the signal. This displays the entire range of input signals while ensuring full RF attenuation and maximum protection for the analyzer. Then, cautiously approach the analyzer input connector with the signal cable while observing the display for large signals. You may want to save this instrument configuration as a user-defined setting in the STORED SETTINGS section of the UTIL menu.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Impedance-Matching Device (optional).

Procedure

This procedure describes a method of connecting signals to the analyzer in a manner that provides maximum protection to the analyzer.

1. If required, connect the impedance-matching pad or transformer to the input of the 2714/2715 (Refer to *Additional Equipment*, page 3).
2. Enable the AUTO modes for RES BW and SWEEP (indicator LEDs ON).
3. Set the reference level to 68.8 dBmV by pressing [REF LEVEL] / [68.8] / [X].
4. Set the span to 180 MHz/div by pressing [MAX]. The readout should indicate 180MHZ/ MAX.
5. Select the PEAK ACQUISITION display mode by pressing [DISP] / [4].

   NOTE: At this point, the analyzer is set up for maximum input attenuation and maximum span. If you would like to save this setup, press [UTIL] / [1] to access the STORED SETTINGS/DISPLAYS menu. Select an unused memory location and press [memory location number] / [X] to store. If you store this setup in memory location 2, it will become the default power-up operating mode.

6. Tentatively approach the input connector with the cable from the signal source while watching the display. If large signal(s) appear, investigate thoroughly to ensure you are not endangering the analyzer or the impedance matching device (if used). Once you are confident that there are no excessive signals present, connect the cable.
7. Examine the entire spectrum for unexpectedly large signals before reducing the reference level.
8. Proceed with your measurements or tests.

Using Markers to Make Measurements

The combination of center frequency, reference level, scale factors, and graticule markings can be used to perform basic measurements. However, in most instances it is easier and more accurate to use the markers. Markers in the 2714/2715 are bright spots that appear on the displayed spectrum. One or two may be displayed, depending on the setup. Pressing the MKR/OFF button repeatedly cycles the marker function between single Marker mode, Delta (or Difference) mode, and OFF. When the markers are turned off, the bright spot remaining at center screen represents the 2714/2715's center frequency.

In the single Marker mode, the on-screen readouts start with an M followed by the frequency and amplitude of the signal at the marker's location. The marker can be moved by rotating the [FREQ/MKRS] knob. You can quickly position the marker to the highest amplitude signal by pressing the [PEAK FIND] button. The marker can be positioned to peaks higher or lower in frequency by pressing the [→] or [←] MKR buttons. You can also position the marker to the next higher or lower amplitude peak by pressing [MKR/FREQ] / [4] and either [W] or [X] as appropriate.

The Delta (Δ) mode is used to measure the difference in frequency and amplitude between two markers. The on-screen readouts start with a D followed by the difference in frequency and amplitude between the two markers. Initially, you will only see one bright spot on the CRT when you enter the Delta mode. This is because the two markers are on top of each other. Rotating the large knob moves one marker relative to the other. Each of the marker control functions mentioned in the previous paragraph can be used to position markers in the Delta mode. You can change which marker is being controlled by using the TRANSPOSE MARKERS command ([MKR/FREQ] / [5]).

Preparing to Make Cable TV Measurements

Because the 2714/2715 is specifically designed for cable TV systems, it has many features that speed up and improve the repeatability of cable TV measurements. One of the first cable TV specific features you should take advantage of is the use of custom channel tables.

When using the 2714/2715's Cable TV mode, measurements are performed on frequencies defined by a channel table. The 2714/2715 has three common cable TV channel tables permanently programmed into its memory; Standard (STD), Harmonically Related Carriers (HRC), and Incrementally Related Carriers (IRC). In addition, the **2714/15 CATV System Test Software** (included with the 2714/2715) lets you create custom channel table(s) to accommodate scrambled channels and/or non-standard channel frequencies – and to omit channels you are not using. The use of custom channel tables can greatly enhance measurements, such as carrier surveys, by automatically measuring all carrier levels (including pilots) without wasting time on unused channels. Once a custom channel table is loaded into the 2714/2715's memory, it remains there (even with the power off) until purposely removed. Refer to *Creating Custom Channel Tables*, page 33, for more information.

As you become familiar with the instrument's capabilities, you will also want to develop custom instrument configurations and measurement processes based on your particular needs. You can store the configurations and processes in the 2714/2715 as Stored Settings and User-Defined Programs (UDPs) for convenient recall when needed. *Verifying correct operation*, page 5, describes storing an instrument setup and *Creating and Using User-Defined Programs*, page 33, describes the use of UDPs.

Carrier Amplitude and Frequency Measurements

Carrier amplitudes and frequencies, both visual and aural, are the most commonly measured characteristics of cable TV systems. The following procedures demonstrate how to use the 2714/2715 to make visual and aural carrier measurements using two different methods: on individual channels using the CARRIER LEVELS function and on multiple channels using the CARRIER SURVEY mode.

Equipment Required

2714/2715 Spectrum Analyzer.

Selecting a channel table:

1. Connect the 2714/2715 to a system test point taking into account the input limitations outlined in *Connecting a Signal to the 2714/2715*, page 7.
2. If not already in the Cable TV MEASUREMENT MODE, press [CATV/APPL] / [8].
3. Go to the CATV MEASUREMENTS SETUP, CHANNEL TABLE menu, (press [CATV/APPL] / [8] / [1]), select a channel table from the available choices, and exit the CHANNEL TABLE menu by pressing [table number] / [W] / [BKSP] / [9] / [CATV/APPL].

Selecting a carrier measurement mode:

Three methods of performing carrier measurements are provided:

0. ACCURATE FREQUENCY AND AMPL: Measures the carrier amplitudes and frequencies of the selected channel(s).
1. ACCURATE AMPLITUDE ONLY: Measures the amplitudes, but not the frequencies, of the selected channel(s). Because the frequencies are not measured, this process takes less time than mode 0.

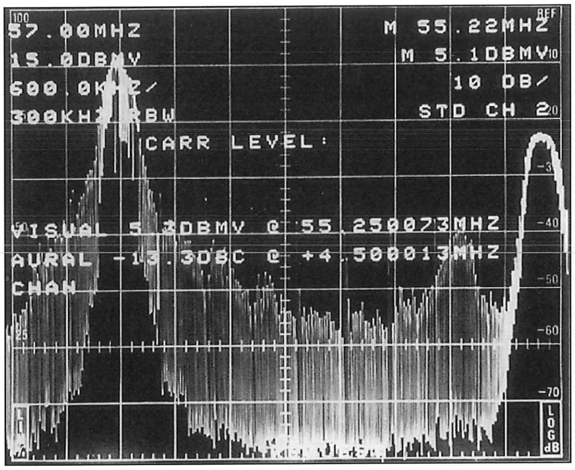


Figure 2. Example of CARRIER LEVELS measurement results.

2. FAST AMPLITUDE ONLY: Rapidly measures the carrier amplitudes, but not the frequencies, of the selected channel(s). This mode is faster than either mode 0 or 1. Its accuracy is reduced by approximately 0.3 dB and its resolution is reduced approximately 0.2 dB relative to modes 0 and 1.

Using CARRIER LEVELS to make measurements on a single channel

Procedure

This procedure measures the visual and aural carrier amplitudes and frequencies on a selected channel.

1. Select a channel by pressing [CHAN/FREQ] / [channel number] / [W] on the keypad or by using the up/down arrows adjacent to the CHAN/FREQ button.
2. Enter the CARRIER LEVELS menu by pressing [CATV/APPL] / [1].
3. Select item 5, SET UP CARRIER LEVELS.
4. Select 0, 1, or 2 based on the combination of measurement speed and accuracy that you desire. Press [BKSP] to return to the CARRIER SURVEY menu.
5. Perform the CARRIER LEVELS measurement by pressing [0]. The 2714/2715 performs the necessary operations to measure the amplitudes and frequencies of both the visual and aural carriers of the channel you selected and displays the results on the CRT. If you would like to perform the CARRIER LEVELS measurement on additional channels, select the channel number using either the keypad or the up/down arrows and press [CATV/APPL] / [0].
6. Exit the CARRIER LEVELS menu mode by pressing [9] in the CARRIER LEVELS menu.

Figure 2 shows a typical result from a CARRIER LEVELS measurement.

Using CARRIER SURVEY to measure visual and aural carriers on all channels

Procedure

This procedure measures the visual and aural carriers on all channels in the selected channel table.

1. If necessary, select an appropriate channel table ([CATV/APPL] / [8] / [1]).
2. Select CARRIER SURVEY from the CATV/APPL menu.
3. Select item 5, SET UP CARRIER SURVEY.
4. Select 0, 1, or 2 based on the combination of measurement speed and accuracy that you desire. Press [BKSP] to return to the CARRIER SURVEY menu.
5. Press [0] to RUN CARRIER SURVEY. When complete, the results can be viewed by pressing DISPLAY RESULTS [2] in the CARRIER SURVEY menu. The results may be saved for later viewing or for downloading to a PC by selecting STORE CURRENT RESULTS [1] in the CARRIER SURVEY menu.

Measurements on visual carriers with suppressed sync

Visual carrier amplitude is normally specified as a maximum RMS value – which occurs during sync pulse time. When analyzing a signal that uses suppressed horizontal sync but retains vertical sync as part of the encryption method, the 2714/2715's MAX HOLD A & B can be used to capture the maximum level. The markers can then be used to perform the amplitude measurement. Alternatively, if a custom channel table is used (refer to *Creating Custom Channel Tables*, page 33), each channel can be classified as scrambled or not and the 2714/2715 automatically measures the maximum carrier level during the vertical blanking interval.

Common Measurement Problems

Several things can lead to inaccuracies or misinterpretation of spectrum analyzer displays. This section will help you become familiar with some of the more common sources of measurement errors.

Resolution bandwidth, sweep rate, and span

When using the cable TV measurement mode, the 2714/2715 automatically uses appropriate instrument settings to obtain optimum results. However, when you manually adjust a spectrum analyzer, the relationships between resolution bandwidth, sweep rate, and span per division must be considered.

The combination of span per division and sweep rate determine how rapidly the analyzer is scanning in frequency. Resolution bandwidth determines the minimum frequency difference that must exist between two signals for the analyzer to differentiate between them. If the analyzer is scanning too fast for a given resolution bandwidth, signals will not have enough time to reach their peak levels as they pass through the analyzer's circuitry and the indicated results will usually be low. Because span per division and resolution bandwidth are usually constrained by the requirements of the measurement, sweep rate is the parameter most often adjusted to avoid measurement errors. Figure 3 is a composite photograph showing how the display of a signal can be distorted if the combination of resolution bandwidth, sweep speed, and span per division are not set properly. The 2714/2715's automatic (AUTO) modes for RES BW and SWEEP should normally be used to avoid errors caused by inappropriate combinations. In situations in which you need to manually set the RBW and SWEEP, the 2714/2715 will

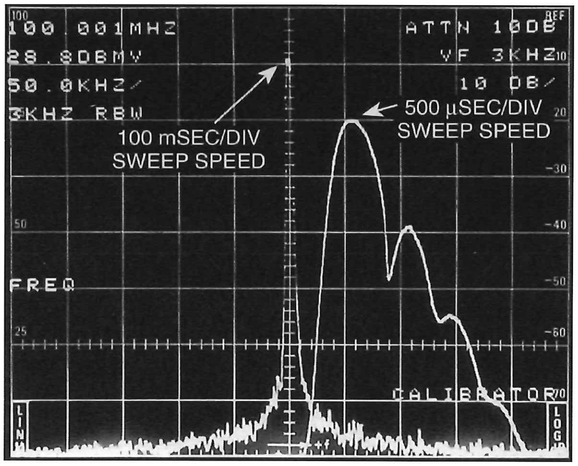


Figure 3. Signal distortion caused by changing the sweep speed from 100 msec/div to 500 µsec/div.

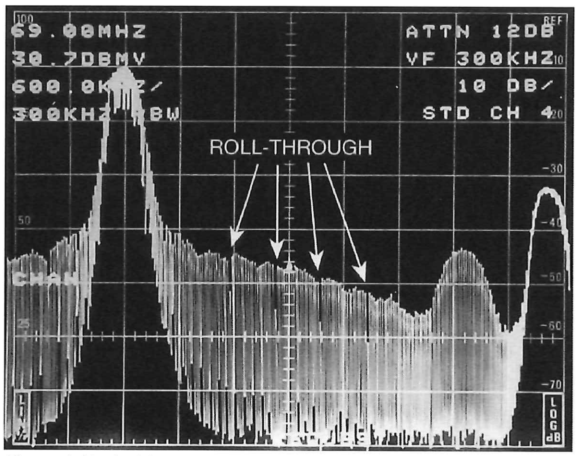


Figure 4. Vertical interval roll-through with no VITS.

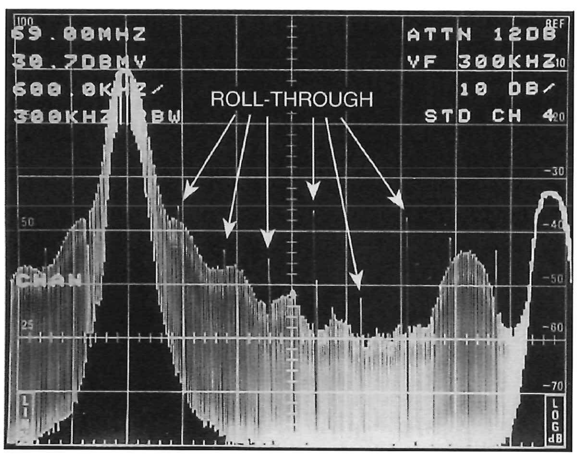


Figure 5. Vertical interval roll-through with multiburst VITS.

display UNCAL ON if you select a combination that might result in measurement errors. Remember, when the 2714/2715 is in an automatic measurement mode, you do not normally need to adjust span/div, resolution bandwidth, or sweep speed – the 2714/2715 controls those functions automatically. AUTO RES BW is normally off when in automatic measurement modes.

Vertical interval roll-through

Vertical interval roll-through is caused by interaction between the vertical rate information in the television signal and the horizontal sweep of the spectrum analyzer. The vertical blanking interval is used to describe the effects of vertical interval roll-through.

The vertical blanking interval (VBI) is the time interval during which the display device in the television receiver is turned off (blanked) in preparation for starting a new vertical scan of the image. For NTSC systems, the VBI occurs every 16.67 msec and lasts for approximately 1.3 msec. For a typical spectrum analyzer setup using 600 kHz/div, 300 kHz RBW, and 20 msec/div sweep, the vertical blanking interval occurs every 16.67/20 = 0.8 divisions as the sweep moves across the CRT. If there are no video signals other than synchronization pulses during the VBI, the spectral display during the VBI shows only the spectral content of the sync pulses, which is insignificant above a few hundred kHz. Therefore, the spectral display has narrow gaps in it at 0.8 div intervals – see Figure 4. If the analyzer sweep is synchronized to the video signal, the gaps in the display will be stationary. However, the more common case is that the analyzer is not synchronized to the video and the gaps move around as a function of the relative timing between the sweep and vertical sync pulses.

Often, data and/or Vertical Interval Test Signals (VITS) are transmitted during the vertical blanking interval. Many VITS have high amplitudes covering a wide frequency range (e.g., multiburst). If the VITS have larger spectral components than typical video signals, the vertical interval roll-through will resemble Figure 5.

If you are not familiar with it, vertical interval roll-through can easily be mistaken for random beats or interference. Fortunately, there are some simple tests that you can use to determine whether or not what you are seeing is vertical interval roll-through:

1. Note the sweep speed – on the 2714/2715 press [SWP/TRIG] – and determine if the peaks occur at 16.67 msec intervals. Roll-through does, but beats or interference normally do not.
2. Change the sweep speed – press the SWEEP up/down arrows. Roll-through changes position, speed, and/or direction but beats or interfering signals do not. At very slow rates, the roll-through may disappear.
3. Turn on the video filter. Roll-through amplitudes decrease but beats and interference usually do not.

Distortion from overdriving the analyzer

Spectrum analyzers, like all electronic instruments, have a limited range of input signals over which they operate. Signals that are too large will cause distortion and inaccurate readings – and can even damage the analyzer. Very small signals will be masked by noise generated within the analyzer. If the maximum linear range of the analyzer's input circuit is exceeded, the instrument will indicate less-than-actual amplitudes. In addition, intermodulation products generated by overdriving the analyzer can easily be mistaken for system CSO, CTB, or noise problems. On the other hand, if the input signal is lower than optimum, the dynamic range of measurements will be limited by the noise floor of the analyzer. When performing automated CSO, CTB, and C/N measurements, the 2715 uses advanced algorithms to automatically adjust its input attenuation and preamp settings for optimum performance. The input attenuation of the 2714 should be manually adjusted for best performance.

