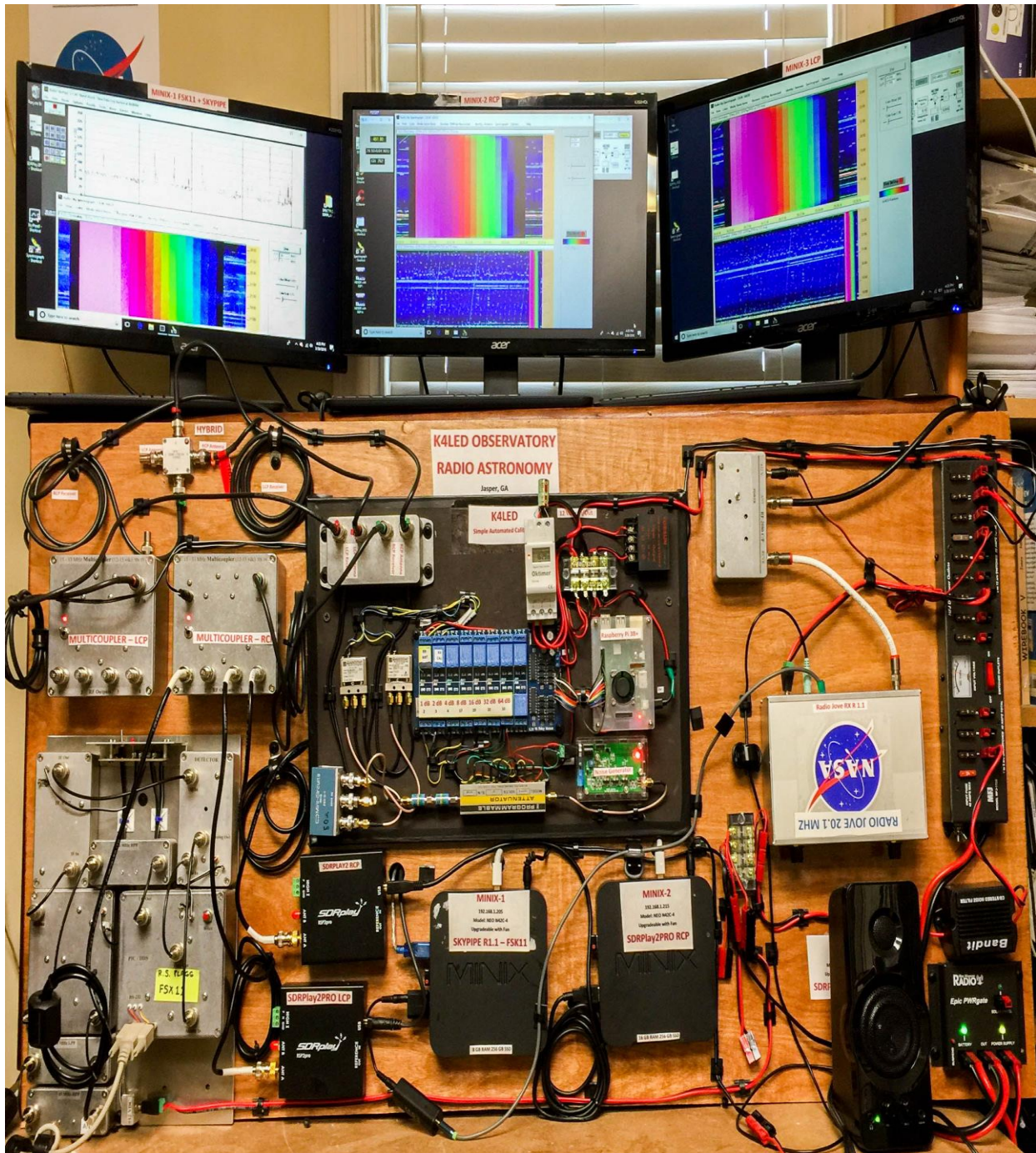# K4LED

## Georgia Amateur Radio Astronomy Observatory

**(Updated: 01/03/2019)**

## Station Data and Configuration

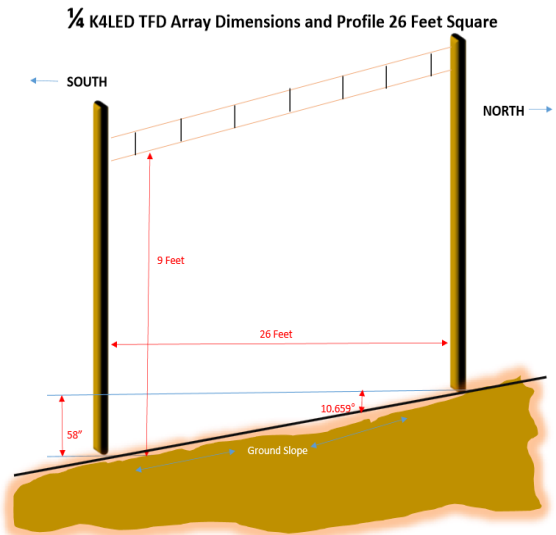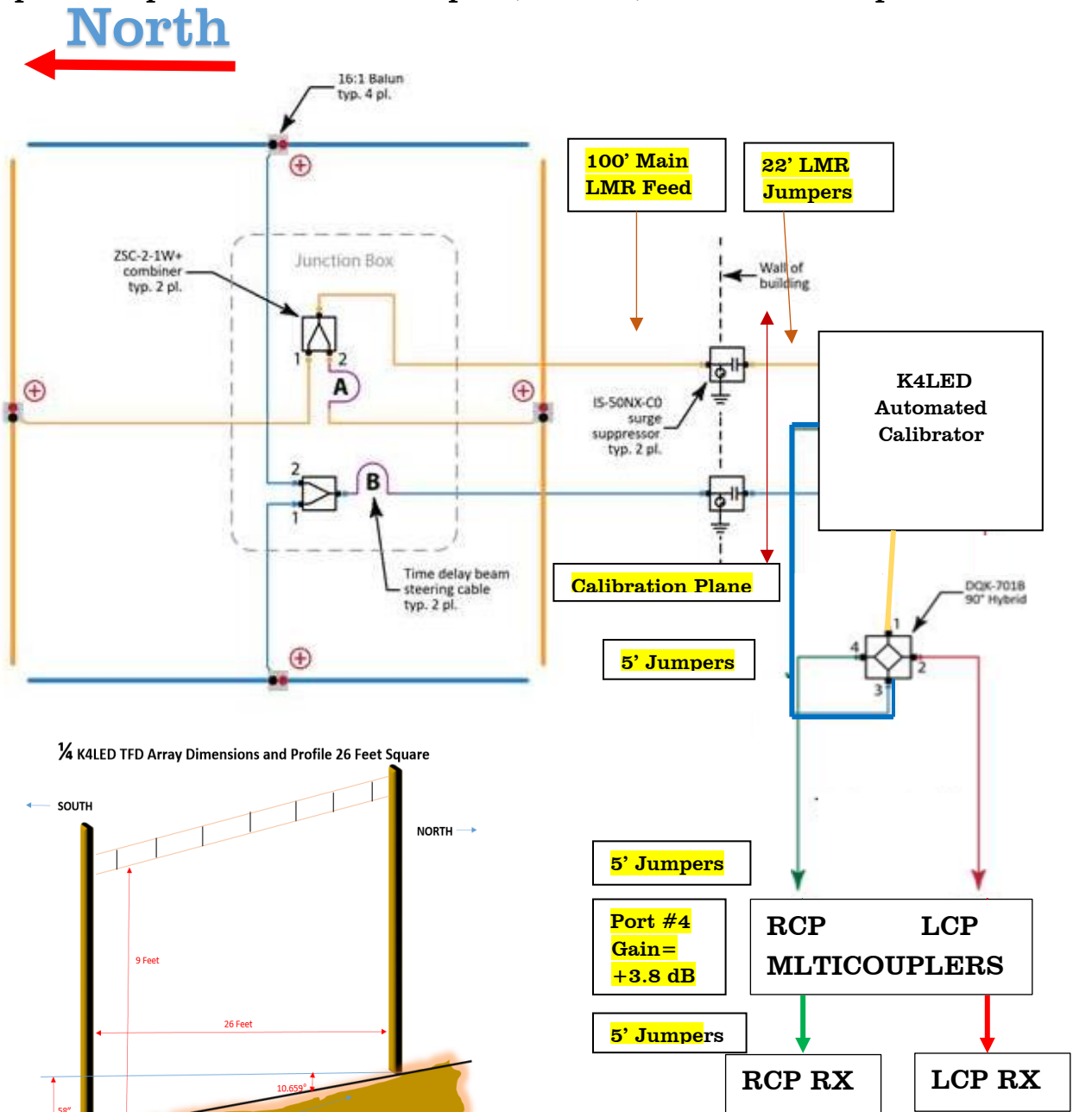**(Entire Station is powered by 12 volt DC battery with Solar Panel and AC charger)**



**NOTE: A new K4LED Radio JOVE web page is now available at:**
http://www.101science.com/radiojove.html

# SECTION I: Antennas

Antennas:

1. Wide band (15 to 30 MHz) Typinski TFD full square array. Currently beam steering is 40S from zenith for the 2019 season. This is a great antenna for spectroscopic observations of Jupiter, the sun, and other radio phenomena.



**North**

16:1 Balun typ. 4 pl.

**100' Main LMR Feed**

**22' LMR Jumpers**

ZSC-2-1W+ combiner typ. 2 pl.

Junction Box

Wall of building

IS-50NX-C0 surge suppressor typ. 2 pl.

**K4LED Automated Calibrator**

**A**

**B**

Time delay beam steering cable typ. 2 pl.

**Calibration Plane**

**5' Jumpers**

DQK-701B 90° Hybrid

¼ K4LED TFD Array Dimensions and Profile 26 Feet Square

SOUTH

NORTH

9 Feet

26 Feet

10.659°

58"

Ground Slope

**5' Jumpers**

**Port #4 Gain= +3.8 dB**

**RCP     LCP MLTICOUPLERS**

**5' Jumpers**

**RCP RX**

**LCP RX**

Note 1: The 10 degree ground slope to the south adds to the 30S steering for an effective 40S beam.

