VLBA TECHNICAL REPORT NO. 9

# The NRAO MKII Correlator

## A Maintenance Manual

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# The MKII Correlator System

## Introduction

The purpose of the MKIIC equipment is to record base band signals at a radio site in such a way that the data can later be decoded and correlated with data taken at other radio sites. The base band signal is passed from a base band converter (BBC) to a MKIIC formatter which samples the analog signal and converts it to a serial pulse train of 1's and 0's. The formatter adds identification, synchronizing, and error checking information to the sampled data and passes the signal to a VHS VCR. The radio data are recorded on the tape recorder video track; time code is recorded on the audio track. If the station has a Data Quality Analyzer (DQA), the data tape can be played back to the DQA to check for correct formatting. Some stations have a "MKIIC Controller" which permits remote control of the VCRs and data quality analysis. The VHS tapes from the various radio sites are shipped to a correlator.

Several MKIIC correlators exist, including the 16 station "Block II" correlator at the California Institute of Technology in Pasadena, a 3 station correlator at Max Planck Institute in Bonn, and the correlator at NRAO in Socorro. The NRAO MKIIC correlator can decode and correlate up to 3 stations simultaneously. The correlator uses time delay circuits to correct for path length differences between stations, and phase rotation to correct for the rotation of the earth. "Exclusive-or" gates then take the product of the data between two stations by finding the correlations of 1's and 0's between two data streams, one stream delayed from the other to five fringes. The results are accumulated and recorded on magnetic tape.

The data output of the NRAO correlator is converted from the time domain to the frequency and space domains on "Cholla," a Convex CP1 computer. The result is a line spectrum of a radio source, or a 2-D radio brightness map of an area of the sky.

The purpose of this document is to provide an overview of the MKIIC correlator system and equipment from a maintenance perspective.

MKIIC Formatter

The MKIIC formatter samples the signal from the base band converter and provides the resulting data in a MKIIC format for recording on magnetic tape. Although several different models of MKIIC formatters exist, the basic electronic designs are very much the same and trace to a design by Martin Ewing, then of CIT. Most of the VLBA sites use either the Noto (Italian) or the CSIRO (Australian) formatter. An unnumbered documentation booklet exists for the Noto formatter. Schematic drawings D54002S003, -006, -007 are on file at the AOC. The CSIRO formatter is undocumented at this writing, but the circuit boards follow the NOTO design closely. The VLA uses a formatter that predates both the NOTO and CSIRO formatters. Drawings for the VLA MKIIC formatter are kept on site.

The formatter samples the incoming base band analog signal at a 4 MHz rate. The internal 4 MHz clock is synchronized with the station maser using an internal PLL and a 5 MHz input from the station clock. The maximum bandwidth of the data signal is 2 MHz. A signal level above a certain threshold (0 volts) is sampled as a 1 and below as a 0, thus the term 2 level 1-bit digitization.

Some formatters have two inputs: 1 for the Upper Side Band (USB) and 1 for the Lower Side Band (LSB). A relay, under the control of the MKIIC controller, selects the input. The default position is LSB. Formatters at the VLBA sites have a 10 db Avantek amplifier added to the signal input.

The data are grouped into frames, each 1/60 second long. The VCR writes the data frames in place of video frames on the magnetic tape. To synchronize the VCR with the formatter, the formatter divides the 5 MHz down to 60 Hz, and outputs that timing signal to the VCR. The VCR is modified so that it uses the formatter 60 Hz in its servo drive circuits in place of an internally generated 60 Hz. There are two video heads; one writes a complete frame of data, then the second head writes the next frame of data.

In addition to the 4 MHz data, each frame contains a beginning-of-frame code (BOF), an helical frame count (HFC) and parity code, a synchronizing code every 512 $\mu$seconds (DPSYNC), and an end-of-frame code (EOF). The formatter generates the codes and inserts them in place of data. More information on MKIIC format is in NRAO Internal Report 187.

Like the audio time code, the video data is bi-phase encoded; that is, a "0" in the data is represented by one signal transition during the clock cycle, and a "1" is represented by two transitions. Early users of the recording scheme found that the 250ns-long clock cycle was too long to hold the recording heads in a full-on or a full-off state, required for data "0". When the data was read back, frequent errors occurred. The solution, called the "anti-bit crowding circuit" adds an even number of transitions to each "0". The transitions occur too rapidly to be faithfully recorded, and are not present in the playback data, but when properly timed, prevent read errors.

The extra transitions are created by two "one-shot" multivibrators: the time from the beginning of the first timing cycle to the beginning of the second is referred to as $T_A$, and the overall time interval for both timing cycles as $T_B$. This writer's experience is that $T_A$ and $T_B$ must be determined experimentally, and are a function of the formatter and the type of VCR used. If the value selected works, it's right. Mercifully, the values selected for a given formatter seem to work with any PV-1360 Panasonic VCR, the VCR

currently in use at all the MKIIC-equipped VLBA sites. Current values for the Noto formatters are shown on the schematic drawings.

The formatter time is manually set to agree with UTC by entering a time, and arming the timing circuit when that exact time comes up on the station clock. A 1PPS input triggers the counting circuit. The counting circuit uses the 5 MHz input to update the formatter clock. Some formatters include a display of the difference between formatter time and station (1PPS) time. The difference should be less than 1 $\mu$second,and more importantly, must be constant during an observing run. Either the falling or rising edge of the 1PPS may be selected to trigger the formatter clock by means of an external switch. The formatter time is recorded on the audio track of the VCR as a bi-phase encoded amplitude-modulated sine wave.

The test pattern function writes a known pattern in place of data for use in diagnosing problems during playback at the correlator. This feature has not been used in many years, and this writer sees no use in recording test pattern at the beginning of the data tapes.

Although problems with the formatters are rare, here are some to watch for:

1. Noise on the signal lines will occur if the shields of the coax connectors are not properly grounded.
2. The phase-locked loop circuit will exhibit "phase-jitter" without careful attention to capacitive decoupling and other noise considerations.
3. The anti-bit crowding circuits have been optimized by trying different values of $T_A$ and $T_B$ to find the values which produce the fewest errors in the decoding process. It is not known how stable the one-shot timing is, so that it may be necessary to repeat the adjustment process if recording quality appears to deteriorate.

In summary, the formatter has three inputs: 1) Data from the BBC (LSB and/or USB), 2) 5 MHz, and 3) 1PPS. And three outputs: 1) Formatted data or video, 2) Time code or audio, and 3) Sync or 60 Hz.

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The NRAO MKII Correlator

Internal Reports 118 and 187 provide a thorough, albeit partially out-of-date, description of the MKII Correlator. Operating instructions for the correlator may be found in Reference 3. Schematics are on file and are listed at the end of this document. The purpose of this section is to provide an overview of the correlator and maintenance information.

The MKII Correlator consists of several chassis of circuit cards which decode and correlate data from 3 stations. Each station, or antenna, is represented by an RCA Model VDT 501 VHS VCR. The correlator is controlled by a Sperry Univac V77 computer. The computer also receives the data resulting from the correlation and writes them to a Wang/Cipher 9-track tape deck. The operation is controlled with knobs and switches on the VCRs and on the electronic chassis, and by a terminal connected to the computer. The terminal has a DDS connection so that correlation parameters can be downloaded from Cholla and written to a "Preptape."

