

R-110 RECEIVER MANUAL ADDENDUM: WIDEBAND OPTION

1. INTRODUCTION

The wideband option adds three extra bandwidths to the standard selection of the R-110B receiver. To do so it adds a new signal path in a separate cardcage plug-in module and replaces the video module as well.

There are currently two sets of wide bandwidths available: 20 - 40 - 100 MHz, and 40 - 100 - 200 MHz. One or the other may be chosen, but not both.

The wideband option is available for both the R-110 and the R-110B receivers. This document is an addendum to their technical manuals. Excerpts may be added to the user's manuals as applicable.

2. INSTALLATION

Physically, the wideband option consists of a new plug-in module for the receiver's cardcage, plus a replacement for the video module, plus modifications to the cardcage coax cable harness. While installation is not especially complicated, it is normally done at the factory during the original construction of the receiver. Retrofitting of the option in the field is possible, but it is recommended that this only be done by authorized factory field service personnel. In addition to installing the modules, configuration storage in the firmware must be modified, using a controlled-access procedure.

3. USAGE IN MANUAL MODE

The three new bandwidths are added to the selections accessed via the bandwidth up/down pushbuttons on the front panel of the receiver. When the widest standard bandwidth (15 MHz in most receiver configurations) is selected, pressing the "bandwidth up" button will select the first of the wideband filters, and so on. Pressing the "bandwidth down" button will select narrower bandwidths until the standard bandwidths are again selected. The buttons have an "auto-increment" mode, in which a new selection is performed every half second or so if a button is held down.

The wideband option uses a signal path that is separate from most of the receiver circuitry. The signal is taken from the wideband (1450 MHz) IF, and amplified and filtered. The signal returns to the normal signal path at the video detector, which has been upgraded as part of the wideband option to afford a wider bandwidth output. The separate wideband signal path places restrictions on the use of the wideband option, due to the fact that the 21.4 MHz IF is bypassed. This means that:

- Only the first conversion is available for tuning. This means that tuning is in increments of 5 MHz.
- The Band 1 and Band 2 signal paths are unavailable. This means that the minimum legal tuned frequency in wideband mode is 20 MHz.

The receiver protects against illegal conditions by refusing to tune below 20 MHz when wideband is selected, and refusing to select a wide bandwidth when tuned below 20 MHz. When in wideband mode only the tuned frequency of the first conversion is displayed, i.e. a multiple of 5 MHz.

The wideband signal path provides its own, separate programmable gain circuits. Although there are only two of these, as opposed to four in the normal signal path, the manual adjustment range of 50 dB is maintained, and is still set via the front panel gain control knob and display.

AGC is also provided for. Usage is the same as for the narrower bandwidths. The function is selected via the appropriate keypad alternate function.

Front end overload and underload detection circuits are provided, and drive the same cardcage status lines as the detectors in the normal signal path. They are used when auto-attenuation is enabled. With auto-attenuation disabled, a front end overload indication when wideband is enabled may be alleviated by increasing the input attenuation, using the appropriate front panel pushbutton.

A new video circuit is provided with the wideband option that is used for both wide and normal bandwidths. This video circuit accepts inputs from the wideband module, the 21.4 MHz IF module, and the DCIF. While the wideband signal path contains a separate detector, the video module provides an output buffer that is capable of delivering the widest available (200 MHz IF) bandwidth into 50 Ohms. In doing so a compromise was settled upon, in that the maximum video output is 3 Volts, as opposed to the 4 Volts available from the standard video module.

Log detection and BFO are unavailable in wideband. If one of these functions is selected at the same time that a wide bandwidth is selected, then the indicator associated with that function will blink. The Z axis output is available. The pulse stretch and slideback options, if present, are operational in wideband mode as well.

In summary, significant effort has been made to make manual control and monitoring of the wideband signal path as similar as possible to that of the normal signal path. The main differences, as mentioned above, are the restricted tuning range and resolution, the reduced maximum video output amplitude, and the lack of some video functions.