Note 2: The attenuation between the sky and the calibration plane is 7.4 dB.

| Item Name | Feed Loss in dB |
|---|---|
| Element | -4.3 |
| Balun | -0.53 |
| Element Feed 26' | -0.52 |
| Combiner | -0.11 |
| Main Feed 100' LMR | -1.22 |
| Polyphaser | -0.01 |
| Jumper 22' LMR | -0.27 |
| Hybrid | -0.17 |
| Jumper 5' to Calibrator | -0.09 |
| Jumper 5' to MC | -0.09 |
| Jumper 5' to Rx | -0.09 |
| TOTAL | -7.4 |

2. R1.2 Dual Radio Jove 20.1 MHz standard dipole kit array. Beam steered to 40S. (Note: At times Radio SkyPipe may be attached to the TFD Array.)
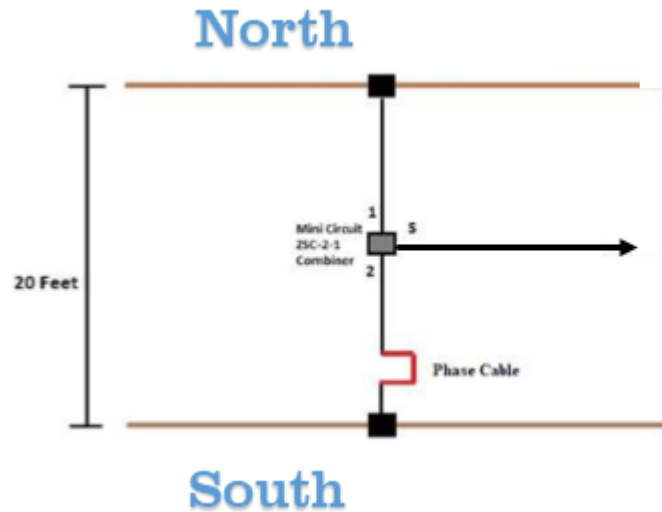


## SECTION II: Receivers (Operated on 12 volt DC battery/Solar/AC charger)

**Flagg FSX11 spectrograph. 15 to 30 MHz, 24x7x365 operation. 300 channels at 800 sweeps. This is an expertly designed and very reliable analog/digital spectrograph.**