The Buffer/Decoder

Video data from the VCR is brought to a decoder card in the buffer chassis. A phase-locked loop (PLL), one on each of the three input cards, locks to the 4 MHz data clock from the VCR, for use in decoding the incoming data. The decode circuitry looks for the BOF at the beginning of each frame; if one is not found, an indicator light on the buffer control chassis flashes, the computer is advised, and that frame is blanked from correlation. The circuitry also looks for the sync character every 512 $\mu$seconds during the frame; not finding one, the circuit will flash an indicator on the correlator control panel, advise the computer, and blank the preceding 512 $\mu$seconds of data.

To verify the data, a circuit flashes an indicator lamp on the correlator control panel for every "one" in the data and a different lamp for every "zero" in the data. Since the data should contain an equal number of one's and zero's, the lamps should be illuminated equally for good data. If one pair of lights is brighter than the other pair, the data are not random. Most likely an error occurred at record time and is not correctable.

The final check on the video is a circuit that checks to see if the helical frame count has incremented by one from the previous frame and checks the frame count parity. If wrong, an error is indicated by lamps on the correlator control panel, the computer is advised, and the correlator is made to resync if an excess number of frame count errors is encountered.

The audio signal is decoded to provide time code for the display and for the computer. The time code may be displayed for only one station at a time; selection is made with a button on the correlator control panel. A flashing "TCD" lamp or a flickering digit in the display indicates bad time decoding. Information for the station number and day number on the time display are not recorded.

An oscilloscope permits viewing the video and audio waveforms, the decoded waveforms, 60 Hz, dropouts, and "Frame." A dropout occurs when a 512 second sync character is not successfully decoded. Frame goes "low" at the end of a data frame and returns to a "high" condition when a BOF is successfully decoded.

Up to this point, no correlation need take place. The computer can be started and data tapes played into the correlator control to examine the quality of the recordings and to find a certain recorded time. Once the tape quality is verified and the times are setup according to the procedure in the Correlator Manual, correlation may be initiated. Where the procedure in the Correlator Manual fails to achieve adequate tape playback quality, further adjustments are described in the section on VCRs.

The VCRs are setup using the "local" mode, selected with a switch on the VCR. When the correct time is selected, the switch is thrown to "remote." In remote, the VCR is in "pause" mode, in which the tape continues to ride on the head cylinder, but the capstan is held stationary. The heads and tape continue to wear as if the VCR were in use. When started, the correlator commands the VCR to "Play" mode.

## The Correlator in Operation

Correlation is initiated by beginning the computer at the appropriate address and pressing the "Start" button on the Correlator Control Panel. The computer commands and messages are described in references 2 and 3; there is no effort to repeat that information in this manual. The correlator is clocked by an internal crystal-controlled oscillator. To synchronize the VCR data with the correlator clock, the decoded data are written to a buffer using a VCR-clocked "Load" pointer, and then read out using a correlator-clocked "Unload" pointer. The Unload pointer must follow the Load pointer by 512 $\mu$seconds to 1024 $\mu$seconds or a "Buffer Error" will be displayed, and the correlation will be commanded to re-sync. The prescribed delay of 750 $\mu$seconds between 60 Hz and BOF is key to achieving the correct timing for this operation. During correlation, 60 Hz Sync for a given VCR is servoed to its respective Unload pointer, so that the data are read at a rate to keep up with the Unload pointer. 60 Hz for all VCRs is the same when not correlating.

The Monostore Memory III serves as a buffer memory or FIFO for stations B and C, so that up to 20 ms of delay may be added to the signal on these stations. A delay in excess of 20 ms may be invoked by "slipping" data frames, 16.67 ms per frame. The delay corrects for the distance between the antennas.

## Correlator Chassis

The 3 data streams from VCRs A, B, and C now pass to the correlator control chassis. Here each data stream is phase shifted by the fringe rotator to correct for the high fringe rate between stations. The amount of fringe rate correction is updated every second by the computer. The fringe rotator has two data stream outputs, one in quadrature with the other.

For background, fringes are an alternating pattern of high and low signal intensity caused by constructive and destructive interference. The high fringe rotation rate is a result of the rotation of the earth which causes the fringe pattern to move or rotate overhead. The greater the distance between the antennas, the higher the fringe rate is likely to be. Quadrature is a phase shift of 90°; one signal is called cosine and the other sine to indicate the phase shift is 90°. Quadrature applied at the fringe rotator output permits capture of both phase and amplitude of the fringes during correlation.

The 3 original unshifted data streams and the phase-shifted data streams now pass to a multiplexer where two of the streams are selected to pass to each of the two correlator chassis. One of the two data streams is delayed so that each channel in the correlation represents a different amount of delay. A station can be correlated with itself, called autocorrelation, or two stations can be crosscorrelated. For autocorrelation, data streams from the same stations are used as the two inputs to the correlator. For crosscorrelation, the unshifted data stream from one station is correlated in chassis 0 with the cosine output of the fringe rotator from a different station, and in chassis 1 with the sine output. The multiplexer and fringe rotator are controlled by the V77 computer. The selected bandwidth, fringe rate, and delay are displayed on the correlator control panel under computer control.

The multiplexer has 8 different mode selections for correlation. The observer is permitted to select various stations for autocorrelation and crosscorrelation, and with different channel assignments. A specific description of the modes is given in reference 3.

Finally, the data bit streams pass to the correlator cards which count the number of correlations of 1's and 0's between pairs of signals. The correlation or multiplication is conducted with X-OR gates, one per channel; a count register or accumulator is associated with each X-OR gate.

There are 576 accumulator channels, 288 in each of the two correlator chassis. The breakdown of channel assignments is different for each mode. The effect of the accumulator is to provide a time average of the correlation. The results of the accumulator pass to the V77 and are the correlation data. The correlator is blanked by BOF and DO errors, during readout, under computer control when re-syncing, and during part of the fringe rotator cycle.

The V77 reads the output of the accumulators and writes the data to magnetic tape. The data are also sent to the Scope Refresh card in the correlator control chassis. This card, which replaces the Memoscope Card mentioned in previous writeups, converts the data to two analog signals, X and Y, for display on the X-Y monitor. The card includes buffers for the data and a clock, so that the display can be automatically refreshed from the buffer memory. The Z output is a pulse which "paints" a dot on the screen located by the X and Y voltages. The center 12 channels of data are displayed.

The alert function signals errors and re-sync operations. The alert can be silenced, or at least subdued, with a disable switch on the correlator control panel. The remote/local switch for the alert is not used.

Time from Station A is read every frame during correlation; too many errors in the time code at this station will cause the correlator to re-sync.

A modification for correlating data from pulsars may be invoked with a switch in the back of the rack. The switch causes the correlation to be blanked for a certain length of time after encountering 16 "0's" all in a row in one of the data streams.