4. USAGE WITH IEEE-488 AND PROPRIETARY EXTERNAL INTERFACES

The IEEE-488 interface allows an external host computer to command and monitor the receiver's operation. The proprietary external interface allows receiver cardcage status plus the output of the DVM option to be transmitted to the host computer more quickly than is possible over the IEEE-488 interface. It nevertheless must operate in conjunction with the IEEE-488 interface since it is unidirectional (transmit only).

The IEEE-488 interface in the R-110 receiver has been designed to be compliant with the requirements of IEEE-488.2, which describes communications protocol, defines a number of "standard" commands and queries, and requires that many features that were options in IEEE-488.1 be present.

The standard and proprietary commands and queries supported by the basic R-110 receiver, and the R-110B, are given in their respective technical manuals. Those pertaining to the wideband option will be reviewed here.

The normal bandwidth commands and queries are extended when the wideband option is present. Wide bandwidths may be commanded in the same manner as normal bandwidths, e.g. <BW 100E6>. If the standard query is issued when a wide bandwidth is selected, the response will be in the standard format, e.g. <100E6>. The wide bandwidths are added to the list returned in response to the <BW? ALL> query.

The same restrictions apply here as in manual tuning: the tuning range is limited to 20 MHz on the low side, and tuning is limited to multiples of 5 MHz. A tuning command containing a frequency that is not a multiple of 5 MHz will be rounded to the nearest legal value. A tuning command containing a frequency below 20 MHz will be rejected.

The proprietary interface outputs buffered overload, underload, and lock status signals, along with DVM data if that option is present. The front end overload and underload signals are taken from the wideband signal path when a wide bandwidth is selected, and from the 21.4 MHz IF otherwise.

5. THEORY OF OPERATION

The hardware that is unique to the wideband option consists of the wideband filter module and the wideband video module. The operation of those two modules will be described here. Descriptions of the rest of the signal path and the supporting hardware, such as synthesizers, the controller, and the power supply, are described in the R-110 and R-110B technical manuals.

The signal feeding the wideband filter module is taken from the microwave module at the output of the first mixer, using a solid state switch. Only one stage of amplification has been provided in front of the mixer, so the signal level at this point is typically very low. The result of the first conversion is an IF frequency of 1450 MHz. No filtering is performed on the signal from the mixer output before passing it to the wideband filter module.

5.1. Wideband Filter Module Operation

The input signal from the microwave module is first given three stages of amplification, increasing the signal level by about 23 dB. Overload / underload conditions are sensed here, using a coupling consisting of a PCB trace laying parallel to the trace containing the main signal. Overload and underload conditioning will be described later. The main signal is then distributed to one of three IF filters, using solid state switches. Unlike the 21.4 MHz IF filters, these are not daisy-chained. Instead, only one filter is selected at a time. Depending on which option has been ordered, these filters can be 20, 40, and 100 MHz, or 40, 100, and 200 MHz. The outputs of the two wider filters are padded to reduce their amplitude, in accordance with the gain scheme that maintains noise amplitude constant over all bandwidths. This means that the amplitude of a given filter output must be reduced by the square root of its ratio to the bandwidth of the next narrower filter. These filters not only set the IF bandwidth, they also act to isolate the 1450 MHz IF signal from the variety of signals produced by the mixer in the microwave module.

Just as the signal was sent to a particular filter using solid state switches, the output of the selected filter is obtained by a second set of switches. The signal from the selected filter is passed through a voltage controlled attenuator, and from there is delivered to a set of four more gain stages. The control for the variable attenuator is supplied by a D/A converter, described later. The attenuator has a range of about 25 dB.

The output of the second set of gain stages is passed through a filter with a bandwidth of 200 MHz, to reduce out-of-band noise. The signal is then passed through a second variable attenuator, also controlled by a D/A converter. The output of the attenuator feeds four more gain stages through a coupling that again consists of a trace laying parallel to the signal trace. The tap signal from the coupling is sent to the IF output when wideband is enabled, using a solid state switch to select between it and the 21.4 MHz IF output. The signal level delivered to the IF output is a function of input signal level the input attenuation setting, selected bandwidth, and the IF gain setting. The maximum gain is about 15 dB.