The optimum input level to the 2714/2715 for intermodulation distortion measurements is 18.8 dBmV (–30 dBm) when no input attenuation (as

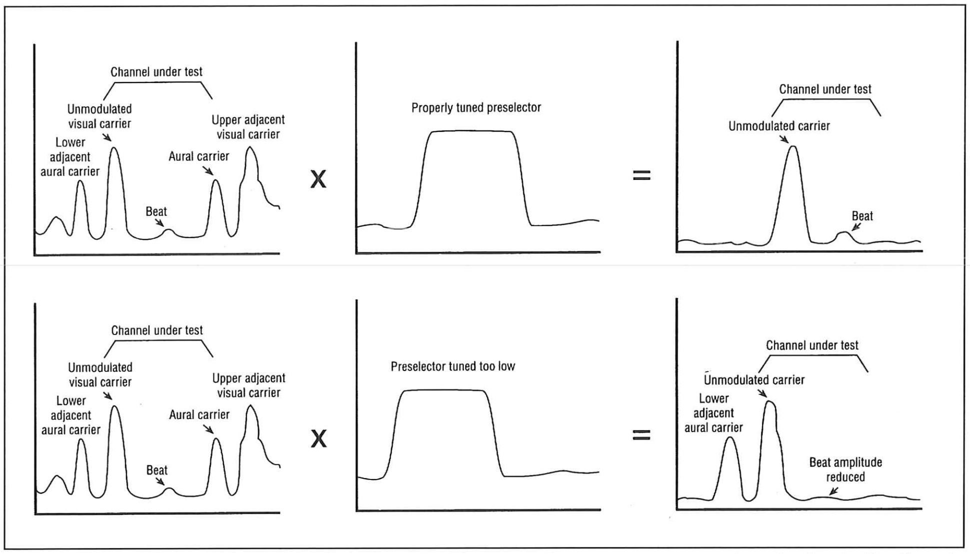


Figure 6. Effects of mistuning a preselector filter. The amplitude of the signal to be measured can be drastically affected if the filter is mistuned.

indicated by the readout in the upper right corner of the display, with markers off) is used. At 18.8 dBmV input, the intermodulation products generated within the instrument are approximately equal to the analyzer's noise floor. This results in the maximum spur-free dynamic range. Greater levels will produce beats that rise above the noise floor. Lower levels will bury the internally generated beats under the noise floor but low-level input signals may also be masked by the noise.

Be especially careful when using the built-in preamplifier. It has approximately 20 dB gain. Therefore, when using the preamplifier with no input attenuation, any combination of signals totaling more than about –2 dBmV will overdrive the analyzer.

The 18.8 dBmV optimum input level is specified in terms of **total** RF input level, not just the amplitude of a single signal. If your system has N channels (including pilot carriers, if any), each of amplitude S_s, the total signal level is given by:

$$S_{tot} = S_s + 10 \log N$$

For example: 60 channels, each at 10 dBmV, will have a total level of 27.8 dBmV or 9 dB above the optimum input level for the analyzer.

Notice from the equation that analyzer-created distortion can be minimized by limiting either the number or the amplitude of signals reaching the analyzer's input circuit. External preselection (bandpass) filters are used to limit the number of signals; input attenuation is used to limit their amplitudes. The REF LEVEL control on the 2714/2715 or external attenuators can be used to provide input attenuation.

Preselectors tend to be expensive, time consuming and, if not used properly, can cause measurement errors. When deciding whether or not to use a preselector with the 2714/2715, consider the following:

1. Preselectors have advantages over input attenuation when performing beat measurements because preselectors do not significantly reduce the amplitudes of signals you wish to measure as attenuators do.
2. Using a preselector significantly increases the dynamic range for measurements such as CTB and CSO. For example, a preselector allows you to measure distortion products that are at –70 dBc on a 60-channel system. However, if you don't need to measure signals that low, you can generally measure CTB and CSO of –60 dB on a 60-channel system (–63 dB on a 30-channel system) without a preselector.
3. If the bandwidth or tuning of a preselector is not correct, it may affect the relative amplitudes of signal components you wish to measure. See Figure 6.
4. If you are measuring the absolute magnitudes of signals, as opposed to relative measurements such as CTB and CSO, be sure to take into account the in-band attenuation (or gain) of the preselector by entering the appropriate number in the EXTERNAL ATTENUATOR/AMPLIFIER menu, accessed by pressing [INPUT] / [6].

A simple test can be used to indicate whether a beat is being generated in the system or in the analyzer:

1. Use an external pad or the 2714/2715's RF ATTENUATION function ([INPUT] / [5] / [desired attenuation] / [Y or Z]) to change the input to the analyzer by a small amount (e.g., 2 to 4 dB).
2. If the display changes more than 1 dB for each dB of input level change, the beat is being caused by intermodulation within the analyzer.
3. If the display changes 1 dB for each 1 dB input change, the beat is being generated external to the analyzer.

Measuring small signals

There are two fundamental limitations on the smallest signal levels that can be measured: the noise floor of the spectrum analyzer, and the system noise.

Signals Close to the Analyzer's Noise Floor:

The lowest signal level that can be detected is limited by noise generated within the analyzer. This is known as the noise floor of the analyzer and is visible as the grass-like horizontal trace present on the display even when no signal is present. To test whether a signal or system noise is below the analyzer noise floor, disconnect then re-connect the signal at the analyzer input. If the lower portion of the display rises when the signal is

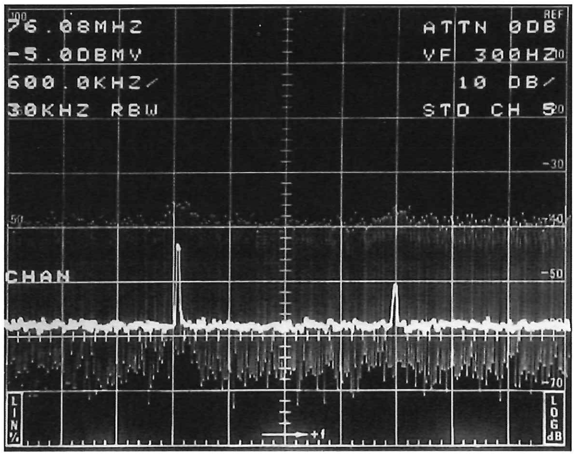


Figure 7. Effect of reducing resolution and video filter bandwidths.

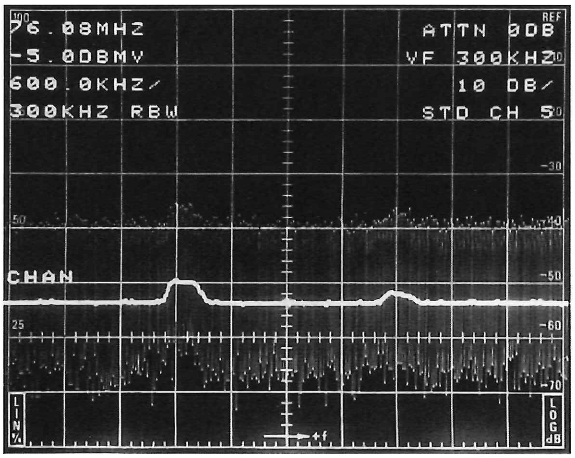


Figure 8. Effect of using ensemble averaging.

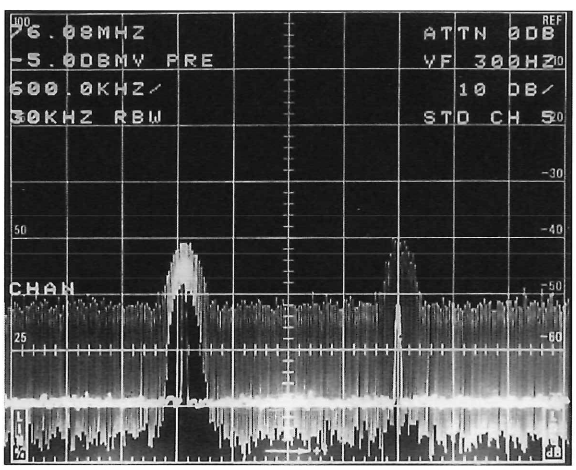


Figure 9. Effect of using the preamplifier and narrowed resolution and video bandwidths.

re-connected, the signal or system noise is above the analyzer noise floor. Several approaches can be taken to increase low-amplitude signals relative to the analyzer noise floor:

1. Remove all RF attenuation (including input attenuation and external pads). For every dB reduction in attenuation, the signal reaching the input of the analyzer increases 1 dB while the analyzer noise floor remains constant. Be certain that the analyzer is not overdriven when the RF attenuation is removed. Remember, even off-screen signals, if too large, will distort your measurements.
2. Reduce the resolution bandwidth and/or the video-filter bandwidth. Reducing the resolution bandwidth should be one of the first approaches considered because it actually reduces the analyzer's noise level. The video filter averages the signals (and noise) at the output of the detector, making signals more apparent.

   For accurate measurements, the resolution bandwidth filter must be at least as wide as the bandwidth of the signal being considered. The video filter should be adjusted depending on whether the peak or average signal level is to be measured. Peak readings require the video filter to be as wide as the signal bandwidth. For average readings (such as CSO or CTB), narrow video filter bandwidth is required. Figure 7 shows the effect of reducing the resolution bandwidth to 30 kHz and the video filter bandwidth to 300 Hz.
3. Use ensemble averaging (available in the 2714/2715 DISP menu). This is another post-detection technique which produces results similar to video filtering without reducing the bandwidth. Ensemble averaging finds the average value over a number of sweeps. Therefore, random signals, such as noise, tend to cancel out. Figure 8 shows the effect of using ensemble averaging.
4. Use the 2714/2715's built-in preamp ([INPUT] / [1]). The signal amplitude is increased while the analyzer's IF gain is decreased by the same amount. The result is that the reference level remains constant but the noise floor decreases by more than 10 dB. When using the preamp, RF attenuation should be set to zero. Make certain you don't overdrive the analyzer. The optimum total input level when using the preamp and no RF attenuation is approximately –2 dBmV. Figure 9 shows the effect of using the preamplifier with reduced bandwidths.

NOTE: All four approaches are effective in improving your ability to measure signals that are close to the analyzer's noise floor. However, because methods 2 and 3 affect the system noise in the same way that they affect the analyzer's noise floor, they provide little or no improvement in the ability to measure system noise that is close to the analyzer's noise floor.

Signals Close to the System Noise:

If the signal you wish to measure is too close to the noise generated by the system you are testing, reducing attenuation or adding amplification will do no good because the system noise will be attenuated or amplified as much as the signal. However, reducing the bandwidth of the resolution-bandwidth and video-bandwidth filters will be effective. Similarly, ensemble averaging will "average out" the noise as it does for noise generated inside the analyzer.

Measuring signals that are only slightly above the noise level may give results that are high by several dB. This is because the analyzer is responding to the signal plus the noise. Figure 10 can be used to determine the correction factor to be applied to the measured results to reflect the true value in such cases. When the signal is much larger (10 dB or more) than the noise, the contribution of the noise becomes negligible and the measurement approaches its true value. When using the 2714/2715's automated C/N, CSO, and CTB measurement routines, amplitude corrections are automatically applied. If the measured signal is within 2 dB of the analyzer's noise floor, the validity of the mea-

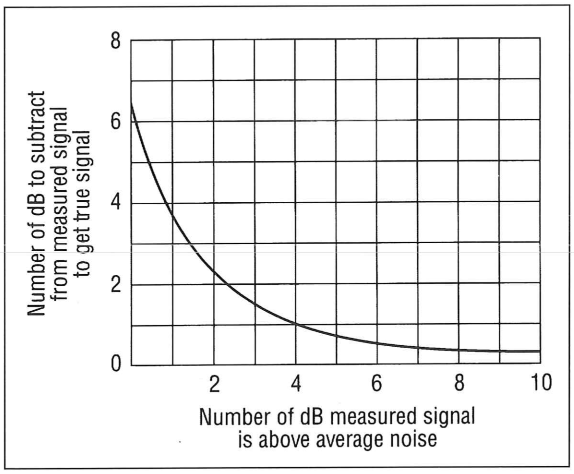


Figure 10. Amplitude corrections for signals within 10 dB of the system noise.

surement should be questioned. The 2714/2715 adds an asterisk (*) to the displayed results of such measurements.

An additional caution: if peak acquisition mode is used without video filtering, a large error occurs when the signal is close to the noise. This is because the analyzer is responding to the peaks of the signal plus noise rather than the average of the signal plus noise. When measuring signals close to the noise floor, use a video filter no wider than 1/100 of the resolution bandwidth to ensure that a good estimate of the average is obtained. This bandwidth is automatically selected by the 2714/2715 when the video filter is activated. Narrower filters can be selected using the UTIL menu. Remember, though, that narrow video filters will also reduce the amplitude of broadband signals such as video.

Non-standard video signals (2715 only)

The 2715's in-service CSO, C/N, and in-channel response measurement routines are performed during the video signal's vertical blanking interval. For accurate results, the video signal must be stable and have standard synchronization pulses. Some video sources (such as some VCRs) produce extraneous pulses during sync time or are not stable enough for accurate measurements. If the results of in-service tests are unrealistic, rerun the tests using a known good video source or use an out-of-service technique.

More Advanced Measurements

The following sections describe procedures for measuring distortion, noise, and frequency response. The procedures assume you are familiar with 2714/2715 controls and basic spectrum analyzer operation. ***Spectrum Analyzer Fundamentals***, Tektronix Application Note 2EW-8380-1, is an excellent reference.

Coherent Disturbances

Coherent disturbances are interfering signals caused by second and third order distortions (CSO and CTB), cross modulation, ingress, co-channel interference, and discrete frequency interfering signals – such as spurious signals from processing equipment. Second- and third-order distortions and cross modulation generate beats at known frequencies and are relatively easy to find and measure. Co-channel interference is also well defined but requires manual analyzer set-up and measurement techniques. Ingress and discrete frequency interference can be more difficult to isolate because the source signals may be intermittent and can vary widely in frequency. Coherent disturbances as much as 55 dB below the visual carrier can be visible on a television set.

CSO and CTB

All active devices in a cable TV plant, such as demodulators, modulators, and amplifiers, distort the signal(s) passing through them to some extent. In fact, distortion can also be caused by some unexpected sources – such as corroded metal connections. Ideally, each channel should be completely independent of all other channels – no interaction. In practice, distortion within the system causes mixing of the various signals, resulting in the generation of additional signals within the spectrum of the cable system. Frequencies of the new signals are commonly referred to as "beat" frequencies.

Distortion causes new signals to be generated at multiples of the input frequency (harmonic distortion) and, when more than one input signal is present, at sums and differences of the input frequencies (intermodulation distortion). Distortion occurring at the second harmonic of the input frequency, or at the sum and difference of two fundamental frequencies, is called second-order distortion. Distortion occurring at the third harmonic, the sums and differences of three fundamental frequencies, or the combination of the second harmonic of one signal and the fundamental of another, is called third-order distortion. Higher order distortions can also be present but are normally small relative to second- and third-order distortions. "Composite second order" (CSO) and "composite triple beat" (CTB) refer to complex combinations of second- or third-order distortions that occur on a particular frequency.

The amplitude of signals generated by second-order distortion change at the rate of 2 dB for each 1 dB change in input level(s). Third-order distortion products change 3 dB for each 1 dB input level change.

NOTE: Cable TV distortion performance is normally specified in decibels relative to the visual carrier (dBc). Second-order distortion, ***relative to the visual carrier****, will change 1 dB for each 1 dB change in input level because, although the amplitude of the distortion product changes 2 dB, the amplitude of the carrier also changes 1 dB, so the overall distortion change* ***relative to the visual carrier*** *is 1 dBc. Similarly, third-order distortion will change 2 dBc per 1 dB input change* ***relative to the visual carrier****.*

The number of possible beats grows rapidly as the number of channels increases. Figure 11 is a plot of the number of possible triple beats for each channel of 300, 450, and 550 MHz systems. The number of possible third-order beats is much greater than the number of possible second-order beats for a given number of channels. The relative amplitudes of second- and third-order beats are a function of the number of channels and the design of the active devices. For single-ended amplifiers and a moderate number of channels, second-order distortion is normally greater than third-order. However, if many channels are present, the number of third-order beats will usually result in CTB being greater than CSO. Also, push-pull amplifier designs tend to cancel second-order distortion. The most common situation is that composite third-order distortions are the largest.

The exact frequencies of the beats depend on the channel plan and the aeronautical band frequency offsets being used on the system under test. Second-order distortions for a standard channel plan tend to occur at frequencies ±750 kHz and ±1.25 MHz relative to the visual carrier frequency. For IRC sys-

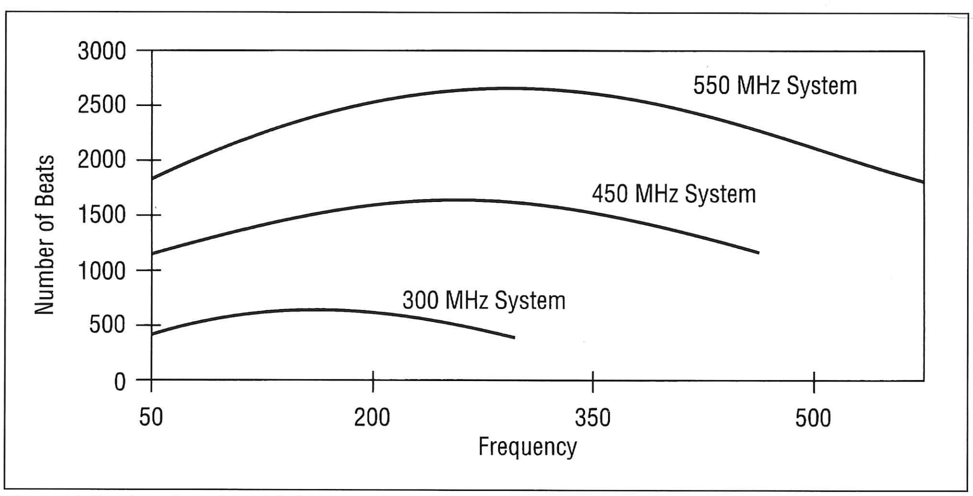


Figure 11. Number of possible triple beats per channel for 300 MHz, 450 MHz, and 550 MHz systems.