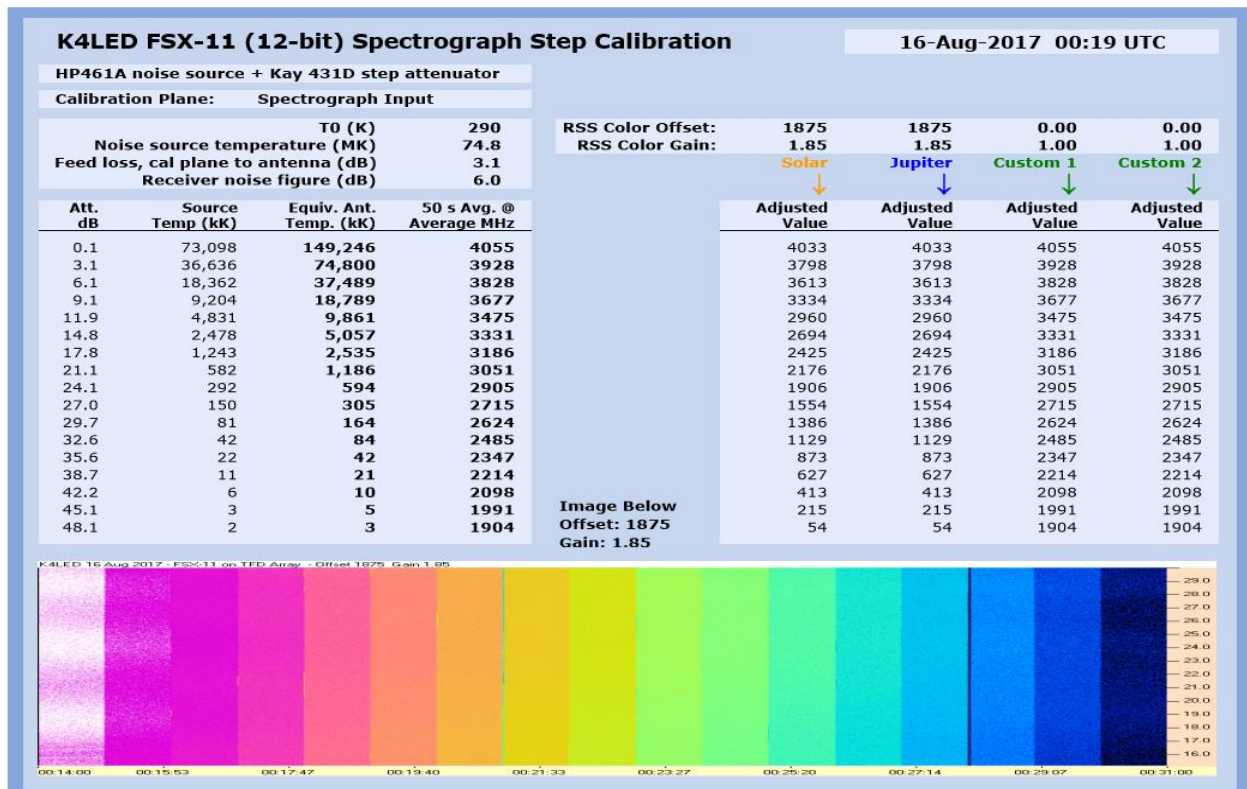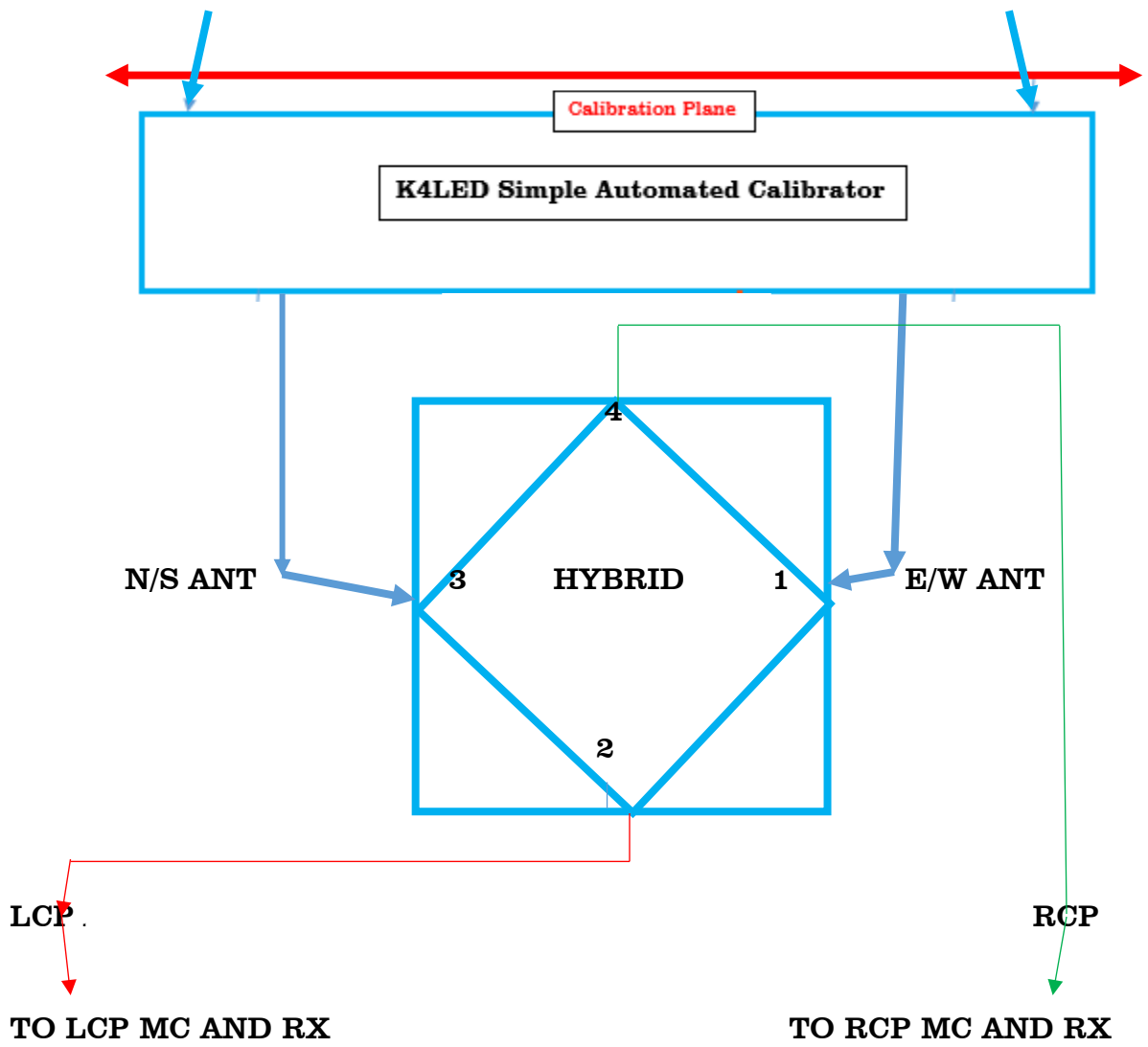1. **Three SDRPlay2PRO spectrograph receivers.  15 to 24 MHz**