Another modification has been added to the correlator which permits the addition of a one-bit delay to the B data and C data. This modification, the so-called "vernier bit," operates on the B-C baseline only. The bit is invoked under program control; notes on the modification are in the copy of Report 187 marked "Master Copy." According to Bill Meredith, the command bits are set with the 60 Hz interrupt. Phil Diamond explains more about fractional bit shift correction on pg. 238 of reference 15.

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An Elsytec FFT and Nova computer are mentioned in the writeups. This equipment has been removed and discarded. FFTs are done on Cholla now.

Service Notes

Lightning-induced transients caused considerable damage to the correlator electronics a number of years ago; Walter Brown remedied the susceptibility by installing latching contactors on the power line. When power fails, the contactors latch the power out, so that subsequent on-off transients will not effect the equipment. A power fail interrupt to the Univac causes the routine to write an EOF to the Cipher tape unit. Walter recommends keeping the equipment off until the power lines stabilize.

Correlator chassis 0 and 1 are powered by a 5 VDC power supply at the top of the correlator rack. If this supply fails, the mode indication on the correlator front panel goes dark, the computer prints "error 69," and the correlator goes into a re-sync mode. A spare power supply is in the cabinet. There are no sense lines from the correlator chassis back to the 5 VDC supply; instead it is necessary to set the supply at 5.44 VDC to get 5 VDC on the chassis power busses. The load draws 120 A. The remainder of the correlator is powered by a power supply at the bottom of the rack. There is no spare for the second supply.

The fans and filters need to be serviced periodically to insure adequate rack cooling.

Switches in the back of the correlator rack permit the selection of MKII format or MKIIC format for each station. All these switches should be in the MKIIC position.

Phil Diamond reports a 1 MHz "birdie" when autocorrelating on station A. Since the birdie is not present when autocorrelating on station B or C, the problem appears to be with Station A only. Another birdie at 2 KHz is most likely introduced by the formatter when it writes the 512 $\mu$secondsync character, according to Durgadas Bagri.

The correlator circuitry is on slide out chassis that fold down for ease of service. There are extra correlator cards and an extender card in the cabinet, but no spares for any of the control cards.

A diagnostic program for the correlator called CORTEST exists on magtape. The routine starts at .loc 3000; when an error is encountered, the routine halts and prints a message. Starting at .loc 6000 will cause the routine to print out results. Univac sense switch 2 up will cause the test routine to stay in one correlator mode.

The operation of the correlator chassis is checked under computer control by placing 8 check channels in parallel with any group of 8 channels in use. If the accumulator results differ between the two sets of channels, the computer will print out an error message.

Use of the second audio channel was never implemented and selection of the second audio channel on the correlator control will disable the correlator from functioning.

The tape deck periodically exhibits a failure in which the feed reel unloads tape even though the unit is "off-line." The problem can be cleared by selecting "Forward" or "Reverse." Incandescent lamps, for sensing BOT/EOT and for sensing tape position in the vacuum chamber, need occasional replacement. A procedure for servicing the Cipher tape deck is given in the Correlator Manual and in the Service Manual for the device.

The model X-Y Tektronix model 603 display units include a memory function which is not used, since the display is updated by a buffer and clock in the control board. A model 602 and a 604 serve as spares; neither of these units include the memory function. A box exists to scale the outputs to the X-Y display unit for use on the Tektronix 602 display unit. The 603 has internal scaling and can be used with or without the scaling box. To check these units, attach a pulse generator to the Z input and a voltage source to the X or Y input.

The Sperry Univac V77 is a repackaged Varian 620i. The bus structure and instruction set are the same between the two machines. The V77 bus is faster than the 620i, which caused timing problems in the control of some of the Varian I/O. An active bus terminator was added to the expansion chassis to alleviate the problem: the terminator turns the bus signals around and the CPU does not reset until it sees the echo. The I/O cards are located in an expansion chassis below the main chassis. The back of the expansion chassis faces the front of the rack, which is covered with an indicator panel. The LEDs on the panel are lit under program control for use in software debugging. Some spare I/O boards may be found in the cabinet.

Also in the cabinet are diagnostic programs on magnetic tape for the Sperry Univac. The programs when loaded and operating theoretically point to locations in the diagnostic listing. The comments in the listing help diagnose hardware failures. This writer has not used any of the Varian diagnostics.

The VCRs require the most maintenance and adjustment. Abbreviated procedures for adjusting and cleaning are given in the Correlator Manual. Detailed instructions are given in a later section of this document.

In summary, the inputs to the correlator are the video and audio data from the VCRs, the data parameters from Cholla, and control functions selected by the operator. The outputs are 60 Hz sync to the VCRs, correlation data to the magnetic tape drive, and indications of operation and data quality on the terminal monitor and the various displays.

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The Data Quality Analyzer

Two Data Quality Analyzers (DQA) exist, one a chassis at the VLA, the other a feature of the MKIIC controller. The purpose is to decode the MKIIC video signal enough to show viability of the recording.

The VLA DQA borrows the decode card from the correlator to decode BOF (beginning-of-frame character), DO (drop out), and HFC (helical frame count)/ HFC parity errors from the video; and to decode time from the audio signal. A missing BOF will cause the BOF error LED to flash on, and increment the BOF error display by 1. If the frame count fails to increment correctly, the frame count error LED will flash on; and if the frame count parity is wrong, the parity LED will flash on. Either of the frame count errors will increment the frame count error display by 1. Finally, a missing 512 μsecond sync character will cause the Drop Out (DO) LED to flash on, and the error display will increment by 1.

Three different integration times may be selected: 1 second, 10 seconds, and 60 seconds. To count the number of errors in a minute, for example, set the integration time on "60," wait until the LEDs are all off, and press "Reset." The display will go blank until the end of 1 minute, and then will display the number of errors encountered during the integration period. The display will update with a new error count every minute.

The only front panel adjustment of the DQA is a vernier dial which alters the phase of the sampling frequency. This writer's experience is that a setting of 790 on the dial is satisfactory for most cases. There are two internal pots to adjust the clock frequencies for the phase-locked loop and the time code decoding. These adjustments should be used only if the frequencies are measured to be off.

The DQA may be used to measure the output of either VCR or the formatter. The DQA displays the quality of the formatter output when the selected VCR is recording. The time display should be the same as the formatter clock, and, in the case of the RCA VCR only, no errors should be displayed. Ignore the "total power" display. In the case of the Panasonic VCR, it may be necessary to connect the DQA to the BVID output instead of the PVID output to achieve a low error rate while decoding the formatter output.

To measure the output quality of VLA VCR #1, for example, select "Position 1" on the VCR selector. Then play a tape on VCR #1 (the bottom one). The error rate ideally will be 0 BOF, 0 HFC, and <12 DO per minute. Some DO errors can be expected just from variation in tape quality.

If the time display does not update, no audio signal is being decoded. If the error display does not update, the 60 Hz Sync input to the DQA is missing. If the error display is all 9's, no video signal is being received. If the error display is all 60's, no BOF is being decoded. With all high numbers, the recording may be defective.

In the event of error, move the VCR position selector switch back and forth between #1 and #2 a few times to see if the DQA will "sync up." Play the "Test Tape" to make sure the VCR and the DQA still work. If the BOF and Frame Count errors are low, but the DO errors are high, check the VCR track centering. If you are preparing to record, try recording and playing back on a different tape. If the replacement tape works, mark the questionable tape for further testing or discard.