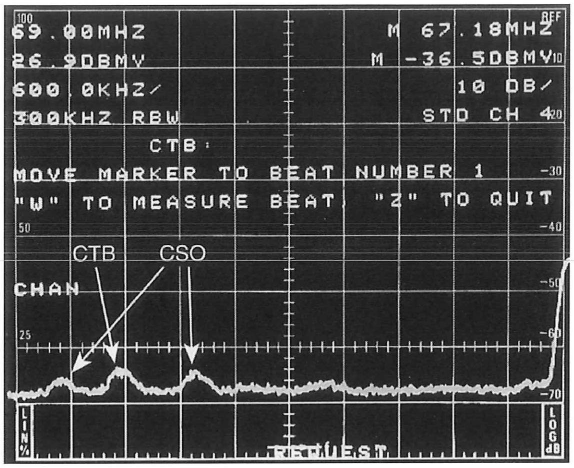


Figure 12. Positioning a marker on a beat. Notice that both second order (CSO) and third order (CTB) beats are present.

tems, they occur at exactly ±1.25 MHz from the visual carriers and, for HRC systems, they occur at the visual-carrier frequencies. Third-order distortions tend to occur at the visual-carrier frequency.

Fiber-optic links are especially likely to exhibit second-order distortion because the transmitters and receivers are single ended. Lack of "roundness" of the fiber (sometimes referred to as poor ovality) can also cause large changes in CSO over an extended time period.

Measuring CSO and CTB. In this section, procedures will be presented to evaluate composite triple beat (CTB) and composite second-order (CSO) distortions at system test points. For information on tests at the output of set-top converters, refer to *Measurements at the Output of Set-top Converters*, page 25.

To accurately evaluate distortions generated within the cable system, you must be certain that no significant level of distortion is generated within the spectrum analyzer itself. Refer to *Distortion from overdriving the analyzer*, page 10, for additional information on avoiding distortion within the analyzer.

The 2714/2715 menu structure has separate menu sections for CTB and CSO measurements. CTB and CSO can each be measured using Interactive, Auto, Auto with Pause for Carrier Off, and Single Sweep test modes. In addition, CSO can be measured using the Continuous mode for analyzing distortions caused by polar mode dispersion within fiber optic systems. The 2715 also provides in-service CSO measurement capabilities. Table I describes the test modes.

The Interactive mode provides the most insight into the measurement process and can also be used to measure coherent disturbances such as ingress and discrete carriers. It will be used to demonstrate the CTB/CSO measurement process.

Table I. CTB/CSO Test Modes Available in the 2714/2715.

Test Mode	Action	Usage
Interactive	Operator positions marker on beats or other coherent disturbances. 2714/2715 automatically performs amplitude and frequency measurements at marker location.	Can be used to measure coherent disturbances such as ingress and discrete carriers in addition to CTB and CSO. Uses NCTA recommended settings.
Auto	2714/2715 automatically performs measurements at the frequencies listed in the test frequency set-up table.	For measurements at frequencies outside of the channel plan or at unused frequencies within the channel plan. Uses NCTA recommended settings.
Auto (Pause for Carrier Off)	2714/2715 automatically performs measurements at the frequencies listed in the test frequency set-up table.	Requires removal of carrier on channel under test. Uses NCTA recommended settings.
Single-sweep	2714/2715 automatically performs measurements at the frequencies listed in the test frequency set-up table.	Fastest automatic measurement mode. Does not use all the NCTA recommended settings. This mode trades off accuracy for speed.
In-Service CSO (2715 only)	2715 performs CSO measurements during the Vertical Blanking Interval using either Interactive or Auto mode.	For in-service measurements of CSO and other coherent disturbances except CTB. Particularly useful for in-service troubleshooting. Video signal must be stable and have standard sync characteristics.
Continuous	2714/2715 performs self-normalizations and CSO measurements over a time period specified by the user (normally from a few hours to 24 hours or more). Upon completion, results may be downloaded to a file for analysis.	For analysis of long term second-order distortions in fiber optic systems caused by polar mode dispersion within the fiber.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Bandpass Filter (optional): See *Distortion from overdriving the analyzer*, page 10.

Procedure – Interactive Mode

This procedure measures CTB and CSO using the interactive mode. It can also be used to measure other coherent disturbances such as ingress and discrete carrier interference.

1. Set the 2714/2715 to the channel to be tested.
2. Peak the preselector filter, if used.
3. Enter the CTB menu on page two of the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [9] / [5].
4. Select CTB SETUP, [5], then INTERACTIVE, [0].
5. Press the backspace key [BKSP] to return to the CTB menu.
6. Press [0], (RUN CTB). The 2714/2715 automatically measures the amplitude of the visual carrier, pauses, and displays the message MOVE MARKER TO BEAT NUMBER 1, "W" TO MEASURE BEAT, "Z" TO QUIT.
7. Disable the carrier for the channel-under-test at the headend.
8. Look for beats in the display (see Figure 12). You may change settings on the 2714/2715 as desired to help view the beats. Reducing the resolution bandwidth (RES BW) and enabling the VID FLTR is quite effective in making the beats more easily visible. Use the large knob to move the marker to the first beat you want to measure (the marker does not need to be exactly centered on the beat – the 2714/2715 will search within 100 kHz of the marker frequency) and press W. The 2714/2715 measures the amplitude and relative frequency of the beat you selected, displays the results on-screen, then instructs you to MOVE MARKER TO BEAT NUMBER 2. If you wish to measure additional beats, repeat the above pro-

cedure. As many as five beats can be measured in this manner. If you decide to end the test after fewer than five measurements, press [Z] to exit the test. At the end of the test, the 2714/2715 returns to the spectral display and prints the worst-case beat amplitude and its frequency (relative to the visual carrier frequency) on the CRT.

9. The results of the test can be stored in the 2714/2715 for later use, can be viewed on the CRT, or (if a printer is connected to the 2714/2715) can be printed by pressing [CATV/APPL] and selecting item 1, 2, or 3 to STORE CURRENT RESULTS, DISPLAY RESULTS, or PRINT CURRENT RESULTS, respectively.

The 2714/2715 also has Automatic, Automatic with Pause, and Single Sweep modes for measuring CTB and CSO. Each of these modes uses a setup table to define where the 2714/2715 is to look for beats. Table II shows typical beat frequencies relative to the visual carrier for NTSC standard, HRC, and IRC systems. The test procedure is very similar to that described for the interactive mode except that the analyzer automatically scans the frequencies specified in the setup table.

Beat measurements on unused frequencies. Beats, such as CSO and CTB, may fall on unused frequencies within a system's bandwidth (e.g., below channel 2, between channels 4 and 5, in the FM broadcast band, or on inactive channels). Measurement of such beats can provide valuable information about the system's performance without the need to interrupt service.

If the input to the analyzer is kept low enough to avoid the need to use a preselector filter (refer to *Distortion from overdriving the analyzer*, page 10), CSO and CTB on inactive channels can be performed using the 2714/2715's AUTO CSO and CTB measurement routines. For example, to measure CTB on an inactive channel:

1. Select a channel near the inactive channel to use as a visual carrier level reference.
2. Referring to Table II, calculate the desired test frequencies for the inactive channel.
3. Select AUTO from the SET UP CTB menu.
4. Adjust the 2714/2715's test frequencies table (item 5 in the SET UP CTB menu) to match the calculated frequencies.
5. Press [0] (RUN CTB) from the CTB menu to perform the test.

Beats on unused frequencies can also be measured using manual techniques. First measure the visual carrier level of a near-by channel, then measure the level of the beat and calculate the difference. When measuring beat amplitudes, adjust the 2714/2715 to the NCTA-recommended settings: (span at 50 kHz/div, RBW to 30 kHz, and video filter to 10 Hz). The video-filter bandwidth can be adjusted from the KEYPAD ENTERED SETTINGS menu ([UTIL] / [2] / [5]).

Table II. Location of Beats for NTSC Standard, HRC, and IRC Systems.

Frequency Plan	CTB	CSO
Standard	f_C	$f_C \pm 750$ kHz, $f_C \pm 1.25$ MHz
HRC	f_C	f_C
IRC	f_C	$f_C \pm 1.25$ MHz

In-service beat measurements (2715 only). During the vertical blanking interval (VBI) there are usually one or more scan lines that have no video signal. By sampling the signal during those times, the 2715 can make coherent disturbance measurements – other than those, such as CTB, that are at the visual carrier frequency – on active channels.

Equipment Required

Spectrum Analyzer: Tektronix 2715.

Bandpass Filter (optional): See *Distortion from overdriving the analyzer*, page 10.

Procedure

This procedure measures CSO on an active channel. The interactive mode is used so that other coherent disturbances such as ingress and discrete carrier interference can also be measured. A video signal meeting basic broadcast standards is required for this test method. Refer to ***Non-standard video signals****, page 13, for more information.*

1. Set the 2715 to the channel to be tested.
2. Peak the preselector filter, if used.
3. Enter the CSO menu on page two of the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [9] / [6].
4. Press [7] if necessary to toggle IN-SERVICE to ON.
5. Select SET UP CSO, [5], then INTERACTIVE, [0].
6. Press the backspace key [BKSP] to return to the CSO menu.
7. Press [0], (RUN CSO). The 2715 automatically finds blank lines to use for the measurement, measures the amplitude of the visual carrier, pauses, and displays the message MOVE MARKER TO BEAT NUMBER 1, "W" TO MEASURE BEAT, "Z" TO QUIT.
8. Look for beats in the display. Use the large knob to move the marker to the first beat you want to measure (the marker does not need to be exactly centered on the beat, the 2715 will search within 100 kHz of the marker frequency) and press W. The 2715 measures the amplitude and relative frequency of the beat you selected, displays the results on-screen, then instructs you to MOVE MARKER TO BEAT NUMBER 2. If you wish to measure additional beats, repeat the above procedure. As many as five beats can be measured in this manner. If you decide to end the test after fewer than five measurements, press [Z] to exit. At the end of the test, the 2715 returns to the spectral display and prints the worst-case beat amplitude and its frequency (relative to the visual carrier frequency) on the CRT.

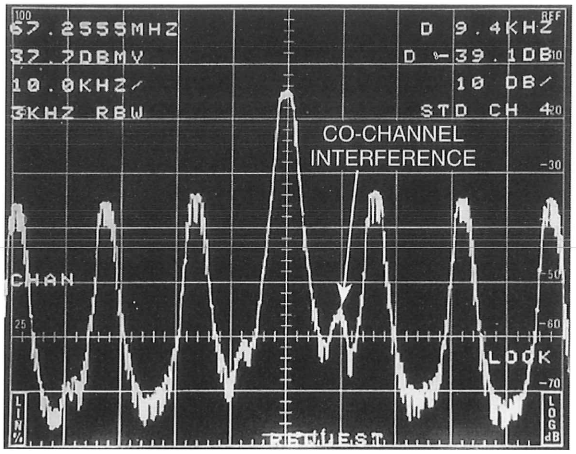


Figure 13. Co-channel interference.

Upon completion, the 2715 rechecks the quiet lines for changes. If changes occurred during the measurement process, the results are displayed with "10" preceding the measured beat value. For example, –56 dB is displayed as –1056 dB. Similarly, if the 2715's accuracy may have been impaired by excessive slope or some other characteristic of the signal, the results are preceded by "20" (–56 dB is displayed as –2056 dB). If both situations occurred, the results are preceded by "30." In any case, you may wish to correct the problem and repeat the test – or use an alternate method to perform the test.

Cross modulation

Cross modulation is the modulation of a carrier by the information on one or more other carriers. It is specified as the ratio, expressed in dB, of the peak-to-peak modulation on the test carrier relative to the carrier peak. Because the peak levels of television signals occur during horizontal sync time, cross modulation in cable television systems is dominated by horizontal rate (15.75 kHz) frequency components. The NCTA recommended practice for performing the test is to measure the amount of modulation on the test carrier while simultaneously 100% modulating all other channels with a 15.75 kHz square wave.

The amount of cross modulation can be estimated by examining the sidebands of the test carrier using 10 kHz/div span, 300 Hz to 3 kHz resolution bandwidth, and video filtering. Cross modulation consists of discrete spectra displaced 15.75 kHz from the unmodulated carrier. When all other channels are simultaneously modulated with a 15.75 kHz squarewave, cross modulation is equal to the magnitude of the first 15.75 kHz sideband +10 dB. For example, if the first sideband is –64 dBc, the equivalent cross modulation is approximately –54 dBc.

The 2714/2715 can automatically measure cross modulation to –48 dBc using the NCTA recommended test conditions.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Bandpass filter (optional): See *Distortion from overdriving the analyzer*, page 10.

Procedure

This procedure automatically measures cross modulation and displays the result.

1. 100% modulate all channels in the system (except the test channel) with a 15.75 kHz square wave. Adjust each channel to its normal operating level. Adjust the test-channel carrier to its normal peak level.
2. Set the 2714/2715 to the channel to be tested.
3. Peak the preselector filter, if used.
4. Enter the CROSS MODULATION menu on page two of the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [9] / [7].
5. Select RUN CROSS MODULATION from the menu, [0].
6 The 2714/2715 measures the peak carrier amplitude, then prompts you to turn off the modulation and press [W] to continue. Since there is no modulation on the test channel, press W. The 2714/2715 performs the cross modulation measurements and calculations, prompts you to turn the modulation back on, and displays the results on the CRT.
7. The results of the test can be stored in the 2714/2715 for later use, or can be viewed on the CRT by pressing [CATV/APPL] and selecting the corresponding menu item.

Co-channel interference

When off-air signals on the same channel but originating from different locations can overlap, the FCC requires that the carriers be offset by ±10 kHz. If a headend is located in the overlap region, it is possible to receive more than one signal on a given channel. When this happens, the co-channel signal appears as an interfering signal displaced by 10 kHz or 20 kHz from the desired carrier. The 2714/2715 can be used to help identify this type of interference.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Bandpass filter (optional): See *Distortion from overdriving the analyzer*, page 10.

Procedure

This procedure demonstrates how to recognize and measure co-channel interference on an in-service channel.

1. Connect the analyzer to the output of the channel processor or to a system test point taking into account the input limitations outlined in *Connecting a Signal to the 2714/2715*, page 7.
2. Peak the preselector filter, if used.
3. Adjust the analyzer as follows:
   a. Select a channel: (press [CHAN/FREQ] / [channel #] / [W]
   b. center the visual carrier: (press [CTR-MEAS] / [TRKG]
   c. Span/div: 10 kHz (press [SPAN/DIV] / [10] / [Y])
   d. Resolution Bandwidth: AUTO
   e. Sweep: AUTO
   f. Video Filter: ON

The display will resemble Figure 13. Carefully examine the areas ±10 kHz and ±20 kHz from the visual carrier. The large signals spaced every

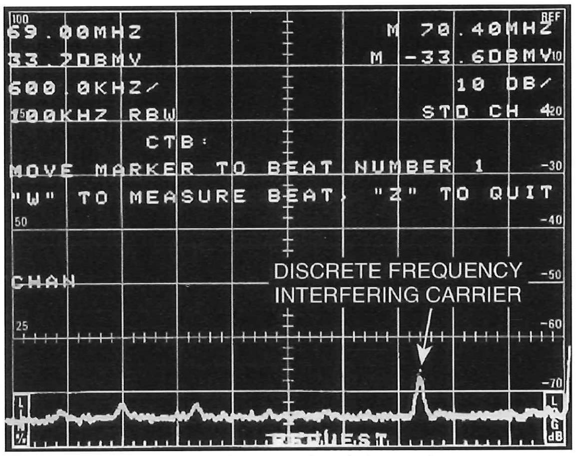


Figure 14. Positioning a marker on an interfering carrier.

15 kHz are frequency components of the horizontal sync pulses on the visual carrier. The level of interfering signals can be measured using either the graticule lines or markers. Video modulation on the desired channel limits detection of co-channel interference to about 60 dB below the desired carrier.

Ingress and discrete frequency interference

Ingress is caused by the inability of the cable system to completely reject local off-air signals. Common sources of ingress are local broadcast stations and transmitters for pagers. Some sources of ingress can be especially difficult to locate if the interfering signal only occurs intermittently or if the source is from mobile communications equipment. Normal leakage detection techniques are usually effective for locating the defect in the system that is allowing off-air signals to get in (and cable signals to get out).

Modulators, processors, demodulators, tape machines, microwave transmitters and receivers, and other types of processing equipment at the headend and hub sites contain oscillators which can be sources of discrete frequency interfering carriers. A quick check at the test point of each piece of processing equipment will reveal such sources of interfering carriers. Be certain to look for spurious signals across the entire bandwidth of the system.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Bandpass Filter (optional): See *Distortion from overdriving the analyzer*, page 10.

Procedure

This procedure uses the interactive CTB measurement mode to search for ingress and other spurious signals.

1. Set the 2714/2715 to the channel to be tested.
2. Peak the preselector filter, if used.
3. Enter the CTB menu on page two of the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [9] / [5].
4. Select CTB SETUP, [5], then INTERACTIVE, [0].
5. Press the backspace key [BKSP] to return to the CTB menu.
6. Press [0], (RUN CTB). The 2714/2715 automatically measures the amplitude of the visual carrier, pauses, and then displays the message MOVE MARKER TO BEAT NUMBER 1, "W" TO MEASURE BEAT, "Z" TO QUIT.
7. Disable the carrier for the channel-under-test at the headend.
8. Look for spurious signals in the display (see Figure 14). You may change settings on the 2714/2715 as desired to help view the signals. Reducing the resolution bandwidth (RES BW) and enabling the VID FLTR is quite effective in making spurious signals more visible. Use the large knob to move the marker to the first signal you want to measure (the marker does not need to be exactly centered on the signal – the 2714/2715 searches within 100 kHz of the marker frequency) and press W. The 2714/2715 measures the amplitude and relative frequency of the signal you selected and then instructs you to MOVE MARKER TO BEAT NUMBER 2. If you wish to measure additional signals, repeat the above procedure. As many as five signals can be measured in this manner. If you decide to end the test after fewer than five measurements, press [Z] to exit the test. At the end of the test, the 2714/2715 returns to the spectral display and prints the worst-case signal amplitude and frequency (relative to the visual carrier amplitude and frequency) on the CRT. Result of all signals measured may be viewed by pressing [CATV/APPL] / [2].