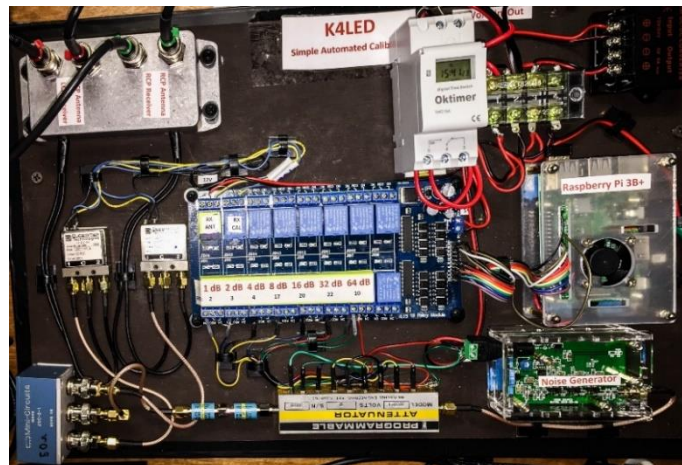2. **Three Flagg RadioJove R1.1 20.1 MHz receivers. (Only one in use at this time.) RF 2080 Calibrator.**



3. **Various amateur radio transceivers. Kenwood TS-2000, Icom IC-7300, ANAN 100D SDR, LimeSDR USB, etc.**
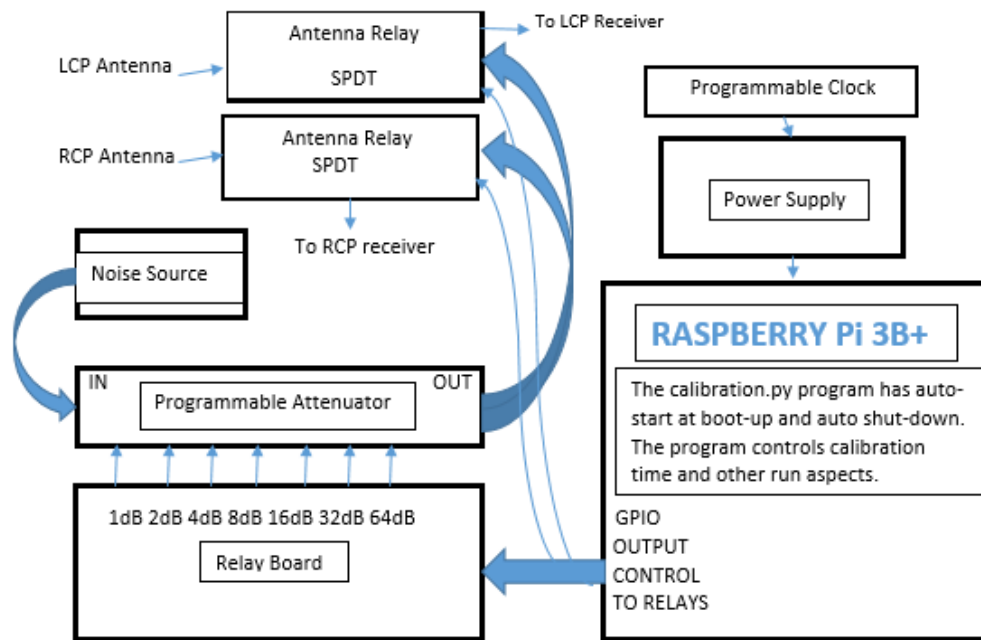
## SECTION III:  Calibration

### K4LED FSX-11 (12-bit) Spectrograph Step Calibration

16-Aug-2017  00:19 UTC

HP461A noise source + Kay 431D step attenuator

**Calibration Plane:** Spectrograph Input

| | | | | | Solar | Jupiter | Custom 1 | Custom 2 |
|---|---|---|---|---|---|---|---|---|
| T0 (K) | | | 290 | RSS Color Offset: | 1875 | 1875 | 0.00 | 0.00 |
| Noise source temperature (MK) | | | 74.8 | RSS Color Gain: | 1.85 | 1.85 | 1.00 | 1.00 |
| Feed loss, cal plane to antenna (dB) | | | 3.1 | | ↓ | ↓ | ↓ | ↓ |
| Receiver noise figure (dB) | | | 6.0 | | | | | |

| Att. dB | Source Temp (kK) | Equiv. Ant. Temp. (kK) | 50 s Avg. @ Average MHz | | Adjusted Value | Adjusted Value | Adjusted Value | Adjusted Value |
|---|---|---|---|---|---|---|---|---|
| 0.1 | 73,098 | 149,246 | 4055 | | 4033 | 4033 | 4055 | 4055 |
| 3.1 | 36,636 | 74,800 | 3928 | | 3798 | 3798 | 3928 | 3928 |
| 6.1 | 18,362 | 37,489 | 3828 | | 3613 | 3613 | 3828 | 3828 |
| 9.1 | 9,204 | 18,789 | 3677 | | 3334 | 3334 | 3677 | 3677 |
| 11.9 | 4,831 | 9,861 | 3475 | | 2960 | 2960 | 3475 | 3475 |
| 14.8 | 2,478 | 5,057 | 3331 | | 2694 | 2694 | 3331 | 3331 |
| 17.8 | 1,243 | 2,535 | 3186 | | 2425 | 2425 | 3186 | 3186 |
| 21.1 | 582 | 1,186 | 3051 | | 2176 | 2176 | 3051 | 3051 |
| 24.1 | 292 | 594 | 2905 | | 1906 | 1906 | 2905 | 2905 |
| 27.0 | 150 | 305 | 2715 | | 1554 | 1554 | 2715 | 2715 |
| 29.7 | 81 | 164 | 2624 | | 1386 | 1386 | 2624 | 2624 |
| 32.6 | 42 | 84 | 2485 | | 1129 | 1129 | 2485 | 2485 |
| 35.6 | 22 | 42 | 2347 | | 873 | 873 | 2347 | 2347 |
| 38.7 | 11 | 21 | 2214 | | 627 | 627 | 2214 | 2214 |
| 42.2 | 6 | 10 | 2098 | | 413 | 413 | 2098 | 2098 |
| 45.1 | 3 | 5 | 1991 | Image Below | 215 | 215 | 1991 | 1991 |
| 48.1 | 2 | 3 | 1904 | Offset: 1875 | 54 | 54 | 1904 | 1904 |
| | | | | Gain: 1.85 | | | | |