The VLA DQA provides no indication of the quality of the data or even if any data is present. It only checks the formatter sync characters. See Internal Report No 185 for more on the VLA DQA.

Phil Dooley developed a DQA as part of the MKIIC controller project. This DQA decodes BOF, HFC/parity, DO, EOF, and test pattern. As well the analyzer looks for a nearly equal number of 1's and 0's in the data. The results are available to the remote controller. This DQA is scheduled to be available to all VLBA sites equipped with MKIIC formatters.

The MKIIC Controller DQA is only marginally useful without support from the host computer. For instance, the circuit counts BOFs and DOs, not BOF and DO errors. It is up to the host to keep count, recognize errors as they occur, and report on them to the operator.

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The MKIIC Controller

The MKIIC Controller provides remote control of the Panasonic VCRs via the MCB on the station computer. Once tapes are loaded in the VCRs, the recorders may be sequenced automatically for an unattended data taking session. A tape may be rewound and recorded over, and a bad VCR may be detected and bypassed. At this writing, the software is implemented to use the controller in only a primitive form.

The MKIIC Controller receives the video, audio, and 60 Hz sync signals from the VCRs for performing data quality analysis. The chassis provides remote control for the VCRs and for selection of upper or lower sideband, and receives status information from both VCRs and formatter. The formatter provides power to the controller. To disable the controller, disconnect the signal cable at the Controller end.

More information on the controller can be found in a pending VLBA Technical Report.

VCRs

Two different VCR types are used in the MKIIC system: the Panasonic model PV1360 and the RCA VDT501. Both are dual video head VHS machines. At this writing 35 Panasonic machines and 32 Blue Boxes are available to the VLBA network, and 8 RCA machines to the VLA and correlator. 5 more older RCA machines also exist.

The RCA machines are used at the VLA and at the MKIIC correlator. The RCAs are used at the VLA because they provide a slightly higher quality recording with that formatter, possibly because the anti-bit crowding circuit is tuned for the RCA rather than the Panasonic. The RCAs at the correlator have extra modifications to make use at the correlator more convenient.

How VCRs Work

The video data and audio data are written on different areas or tracks on the magnetic tape. The video information is written on diagonal or helical tracks, 1 frame per track, 60 frames per minute. As a result the tape moves quite slowly, 3.7 inches per second at LP, the speed used for all MKIIC recording, but the speed of the record head with respect to the tape is much faster, approximately 30 feet per second. In this way, a signal with a bandwidth in excess of 4 MHz can be recorded while conserving tape. The record time for a VHS cassette at LP is 4 hours.

The head cylinder rotates at 30 rpm. It houses two heads located 180° apart so that only one of the heads is in use at any given time. Adjacent tracks are written by different heads. The head cylinder includes a magnetic transducer to generate a pulse called the PG (pulse generator) once per revolution. In record, PG is servoed to the 60 Hz Sync to maintain the proper position relationship of the head cylinder with the 60 Hz from the formatter.

A separate head writes the 3.84 KHz audio information on a linear track along the edge of the tape. Only one of the two audio tracks is used. The audio head assembly includes a control head that records PG on a control track parallel to the audio track.

During playback, the capstan is servoed to maintain the correct rate relationship between the PG from the head cylinder and the playback PG from the control track. The head drum servo maintains the correct position relationship between the PG and the 60 Hz Sync. The head switch time may be retarded along the tape by delaying the 60 Hz sync or may be advanced or retarded by adjusting the "PG shifter."

There are two erase heads: one for full erase located to the left of the head cylinder; the other erase head is mounted to the left of the audio head and erases only the audio track. The audio erase insures that audio recording begins immediately after Record is selected since the tape advances from left to right. Previous information on a tape is erased as part of the recording process so that there is no need to de-Gauss a cassette tape before use.

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## NRAO Machines

The VCR machines at NRAO are modified to meet the requirements of the MKIIC system. The servo drive circuit for the video head cylinder drive uses an external 60 Hz in place of one internally generated to synchronize the machines with formatter or correlator. The tuners are removed and the video data input signal injected into the head drive circuit, bypassing all the color circuitry. Playback video is lifted immediately after the read head amplifier circuit. BNC connectors are added for audio track input and output, but the audio circuits are otherwise unmodified. Basic operating instructions for the VCRs are given in Reference 4.

The RCA units include a circuit board which routes inputs and outputs and displays their respective amplitudes on a meter. A comparator amplifies and squares up the video playback signal for input to the correlator decoder card. A passive filter is included for the video input.

The circuit board and meter for the Panasonic VCRs are located externally in the so-called Blue Box, though passive filters have been added to the video in and video out signals in the Panasonic chassis.

A single integrated circuit (IC) in the Panasonic includes the servo control circuits for both the capstan and the head cylinder. To inject the external 60 Hz, two identical servo ICs were mounted to a circuit card to separate the two drive circuits; the card is mounted on the socket in place of the original servo IC. The card includes a pot which retards the external 60 Hz. If this card is removed and one of the servo ICs installed in the socket, the unit may be used for normal video playback, using the RF connectors rather than the BNCs. The connection to the BNCs need not be removed. Left in this state accidentally, the recorder will appear to work, but will neither record nor playback synchronized with MKII equipment. Incidentally, if the modification board comes loose from its socket, the VCR will misbehave in a totally awesome way, possibly eating your tape.

Six of the RCA VCRs include modifications for use on the MKIIC correlator. The PG shifter adjustment pot is brought to the front of the machine. The pot is used to advance or retard the head switch. The playback head signal is brought to an external BNC connector to permit monitoring the analog information on an oscilloscope before the signal is amplified and "squared-up" for input to the correlator. The monitor signal must be used to examine the "eye-patterns."

## Test Tape

The so-called "Test Tapes" are cassettes recorded by Richard LaCasse and George Grove at Green Bank using carefully calibrated RCA VCRs. The tapes, with test pattern recorded in standard MKIIC format, are useful in checking VCR, DQA, and decoder functions. A stash of test tapes is located in the VLBA operations area.

## Panasonic Adjustments

Remove the cover of the Panasonic by removing the four screws marked with an arrow, two on the back and two on the bottom. Slide the cover back about 3/4" and lift up. Note that the speed "LP" must be selected for all use and all adjustments of the VCR.

The Panasonic Service Manual describes a procedure to center the tracking and to "peak up" the audio and video signals. Using a LaCasse test tape, first peak up the playback audio amplitude as described in the Service Manual, Section II. The audio amplitude must be at least 1.5 volts p-p to work with the MKIIC Controller DQA. If not, adjust the "pb amplitude" pot on the Panasonic circuit board.

Instead of placing the track centering adjustment on the center detent, move it to about -30%, where -100% is fully counterclockwise and +100% is fully clockwise. Now peak up the video amplitude using the special tool. The video signal on the recorded tape should now be centered when played back at the correlator. If the video frame rolls off at the edges, peak up the signal with guide post adjustments, as described in the Service Manual.