Carrier-to-Noise Ratio

Carrier-to-noise ratio (C/N) is the power ratio, expressed in dB, between the peak visual carrier amplitude and the total noise power in the channel bandwidth – usually taken to be 4 MHz for NTSC systems and 5 MHz for many PAL systems. Acceptable levels of C/N are a function of program content, viewer sensitivity, and television receiver design. If modulation percentages are within normal ranges, C/N of at least 40 dB are required for generally acceptable picture quality. Picture impairments at 30 dB C/N are quite objectionable.

To measure noise, no signals can be present within the measurement bandwidth. In practice, there are normally multiple spurious signals within each channel – making it nearly impossible to use wide bandwidth settings for noise measurement. Therefore, noise is measured at reduced bandwidths and at frequencies known to have no signals present. A correction factor is applied to arrive at the equivalent wide bandwidth noise level. Refer to the sidebar *Correction Factors for C/N Measurements* for details on the calculation. The 2714/2715 automatically performs the calculations to ensure correct C/N measurement results.

If the visual carrier is 10 dBmV or greater, you should be able to accurately measure C/N of at least 50 dB. For lower carrier levels, you may need to use the internal preamp. If so, be careful to not overdrive the analyzer. Refer to *Signals Close to the Analyzer's Noise Floor*, page 11. The 2715 automatically enables its internal preamp when necessary. A preselector filter is not usually required when making C/N measurements in a distribution system. However, measurement of very high C/N, such as at headends, requires a preselector for the greatest accuracy.

The 2714/2715's AUTO (in-service, guardband) mode performs in-service C/N measurements by measuring the noise level at frequencies between the visual carrier of the test channel and the aural carrier of its lower adjacent channel. For accurate results, the modulator or processor must provide adequate signal suppression at the channel boundary. Also, the frequency response between the visual carrier of the test channel and the aural carrier of the lower adjacent channel should be essentially flat at the test site. Bandpass filters, traps, and diplexer filters can affect the frequency response at the channel boundary and cause inaccurate readings. The AUTO (in-service, guardband) mode should NOT be used at the output of set-top converters.

Table III summarizes the C/N measurement modes available.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Bandpass Filter (optional): See *Distortion from overdriving the analyzer*, page 10.

Procedure 1 – Automatic C/N Measurement Using the Guardband

This procedure uses the 2714/2715's AUTO (in-service, guardband) mode to perform C/N measurements on the selected channel. The 2714/2715 automatically measures the amplitude of the visual carrier, searches the frequencies between the visual carrier and the lower adjacent aural carrier for the minimum level, measures that minimum level, performs the necessary calculations, and displays the results.

1. Set the 2714/2715 to the channel to be tested.
2. Enter the CARRIER TO NOISE menu on the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [5]. Select CARRIER/NOISE SETUP by pressing [5]. If not already set for the AUTO mode and the desired noise bandwidth, adjust those settings as necessary. Exit the SETUP menu by pressing [BKSP].
3. Press [0] to RUN CARRIER/NOISE AUTO. The 2714/2715 performs the measurement and displays the results on the screen. If you would like to save the results, press [CATV/APPL] / [1].

Correction Factors for C/N Measurements

The 2714/2715 automatically applies appropriate C/N correction factors. You do not need to perform any additional calculations when using a 2714/2715.

Spectrum analyzers are usually designed to detect the peak of the incoming signal and calculate an equivalent RMS value. When noise is applied, the detector responds to the average of the noise envelope, which is much lower than the peak and 1.05 dB lower than the RMS noise level. Therefore, 1.05 dB must be added to the results due to the design of the detector. Also, spectrum analyzers compress signals logarithmically to provide wider on-screen dynamic range. Logarithmic compression reduces the average noise level by an additional 1.45 dB. Therefore, a total of 1.05 + 1.45 = 2.5 dB must be added to the measured noise level when in the logarithmic mode.

C/N is typically specified over the channel bandwidth (taken to be 4 MHz for NTSC). To avoid errors caused by spurious signals within the channel, measurements are made over a narrower bandwidth and a correction factor is applied. Because of the shape of its filter skirts, the noise bandwidth of an analyzer is normally not the same as its resolution bandwidth. For resolution bandwidth filters, such as the 2714/2715's, that are specified at 6 dB, the noise bandwidth is typically 80% of the resolution bandwidth.

The 2714/2715 automatically applies the following compensation factors when calculating C/N ratios.

Source of Error	Correction Factor
Envelope detection and log amplification	2.5 dB
Measurements at reduced bandwidth	10 log (Equivalent Noise BW of RBW filter)

NOTE: Each filter in the 2714/2715 is individually characterized during self-normalization. Therefore, there is some variation of correction factors between filters. You can find the actual values under the UTIL menu by pressing [UTIL] / [5] / [5] / [4] / [9] / [1].

If the noise being measured is too close to the noise floor of the analyzer, the analyzer's internal noise will affect the measurement. In that case, an additional correction factor must be used. The 2714/2715 also automatically compensates for noise close to its noise floor. The message NOISE LEVEL LESS THAN 2 DB is displayed if the noise is so close to the 2714/2715's noise floor that an accurate measurement cannot be made.

Refer to ***Random Noise Measurement with the Spectrum Analyzer***, Tektronix application note 2EW-8959-0, for a detailed description of noise measurement techniques using a spectrum analyzer.

Table III. 2714/2715 C/N Measurement Modes.

Test Mode	Advantages	Disadvantages
Interactive	Operator selects C/N measurement frequency. Allows measurement within the channel bandwidth. Also effective for detecting coherent disturbance problems.	Typically performed with channel out of service. Requires more operator skill than other methods.
Auto (Pause for Carrier Off)	Measurement is made within the channel bandwidth. Requires little operator skill.	Performed with channel out of service. Always measures C/N at 2.7 MHz offset from the visual carrier.
Auto (In-service, Guard Band)	Fully automatic. Performed with channel in service. Requires little operator skill.	Measurement is made outside of the channel bandwidth. Presence of filters or set-top converter may affect accuracy.
In-Service (2715 only)	In-service technique using either automatic or interactive mode. Measurements can be made within the channel bandwidth. The interactive mode is also effective for detecting coherent disturbance problems. Measures system noise and video noise.	System noise may be masked by video noise. Useable only on modulated channels. Video signal must be stable and have standard sync characteristics.

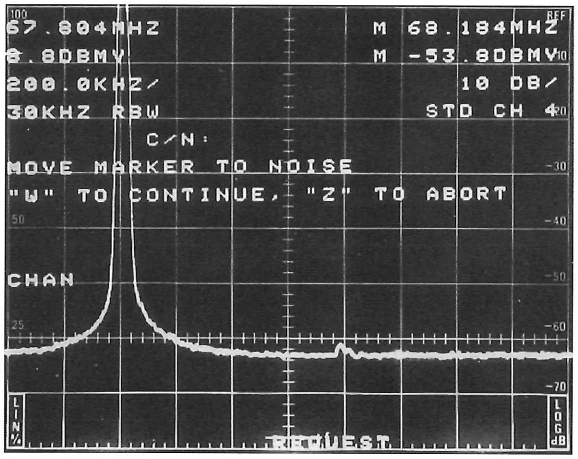


Figure 15. Using the interactive mode to measure carrier to noise ratio.

NOTE: Measurements made using the AUTO (in-service, guardband) mode does not include noise generated by modulators, processors, etc. However, when making measurements in a distribution system, noise generated by headend equipment is usually so low relative to typical amplifier cascades that it can be ignored.

Procedure 2 – Out-of-Service C/N Measurement

If the guardband is not suitable for automatic C/N procedures, an out-of-service technique can be used. This procedure uses the 2714/2715's INTERACTIVE C/N measurement mode. The 2714/2715 automatically measures the amplitude of the visual carrier, pauses for you to remove the signal and position a marker, then measures the noise level at the marker position, performs the necessary calculations, and displays the results.

1. Set the 2714/2715 to the channel to be tested.
2. Enter the CARRIER TO NOISE menu on the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [5]. Select CARRIER/NOISE SETUP by pressing [5]. If not already set for the INTERACTIVE mode and the desired noise bandwidth, adjust those settings as necessary. Exit the SETUP menu by pressing [BKSP].
3. Press [0] to RUN CARRIER/NOISE INTERACTIVE. The 2714/2715 measures the visual carrier level and pauses with the message MOVE MARKER TO NOISE displayed. Turn off the signal at the headend. If using a modulator, replace its video input with a terminator. If using a processor, remove its antenna connection and terminate its input. Move the marker to a position above the visual carrier frequency that is representative of the noise level. Normally, the noise level will be constant across the trace. If beats or other coherent disturbances are present, be careful to avoid positioning the marker on them. Figure 15 is a typical display. Press [W]. The 2714/2715 will complete the measurement and display the results on the CRT.

In-service C/N measurements using the 2715

During the vertical blanking interval (VBI) there are usually one or more scan lines that have no video signal. By sampling the signal during the "quiet lines," the 2715 can make in-service C/N measurements within the bandwidth of the channel-under-test. Either automatic or interactive measurement modes can be used.

The following procedure describes the automatic method. For interactive measurements, simply select INTERACTIVE in step 4 and follow the on-screen prompts as the test proceeds.

Equipment Required

Spectrum Analyzer: Tektronix 2715.

Bandpass Filter (optional): See *Distortion from overdriving the analyzer*, page 10.

Procedure

This procedure uses the 2715's AUTO mode to perform in-service C/N measurements on the selected channel. The 2715 automatically measures the amplitude of the visual carrier, searches the vertical blanking interval for quiet lines, and performs the C/N measurement at +2.7 MHz offset during the quiet lines. It then rechecks the quiet lines to ensure they didn't change during the measurement and displays the results. A video signal meeting basic broadcast standards is required for this test method. Refer to ***Nonstandard video signals****, page 13, for more information.*

1. Set the 2715 to the channel to be tested.
2. Enter the CARRIER TO NOISE menu on the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [5].
3. If not already selected, press [7] to select the IN-SERVICE measurement mode.
4. Select CARRIER/NOISE SETUP by pressing [5]. If not already set for the AUTO mode and the desired noise bandwidth, adjust those settings as necessary. Exit the SETUP menu by pressing [BKSP].
5. Press [0] to RUN CARRIER/NOISE AUTO. The 2715 performs the measurement and displays the results on the screen.

Upon completion of the measurement, the 2715 rechecks the quiet lines for changes during the measurement process. If changes occurred, the results are displayed with "10" preceding the measured C/N. For example, 46.3 dB is displayed as 1046.3 dB. In that case, you may wish to repeat the test.

NOTE: Because it includes both cable TV system noise and noise on the incoming video signal, this technique more accurately reflects picture quality than the other C/N measurement methods. If you wish to evaluate only the cable TV system contribution to C/N, the noise level of the video signal must be negligible or one of the other measurement techniques should be used.

Because the noise level can vary with frequency, C/N measurements should be made at high- and low-frequency extremes of the system.

Hum and Low-Frequency Disturbances

Hum and low-frequency disturbances are undesired modulation of the visual carrier at power line or other low frequencies. They are specified as the ratio of the peak-to-peak variation in visual signal level relative to the peak visual signal level. If a hum signal is sinusoidal, 4% hum will probably not be visible on a television set. If it contains fast edges, 2% or less may be visible. Because the power line and vertical sync frequencies are very close to each other (e.g., 60.00 Hz and 59.94 Hz respectively in the U.S.), it's difficult to differentiate between the two when the channel is in service. Consequently, a CW carrier should be used if only hum (excluding other low-frequency disturbances) is to be measured. Normally, a preselector filter is not required for hum and low-frequency disturbance measurements. However, if the signal amplitudes are high enough to produce distortion within the analyzer, attenuation and/or a preselector should be used.

The 2714/2715 has an automatic mode for measuring hum and low-frequency disturbances.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Bandpass Filter (optional): See *Distortion from overdriving the analyzer*, page 10.

Procedure

This procedure automatically measures hum and low-frequency disturbances. If you wish to measure power-related hum only, perform the test on an unmodulated carrier.

1. Set the 2714/2715 to the channel to be tested.
2. Select the HUM/LFD menu on the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [6].
3. If necessary change the power-line frequency under item 5 of the menu.
4. If you would like to measure hum only, remove the modulation on the channel under test. For hum and other low-frequency disturbances, the modulation should remain on.
5. Select RUN HUM/LFD from menu [0].
6. The 2714/2715 performs the hum/low-frequency disturbances measurements and calculations and displays the results on the CRT.

NOTE: The 2714/2715 displays the fundamental, second harmonic and total hum. The total hum is the vector addition of the fundamental and second harmonic. Because its magnitude depends on the amplitudes and relative phases of the two signals, it will normally be less than the simple arithmetic sum of the fundamental and second-harmonic components.

In-Channel Response

In-channel response is the variation in gain between the frequency limits of a channel. For NTSC systems, it's often specified as the peak-to-peak variation in gain measured between 0.75 and 5 MHz above the lower boundary frequency of the channel. It's sometimes specified in ±dB (one-half of the peak-to-peak value). A common requirement is that the peak-to-peak variation be less than 4 dB (±2 dB).

In-channel response problems can be caused by a number of factors such as:

- Modulator frequency response
- Demodulator or processor frequency response
- Multipath on off-air signals
- Frequency response of channelized microwave transmitters
- Roll-off caused by traps on adjacent channels
- High-frequency roll-off in the distribution system

In-channel response is measured using test signals specifically developed for evaluation of frequency response. It can be measured automatically using a full-field multiburst test signal or can be measured in-service using a special Vertical Interval Test Signal (VITS) and manual procedures. The 2715 can perform in-service in-channel response measurements automatically using commonly available VITS.

Out-of-service measurements

The 2714/2715 has an automated procedure for measuring in-channel response using a full-field multiburst test signal. Multiburst signals consist of packets of constant amplitude sine waves, at various frequencies, covering the bandwidth of the channel being tested. Many multiburst generators include a packet at 3.58 MHz. Others, such as the Tektronix TSG 120 Opt. 2, have a packet at 3.75 MHz instead. The 3.75 MHz packet provides a signal at the output of the modulator which is 5.00 MHz above the lower channel boundary. The 3.58 MHz packet provides a signal 4.83 MHz above the boundary. If it's critical that the response be measured at exactly 5.00 MHz, a generator with a 3.75 MHz packet should be used.

For this test, the multiburst packets must all have equal amplitudes as measured by a spectrum analyzer. Many multiburst generators produce packets that are flat when measured with an oscilloscope or waveform monitor but, due to differences in the widths of the packet envelopes, do not appear flat on a spectrum analyzer. If in doubt, check the output of the generator with the 2714/2715.

Any extraneous signals such as ID signals from the test signal generator or VITS inserted between the test signal generator and the modulator should be turned off to ensure they do not interfere with this test.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Multiburst Signal Generator: Tektronix TSG 90, TSG 120 Opt. 2.

Procedure

This procedure demonstrates in-channel response measurement by substituting a multiburst test signal for the video signal at the headend. Variations in the multiburst packets are then measured in the field. This procedure is most easily applied to channels that use modulators. Processed channels can be tested in a similar

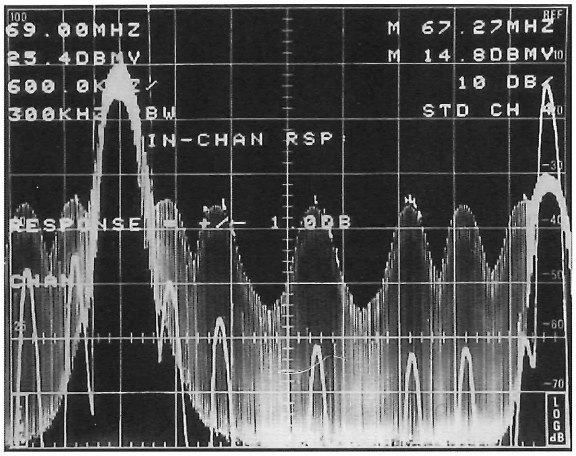


Figure 16. In-channel test results using the AUTO mode. The background trace is at 1 dB/div.

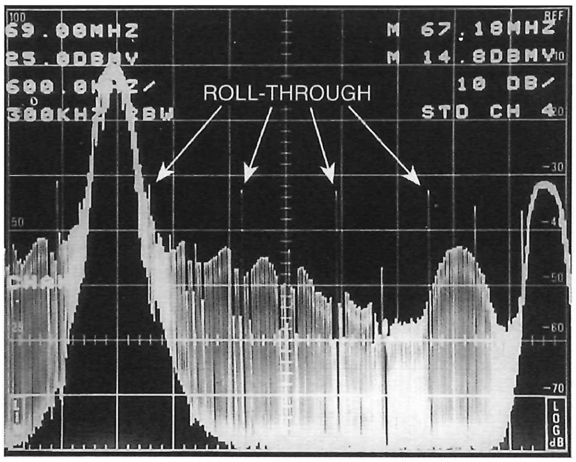


Figure 18. High-level sweep visible as vertical-interval roll-through.