The output of the set of four gain stages is padded lightly to set the signal level to approximately +6 dBm with -52 dBm at the module input. This signal feeds the wideband detector, which consists of two more gain stages driving a pair of diodes, followed by a buffer amplifier to ensure sufficiently high impedance at the diodes. The gain of this amplifier is less than unity because it is limited to about 1 Volt output at the necessary bandwidth, while the diodes need to be driven as strongly as possible in order to maximize the instantaneous dynamic range. The output of the buffer amplifier is sent to the wideband video module.

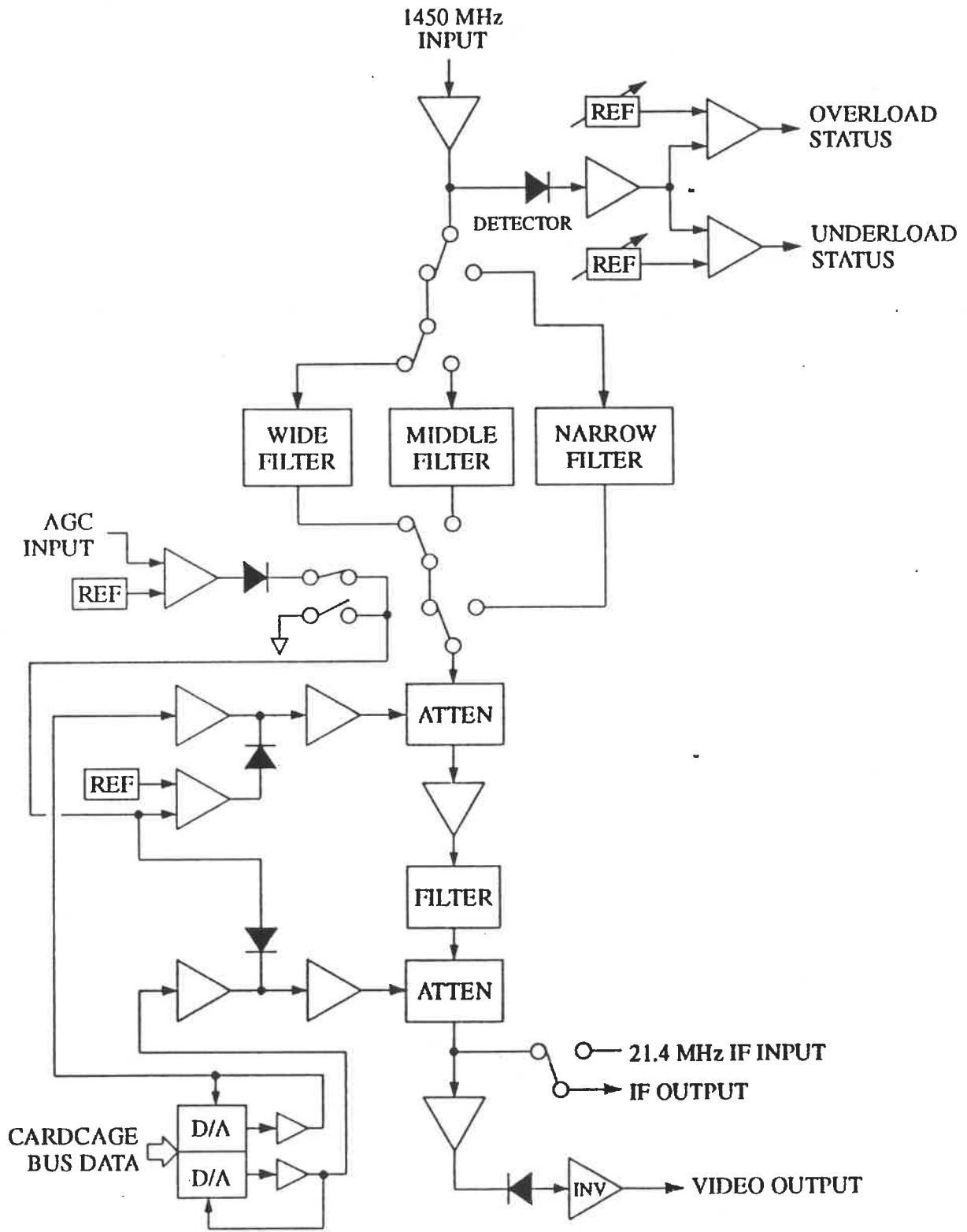


Figure 1: Wideband Filter Module Block Diagram

The overload / underload pickoff is peak detected with a diode and a low-pass filter, and is then buffered by an opamp. The amplifier output is fed to individual comparators for overload and underload, the references for which are set by trimpots, based on a reference that provides temperature correction by means of a diode and an opamp buffer. The comparator outputs are gated with an enable signal, and finally control individual drivers that are set up to provide a high-impedance output to the cardcage status lines (which are supplied with pullup resistors) when status is "good", and to provide a low-driven output when status is "bad". Overload status is applied to cardcage bus STAT1, and underload status is applied to cardcage bus STAT3, both of which are shared with similar status signals supplied by the 21.4 MHz IF. The 21.4 MHz IF will not be enabled when the wideband option is in use, and vice versa.

Intelligent gain control is provided by a double 12 bit D/A converter IC, which is connected to the cardcage control bus. Since this is an 8 bit bus, four addresses are used to load data into holding registers in the IC, plus a fifth address to apply all of it to the outputs simultaneously. The D/A converter IC outputs are current mode, so a pair of opamps are used to convert to voltage mode, as required by the attenuators. Note that the attenuators are not perfectly linear, so that the firmware maintains individual and unique calibration tables for each of them. One of the procedures required when initially configuring a receiver or when replacing the wideband filter module is to connect the receiver to an IEEE-488 interface-based system and run an automated calibration program on the host computer. This updates the calibration tables for the attenuators and provides gain control accuracy that is nominally within 1 dB of the front panel display for "regular" signals. A +10V precision reference is inverted by an opamp to provide a stable reference voltage for the D/A converters.