The only adjustment for the Blue Box is the "record level" trimpot on the front. The adjustment sets the voltage level of the VID IN signal Blue Box output to the VCR. The level must be examined under load with the VCR in "STOP" or "RECORD". This writer's experience is that the pot should be set to peg the meter on "VID IN" plus 1 turn. If the level is too low, the correlator will report a high DO rate; if too high, the correlator will report BOF and BUF errors. The record level for the best possible recording may change slightly as a function of the brand and vintage of tape used; but in practice, a single record level seems to be satisfactory for all tapes.

The Panasonic outputs a low-true level to the Blue Box in "STOP" or "RECORD" using the signal cable connected to the 15 contact D connectors. In RECORD, the meter will indicate no video signal and no video signal will be recorded if the connection is absent. A short between contacts 2 and 4 on the Blue Box D connector may be used as a temporary expedient if the cable is absent. The meter reading for video on playback may be of use if you are familiar with "normal" readings for that meter; this writer's experience is the each Blue Box has a character all of its own. Comparison with the test tape may be useful.

The eye pattern of the video may be checked by looking at the VID OUT signal from the VCR.

After making adjustments, record a tape and play it back to a DQA or at the correlator to insure the unit may still be used successfully.

RCA Adjustments

Remove the top cover of the RCA VCR by loosening the back, removing the track centering adjustment knob, and removing screws from the top cover. For the TE180s, lift the cover very carefully to prevent ripping the ribbon connector loose from its mooring, which will invariably break a pin off the connector.

There are 3 adjustments for the audio/control head assembly. To center the track, move the track centering knob to the center detent position, then use the "L" shaped tool and the notch at the base of the head assembly to move the heads along the tape track until the video output from the test tape is peaked. Peak the video some more by moving the heads vertically with the screw adjustment (see Section 3 of RCA Service Manual). Finally, peak the audio track from the test tape by adjusting the allen screws located on either side of the head assembly, while observing the audio signal display on the oscilloscope. It may be necessary to iterate through the adjustments a few times to get the video and audio both peaked at the same time. Rounded

corners on the video data frame can be peaked up with guide post adjustments. Decoding of the audio signal can be improved by adjusting the gain pots on the front of the VCR, a procedure discussed further on.

The RCA recorders are used for recording at the VLA. Record level is adjusted with a pot near the meter. A meter reading for the video signal of 0.8 to 1.0 has been used successfully for recording at the VLA. The setting that produces the least error when reading back to the DQA or correlator is the correct one. Reading the meter on playback may be of some use if one is familiar with "normal" readings for playback on that recorder. Comparison with the test tape is useful. The "low video level" indication is flawed.

The timing between the 60 Hz and the BOF should be 750 $\mu$seconds as described for the Panasonic VCRs. Record a test tape and play it back to the DQA after making adjustments to insure the VCR may be used successfully.

More adjustments for the RCA VCR, using the correlator to measure results, are explained below.

BOF/60 Hz Timing Adjustments

The standard delay between the negative transition of the 60 Hz sync and the BOF is 750 $\mu$seconds. To achieve this timing for recording, connect the VCR to the VLA DQA or the Correlator and while observing the relative timing of the 60 Hz and the decoded "Frame" signal, adjust PG shifter; and, in the case of the Panasonic VCR, the 60 Hz delay on the servo modification board, until the timing is correct. The timing insures the BOF will be decoded during the correct time window on the correlator decoder card. Specifically, the time interval is between the falling edge of the 60 Hz to the rising edge of Frame, when BOF occurs. Frame is available on BNCs at both the VLA DQA and the correlator. This writer's experience is that a delay something less than 750 $\mu$seconds is the only possible adjustment on some machines. Try to make the delay the same on all machines at a given site.

VCR Adjustments at the Correlator

Instructions for adjusting the RCA VCRs for playing back data to the MKIIC correlator are given in the Correlator Manual (reference 3). An expanded version of those instructions is given below. These additional procedures should only be used in the event the steps given in the Correlator Manual fail. Always check the operation of the station with a Test Tape before proceeding. The Test Tape must be made to work first.

The correlator provides several indications of video and audio data quality. The red-lensed segmented display lights on the correlator control panel display BOF, HFC/parity, DO, and BUF errors in the video data. In addition, the VCR video output, the decoded video data, drop outs, frame, VCR audio output, and decoded audio data are all displayed on the oscilloscope. The computer resets the error display indications; if the "Computer Off" indicator is lit on the correlator control panel, start the computer at address 40 to reset the error displays. Make sure no one is correlating before entering commands on the computer.

The first step in making adjustments to the audio and video output signals is to assign the VCR station, 1, 2, or 3, to a correlator station, A, B, or C, using the wafer switch on the left side of the correlator rack. For example, if VCR Station 1 is assigned as "B," the status indicators for

Station B on the correlator are assigned to VCR 1, and the decoder card for B will receive video and audio from station 1. Oscilloscope channel 2 will also be assigned to VCR 1, except that the video signal is not switched. Video from VCR station 1 is always displayed on oscilloscope channel 1, station 2 on channel 2, and station 3 on channel 3.

Next, select 60 Hz as the external oscilloscope trigger; set the time base for 5 ms; set the amplitude on all 4 channels for 10 mv; and select a multiplexed display so that all oscilloscope channels display a trace. For the above example, select video on oscilloscope channel 1, select "DO" for channel 2, and "Frame B" on channel 4. A video frame is 1/60 second long; each frame is separated from the next by a short discontinuity or low amplitude region. Adjacent frames are played back by alternate read heads.

Now move the track centering knob on VCR 1 until the video amplitude is peaked as displayed on the oscilloscope. The video can also be peaked with the meter on the VCR, but the oscilloscope provides more information. The "low video level" indication on the VCR has not been useful. Follow the centering procedure described earlier in this section if you run into a problem at this point.

If the BOF error light is lit for channel B on the correlator, move the 60 Hz vernier dial CCW until the error indication goes out and the BUF error light goes on, then split the difference. Conversely, if the BUF error light is lit, move the vernier CW until both BUF and BOF are extinguished. If the vernier reaches a limit, move the vernier back to "5," and adjust the "60 Hz" trimpot (PG Shifter) on the front of the VCR using the little green screwdriver. The directions are opposite; that is, rotate the pot CW, if the BOF error light is lit, and CCW for BUF. Perform the same operation as you did with the vernier dial, positioning the pot halfway between the BOF and BUF error indications. The specified timing between the negative transition of the 60 Hz sync and the BOF (positive transition of "frame"), is 750 $\mu$seconds; but this writer's experience is that whatever works, is right.

If BOF and DO error indications continue, try adjusting the PLL phase on the correlator. Nearly full CCW is the usual position for this knob. If the errors continue, try adjusting the track centering to reduce the errors. Iterating between 60 Hz delay adjustments and track centering adjustments will sometimes reduce error; the two adjustments interact since both shift PG. For reference, the vernier dial delays 60 Hz from the correlator, and the 60 Hz trimpot shifts PG; they both have the same effect of adjusting the head switch position, but the trimpot has more range. The only real reason to use the vernier pot is to save wear and tear on the "60 Hz" trimpot on the VCR.

There is a problem with the station A decoder card which causes it to decode a DO error at the beginning of each frame if the 60 Hz timing is towards the "BUF" error end. Turning the vernier knob CW corrects this problem.