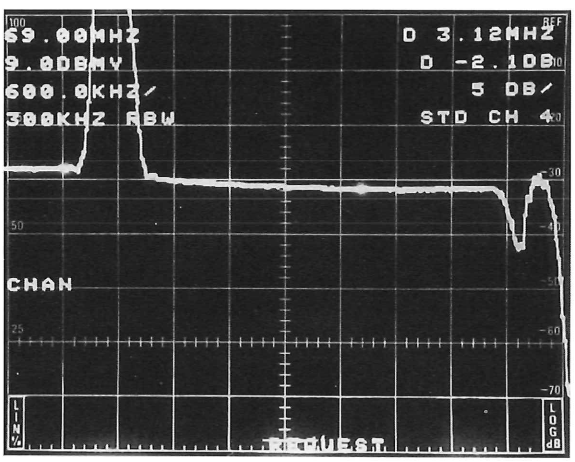


Figure 19. In-channel response using a high-level sweep test signal.

manner by connecting the multiburst signal to a modulator and connecting the output of the modulator to the processor (be sure to measure and log the in-channel response of the test modulator).

1. Set the 2714/2715 to the channel to be tested.
2. Enter the IN-CHANNEL RESPONSE menu on page two of the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [9] / [8].
3. Select IN-CHAN RESP SETUP by pressing [5]. If not already set for the AUTO mode and multiburst frequencies that match those of the generator, adjust those settings as necessary. The frequencies of the multiburst packets can be found in the generator's operator's manual. Exit the SETUP menu by pressing [BKSP].
4. Press [0] to RUN IN-CHAN RESP. The 2714/2715 will prompt you to TURN ON THE TEST SIGNAL and push "W" TO CONTINUE. When the test signal appears, push [W].
5. The 2714/2715 performs the measurement, prompts you to turn off the test signal (reconnect the original video signal), and displays the results.

Figure 16 shows in-channel response of 1.0 dB.

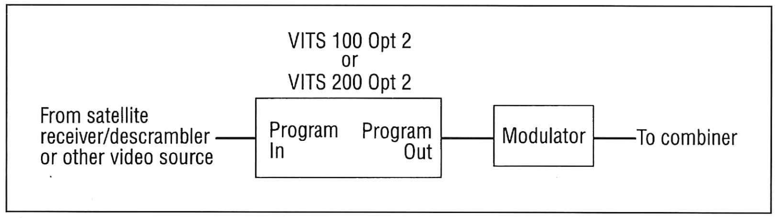


Figure 17. Setup of equipment in the headend for in-service measurement of in-channel response.

In-service measurements using a high-level sweep test signal

In-channel response can be measured on an active channel by using a Vertical Interval Test Signal (VITS) specifically developed for measuring in-channel response in cable TV systems. The test signal sweeps from 0.1 to 4.2 MHz and is higher amplitude than normal video. The MAX HOLD function in the 2714/2715 is used to plot the frequency response of the test signal and ignore the other (lower amplitude) signals.

The high-level sweep signal is available in the Tektronix VITS 100 Opt 2 and VITS 200 Opt. 2 VITS Inserters.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

VITS Inserter: Tektronix VITS 100 Opt. 2 or VITS 200 Opt. 2.

Procedure

This procedure uses a high-level VITS sweep signal for analyzing in-channel response using the spectrum analyzer's MAX HOLD function.

1. Connect the video signal to the PROGRAM IN connection on the back of the VITS inserter and connect the PROGRAM OUT signal from the VITS inserter to the modulator as shown in Figure 17. The BYPASS switch, on the front of the VITS inserter should be in the out position (bypass LED off).
2. Set the 2714/2715 to the channel to be tested and adjust the REF LEVEL so that the visual carrier is near the top graticule line.
3. The spectral components of the high-level VITS sweep signal should be visible as vertical-interval roll-through above the normal video signal, see Figure 18. Change to 5 dB/div by pressing the VERT SCALE [10/5/1] button.
4. Press [D] to turn off DISPLAY STORAGE register D; press [A] to turn on DISPLAY STORAGE register A, then press [MAX HOLD A&B]. After approximately one minute, the display should resemble Figure 19.
5. Press [PEAK FIND] to center the marker at the top of the visual carrier.
6. Press [MKR / Δ / OFF] to enter the marker delta (D) mode.
7. Turn the FREQ/MKRS knob until the second marker is 500 kHz below the visual carrier frequency. The read-

out should indicate "D –0.50MHZ."

8. Press [MKR/FREQ] / [5] to transpose the markers.
9. Adjust the FREQ/MKRS knob until the readout indicates "D 4.25MHZ" indicating that there is 4.25 MHz between the two markers. The markers are now set to 0.75 and 5 MHz above the lower channel boundary.
10. Staying within the range between 0.75 and 5 MHz above the channel boundary, reposition the two markers to the maximum and minimum levels of the swept-frequency signal. The readout indicates the peak-to-peak difference in amplitude between the two markers. Figure 19 indicates a 2.1 dB peak-to-peak (±1.05 dB) in-channel response variation.

In-service measurements using the 2715

The 2715 can perform in-service in-channel response measurements on commonly available vertical interval test signals (VITS), including: multiburst, line sweep, and the Philips ghost cancellation reference signal.

When using the 2715's automatic mode, measurements are performed at frequencies specified in the SET UP IN-CHAN RESP TEST FREQUENCIES table ([CATV/APPL] / [9] / [8] / [5]). The frequency table can be adjusted to meet your particular needs. The default setting matches common cable TV multiburst frequencies (including a packet at 3.75 MHz). The INTERACTIVE mode allows you to position markers at desired measurement points (typically at the maximum and minimum levels within the bandwidth being checked).

To perform in-service in-channel response tests, the 2715 must be programmed to run the test on a scan line that contains an appropriate VITS. You can use the VIEW MODULATION (LINE) function ([CATV/APPL] / [9] / [2]) to help locate test signals. Turn the readout on to display the line number of the signal. You may also want to increase the resolution bandwidth to assist in identifying the signals. In some cases, there may not be an appropriate VITS on the incoming signal and you will need to use a VITS inserter (such as the Tektronix VITS 100 or VITS 200) to provide the test signal.

Equipment Required

Spectrum Analyzer: Tektronix 2715.

VITS Inserter (optional): Tektronix VITS 100 or VITS 200.

Procedure

This procedure demonstrates in-service in-channel response measurement using the 2715's interactive mode. Refer to the preceding paragraphs for information on locating an appropriate VITS. A video signal meeting basic broadcast standards is required for this test method. Refer to ***Nonstandard video signals****, page 13, for more information.*

1. Set the 2715 to the channel to be tested. Check the visual carrier level. If it's less than 0 dBmV, enable the preamplifier ([INPUT] / [1]).
2. Enter the IN-CHANNEL RESPONSE menu on page two of the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [9] / [8].
3. If item 0 (RUN IN-CHANNEL RESP) is not already set to INTERACTIVE, press [5] to SET UP IN-CHANNEL RESP and then press [0] to select INTERACTIVE. Press BKSP to return to the previous menu.
4. If IN-SERVICE is set to OFF, press [7] to toggle it to ON.
5. Enter the line number of the VITS you wish to use by pressing [6] and following the on-screen instructions.
6. Press [0] to start the test. The 2715 displays the spectrum of the signal during the line number specified in step 5 and prompts you to MOVE MARKER TO FIRST LOCATION. If necessary, press [MKR] / [Δ] / [OFF] to enter the single marker (M) mode.
7. Use the large knob to position the marker to the maximum signal level within the frequency range over which you wish to measure. The marker frequency readout indicates the frequency as you position the marker. Press "W" to continue.
8. Position the marker to the minimum level within the desired frequency range and press "W." The readout indicates ± one-half the peak-to-peak difference in amplitude between the two markers. If you wish to store the results in the 2715's internal memory, press [CATV/APPL] / [1].

Measuring Depth-of-Modulation

Depth-of-modulation is normally specified as 87.5%, sync tip to 100% white. Stated another way, the amplitude of a peak white signal should be 12.5% of the sync tip amplitude. If the depth-of-modulation is low, signal-to-noise ratio will suffer. If too high, the carrier level may be zero during video peaks, resulting in picture distortion and audio buzz.

You can use the 2714/2715 to measure depth of modulation while a channel is in service. Best accuracy is obtained if the channel has a Vertical Interval Test Signal (VITS) that includes a 100% white bar and if the PC software is used to include that VITS line in the channel table (see *Creating Custom Channel Tables*, page 33). If no VITS is present, the 2714/2715 can still be used to measure depth-of-modulation on active video. However, the results depend on the characteristics of the video signal at the time of measurement, so you may need to perform the measurement multiple times to obtain accurate results.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Procedure

This procedure automatically measures depth-of-modulation and displays the results.

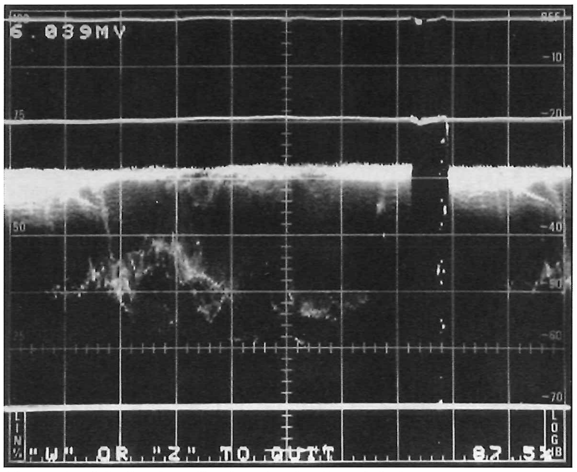


Figure 20. Display for adjusting depth-of-modulation.

1. Ensure that the modulator's video input signal is 1 volt peak-to-peak.
2. Set the 2714/2715 to the channel to be tested.
3. Enter the MODULATION DEPTH menu on the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [3].
4. Press [0] to RUN MODULATION DEPTH. The 2714/2715 performs the measurement and displays the results on screen.

Adjusting depth-of-modulation

The 2714/2715's MODULATION DEPTH ADJUSTMENT MODE automatically displays the demodulated video signal and provides a reference line to aid in making adjustments. Many VITS include a 100% white level which can be used for the adjustment. If an appropriate test signal is not available on the program video, a VITS inserter with 100% white signals can be used instead. Make certain that the level from the signal generator and the normal video levels are equal. If you use active video to adjust depth of modulation, be certain to make the adjustment based on 100% white level signals. You may need to wait for the video source to provide the appropriate level.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Procedure

This procedure puts the 2714/2715 in a mode that can be used to monitor depth-of-modulation while adjusting a modulator. The 2714/2715 periodically adjusts its gain to maintain the sync tips at the top graticule line.

1. Ensure that the modulator's video input signal is 1 volt peak-to-peak.
2. Set the 2714/2715 to the channel to be tested.
3. Select MODULATION DEPTH (item 3) from the CATV/APPL menu.
4. Press [5] to enter the SETUP ADJUSTMENT MODE. Four selection items are presented:
   - 0: VIEW MODULATION MODE

     Provides a choice of displaying either one line or one field of demodulated video. The decision to use one line or one field display is a matter of user preference. If the signal contains VITS, all of them are visible using the one-field display. The one-line display shows the individual line as set up in the channel table (line 17 default).
   - 1: TARGET LINE

     Used to specify the modulation level at which the target line will be displayed. For U.S. systems, this is normally set to 87.5%.
   - 2: CYCLE DELAY

     Determines how frequently the display cycles between demodulated video and the target line.
   - 3: TARGET LINE DURATION

     Determines how long, as a percentage of the complete cycle time, the target line is displayed.
5. After making the desired selections, press [BKSP] to return to the MODULATION DEPTH menu.
6. Press [6] to ENTER ADJUSTMENT MODE. The 2714/2715 displays the demodulated video and target line as set up in steps 1 through 4. The amplitude of the sync tip is displayed in the upper left corner and the target level is displayed in the lower right corner of the display. Figure 20 shows a typical display. Adjust the modulation level so that the 100% white signal just meets the target. When finished, exit the adjustment mode by pressing [W] or [Z].

Frequency Deviation

The 2714/2715 provides several methods for evaluating the deviation of aural carriers. Manual methods, including the very accurate Bessel null method, are described in the Tektronix application note ***Spectrum Analyzer Fundamentals***. The 2714/2715's Cable TV measurements mode also provides two quick methods for checking and setting deviation.

Automatic aural (FM) deviation measurement

Deviation measurement on active signals is subject to programming content during the measurement. The most accurate measurements are obtained using fixed-amplitude audio-test signals. With either test signals or live audio, you can use the 2714/2715's automatic modes to measure deviation over a specified time period then decide whether or not the program content was appropriate for an accurate reading. If not, you can re-run the measurement or, using the INTERACTIVE (RESUME/ACCEPT) mode, collect data for an additional time period. The 2714/2715 measures the peak deviation during the specified time period then computes a "mean peak deviation" and displays the results.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Procedure

This procedure measures FM deviation on an in-service channel by sampling the peak deviation during a specified time period and calculating the "mean peak deviation" from the data.

1. Set the 2714/2715 to the channel to be tested.

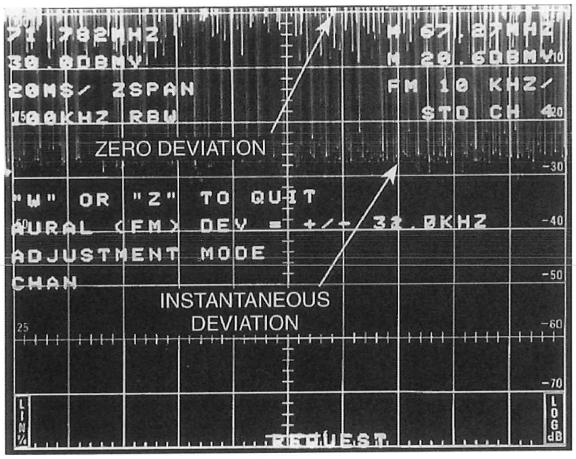


Figure 21. Frequency deviation using the 2714/2715's Adjustment mode.

2. Enter the AURAL (FM) DEVIATION menu on the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [4].
3. Select item [5], SET UP AURAL (FM) DEVIATION.
4. Select INTERACTIVE (RESUME/ACCEPT) if you want the 2714/2715 to measure the deviation over the specified time period then offer you the opportunity to either accept the results or continue the measurement process, or select AUTO if you want the 2714/2715 to perform the measurement once and display the results.
5. If desired, change the amount of time over which the 2714/2715 measures the deviation by modifying the MEASUREMENT TIME in item 5. Press [BKSP] to return to the previous menu.
6. Press [0] to run the FM deviation test.

Using the aural (FM) adjustment mode

With the 2714/2715, you can observe instantaneous in-service frequency deviation. In effect, the analyzer becomes a high-speed deviation meter. This mode provides a quick look at frequency deviation for making coarse adjustments to modulators. It's most useful with constant-tone modulation. The out-of-service Bessel null method, described in ***Spectrum Analyzer Fundamentals*** can be used for greater accuracy.

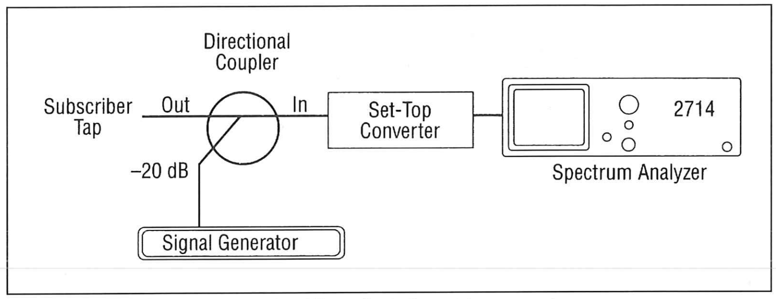


Figure 22. Setup for measurements at the output of a set-top converter.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Procedure

This procedure puts the 2714/2715 in the FM deviation adjustment mode.

1. Set the 2714/2715 to the channel to be tested.
2. Enter the AURAL (FM) DEVIATION menu on the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [4].
3. Select ENTER ADJUSTMENT MODE by pressing [6]. Figure 21 shows a typical display using a constant-amplitude tone. The readout and the downward deflection of the trace indicate the amount of deviation. Typical displays of active signals vary widely depending on program content. The wide variations in deviation should normally be ignored when analyzing this type of display.
4. If desired, adjust the modulator to obtain the desired degree of modulation.

Measurements at the Output of Set-top Converters

There are two basic types of set-top converters; RF (or heterodyne), and baseband (or volume control) converters.

RF converters

RF converters heterodyne the selected channel to the converter's output channel – typically 2, 3, or 4. The converter's output frequency and amplitude should be checked to ensure they are within requirements. Be certain to check both the visual and aural carriers because the frequency response of this type of converter may affect the visual-to-aural carrier ratio.

If the converter has no AGC or AFC, normal measurement techniques can be used. However, if present, AGC and AFC circuits can cause problems when making measurements, such as CTB, that require removal of the picture carrier. With no carrier present, the AGC will increase the gain, raising the apparent level of the system noise and beats. Converters with AFC may lock to the lower adjacent aural carrier if no visual carrier is present.

An unmodulated substitution carrier can usually be used to allow measurements at the output of such converters. By offsetting the substitution carrier approximately 300 kHz, CTB and on-frequency ingress will be visible above the substitution carrier frequency. When performing measurements using a substitute carrier, it's important to set its level to match the original signal. If the substitution carrier is set too low, the converter's AGC increases the gain which causes the system noise and coherent disturbances to appear larger than they actually are.

Coherent disturbance measurements at the output of set-top converters

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

CW Signal Generator: Capable of producing a signal equal in amplitude and 300 kHz lower in frequency than the visual carrier of the channel under test – as measured at the input to the converter when connected as shown in Figure 22.

Directional Coupler: 20 dB, installed "backwards" as shown in Figure 22.