**Calibration Plane**

**K4LED Simple Automated Calibrator**

**N/S ANT**          **3**          **HYBRID**          **1**          **E/W ANT**

**4**

**2**

**LCP** .

**RCP**

**TO LCP MC AND RX**          **TO RCP MC AND RX**

**K4LED Simple Automated Calibrator**

## Diagram Labels

**Antenna Relay** — SPDT — LCP Antenna → — To LCP Receiver

**Antenna Relay** — SPDT — RCP Antenna → — To RCP receiver

**Programmable Clock**

**Power Supply**

**Noise Source**

**Programmable Attenuator** — IN — OUT

1dB 2dB 4dB 8dB 16dB 32dB 64dB
**Relay Board**

**RASPBERRY Pi 3B+**

The calibration.py program has auto-start at boot-up and auto shut-down. The program controls calibration time and other run aspects.

GPIO
OUTPUT
CONTROL
TO RELAYS

---

Notes: This automated calibrator was designed with off the shelf modules to keep it simple and facilitate replication by those with little electronics background. The Python control program is loaded into a Raspberry Pi computer.  However almost any computer or controller with sufficient GPIO output pins that can utilize python software should work. The calibrator starts automatically with power on by the programmable clock. The antenna relays controlled by the computer program switches the receiver(s) from the antenna to the calibrator programmable attenuator output at the start of a calibration run.  The noise source is attenuated in steps by the programmable attenuator from 0 dB to -127 dB controlled by the Python Calibration.py program running on the Raspberry Pi 3B+ computer.  After the calibration run is complete the antenna relay is released returning the receiver(s) input to the antenna.  All voltages needed are provided by the power supply package. After the calibration program has shut-down the programmable clock removes all power to the calibrator.  The real time programmable clock has a battery back up in case of total power failures. The cost to replicate this simple automated calibrator should be around $265. The full python code is provided to facilitate replication of this calibrator designed primarily for Radio Jove Observatories. Fabrication and use is at your own risk.

1@ Programmable Attenuator, Weinschel Engineering, 0-127 dB 12 volts DC (eBay) $100
2@ Antenna Relay, Ducommun Technologies, Model 2SE1T11JA 12 volt DC (eBay) $40
1@ Raspberry Pi, Model 3B+ (Amazon) $35
1@ Relay Module, 16 relays (Amazon) $29
1@ Noise generator, BG7TBL 2016-03-06 (eBay) $16
1@ Tobsun EA25-5v 12v to 5v converter (Amazon/eBay) $8
1@ OKTimer THC15A, 12 volt DC version (Amazon) $15
1@ Misc. wire, connectors, cables, etc. $20


Notes:  Currently the K4LED clock timer is set to run a calibration at 00:10 UT to 00:20 UT and also at 12:10 UT to 12:20 UT.  Up to 17 calibrations per day are possible. If you use the OKTimer be sure to get the 12 Volt DC model.  There are several different models with different voltage types. The timer/clock has a turn on glitch that was dampened with a 1000 uf electrolytic capacitor across the timer input. An on time of 10 minutes is set for a calibration run to make sure the Raspberry Pi has time to load at boot and shut-down after the program finishes. Buttons on the timer allow for a manual ON/OFF/AUTO modes. Otherwise the calibrator is totally powered down by the timer/clock except for calibration runs.  The antenna relays are latching type so only a momentary pulse is needed to trip the relay to latch the receivers either to the calibrator or to the antenna. Therefore constant relay voltage is not required.