Automatic gain control (AGC) is provided by a circuit that takes its input from the video signal, buffers and peak-detects it, and combines it into the signals from the D/A converter outputs. This is somewhat complicated, involving several stages of selectable gain and offset tweaking, depending upon whether or not AGC is enabled. Diodes couple the AGC voltage into the gain control signals, so that the AGC is only effective when the attenuation required is greater than that set by the D/A converters. When operating with AGC enabled, the front panel gain control is normally left set to maximum, to give the AGC circuit its maximum control range. The AGC signal to the first attenuator is delayed from that to the second, to avoid degrading the noise figure.

As described above, filter selection is performed by solid state switches, with only one filter selected at a time. Control of these switches is provided by a latch connected to the cardcage control bus. Latched control bits drive comparators, which output the required (non-TTL) control voltages for the switches. The same latch also supplies control bits for wideband and overall module enable.

5.2. Wideband Video Module Operation

The wideband video module performs the same functions as the standard video module, with increased bandwidth for those functions that involve the wideband signal path. The log detector, 21.4 MHz linear detector, and BFO are essentially duplicates of the circuitry on the standard module. The video and Z axis amplifiers are different. Additional connectors are provided for wideband inputs and outputs.

There are four signal inputs to the wideband video module: one from the wideband filter module, two from the 21.4 MHz IF, and one from the DCIF module. The 21.4 MHz IF is tapped in two different places, once for AM and BFO detection and once for log detection, so that the gain distribution will work out correctly in each case. The requirements for each are different because the log detector has over 70 dB of dynamic range while the linear detector has only a little more than 30 dB. The BFO uses the same input as the AM detector because here the available dynamic range is not a consideration.