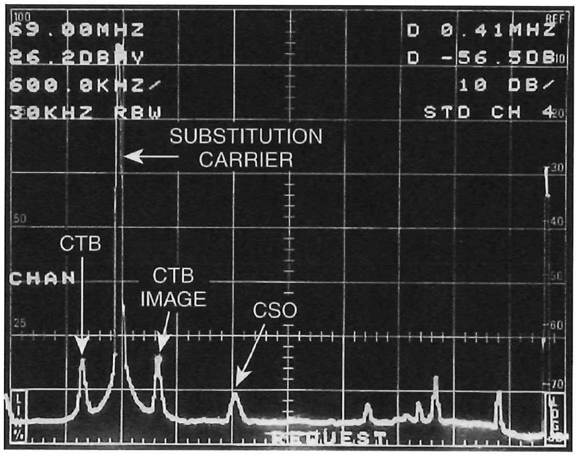


Figure 23. CTB at the output of a set-top converter.

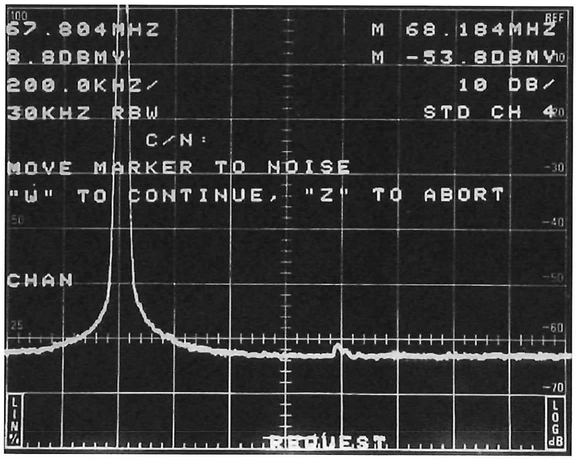


Figure 24. C/N at the output of a set-top converter.

Procedure

This procedure describes coherent disturbance measurements at the output of an RF set-top converter that has AGC and AFC circuits.

1. Set up the equipment as shown in Figure 22. Initially, bypass the set-top converter by connecting the directional coupler directly to the analyzer. Set the output of the generator to zero.
2. Use PEAK FIND to measure the visual carrier amplitude. Turn off the visual carrier at the headend.
3. Using the 2714/2715 as the frequency and amplitude indicator, adjust the generator to 300 kHz higher in frequency and to the same amplitude as measured in step 2.
4. Connect the directional coupler to the converter as shown in Figure 22. Adjust the set-top converter to the channel to be tested. Connect the 2714/2715 to the output of the converter and set it to the converter's output channel.
5. Use the marker to measure the amplitude of the substitution carrier at the output of the converter.
6. Adjust the 2714/2715 for 30 kHz RBW, video filter on, and set ensemble averaging for MEAN and 10 averages ([DISPLAY] / [ENSEMBLE AVERAGING]).
7. Use the delta marker mode to measure the beats, if any. Figure 23 shows CTB of –56.5 dB relative to the visual carrier.

HINT: The need to re-adjust the amplitude and frequency of the replacement carrier for each test channel and test site can be avoided by using a programmable generator at the headend. The generator is connected to the combiner network and is programmed for the appropriate substitution-carrier amplitude and frequency for each channel to be tested. It is then a simple matter to turn off the modulator and select the appropriate stored set-up in the generator to perform the test. Spurious outputs from the generator must be low to avoid interfering with other channels when using this technique.

Carrier-to-noise measurements at the output of set-top converters

It's best to use out-of-service techniques – or the 2715's automatic in-service measurement capability – for C/N measurements at the output of RF set-top converters. If the converter has AGC or AFC circuits, an unmodulated carrier, at the visual-carrier amplitude and frequency, must be present during the out-of-service measurement.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

For tests on processed channels: Replacement Carrier Generator, either automatic or manual.

Procedure

This procedure describes out-of-service carrier-to-noise ratio (C/N) measurements at the output of an RF set-top converter that has AGC and AFC circuits.

1. If testing a processed channel, make certain the replacement carrier is equal in amplitude to the original visual carrier. If the channel processor does not provide an automatic replacement carrier, a CW carrier may be manually inserted at the headend.
2. Set the 2714/2715 to the converter's output channel. If you have created a custom channel table for use with the set-top converter, as described in *Creating Custom Channel Tables*, page 33, set the 2714/2715 to the channel to be tested.
3. Adjust the set-top converter to the channel to be tested.
4. Enter the CARRIER TO NOISE menu on the CATV MEASUREMENTS menu by pressing [CATV/APPL] / [5]. Select CARRIER/NOISE SETUP by pressing [5]. If not already set for the INTERACTIVE mode and the desired noise bandwidth, adjust those settings as necessary. Exit the SETUP menu by pressing [BKSP].
5. Press [0] to RUN CARRIER/NOISE INTERACTIVE. The 2714/2715 measures the visual carrier level and pauses with the message MOVE MARKER TO NOISE displayed. Remove the modulation at the headend. If using a modulator, replace its video input with a terminator. If using a processor, enable the replacement carrier. Move the marker to a position above the visual carrier frequency that is representative of the noise level. Normally, the noise level will be constant across the trace. If beats or other coherent disturbances are present, be careful to avoid positioning the marker on them. Figure 24 is a typical display.
6. Press [W]. The 2714/2715 completes the measurement and displays the results on the CRT.

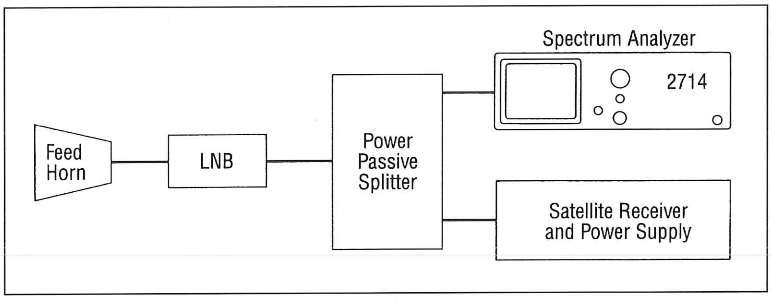


Figure 25. Equipment setup for satellite down-link measurements.

NOTE: If the AGC in the converter responds to the peak of the visual carrier, the converter may increase its gain when video is removed from the modulator, causing lower than actual C/N readings. In that case, either the modulator's unmodulated carrier level must be increased to equal its peak output when modulated or a substitution carrier, equal in amplitude to the peak of the modulated carrier, must be used.

Baseband converters

Baseband (or "volume control") converters demodulate the visual and aural carriers and use the resulting baseband signals to modulate carriers at the output frequencies. Their output carrier levels and frequencies are essentially independent of input levels. Measurements that do not require removal of the visual carrier or modulation can be made on baseband converters using normal procedures. The substitution carrier method can be used on some baseband converters, but others require sync pulses for proper operation of their AGC and AFC circuits. In such cases, contact the manufacturer to obtain appropriate test procedures.

Setting Up Satellite Down-Links

The 2714/2715 is especially useful for setting up and maintaining satellite down-link stations. Locating satellites, pointing antennas, lining up feed horns, identification of interfering signals, and measuring carrier-to-noise are all possible.

This section deals with problems relating primarily to optimum geometrical orientation of antenna components. The general equipment set up is as indicated in Figure 25. For this sample procedure, a 2714/2715 and an LNB that converts the C-Band signals to L-Band (950 MHz to 1450 MHz) is used. 950 MHz to 1450 MHz (or 950 MHz to 1750 MHz in some geographical areas) is the most common LNB output frequency range. Other common LNB output frequencies are 270 MHz to 770 MHz and 450 MHz to 950 MHz. You will need to make minor modifications to the sample procedure if the LNB you are using has something other than a 950 MHz to 1450 MHz output range.

LNBs typically have a 75Ω source impedance, but their signal amplitudes are sometimes specified in dBm. In the procedures which follow, measurement results are in dBmV. To convert to dBm (in a 75Ω system), subtract 48.75 dB. For example, 10 dBmV – 48.75dB = –38.75 dBm.

Remember when viewing down-converted signals that C-band signals are down converted in reverse frequency order: 3.7 GHz becomes 1450 MHz and 4.2 GHz becomes 950 MHz. Ku-band signals occur in the same order after down conversion (11.7 GHz @ 950 MHz and 12.2 GHz @ 1450 MHz).

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Power Passive Splitter and Receiver/Power Supply as shown in Figure 25.

Procedure

This procedure aligns an antenna and feed horn. It's assumed that the antenna is approximately positioned correctly and that a C-band LNB, with an output frequency range of 950 MHz to 1450 MHz, is being used. If a different type of LNB is being used, make the appropriate corrections in steps 2 and 3.

1. Connect the equipment as shown in Figure 25.
2. Exit the CATV mode by pressing [CATV/APPL] / [8] / [0] and set the spectrum analyzer controls as follows:
   a. Center Freq: 1200 MHz (the center of the LNB's output frequency range).
   b. Freq Span/div: 50 MHz.
   c. Resolution BW: 5 MHz (AUTO).
   d. Sweep: 50 msec/div (AUTO).
   e. Display mode: Peak.

   These settings enable you to view the entire 950 to 1450 MHz range of the down converter. If you are working with a 950 to 1750 MHz system, set the Center Freq to 1350 MHz and the Span/div to 80 MHz.
3. Because the down converter LO is above the transponder frequencies in the C-band, you will need to enter a minus offset in the 2714/2715. Calculate the offset by adding the low frequency of the C-Band signal to the low frequency LNB output frequency (4200 MHz + 950 MHz = 5150 MHz for this sample procedure). Use the SETUP TABLE from the Marker/Frequency Menu to enter the offset. Then toggle item 4 until it indicates ON MINUS.
4. Set the antenna to the elevation and azimuth of the desired satellite. Set the feed horn rotation at 45°. Carefully move the antenna while observing the transponders or the beacon signals until maximum amplitude is achieved.
5. After the antenna direction is optimized, align the feed horn. Move the feed horn in all directions and rotate it until the desired signal is maximized. On satellites carrying only 12 transponders, all channels are horizontally polarized; you can null them out by rotating the feed horn 90°. On 24-transponder satellites, the even channels are one polarization and the odd

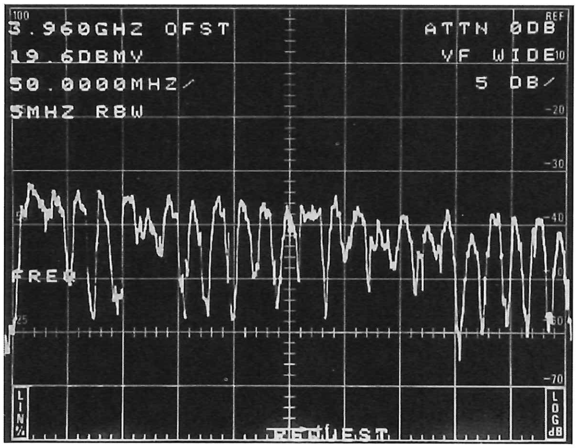


Figure 26. Transponders with feed horn set between polarizations.

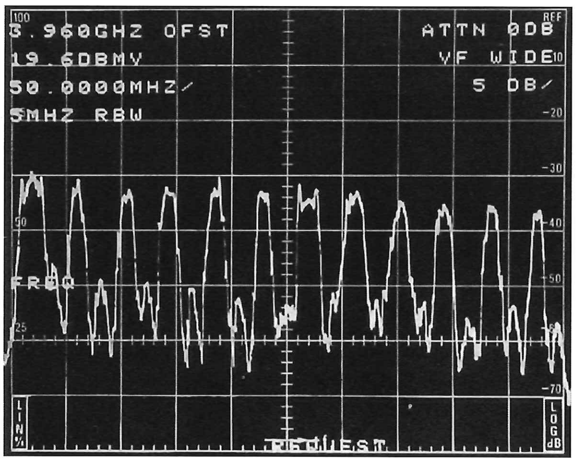


Figure 27. Transponders with one polarization nulled out.

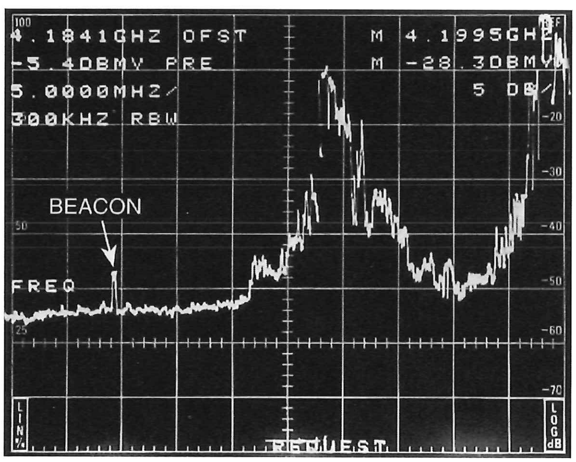


Figure 28. Satellite beacon signal.

channels are the opposite polarity. You can null either set by rotating the feed horn. Transponders can occur every 20 MHz in the C-band starting at 3720 MHz. On 24-transponder satellites, the polarization is alternated from transponder to transponder to avoid interference since their occupied bandwidths (±18 MHz) overlap in frequency. The feed horn can be rotated between polarizations to see all transponders or, dual-polarization feed horns (orthomode transducers) or separate feed horns can be used to receive adjacent transponders simultaneously. Figure 26 shows all active transponders on a satellite with the feed horn between polarizations.

Figure 27 shows the same set of transponders with the feed horn adjusted to null one polarization. Because the LO in the block-down converter is above the transponder frequencies, the frequency axis runs backwards (4200 MHz is on the left and 3700 MHz is on the right). Nevertheless, the 2714/2715's frequency offset feature results in the center frequency being correctly indicated. To determine the frequency of any transponder, simply place the signal at center screen and read the center frequency.

6. You can use the FM video monitor mode to view the non-scrambled transponder video signals. The monitor is useful for identifying transponders and specific program material.
   a. Center the transponder signal of interest and set the span to 5 MHz/div.
   b. Adjust REF LEVEL to place the signal near the top of the screen.
   c. Turning on the preamp ([INPUT] / [1]) may improve video quality.
   d. Select item 0 from the SETUP TABLE of the Demod Menu to change its status from BROADCAST to FM.
   e. Select item 3 from the Demod Menu to turn on the FM video monitor. Reselect item 3 to turn off the monitor when you are finished.
7. Each satellite also transmits one or more beacon signals. The beacon signal is present and can be used for alignment purposes even if all transponders are inactive. On Westar satellites, the beacon is at 4199 MHz and on Satcom and Comsat satellites, it occurs at 3700.5 MHz. The beacon amplitude is much lower than the transponder amplitude. A typical beacon signal is shown in Figure 28.
8. Read the amplitude of the transponders and beacon with the marker for reference.

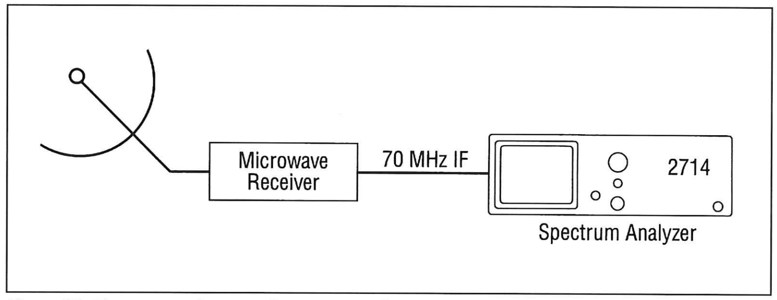


Figure 29. Measurements on a microwave receiver.

Aligning microwave links

Alignment of point-to-point microwave links is essentially the same as aligning satellite down-link equipment. Whether siting new antennas or recalibrating old, the satellite procedures can be used. Equipment setup is similar to Figure 29. If the 70 MHz IF output of the microwave receiver is 50Ω, a matching pad or transformer may be necessary between the receiver and the 2714/2715 for accurate measurements. Refer to *Impedance-matching pads or transformers*, page 3. Follow the procedures in other parts of this application note for measuring signal amplitudes, carrier-to-noise ratios, etc.

Return Loss

Impedance mismatches, broken or loose connectors, cracked cables, improperly tuned antennas, and other factors can reduce the amount of signal energy transferred

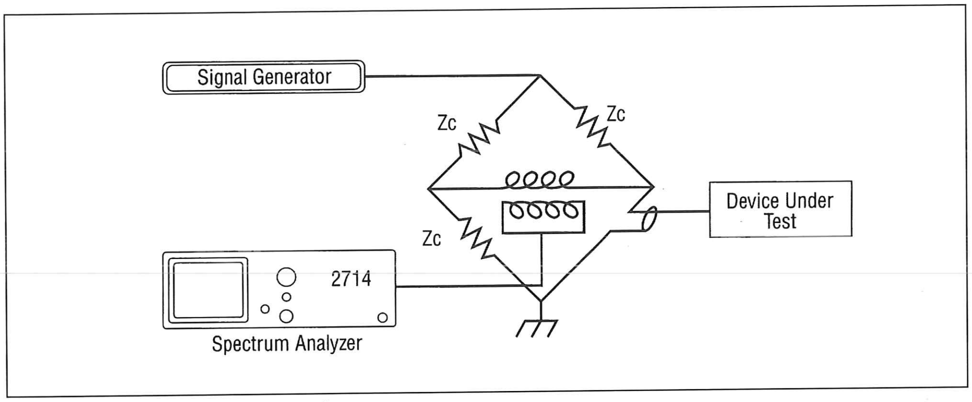


Figure 30. Return-loss measurement setup.