# AUTOMATED CALIBRATION COLOR BAR TEST PATTERN AND DATA
## ACTUAL MEASURED DATA
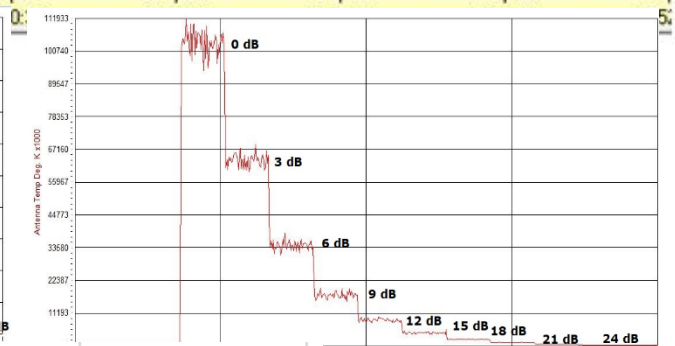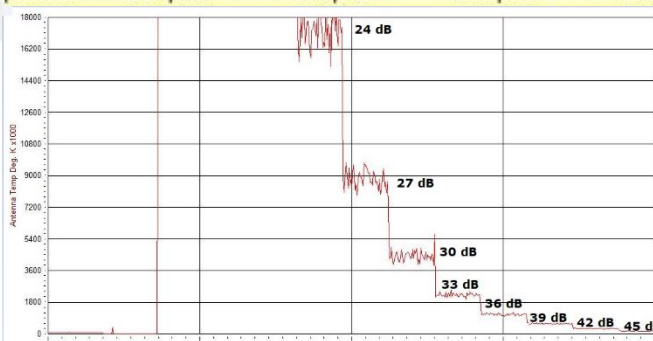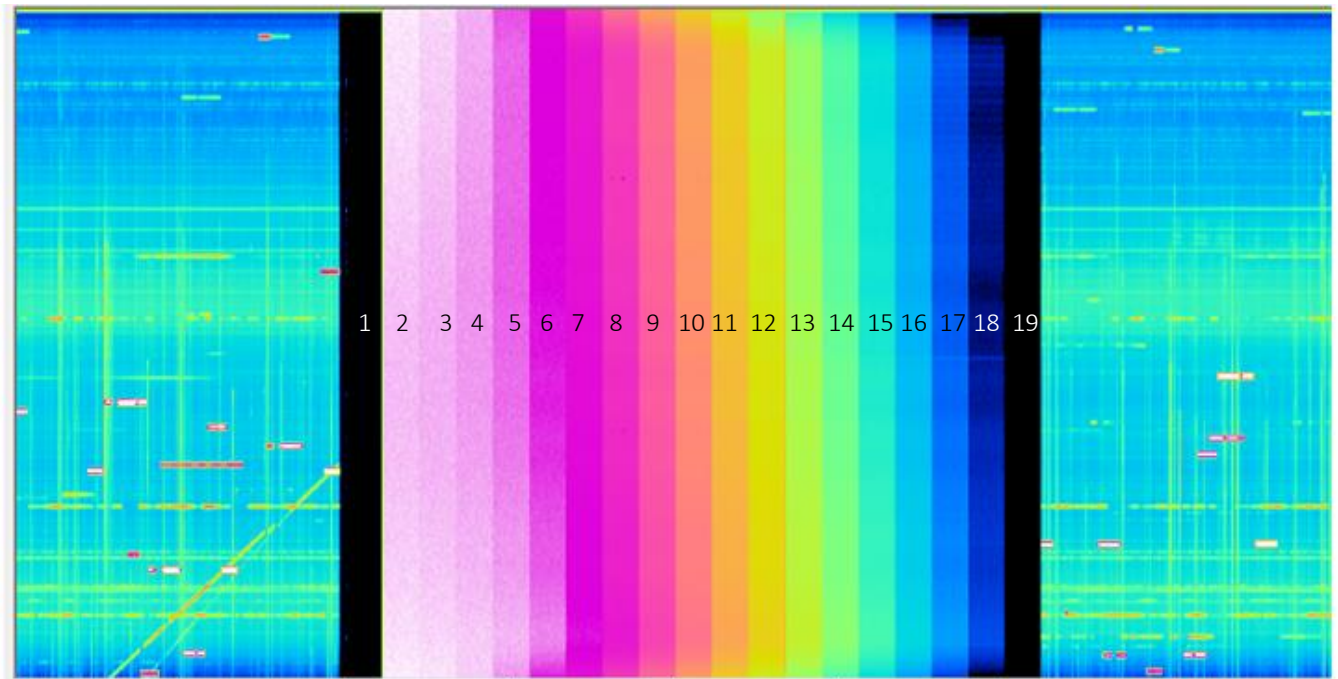


| STEP | TEMPERATURE | ATTENUATION |
|------|-------------|-------------|
| 1 | >1 kK | 101 dB |
| 2 | 104.0 MK | 0 dB |
| 3 | 66.9 MK | 3 dB |
| 4 | 36.3 MK | 6 dB |
| 5 | 19.1 MK | 9 dB |
| 6 | 9.6 MK | 12 dB |
| 7 | 4.5 MK | 15 dB |
| 8 | 2.3 MK | 18 dB |
| 9 | 1.2 MK | 21 dB |
| 10 | 602.0 kK | 24 dB |
| 11 | 296.6 kK | 27 dB |
| 12 | 133.0 kK | 30 dB |
| 13 | 92.2 kK | 33 dB |
| 14 | 51.6 kK | 36 dB |
| 15 | 32 .0 kK | 39 dB |
| 16 | 22.6 kK | 42 dB |
| 17 | 17.9 kK | 45 dB |
| 18 | 12.0 kK | 48 dB |
| 19 | >1 kK | 101 dB |

(Note: Actual measurements were taken to show any programmable attenuator inaccuracies.)