The head amplifier, a silver-colored assembly at the back center of the VCR, must be adjusted if BOF and DO errors persist. There are 5 adjustments on the amplifier, two for each head, and a balance adjustment. C552 is the "peaking" adjustment and R589 the "equalization" adjustment for 1 head; C555 and R593 the corresponding adjustments for the other head. Looking at the "Frame" and "DO" traces on the oscilloscope, you may see that the errors always occur on the same head. You can determine which is the recalcitrant head by touching the peaking adjustments and examining the video trace to see which head is affected.

Using the little green screwdriver, adjust peaking for the misbehaving head for minimum amplitude. Caution: the adjustable components are easily broken, so be gentle. The peaking adjustment just repeats after 1 turn, so no more than 1 turn is necessary.

Now increase the video amplitude with the equalization adjustment until the error rate gets worse, back down until the error rate gets worse again, and stop at a point midway between. Readjust peaking, and iterate between the adjustments until the error rate is at a minimum. At this point, iterating between track centering, 60 Hz delay, and head amplifier adjustments may help in especially severe cases. For reference, peaking and equalization for an image display would be set with a prescribed procedure and test equipment, but in our case, the correct position is one where the error rate is reduced. Finally, balance the amplitudes between heads 1 and 2 with the balance pot, R591.

If error indications persist, try playback on different machines. If one VCR consistently begins to have more trouble than the others with weak tapes, consider sending the machine to a repair facility.

Audio track problems are indicated by the TCD error light next to the time code display on the correlator control panel, or by errors in the time code display itself. Assuming the audio track is centered as well as possible, adjust the gain pots E and G on the front of the VCR. The audio signal is a two level amplitude-modulated sine wave; both E and G change overall gain, but G changes relative amplitude of the high and low level modulation as well. This writer adjusts G CW (increased gain) until the TCD light illuminates, then backs off a few turns. He then turns the E pot CW (increased gain) until errors occur and backs off. Iterate between pots as necessary to obtain a stable time display. Time is only displayed for 1 station at a time, selected by the switch on the correlator. If problems persist at this point, look at the audio signal with an oscilloscope. If the signal is absent, adjust the audio head height with the allen screws. Otherwise, try increasing the gain with the external Radio Shack audio amplifier. If the audio is not synced with 60 Hz, or has large amplitude excursions, the tape may not be recoverable.

The audio signal to the decoder card must be at least 1 volt p-p. Use the Radio Shack audio amplifier if the audio signal from the VCR is weak.

Occasionally, a tape defies successful decoding. The oscilloscope can be used for the autopsy. Select the video data as the only trace displayed to improve CRT intensity. Use the time delay controls to display the beginning of frame and look for the BOF. It consists of 24 bits: 001100110011001100110011 and will appear as 6 evenly spaced positive pulses. The absence of the BOF character will readily explain an uncorrectable BOF decoding error. Now turn the time delay off, set the time base at 1 $\mu$second or faster, set the trigger to the video signal itself instead of the external 60 Hz, and again select the video signal as the only trace. The oscilloscope display will be a confusing array of sinusoidal waveforms with some recognizable characteristics: one of the sinusoids will be 4 MHz, all waveforms should have equal amplitude above and below the baseline, and the zero crossings should be bunched tightly together so that "dark" spaces appear in the waveform where no traces intervene. The dark spaces are "eye patterns" caused by the limitation of the signal to 4 MHz and its harmonics. The size of the eyes are a measure of the phase jitter; the smaller the eye, the poorer the quality of the playback, and the greater the likelihood of error. The

absence of BOF and poor eye quality are not correctable on a recorded tape; the corrective action is to investigate problems at the source of the recording.

A high DO rate on a tape may indicate the record heads were dirty or a problem with the tape itself. One source of DOs is a dirty tape or one with a defective magnetic coating. A suspected bad tape should be disposed of immediately or at least marked for further testing. Otherwise, it will be used again.

## Using the Panasonic VCR at the Correlator

The Panasonic model PV1360 VCR may be used in place of the RCA VCRs to playback tapes to the correlator. A 60 Hz Sync delay assembly in the cabinets may be used in place of the boxes with the vernier knobs. Connect 60 Hz from the correlator to the input of the Sync delay assembly, and connect the output to the 60 Hz input on the Panasonic. Power the assembly with 5 VDC.

Connect VID OUT from the Panasonic to the "Monitor" cable, the one with the red band. Also connect VID OUT to VID OUT on the Blue Box. Connect video to the correlator with the brown-band cable to the PVID output on the Blue Box.

Connect AUD OUT on the Panasonic to the input of the Radio Shack audio amplifier, and the audio input to the correlator to the output of the amplifier. With an oscilloscope, adjust the output of the amplifier during playback to be 2 volts p-p.

Adjust the trimpot on the 60 Hz Sync Assembly as you would for the vernier pot when using the RCA VCRs. If there is not enough range, take the bottom cover off of the Panasonic, and adjust PG shifter. Monitoring the Sync Assembly inputs and outputs on an oscilloscope is recommended.

Adjust track centering as necessary to achieve adequate decoding quality. There are head adjustments on the Panasonic as well, but this writer has not had to use them.

If the Panasonic use is to become permanent, consider providing a 5 VDC supply for the existing vernier-knob boxes and changing the output connection to a BNC. The box could then be used with both RCA and Panasonic VCRs. Also, remote control of the "Pause/Play" function should be added for more convenient starting at a prescribed time.

## Panasonic and Blue Box Cabling at the VLBA

Several Panasonic VCRs are connected to a single formatter at the VLBA sites to permit sequenced operation for data runs in excess of 4 hours. The video, audio, and 60 Hz formatter outputs must be daisy-chained through the Blue Boxes. Each Blue Box includes an amplifier which repeats video data received from the RVID input to the BVID output. Thus the BVID output of the first Blue Box should be connected to the RVID input of the next box, and so on. Audio and 60 Hz are daisy-chained externally using BNC "T" connectors to the RAUD and 60 Hz inputs, respectively.

The inputs and outputs on the bottom half of the Blue Box are connected to the like-labelled BNCs on the VCR. A signal cable connects a low true line from the VCR to the Blue Box when the VCR is recording. Where a MKIIC controller is present, the signal cable is joined with a second cable that

passes to the controller. The playback video output of the Blue Box, PVID, is also connected to the MKIIC controller.

To remove a VCR from use, no connections need to be changed at the Blue Box, unless the Blue Box is also removed. If the Blue Box is removed, leave the "T" connectors on audio and 60 Hz, and connect the RVID cable to the BVID cable with a plug-to-plug BNC adapter. To disable the MKIIC controller from operating a VCR, disconnect the control cable at the controller end.

VCR Maintenance

The heads on the VCRs are typically cleaned in normal use by a slight abrasiveness in the magnetic coating on the tape. The quality of the tapes used at NRAO are unlikely to leave a residue. In fact, cleaning the heads is more likely to do harm than normal use. The heads must not be cleaned with cotton swabs or any other medium likely to hook threads on the head. Use alcohol-soaked Tex Wipes or chamois swabs soaked in alcohol or tri-fluor tri-chlorethane. Tri-fluor, tri-chlorethane is believed to leave a thinner residue film. Always clean in the direction of tape travel to reduce the hazard of snagging the head and dislodging it. Clean all the dust out of the unit before cleaning the heads. Clean all surfaces that carry tape and surrounding surfaces with a Tex Wipe. Based on current usage, the VCRs should be cleaned once every 6 months.