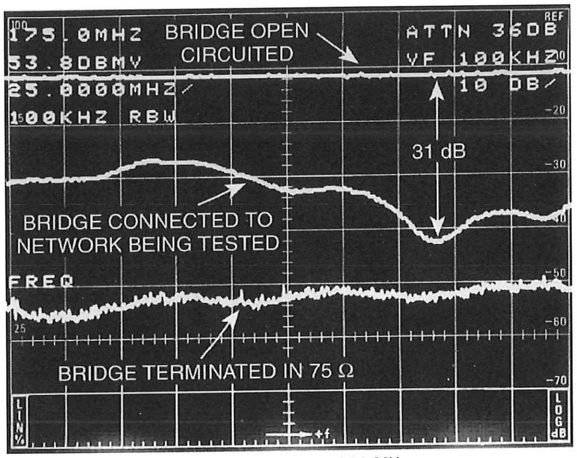


Figure 31. Return-loss plotted from 50 to 300 MHz.

through a system. Under these conditions, part of the signal is reflected back toward the source. The ratio of the power sent to that returned, stated in decibels, is referred to as the return loss of the system.

In addition to providing less than optimum power transfer between components of a system, reflected signals cause standing waves on transmission lines – as evidenced by ghosts and variations in signal amplitude at various points along the line. The ratio of the maximum amplitude to the minimum amplitude of a signal along a transmission line is the Standing Wave Ratio (SWR). Standing waves also cause the amplitude of the signal at a given point along the line to vary as a function of frequency. Consequently, the peak-to-valley ratio can be affected.

The mathematical relationships between return loss and SWR are:

$$\text{Return Loss} = 20 \log \frac{(\text{SWR} + 1)}{(\text{SWR} - 1)}$$

or

$$\text{SWR} = \frac{1 + 10^{-(\text{Return Loss}/20)}}{1 - 10^{-(\text{Return Loss}/20)}}$$

Measuring return loss

Return loss can be measured using a spectrum analyzer, signal source, and return-loss bridge. The return-loss bridge and the generator must be designed for the characteristic impedance of the device to be tested. The signal source must provide signals over the frequency range to be checked. If the signal source is capable of sweeping in synchronism with the sweep of the spectrum analyzer (a tracking generator), it is possible to quickly and accurately measure and plot return loss over a wide frequency range.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Return Loss Bridge: Wavetek FB40-75.

Signal Source: Tracking Generator (Tektronix 2707 Opt. 01) or a CW generator that covers the frequency span of the desired test.

Procedure

This procedure describes making return loss measurements using the 2714/2715 Spectrum Analyzer, a return-loss bridge, and a CW generator.

1. Connect the equipment as shown in Figure 30. If the generator does not have a 75Ω output impedance, use an appropriate minimum-loss pad or transformer between the generator and the return loss bridge. A 6 or 10 dB pad at the output of the generator can be used to further reduce the effects of an impedance mismatch between the generator and the bridge.
2. Set the 2714/2715 center frequency to the center of the frequency span over which you wish to make measurements. If the signal generator needs to be adjusted (bandswitched) to cover the complete test span, select an appropriate span and set the 2714/2715's center frequency to its center.
3. Set the SPAN/DIV to one tenth of the total frequency span you wish to cover.
4. Open circuit the output of the return-loss bridge. Set the signal generator frequency to approximately the center frequency and adjust the reference level so the signal generator amplitude is near the top graticule line.
5. Activate MAX HOLD in waveform A (turn off all active display registers then press [A] / [MAX HOLD A&B]) and slowly sweep the signal generator across the frequency span you wish to analyze. The 2714/2715 should show a roughly flat horizontal line across the top of the screen (similar to the top line in Figure 31). This represents the response of the generator, bridge, and test leads when all energy is reflected. Save the waveform by pressing [SAVE ENABLE] / [A].
6. Terminate the bridge in its characteristic impedance and activate MAX HOLD in waveform B. Again sweep the generator slowly across the frequency span. This time you should see a roughly flat horizontal line 30 to 60 dB below the previous line (similar to the bottom line in Figure 31). This represents the response of the leads when all energy is absorbed. Note the amplitude of the line. It's the lowest possible voltage that can be observed from the device-under-test, and only when the impedance of the device exactly equals the bridge characteristic impedance.

7. Connect the device to be tested. Once again slowly sweep across the test frequencies.
8. The resulting curve should be somewhere between the amplitudes of step 5 and step 6. The return loss is the difference between the amplitude in step 5 and this curve. Figure 31 is a plot of the return loss of a network plotted from 50 MHz to 300 MHz.

HINT: A directional coupler or splitter can be used for approximate return loss measurements or for making adjustments (such as tuning an antenna). Simply connect the directional coupler or splitter as shown in Figure 32 and perform the steps outlined above. Return-loss measurements using directional couplers or splitters are typically limited to 20 to 30 dB. Figure 33 shows the return loss, measured using a 30 dB directional coupler as a return loss bridge, for a 109.25 MHz 1/2 wavelength antenna. The strong dip in the curve occurs at the antenna's resonant frequency.

NOTE: When making return-loss measurements on antennas, you are actually transmitting the signal. Be certain to keep the signal level low and the measurement brief.

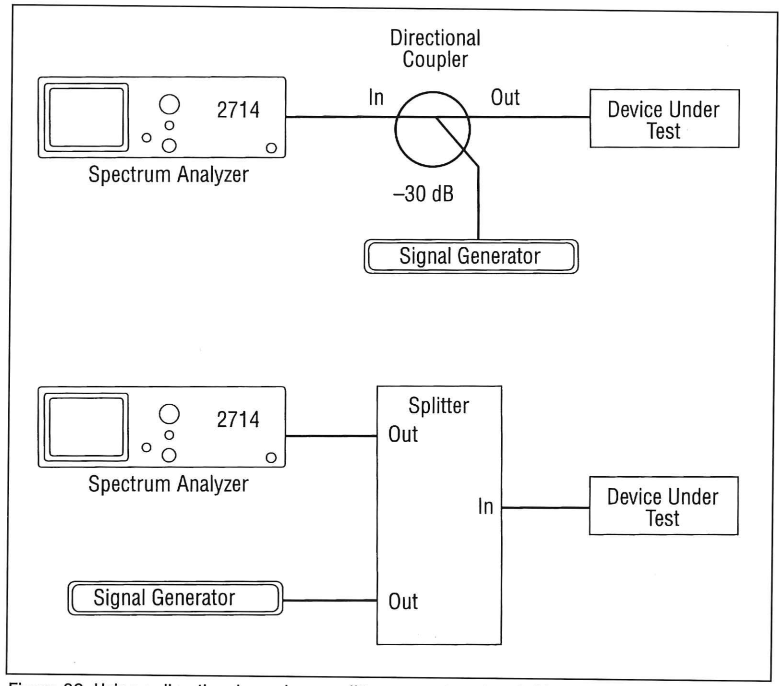


Figure 32. Using a directional coupler or splitter as a return-loss bridge.

Using a Tracking Generator to Measure Frequency Response

A tracking generator (TG) is a sinusoidal signal source whose output frequency sweeps with, or tracks, the current input frequency of the spectrum analyzer to which it is attached. Such devices make it possible to conveniently measure the amplitude transfer functions of two-port devices such as filters or amplifiers. In a reflection mode with a return-loss bridge, the characteristic impedance or VSWR of devices such as antennas or transmission lines can be determined as a function of frequency.

The Tektronix 2707 External Tracking Generator provides tracking generator capabilities for the 2711, 2712, 2714, and 2715 spectrum analyzers.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Tracking Generator: Tektronix 2707 Opt. 1.

Procedure

The amplitude transfer function of a two-port device is the difference in decibels between its output signal amplitude and its input signal amplitude. Because the difference usually varies with frequency, it is necessary to measure it continuously (or at least at a number of points) across the frequency span of interest. The spectrum analyzer/tracking generator combination provides a powerful tool for making this measurement.

1. Connect the equipment as in Figure 34. Temporarily connect the output of the tracking generator directly to the input of the spectrum analyzer. For accurate results, all input and output impedances should match. Use pads where necessary to provide correct impedance matches. Set the generator output amplitude (press [DEMOD] / [5] / [value]) to the device-

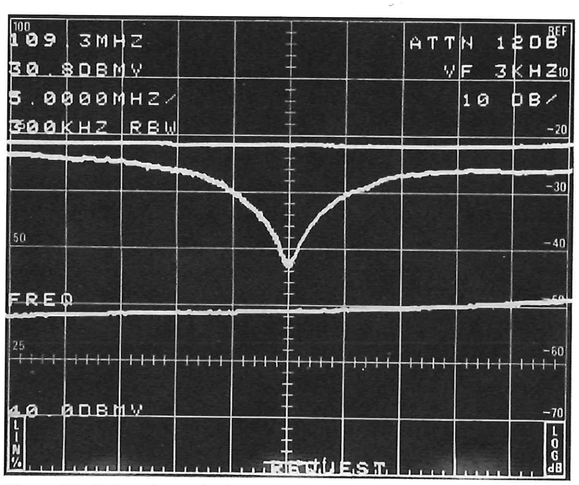


Figure 33. Return-loss of a 109.25 MHz antenna.

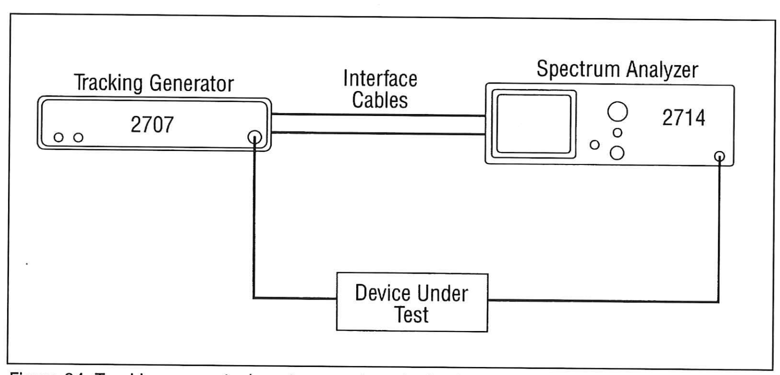


Figure 34. Tracking generator/spectrum analyzer test setup.

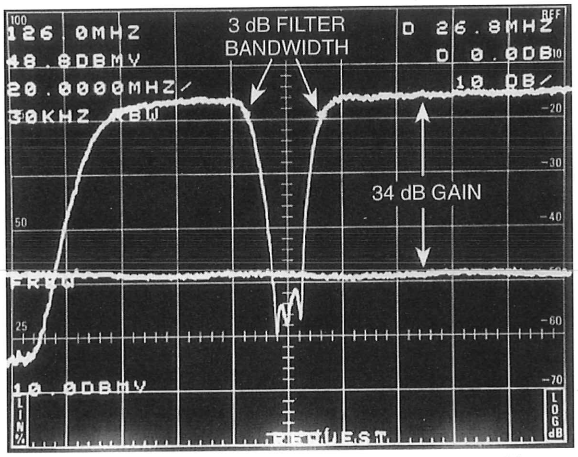


Figure 35. Swept response of UHF/VHF/FM Amplifier with the FM trap enabled.

under-test (DUT) input amplitude specified by its manufacturer, or to its intended operating value. For instance, a manufacturer may specify the gain of an amplifier with 0 dBmV input.

2. If the device to be tested attenuates the signal, adjust the reference level until the TG signal level is near the top graticule line. If the device to be tested is an amplifier, set the reference level so the TG output is below the top graticule line by the amount of the amplifier gain plus about 10 dB. If the attenuation or gain is less than 20 dB, use the 5 dB/div vertical scale factor for increased resolution.
3. Set the analyzer as follows.
   a. Center Freq: Center of frequency range of interest.
   b. Freq Span/div: 0.1 x frequency range of interest.
   c. Resolution BW: AUTO or as desired.
   d. Trigger: FREE RUN (press [SWP/TRIG] / [0]).
   e. Display Mode: PEAK (press [DISP] / [4] if currently in MAX/MIN).
4. A line similar to the lower trace in Figure 35 appears. The line represents the input to the DUT as a function of frequency, including any response variations due to the cables, spectrum analyzer, or tracking generator. Save the result in register A.
5. Without altering any controls, connect the output of the tracking generator to the input of the DUT and connect the output of the DUT to the spectrum analyzer as shown in Figure 34. View the B register. A second trace representing the device output as a function of frequency appears. The difference between the A and B registers is the transfer function.
6. Press [DSPL] / [2] to activate the B, C MINUS A feature.

   Normally, zero difference is the middle of the screen, but if the trace rolls off the top of the screen, you can offset the zero point (it's not necessary, but may look more pleasing). Press [DSPL] / [3] on the spectrum analyzer to change the offset if desired.
7. The markers can be used to measure various aspects of the display. For example, in Figure 35 the markers have been positioned to measure the 3 dB bandwidth of the FM trap (in this case, the filter is a band-reject filter).

   Figure 35 shows the response of an inexpensive UHF/VHF/FM Amplifier with the FM trap enabled.

Using a Computer with the 2714/2715

The combination of a 2714/2715 and a computer creates an extremely versatile measurement and report generating combination. Refer to *Additional Equipment*, page 3, for computer and interface requirements. There are two aspects of connecting a computer to the 2714/2715: making the physical connections, and adjusting the communications parameters.

This section describes setting up the 2714/2715 and computer for RS-232 communications. If you wish to use a GPIB interface, refer to the ***2714/15 Spectrum Analyzer User Manual*** for complete instructions.

Connecting a Computer to the 2714/2715

Most personal computers have one or more serial communications (RS-232) ports available to interface to peripheral devices. Usually, either a 9-pin or 25-pin "D" connector is used. Null-modem cables are available to connect either type to the communications port (J104) on the back of the 2714/2715. Some commercial cables will not work properly because they do not contain all of the necessary connections. If you need to check the wiring of a cable or if you wish to make your own, refer to the wiring charts in Table IV for the proper connections.

Setting RS-232 communications parameters

2714/2715 Setup

The 2714/2715 and the computer's communications parameters must match for proper operation. The 2714/2715's RS-232 communications setup is accessed via the UTIL, SYSTEM CONFIGURATION, COMMUNICATION PORT CONFIG menus ([UTIL] / [4] / [0] / [2]).

Unless you have other specific needs, set the RS-232 parameters for the default values:

STATUS	ON LINE
BAUD RATE	9600
DATA BITS	8
PARITY	NONE
EOL	CR
FLOW CONTROL	HARD (RTS/CTS)
ECHO	OFF
VERBOSE	OFF

*NOTE: Set EOL to LF if you will be using the 2714/2715 with the **CSS 500 Software**. All other 2714/2715 settings are identical for the **2714/15 CATV System Test Software** and the **CSS 500 Software**.*

Computer Setup

Access to the communications parameters in the ***2714/15 CATV System Test Software*** is via the SETUP and INSTRUMENT COMM. SETUP menus. Select CREATE NEW INSTRUMENT COMM. SETUP, name the setup, select RS232 and enter a description, if desired. Next, select a COMM PORT # (selected from those available on the computer), a BAUD RATE (9600 if the example above is used), and a TIME-OUT TIME (30 seconds is the default).

For the ***CSS 500 Software***, the communication parameters can be adjusted from the CONFIGURE, CONNECTIONS menu.

Connecting a Printer or Plotter to the 2714/2715

A printer or plotter may be connected directly to the 2714/2715 to perform screen plots and (for RS-232 systems) data print outs. Refer to *Additional Equipment*, page 3, for printer or plotter compatibility requirements and for interface requirements. Be certain to use the correct cable. The RS-232 cable required for printing is different than the one for connecting the 2714/2715 to a computer. A cable of the type that is used to interconnect a computer and a serial printer is required. Refer to Appendix A of the ***2714/15 Spectrum Analyzer Programmer Manual*** for complete RS-232 cable information.

Setting the 2714/2715's RS-232 communications parameters

The communications parameters of the 2714/2715 and the printer must match for proper operation. The following list indicates typical requirements. However, printer requirements vary, so check the printer documentation to fine-tune the set-up. The 2714/2715's RS-232 communications setup is accessed via the UTIL, SYSTEM CONFIGURATION, COMMUNICATION PORT CONFIG menus ([UTIL] / [4] / [0] / [2]).

STATUS	ON LINE
BAUD RATE	Maximum supported by printer or 9600, whichever is less
DATA BITS	7
PARITY	Check the printer manual for requirements
EOL	CR, some printers may require CRLF
FLOW CONTROL	SOFT (XON/XOFF)
ECHO	OFF
VERBOSE	OFF

Table IV. Wiring Chart for 9-pin and 25-pin PC to 2714/2715 Cables.

2714/2715 Connector		9-Pin PC Connector		25-Pin PC Connector	
Pin	Use	Pin	Use	Pin	Use
1	DCD	7	RTS	4	RTS
2	RXD	3	TXD	2	TXD
3	TXD	2	RXD	3	RXD
4	DTR	6	DSR	6	DSR
5	GND	5	GND	7	GND
6	DSR	4	DTR	20	DTR
7	RTS	1, 8	CTS, DCD	5, 8	CTS, DCD
8	CTS	7	RTS	4	RTS
9	n.c	9	n.c.		n.c.

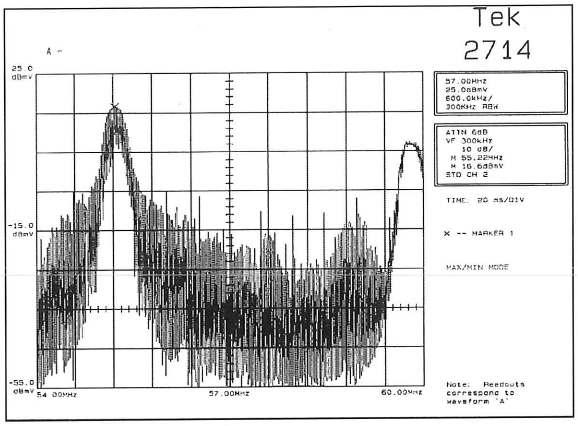


Figure 36. Typical screen plot.