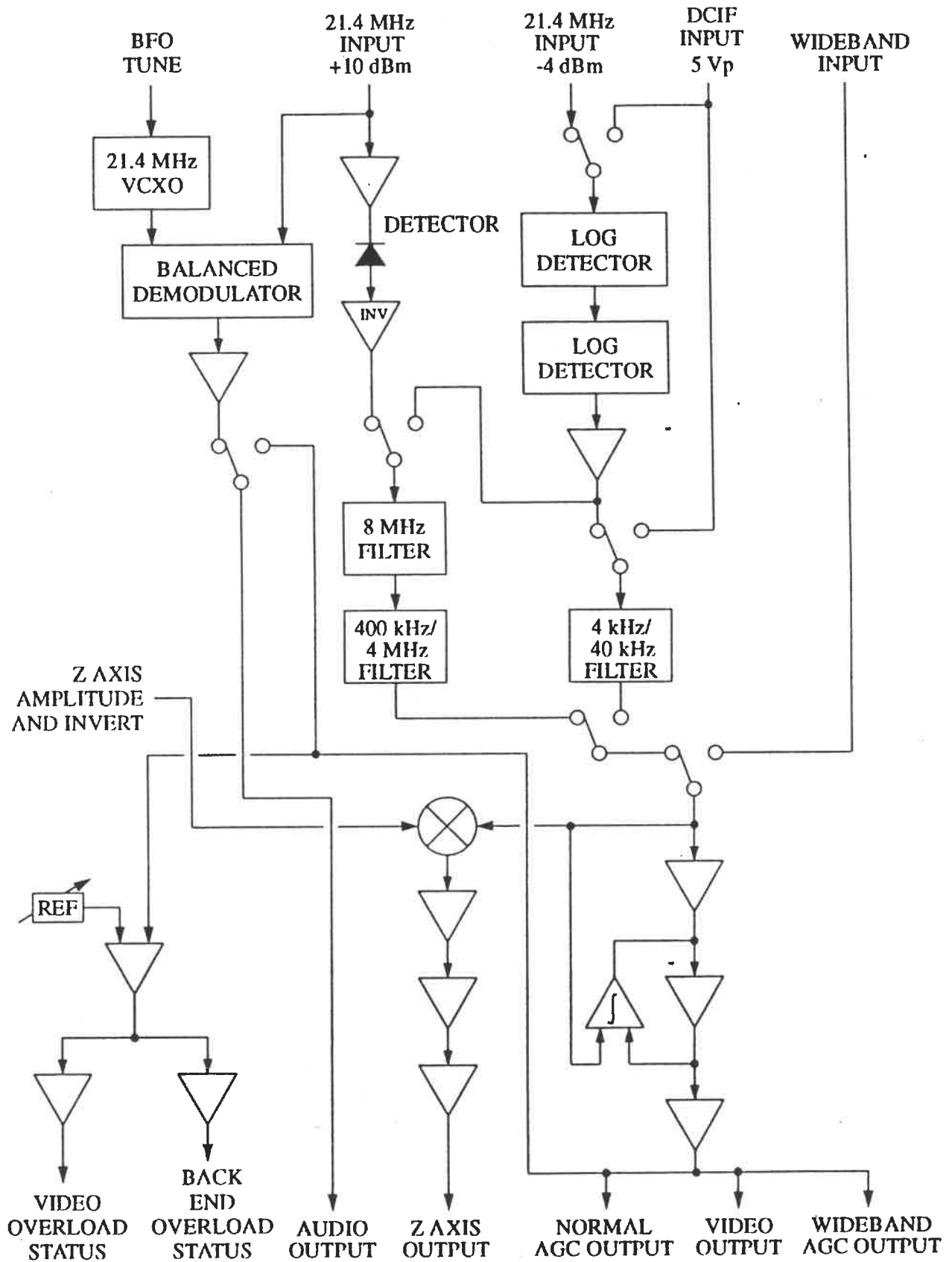


Figure 1: Wideband Video Module Block Diagram

The 21.4 MHz IF input destined for wideband AM detection arrives at a maximum level of +10 dBm and is routed to the detector circuit through a pad and an AC coupling. The pad is selected to place the full-scale value of the input at the detector overload threshold. While the detector itself is basically a diode, dynamic range is maximized by placing the diode behind a tuned amplifier which steps the signal level up to a point where the effect of the turn-on characteristic of the diode is minimized. The tuned amplifier is based on a transistor and a low-Q tuned network. The diode is followed by an opamp, to maintain the impedance at the detector diode and to provide thermal compensation. The gain of the opamp is trimmed during test to establish end-to-end gain. A second transistor acts as a switch to disable the detector when it is not in use. The detector is followed by a carrier-removal filter that consists of a series of L-C low-pass filters, totalling 8 poles with a corner at 8 MHz. This filter is also used by the log detector.