There are two types of cleaning cartridges: the wet kind perform the same function as the Tex Wipe; the dry kind have an abrasive surface to remove caked residue from the heads. As mentioned earlier, caked residue is unlikely to occur with good quality tapes. If a head seems weak, and inspection with a loupe shows caked residue, playing a dry cleaning cartridge for a FEW SECONDS may remove the residue. Using the dry tape for a longer period wears the head unnecessarily.

When cleaning the heads, inspect the rubber belts and pinch rollers for cracking. Cracked belts may be replaced on site or the unit can be returned to a repair facility.

When returning a VCR to a repair facility, send along a signal generator and instructions on how to inject an external 60 Hz (Appendix B). Two recorders and a test tape permit the repair facility to generate a MKIIC signal for testing the record function.

The most frequent failure on the Panasonic VCRs is the servo modification board coming loose. The VCR will not play, record, or rewind correctly. To repair, remove the machine's cover and reinsert the board. With the RCA, the most frequent failure is the reel sensor lamp. Lamp failure locks out "power on" so that the machine is completely dead. Spare lamps are in the correlator cabinet; the lamps are soldered in place.

Acknowledgments:

Walter Brown tirelessly spent hours and days with this writer going through all the schematics, notes, and procedures for the MKII correlator before it was brought to the AOC in Socorro. Walter contributed significantly to the operation of the correlator when it was in Charlottesville, built the "Blue Boxes," and modified the Panasonic VCRs.

I also thank Craig Walker for his helpful suggestions with this report and with the care and operation of the correlator, in general.

References:

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4. The VLA MKII Data Gathering System, C. Janes, March 1991, VLA Technical Report 67.

5. The Mark II Data Quality Analyzer/Decoder, LaCasse, February 1978, Electronics Division Internal Report 185.

6. The New Mark II "Formatter," A. Gallerani, 1988, unnumbered.

7. The MKIIC Controller, Dooley, Harden, and Janes, 1991, pending release.

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9. Service Manual for the VDT501 VCR, RCA.

10. Service Manual for the VET180 VCR, RCA.

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15. Very Long Baseline Interferometry: Techniques and Application, edited by Marcello Felli and Ralph Spencer, NATO ASI Series, Series C Math and Physical Sciences Vol 283, Kluwer Academic Publishers, 1989.

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# Mark II Drawing Index

## Cables, Wiring

| | | |
|---|---|---|
| Correlator Control Backplane | C2519W02 | (8) |
| Buffer Backplane | C2519W03 | (7) |
| Correlator Organization | none | (1) |
| Cables | C2519W01 | (2) |

## Univac V77 interfaces

| | | |
|---|---|---|
| Scope Refresh | C2519L17 | (1) |
| Arithmetic Processor & LED Interface | none | (1) |

## Buffer

| | | |
|---|---|---|
| Buffer Decoder, ABC | C2519L11 | (2) |
| Buffer A | C2519L02 | (2) |
| Buffer Load Control B(C) | C2519L17 | (1) |
| Buffer Unload Control 1 B(C) | C2519L01 | (3) |
| Buffer Unload Control 2 B(C) | C2519L15 | (2) |
| Buffer Recorder Control 1 | C2519L13 | (2) |
| Buffer Recorder Control 2 | C2519L12 | (2) |

## Correlator Control

| | | |
|---|---|---|
| Buffer Interface | C2519L08 | (2) |
| Fringe Rotator | C2519L04 | (1) |
| Delay | C2519L06 | (1) |
| Master Clock | C2519L10 | (2) |
| TC Counter | C2519L09 | (1) |
| Memoscope, Alert | C2519L05 | (1) |
| TCD Display | C2519L03 | (1) |

## Correlator

| | | |
|---|---|---|
| Control | C2519L16 | (2) |
| Correlator | C2519L07 | (1) |

Section 35

Mark II Check List

FORMATTER

1. 5 Mhz ok. ("Lock" light on)

2. Time set to WWV.

3. "Time ok" light on. If not, resync. to VLBA 1 sec tic.

4. Less than 1 microsecond between Mk II and VLBA 1 sec tics.

5. Difference between Mk II Formatter 1PPS and GPS Receiver not more than 5 microseconds. If more than this notify AOC Operations and LO-IF Group befor re-sync of station timer.

5. Cable to Mark II plugged into proper input.
   a. Correct BBC.
   b. Correct sideband (upper for C band, lower for L Band).
   c. Does data light on formatter go out if cable unplugged?

6. "Data Level" light on.

7. Sampled data has roughly equal time in both states.

RECORDERS

8. Record some data on each machine.

   A. Record video leval near 1 (full scale on dial).
   B. Record audio ok.
   C. Sync ok.

9. Playback each test tape.

   A. Playback video level above 0.2.
   B. Playback audio level ok.
   C. Playback of test pattern ok on scope.

   D. If DQA is available:
      i. Error rates ok (most frame and bof errors near 0, dropouts less then about 5/sec)
      ii. Time decoding and displaying correctly.
      iii. Decoded data has rough balance of 1's and 0's.

Mark II Check List -- Observing:

1. Recorder start times set.

2. "Data Level" light on.

3. "Time ok" light on.

4. "Lock" light on.

5. Displayed time correct. (Check and set with WWV 202-653-1800)

6. Proper programming for recorders ( time and date ) and tape installed in recorder.

Appendix B.

Information for External Repair Service concerning the
NRAO MKIIC modified RCA VCR machines

Prepared by C. Janes, February 19, 1991

The NRAO RCA VCRs are modified so that during playback the video from the head amplifier goes directly to an NRAO circuit board mounted internally in the VCR cabinet. This circuit board amplifies the video and routes signals to the signal meter and to external connectors. During record, the video signal is injected after the chrominance and luminance circuits. The tuner is removed. The audio circuits are unmodified.

The head cylinder and capstan are servoed to an external 60 Hz signal called "Sync." It is necessary to provide an external 0 to 5 VDC 60 Hz pulse with a signal generator in order to operate the units. The 60 Hz must be a pulse, not a sine wave. The signal generator can be set to 60 Hz by adjusting the frequency while examining the signal on an oscilloscope until the signal is synchronized with line frequency. The 60 Hz signal is connected to "EXT SYNC" on the VCR.

The color circuits, chrominance and luminance, are not used in the NRAO application and are typically disabled. Audio track 2 is also not used. The repair service is not to provide any repair or adjustment of these circuits. Repair should be limited to the work necessary to record and playback the video signal as described in the next paragraph, record and playback an audio signal on track 1, and to synchronize to the external 60 Hz signal.