Initiating screen plots and data print outs

Be certain that the 2714/2715's communications port is on line ([UTIL] / [4] / [0] / [1 or 2]) before attempting to plot or print directly from the 2714/2715.

Press [PLOT] to plot an image of the screen. Figure 36 is a typical plot. If you would like to add labels to the plot, refer to *Adding Titles and Labels* in chapter 7 of the ***2714/15 Spectrum Analyzer User Manual*** for detailed instructions.

You can also print the on screen readout data (if you are using the RS-232 communications option) by pressing [UTIL] / [9] / [0].

Creating Custom Channel Tables

Channel tables are used by the 2714/2715 to tune to different channels within the cable TV system. Tables customized for your system can be used to speed up carrier survey and frequency response measurements and to accommodate non-standard frequencies. You will probably want to create at least two custom tables; one for your channel plan and another for use with set-top converters. Custom channel tables can be created using either the **2714/15 CATV System Test Software** or the **CSS 500 Software**.

Equipment Required

Spectrum Analyzer: Tektronix 2714/2715.

Computer, Software, and Interface Cables: Refer to *Additional Equipment*, page 3.

Process

*The following process demonstrates how to use the **2714/15 CATV System Test Software** to create a channel table for use with set-top converters. With this table, you can correctly log the channel number being measured (as opposed to always logging the converter's output channel number).*

1. Start the **2714/15 Cable TV System Test Software.**
2. From the main menu, select CHANNEL TABLES, then select CREATE NEW TABLE.
3. New tables are most conveniently created by starting with a copy of an existing table. Select an appropriate table from the list presented.
4. In the CHANNEL TABLE COMMON ENTRIES menu:
   a. Enter a table name (the table name will be displayed on the 2714/2715's readout, you may want to keep it short.)
   b. Select NTSC, PAL, or SECAM.
   c. If you will be conducting tests on multiple systems, you may want to enter the system name. This is optional.
   d. If necessary, modify the channel width and aural frequency offsets
   e. If desired, enter a description of the channel table.
5. The selected existing channel table appears.
6. If channels are listed that you do not want in your table, mark them for deletion by highlighting them using the UP and DOWN arrows on the computer keyboard and pressing [D].
7. Use the UP/DOWN arrows to scroll to the first channel that you would like to modify and press the [ENTER] key. A menu of channel parameters will appear.
8. Use the TAB key to position the cursor to the CARRIER FREQUENCY position.
9. Enter the visual carrier frequency of the set-top converter's output channel (e.g., 61.25 for U.S. channel 3. The software automatically calculates the CHANNEL EDGE frequency and writes it in the next position.
10. If you would like to change any other parameters in the table, refer to the ***2714/15 Spectrum Analyzer Cable TV System Software Manual*** for detailed explanations.
11. Enter [CTRL-Q] to accept the changes.
12. Highlight the next channel to be modified and repeat steps 8 through 10. When finished with the modifications, press [CTRL-Q] to exit the edit menu.

To copy the table to the 2714/2715, interconnect the 2714/2715 and the computer as described in *Connecting a Computer to the 2714/2715*, page 32 and select SEND TABLE TO INSTRUMENT from the CHANNEL TABLES menu. A list of channel tables will appear. Select the newly created table and press [RETURN].

Your new table may now be selected by pressing [CATV/APPL] / [8] / [1] on the 2714/2715 or by accessing the SELECT CHAN TABLE menu in the ***2714/15 Cable TV System Test Software*** via the MEASUREMENT and SETUP menus.

Creating and Using User-defined Programs

A very powerful feature of the 2714/2715 is the ability to create and execute sequences of commands called User-Defined Programs (UDPs). Once UDPs are created, complex procedures can be simplified to a few keystrokes.

There are two methods of creating UDPs: using the front-panel keypad on the 2714/2715, or using the **2714/15 Cable TV System Test Software** that is provided with the 2714/2715. The USER DEF chapter of The Menus section of the ***2714/15 CATV Spectrum Analyzer User Manual*** has a good example of how to create a UDP using the keypad. This discussion describes how to use a computer to create a System Test Program which is

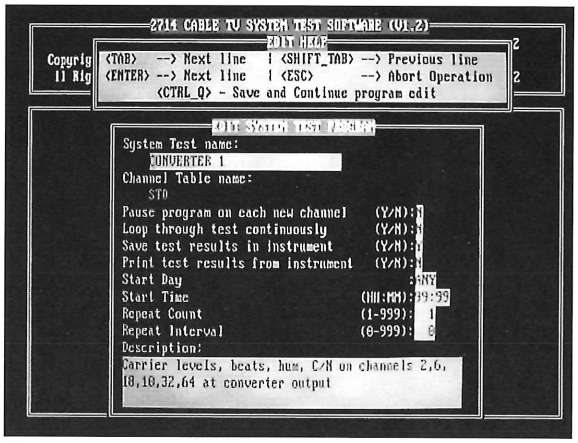


Figure 37. Page 1, creating a System Test Program.

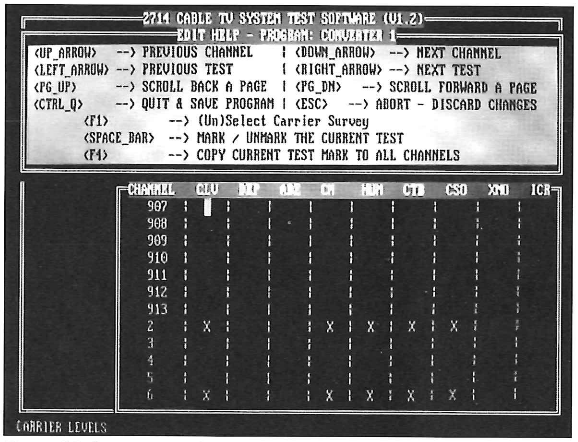


Figure 38. Page 2, creating a System Test Program.

then transferred to the 2714/2715 as a UDP.

Suppose you need to run a sequence of tests, at multiple test sites, that include measurements on a particular selection of channels. For instance, a proof-of-performance test sequence might include carrier levels, second- and third-order beats, hum, and carrier-to-noise ratio – all measured on several channels at the output of a basic RF (no AGC or AFC) set-top converter. By using a UDP to sequence through the tests, nothing will be forgotten, the UDP can command the 2714/2715 to store the results after each measurement (you don't need to worry about logging the measurements), and the consistent test procedure aids with communications between the test sites and the headend.

A computer can be used to create a System Test Program which, when transferred to the 2714/2715, becomes a UDP. The UDP should be tested to make certain it operates as expected. Once correct operation is verified, the 2714/2715 can be transported to test sites to perform the measurements. The UDP remains in the 2714/2715, even if power is removed, until you delete it from the 2714/2715's memory.

Procedure

This procedure demonstrates how to use a computer to create a System Test Program, then transfer the System Test Program to the 2714/2715 where it becomes a User-Defined Program. Refer to Figures 37 and 38 as you go through this example.

If you have not done so, create a channel table for use with the set-top converter. Refer to *Creating Custom Channel Tables*, page 33.

1. Start the **2714/15 Cable TV System Test Software.**
2. Select MEASUREMENTS, SYSTEM TEST PROGRAMS, CREATE NEW PROGRAM.
3. Enter a name for this program – CONVERTER 1 for example.
4. Select the Channel Table Name that you previously created for use with a set-top converter.
5. In this case, you will need to adjust the converter for each channel, so enter Y in the "Pause program on each new channel" position.
6. Enter N for "Loop through program continuously."
7. Enter Y for "Save results in instrument."
8. Enter N for "Print results from instrument."
9. The Start Day and Start Time are used to automatically begin the test sequence on a certain day and time. Selecting ANY and 99:99 for these two items will cause the 2714/2715 to begin the measurement sequence when selected from the UDP menu.
10. Enter 1 for "repeat count" to run the test a single time each time it is initiated.
11. Enter 0 for Repeat interval.
12. A description may be entered to remind you of the purpose of the test program. For instance, you might enter "carrier levels, beats, hum, C/N on channels 2, 6, 8, 10, 32, 64 at converter output." Press the return key at the end of each line of text.
13. A matrix appears with the channel table you selected. Move the cursor to the appropriate row and column in the matrix and press the space bar to select that particular test. For example, to perform each of the tests on channel two, select CLV (carrier levels), CN (carrier-to-noise ratio), HUM, BEA (beats), and XMO (crossmod) by positioning the cursor to each of the desired tests and pressing the space bar.
14. Continue marking the appropriate rows and columns until all the desired selections have been made. Enter CTRL-Q when finished.
15. Enter the amount of external attenuation/amplification (normally 0) and the power line frequency (e.g., 60 Hz in the U.S.) as requested.
16. Select the desired CTB measurement mode from auto with Pause for carrier off or Single sweep (the Auto is only used for measurements on "empty" channels or at frequencies outside the channel plan). If necessary, change the beat frequency look-up table (normally no changes are needed). When finished enter CTRL-Q to return to the previous menu.
17. Repeat step 16 for the CSO measurement.
18. If you want to check the program, you can select EDIT EXISTING PROGRAM and CONVERTER 1 to review and make changes to the program.
19. Make certain the 2714/2715 and computer are interconnected via an appropriate RS-232 or GPIB interface cable, then select SEND PROGRAM TO INSTRUMENT to transfer the program to the 2714/2715.

Proof-of-Performance Tests

Proof-of-performance tests may be substantially different than system analysis or maintenance tests. "Proofs" compare the system's performance against minimum standards. Consequently, performance need only be measured to those requirements, as opposed to determining exact magnitudes. For example, it is easier and faster to measure CTB to –60 dBc than it is to measure it to –70 dBc. If the proof-of-performance requirement is –51 dBc, you may not want to take the extra time to search for beats that are beyond –60 dBc.

If proof tests interrupt customer service, it's important to complete the tests as quickly as possible. Several things can be done to reduce the amount of time spent performing proofs:

- Check and cross-check the calibration of all instruments before beginning the tests.
- Create custom channel tables for measurements at the output of set-top converters. With such tables, you can correctly log the channel number with the measurement results (see *Creating Custom Channel Tables*, page 33 for an example of creating a table for use with a set-top converter).
- Use user-defined programs (refer to *Creating and Using User-defined Programs*, page 33) – they can save a lot of time by automatically selecting channels, performing tests, and logging the data. If you will be performing measurements at taps and at the output of set-top converters, create two UDPs – one for the taps and one for the converter. When running tests at the output of a converter, it is easy to forget to change the converter channel setting as the tests proceed. UDPs can help you avoid such mistakes by pausing and prompting you to change the channel when required.
- Develop standard procedures for the test sequences. For example, to minimize the amount of time spent changing connections between the tap, converter, and analyzer in the field, you may want to complete all of the tests required at the tap first, then do all of the converter tests. Standardized procedures also speed up communications between the test sites and the head end.
- Use a preselector filter only when required. Measurements to typical proof-of-performance standards can usually be done without a preselector if the input levels are within the limits described in *Distortion from overdriving the analyzer*, page 10.
- Consider using interactive rather than fully automatic test methods. Automatic methods are the easiest to use and yield the most consistent results. However, they usually take longer than interactive methods. The interactive or single sweep methods for measuring CSO and CTB can save substantial time over the fully automatic methods.
- Be familiar with the test instrument requirements for automated measurements. For example, when running C/N tests using the 2714/2715's "Auto (Pause for Carrier Off)" mode, the 2714/2715 will prompt you to TURN THE CARRIER BACK ON, "W" TO CONTINUE .... In that particular case, the 2714/2715 has completed its measurement routine and is simply reminding you to replace the carrier. The person at the test site does not need to wait for confirmation that the carrier has been replaced before proceeding.
- Be alert during the tests. If you discover problems while the tests are in process, you may be able to correct the problems before spending time at other test points. Pay attention to the data as the 2714/2715 is performing measurements and logging the results. If you find unexpected results, log the data – either manually or in the 2714/2715. Spectral waveforms can be captured using the 2714/2715's [UTIL] / [STORED SETTINGS/DISPLAYS] menu or by using a camera or printer.
- Use a portable computer at the test site. Although it takes specific actions to erase the data from the 2714/2715's memory, its good to download the data periodically as extra protection against accidental erasure. The computer can also be used to manually log additional data.

Generating Reports

Once a series of measurements have been performed and the data logged, you will probably want to generate reports so the data can be easily reviewed. If you use the data logging capabilities of the 2714/2715 in conjunction with either the **2714/15 CATV System Test Software** or the **CSS 500 Software**, it's a simple matter to produce professional quality reports.

Consider the following points when generating reports:

- When collecting data, be certain the name of the site or the name of the operator is different for each test site. The **2714/15 CATV System Test Software** sorts data by test site and operator.
- The data can be exported from the **2714/15 CATV System Test Software** as standard database format (.dbf) files. The files can then be used with most popular database and spreadsheet programs to provide increased flexibility in structuring the report.
- In most cases, it's best to arrange the data by test site rather than by test type.
- The chief technician or engineer will probably want all the data to aid in maintenance and troubleshooting. Others may only need summary information relative to proof-of-performance criteria.

Chanl Numbr	Start Date	Start Time	End Date	End Time	Visual Ampl (dBmV)	Aural Ampl (dBc)
2	02/08/94	16:58:04	02/08/94	16:58:04	15.5	-15.6
3	02/08/94	16:02:35	02/08/94	16:02:35	15.7	-14.0
3	02/08/94	16:58:04	02/08/94	16:58:04	15.4	-14.3
4	02/08/94	16:58:04	02/08/94	16:58:04	15.8	-13.8
5	02/08/94	16:58:04	02/08/94	16:58:04	17.1	-15.5
6	02/08/94	16:58:04	02/08/94	16:58:04	16.2	-14.7
7	02/08/94	16:58:04	02/08/94	16:58:04	17.2	-13.9
8	02/08/94	16:58:04	02/08/94	16:58:04	17.4	-14.9
9	02/08/94	16:05:47	02/08/94	16:05:47	17.6	-13.6
9	02/08/94	16:58:04	02/08/94	16:58:04	17.9	-14.6
10	02/08/94	16:58:04	02/08/94	16:58:04	16.2	-13.7
11	02/08/94	16:58:04	02/08/94	16:58:04	16.1	-16.1
12	02/08/94	16:08:51	02/08/94	16:08:51	16.0	-15.2
12	02/08/94	16:58:04	02/08/94	16:58:04	16.4	-16.5
13	02/08/94	16:58:04	02/08/94	16:58:04	16.0	-15.4
14	02/08/94	16:58:04	02/08/94	16:58:04	15.1	-15.1
15	02/08/94	16:58:04	02/08/94	16:58:04	17.2	-15.1
16	02/08/94	16:58:04	02/08/94	16:58:04	17.5	-13.6
17	02/08/94	16:58:04	02/08/94	16:58:04	18.7	-15.0
18	02/08/94	16:58:04	02/08/94	16:58:04	20.6	-15.6
19	02/08/94	16:04:40	02/08/94	16:04:40	17.5	-14.0
19	02/08/94	16:58:04	02/08/94	16:58:04	17.8	-14.2
20	02/08/94	16:58:04	02/08/94	16:58:04	17.9	-14.2
21	02/08/94	16:58:04	02/08/94	16:58:04	17.2	-14.0
22	02/08/94	16:58:04	02/08/94	16:58:04	17.6	-14.9
23	02/08/94	16:58:04	02/08/94	16:58:04	17.0	-15.5
24	02/08/94	16:58:04	02/08/94	16:58:04	16.4	-15.1
25	02/08/94	16:58:04	02/08/94	16:58:04	17.3	-15.2
26	02/08/94	16:10:19	02/08/94	16:10:19	16.5	-15.8
26	02/08/94	16:58:04	02/08/94	16:58:04	16.5	-15.7
27	02/08/94	16:58:04	02/08/94	16:58:04	16.6	-15.1
28	02/08/94	16:58:04	02/08/94	16:58:04	16.8	-15.1
29	02/08/94	16:58:04	02/08/94	16:58:04	15.2	-13.4
30	02/08/94	16:58:04	02/08/94	16:58:04	16.7	-14.1
31	02/08/94	16:58:04	02/08/94	16:58:04	16.8	-14.9
32	02/08/94	16:11:27	02/08/94	16:11:27	16.8	-14.8
32	02/08/94	16:58:04	02/08/94	16:58:04	16.7	-14.8
33	02/08/94	16:58:04	02/08/94	16:58:04	17.8	-13.5

Figure 39. 2714/15 CATV System Test Software report generator tabular output format.

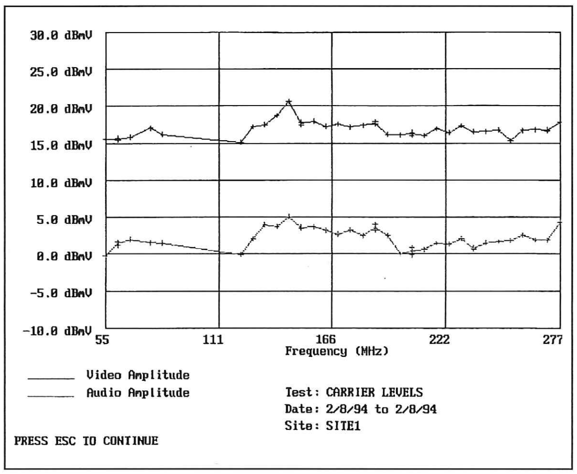


Figure 40. 2714/15 CATV System Test Software report generator graphical output format.

- Graphical presentation can be a very powerful method for displaying data and trends. The **2714/15 CATV System Test Software** report generator provides both tabular and graphical output formats. Figures 39 and 40 show examples of each. The **CSS 500 Software** allows you to export the data for further manipulation by other Windows-compatible programs.

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