End-to-end gain of the 21.4 MHz AM detector is 10 dB, so that a +10 dBm input will produce a full-scale output of 0 - 3 Volts peak. Dynamic range at full scale output is at least 30 dB.

The output of the filter provides the input for a second, selectable video noise filter. This filter is a one-pole low-pass R-C configuration, in which any combination of two capacitors may be selected by the firmware. In actual usage only one (or none) of these is selected at a time, however. The corners are at 400 kHz and 4 MHz. Selection is based on the selected 21.4 MHz IF bandwidth. Table 1 shows the correlation between IF bandwidth and the selected video filter, including the filters in the DCIF video signal path (described below).

The input for the log detector can come from one of two places, either from the other 21.4 MHz IF input (the one that doesn't supply the AM detector) or from the DCIF. Selection is made by a relay under the control of the firmware. A termination resistor is switched onto the 21.4 MHz IF input when it is not in use. Furthermore, the input from the DCIF may be switched around the log detector, bypassing it, when a linear characteristic is desired. When routed through the log detector, the DCIF signal, even though it arrives already detected and carrier-filtered, is given the same log-compression gain characteristic as the detected signal from the 21.4 MHz IF.

The log detector consists of a pair of log amplifier/detectors, which output in current mode, followed by a linear amplifier, which provides a voltage output. The IF signal from the input is fed in series from the first log amp to the second, while their detected video outputs are summed at the voltage amplifier. An input offset adjustment is provided to null the output of the log amps. A resistor is selected during module test to set the full scale output level at the output of the voltage amplifier. The voltage amplifier output is sent along two paths. One path is to the same 8-pole carrier removal filter used by the 21.4 MHz AM detector, selected by a relay under firmware control. The other path is through another relay that selects between this and the raw DCIF input, again under firmware control. The signal that is selected by the relay is passed through another video filter, which provides a fixed corner at 40 kHz and a selectable corner at 4 kHz. The outputs of this and the other video filter are now recombined into a single path, using another relay, again under firmware control. This signal is padded and delivered to yet another relay, that selects between it and the input from the wideband filter module. This signal, then, is delivered to the video and Z axis amplifiers.

Gain of the log detector is such that at full scale, every 10 dB coming in will produce 375 mV at the video output. Dynamic range at full scale is in excess of 70 dB. The front end of the log detector has a bandwidth of 120 MHz, much greater than the 8 MHz maximum bandwidth of the carrier removal and video filters that follow.

The BFO detector consists of a 21.4 MHz Clapp oscillator based on a crystal and driven by a transistor, fine-tuned by a varactor diode. An on/off switch is provided by a FET switch, which disables the oscillator by removing power from it. Tuning frequency control is provided by a potentiometer on the receiver front panel. A constant current source based on a FET drives the front panel control, developing a voltage which varies linearly with its setting while requiring only one "hot" line and a return running off of the module. The voltage derived from the control setting is used to tune the varactor. A trimmer on the module is used to set the center frequency, while a variable inductor is used to set the adjustment range.

The oscillator drives a mixer, the other input of which is the same tap of the 21.4 MHz IF used by the AM detector. The difference output generated by the mixer is offset from baseband by an amount determined by the front panel control setting, within a range of +/- 4 kHz. The output of the mixer is filtered to remove unmixed and summed products, and is amplified by an opamp. The output of this amplifier is sent to the audio output when enabled, routed by a FET switch under firmware control. For a full-scale input of +10 dBm, the output will be 1.6 Volts peak-to-peak. Dynamic range is not a consideration because the BFO is used for detection of CW signals.