The playback video may be monitored at TP321 or at the VIDEO MONITOR OUTPUT, a BNC connector off to itself on the left hand back side of the chassis. This connector is mounted on a PC board, so be gentle lest you break the board mounting. On an oscilloscope triggered internally, the video signal consists of a 4 MHz signal with harmonics. The zero-crossings should be bunched together to give a well-defined "eye" pattern, a blank area where no traces appear. With the oscilloscope triggered on the external 60 Hz, the peak-to-peak (p-p) amplitude should be 100 to 150 mv, peaking when the track centering knob is at the center detent position. There is a 1 ms long blank period for the head switch at the end of every 1/60 second frame of data. The amplitude of the signal should be uniform between head gaps, with no "sag" of amplitude at the center of the frame or rounded corners at the beginning and end of the frame. There does not appear to be any advantage to examining the video signal on a video monitor, and such a test is not recommended. Examination of the video signal with a monitor must not be substituted for examination with an oscilloscope.

The repair manual describes the track centering and guide post adjustments for a correct video output waveform. The peaking, equalization, and balance adjustments in the head amplifier are typically adjusted during use at NRAO, and the repair service is not responsible for an alignment of these adjustments other than that necessary for checkout of the video circuits.

To check recording, it is necessary to have two modified VCR units. One of the units is used for playback of an NRAO Test Tape. DO NOT RECORD ON THE TEST TAPE. The units are synchronized by connecting the "EXT SYNC" on both machines to the same 60 Hz external source. Connect VIDEO OUT and AUDIO OUT

on the playback machine to the VIDEO IN and AUDIO IN, respectively, of the recording machine. If the playback machine is a modified Panasonic VCR, VID OUT must pass to the amplifier/clipper circuit first. The circuit is provided in a separate box by NRAO.

The video output on the BNC at the right side back of the machine is the output of the NRAO amplifier board. The signal is amplified and shaped into a digital waveform. The repair service is not responsible for this signal nor the repair of the amplifier board nor the meter circuit, only the video signal input to the amplifier board.

Audio track 1 is used for an amplitude-modulated 3.84 KHz time code signal. The AUDIO OUT BNC and RCA connectors and AUDIO IN BNC and RCA connectors are hardwired together so that either can be used for checkout. This signal should be peaked at about 1.5 v p-p when the video track is centered. The amplitude during playback should be constant, and the modulation of the waveform should be synchronized with the 60 Hz Sync.

The adjustments described in the service manual should be used to align the audio signal. Some recorders have "E" and "G" adjustments on the front, which are used to adjust the high amplitude and low amplitude of the amplitude modulation. These adjustments are used by NRAO during normal operation so that alignment other than that necessary to checkout audio playback is not required.

Connecting the audio signal to a speaker only provides a 60 Hz humming sound and is not recommended. Connection to a speaker may not be substituted for checkout of the audio signal with an oscilloscope.

At the beginning of every video data frame is an encoded beginning-of-frame (BOF) character. During normal operation, the time interval between the external 60 Hz Sync and the BOF is adjusted for 720 microseconds, using PG Shifter. Some recorders have PG Shifter brought to the front of the unit for routine adjustment. Consequently, the repair service is not responsible for adjusting PG Shifter other than that necessary for repair and checkout of the head cylinder and capstan servo circuits.

RCA VCR Tools Available at NRAO.

Peacock Dial Gauge 107-F
Waters Torque Watch Gauge 651C-2
RCA Height Jig VFK C139
Height Reference Plate RCA 144390, 144609
Tape guide adjustment tool 144389
Audio head azimuth adjustment tool
Audio head height adjustment tool

Information for External Repair Service concerning the
NRAO MKIIC modified Panasonic VCR machines

Prepared by C. Janes, February 19, 1991

The NRAO Panasonic VCRs are modified so that during playback the video from the head amplifier goes directly to a BNC connector on the back of the VCR cabinet. During record, the video signal is injected after the chrominance and luminance circuits. The tuner is disconnected. The audio circuits are unmodified. The IR window for remote control is not used.

The head cylinder and capstan are servoed to an external 60 Hz signal called "Sync." It is necessary to provide an external 0 to 5 VDC 60 Hz pulse with a signal generator in order to operate the units. The 60 Hz must be a pulse, not a sine wave. The signal generator can be set to 60 Hz by adjusting the frequency while examining the signal on an oscilloscope until the signal is synchronized with line frequency. The 60 Hz signal is connected to "EXT SYNC" on the VCR.

The color circuits, chrominance and luminance, are not used in the NRAO application and are typically disabled. Audio track 2 is also not used. The repair service is not to provide any repair or adjustment of these circuits. Repair should be limited to the work necessary to record and playback the video signal as described in the next paragraph, record and playback an audio signal on track 1, and to synchronize to the external 60 Hz signal. The remote control functions are wired to a rear connector. The repair service is not responsible for repairing or checking out the remote functions, unless directed otherwise by the repair order.

The playback video may be monitored at VID OUT, a BNC connector on the back of the unit. The video out on the RCA connector is not used and repair of circuits between the VID OUT BNC and the RCA connector are not to be performed. On an oscilloscope triggered internally, the video signal consists of a 4 MHz signal with harmonics. The zero-crossings should be bunched together to give a well-defined "eye" pattern, a blank area where no traces appear. With the oscilloscope triggered on the external 60 Hz, the peak-to-peak (p-p) amplitude should be around 500 mv, peaking when the track centering knob is at the center detent position. There is a 1 ms long blank period for the head switch at the end of every 1/60 second frame of data. The amplitude of the signal should be uniform between head gaps, with no "sag" of amplitude at the center of the frame or rounded corners at the beginning and end of the frame. There does not appear to be any advantage to examining the video signal on a video monitor, and such a test is not recommended. Examination of the video signal with a monitor must not be substituted for examination with an oscilloscope. The repair manual describes the track centering and guide post adjustments for a correct video output waveform.

To check recording, it is necessary to have two modified VCR units. One of the units is used for playback of an NRAO Test Tape. DO NOT RECORD ON THE TEST TAPE. The units are synchronized by connecting the "EXT SYNC" on both machines to the same 60 Hz external source. Connect VIDEO OUT and AUDIO OUT on the playback machine to the VIDEO IN and AUDIO IN, respectively, of the recording machine. If the playback machine is a Panasonic, the VID OUT must go to the amplifier/clipper circuit first. The circuit is provided by NRAO in a separate box.

Audio track 1 is used for an amplitude-modulated 3.84 KHz time code signal. The AUDIO OUT BNC and RCA connectors and AUDIO IN BNC and RCA

connectors are hardwired together so that either can be used for checkout. This signal should be peaked at about 1.5 v p-p when the video track is centered. The amplitude during playback should be constant, and the modulation of the waveform should be synchronized with the 60 Hz Sync. The adjustments described in the service manual should be used to align the audio signal.

Connecting the audio signal to a speaker only provides a 60 Hz humming sound and is not recommended. Connection to a speaker may not be substituted for checkout of the audio signal with an oscilloscope.

At the beginning of every video data frame is an encoded beginning-of-frame (BOF) character. During normal operation, the time interval between the external 60 Hz Sync and the BOF is adjusted for 720 microseconds, using PG Shifter. Consequently, the repair service is not responsible for adjusting PG Shifter other than that necessary for repair and checkout of the head cylinder and capstan servo circuits.