Table 1: Video Noise Filter Selection

Bandwidth Range	Filter Corner
200 Hz - 2 kHz	4 kHz
2.5 kHz - 20 kHz	40 kHz
50 kHz - 200 kHz	400 kHz
300 kHz - 2 MHz	4 MHz
4 MHz - 15 MHz	None

The video amplifier is upgraded in the wideband video module. It consists of three stages, plus a DC servo amplifier. The first two stages provide gain, with the first stage providing most of it because the second, while it can provide high output levels, is limited in its maximum gain capability. The final stage is a unity gain buffer that drives the video output on the front panel of the receiver through a resistor that sets the source impedance to 50 Ohms. It also feeds the 21.4 MHz IF and wideband filter module AGC inputs, the audio output (through a FET switch that selects between the video output and the BFO output), and the video overload detector. The maximum available output is 3 Volts peak, and the maximum bandwidth is about 100 MHz. The DC servo amplifier is looped around the second stage amplifier, acting as an integrator that compares the input to the output and generates a correction voltage to yield zero DC output. Trimpots are provided to pre-correct the offset for both the wideband and 21.4 MHz IF / DCIF inputs. The appropriate trimpot voltage is selected by means of FET switches.

The Z axis amplifier is also upgraded in the wideband video module. It consists of an analog multiplier followed by a current-to-voltage converter, followed by an amplifier stage and an output buffer stage. The analog multiplier is used for gain control and signal inversion. A constant current source based on a FET drives a potentiometer on the front panel of the receiver. The pot setting therefore establishes the voltage drop across it, requiring only a hot line and a return, which can be configured as a coax cable to minimize noise pickup. The voltage is buffered by an opamp and selectively inverted by a FET switch in conjunction with another amplifier, under firmware control. The FET switch sets the gain of the amplifier to +/-1 by supplying signal to both differential inputs (gain = +1) or grounding the positive input (gain = -1). The output of this amplifier provides the control voltage for a four-quadrant multiplier that processes the video signal accordingly. The output of the multiplier is in differential current mode, and is converted to single-ended voltage mode by an opamp. The next stage adds gain and generates a large output signal range. The final stage is a unity-gain buffer followed by a resistor that sets the source impedance to 50 Ohms. The output capability of this circuit is again 3 Volts peak at 100 MHz bandwidth.

The overload detector consists of a high-speed comparator that measures the video output against a reference set by a trimpot. The output is inverted by a transistor that provides a faster slew rate and also extends narrow pulses. The transistor output controls a pair of drivers that drive two of the cardcage bus status lines. The drivers are configured to have high-impedance outputs when status is "good" (the cardcage bus status lines are supplied with pullup resistors to make this state float high), and low-driven outputs when status is "bad". This allows multiple drivers to be connected to a single status line, with any one of them able to report "bad" status. The two cardcage bus status lines used here are STAT2 (back end overload) and STAT7 (video module overload). Currently each of these two lines is used only by the video module.

The cardcage bus control interface consists of address decoding and a pair of latches. The latches provide control for video filter selection, DCIF / 21.4 MHz IF / wideband input selection, log detector selection, BFO selection, and Z axis selection and inversion control.

6. MAINTENANCE AND FIELD SERVICE ADJUSTMENTS

Preventative maintenance for the wideband option hardware is the same as for the rest of the receiver. Hardware calibration may be required periodically, or when a module is replaced. Field service adjustments are described in the following paragraphs.

6.1. Wideband Filter Module Field Service Adjustments

The wideband filter module provides just two field service adjustments, these being the overload and underload thresholds. In order to have access to the adjustment components, the module must be raised above the cardcage using a cardcage bus extender and coax cable extensions.

6.1.1. Overload Threshold Adjustment

Procedure:

1. Remove the coax cable from module connector J1 and connect a microwave signal generator. Apply a CW signal at 1450 MHz and -3 dBm.
2. Select 40 MHz bandwidth.
- 3.) Adjust trimpot R39 so that the front overload indicator on the front panel of the receiver just comes on.

6.1.2. Underload Threshold Adjustment

Procedure:

1. Use the same signal generator hookup as the foregoing procedure. Reduce the amplitude to -16 dBm.
2. Monitor connector P1 (the cardcage bus connector) pin B20 with a voltmeter.
3. Adjust trimpot R41 so that the voltage on pin B20 just switches from near +5V to near 0V.

6.2. Wideband Video Module Field Service Adjustments

The wideband video module provides many of the same adjustments as the standard video module, since it uses many of the same circuits. In order to have access to the adjustment components, the module must be raised above the cardcage using a cardcage bus extender and coax cable extensions.

6.2.1. Log Detector Null Adjustment

Procedure:

1. With no signal applied and the coax cable removed from J2, monitor U3 pin 6 with a voltmeter.
2. Select log detection on the front panel of the receiver. Select a bandwidth that is not wideband.
3. Adjust trimpot R22 for minimum voltage at U3 pin 6.
4. Disable log detection. Reconnect the cable to J2.

6.2.2. BFO Center Frequency Adjustment

Procedure:

1. Remove the coax cable from module connector J1 and connect a signal generator. Set the signal generator to CW at 21.4 MHz, -10 dBm.
2. Select BFO on the front panel of the receiver, with a compatible bandwidth (e.g. 1 MHz).
3. Monitor U28 Pin 6 with an oscilloscope.
4. Adjust trimpot R106 so that the beat frequency indicated on the oscilloscope with the BFO control on the receiver's front panel fully counterclockwise is the same as the beat frequency indicated with the control fully clockwise. Make sure that there is a null in between.
5. Restore the coax cable connection to J1.

6.2.3. Video Amplifier Offset Adjustments

Procedure:

1. With no signal applied, set the receiver gain control to minimum.
2. Select a DCIF bandwidth (e.g. 20 kHz) on the front panel of the receiver.
3. Monitor J8 with a voltmeter.
4. Adjust trimpot R65 for minimum output **WITHOUT EVER LETTING THE VOLTAGE AT J8 GO NEGATIVE.**
5. Select a wide bandwidth (e.g. 100 MHz) on the front panel of the receiver.
6. Adjust trimpot R64 for minimum output at J8 **WITHOUT EVER LETTING THE VOLTAGE AT J8 GO NEGATIVE.**

6.2.4. Z Axis Amplifier Offset Adjustment

Procedure:

1. With no signal applied, set the receiver gain to minimum.
2. Select a wide bandwidth (e.g. 100 MHz) and enable the Z axis function, no inversion, on the front panel of the receiver.
3. Monitor J10 with a voltmeter.
4. Adjust trimpot R154 for minimum output **WITHOUT EVER LETTING THE VOLTAGE AT J10 GO NEGATIVE.**

6.2.5. Z Axis Amplifier Multiplier Null Adjustment

This adjustment is occasionally necessary, but requires a fairly complicated test setup. If this adjustment must be performed, contact the factory for a suggested procedure with available test equipment.

6.2.6. Overload Threshold Adjustment

Procedure:

1. Remove the coax cable from module connector J3 and apply 5.25 VDC.
2. Select a bandwidth of 20 kHz to select J3 as the module input.
3. Adjust trimpot R96 so that the back overload indicator on the front panel of the receiver just comes on.

7. CONTROL INTERFACE

The control interface for the wideband module consists of six contiguous write-only ports mapped into the microcontroller's external read/write memory space. The first four addresses are for the gain control DACs, the fifth is a strobe to load the DAC, and the sixth loads a control latch.

Address 60H = DAC A low byte:

Bits 0 - 7 = DAC A bits 0 - 7

Address 61H = DAC A high nibble:

Bits 0 - 3 = DAC A bits 8 - 11

Bits 4 - 7 = spare

Address 62H = DAC B low byte:

Bits 0 - 7 = DAC B bits 0 - 7

Address 63H = DAC B high nibble:

Bits 0 - 3 = DAC B bits 8 - 11

Bits 4 - 7 = spare

Address 64H = DAC load strobe

Bits 0 - 7 = unused

Address 65H = control latch:

Bit 0 = BW #1 enable (the narrowest)

Bit 1 = BW #2 enable (the middle one)

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