## SECTION IV:  Computers – Minix NEO N42C-4



**FSX11+ Skypipe        SDRPlay2PRO RCP        SDRPlay2PRO LCP**

1. 3@ Minix NEO N42C-4 mini-computers.  This model is upgradeable and has a fan for cooling and runs latest windows 10.  Minix-1 runs the SkypipeII strip chart and FSK11 Spectrograph on same computer.  Note: the audio-in is mono only. Use a USB soundcard for stereo microphone input. Minix-2 runs SRPlay2PRO RCP. Minix-3 runs SDRPlay1PRO LCP.  The computers 12 volt input gets very noisy. It is recommended to keep this voltage isolated.

2. The MINIX NEO N42C-4 includes 2xSODIMM slot (dual channel) RAM, maximum support 8GB + 8GB, i.e. maximum of 16 GB.  Below is a list of DDR3L Memory that's tested and verified to be compatible.
   Kingston BKMH0871451 4GB
   Kingston BPMK16A1447 8GB
   Samsung M471B5173EB0-YKO 4GB
   Samsung M471B1G73QH0-YKO 8GB
   Kingston Technology HyperX Impact - HX316LS9IBK2

3. The procedure for adding an SSD drive to the N42C-4 is incomplete and misleading.  I have upgraded three so far and written below a lessons learned to help you.  It really is an easy procedure. The maximum SSD is 512 GB.

# Procedure to add an SSD drive to a MINIX NEO N42C-4

Take the four rubber feet off the bottom of the Minix computer.

Unscrew the four hidden screws.

Install the new SSD drive into the socket and secure with the top screw.

Here is a list of known compatible M.2 SSD drives for the N42C-4. Must be 512 GB or smaller.

Intel SSDSCKHW120A4 120GB

Kingston SM2280S3G2 120GB
Kingston SM2280S3G2 240GB
Kingston SM2280S3G2 480GB
Lenovo GXB0M41970 128GB
Samsung MZ-N5E120 120GB
Samsung MZ-NTY1280 128GB
Samsung 850 EVO 500GB
SanDisk SD7SN6S 128GB
SanDisk SD8SN8U 256GB
SanDisk SD8SN8U 512GB
Transcend TS256GMTS800 256GB
Western Digital Model WDS240G1G0B-00RC30 240 GB

You must now download and install the special MINIX WIN10 installer.

Download (FTP) the MINIX WIN10 installer from HOST NAME: ftp.minix.cloudftp.hk, USER NAME: f104556.public, PASSWORD: public. Use the FTP program called WINSCP. Filezilla will not work well for this large program.

Un-zip the downloaded file named OSWIN10RS2GDM-N42C-4-EN-US-Pro-Vo2-20171110.zip

Format a 16 GB or larger USB thumb drive with NTFS and copy the unzipped folders to this thumb drive. Name this thumb drive WINPE. It must be named WINPE or the installer program shell can't find the files it needs. Put this thumb drive in the N42C-4 computer USB slot.

Power up your MINIX computer while hitting the Del key to go into the BIOS.

Arrow across to CHIPSET. Set South Cluster to DISABLED.

Press Fn F4 key to save and exit.

Restart MINIX while hitting the delete key to go back into the BIOS.

Arrow over to BOOT. Set the top boot line to boot from WINPE your thumb drive.

Reboot your computer and let the installer run. It will take at least 15 minutes. Do not do anything.

Your computer will reboot at the end of the WIN10 install. On the left side run the clean-up test then reboot. You now have WIN10 installed on your new SSD drive and the internal version is disabled.

## SECTION V: Software

1. **SkyPipeII Pro, strip chart, version 2.7.34** This program from RadioSky Publishing is a powerful tool for amateur radio astronomy.

2. **Spectroscope, v 2.9.0** This software allows you to view signals from special frequency-sweeping receivers at the Windward Community College Radio Observatory (WCCRO) and the University of Florida Radio Observatory (UFRO) and from many volunteer radio astronomers. These receivers, called spectrographs, allow you to see how radio signals are distributed across a 10 MHz wide swath of radio spectrum. The receivers were designed and built by Richard Flagg to be sensitive and fast enough to detect changes which occur in

the radio emissions of the Sun and Jupiter. This software, produced by Radio-Sky Publishing, will run on most modern Windows based computers with an internet connection speed of 56K or more. There is no charge for use of the software for non-commercial users. You can download it from http://jupiter.wcc.hawaii.edu/spectrograph_software.htm All the receivers at K4LED are running RSS version 2.8.50.

3. **Radio Jupiter Pro,** This is Radio-Sky Publishing's multi-function observing aid for Jupiter's decametric radio emissions. This program predicts most likely times for Jupiter radio storms, and displays Jupiter visibility information graphically. Predictions are customized to your location. See help page at http://www.radiosky.com/rjpro/rjprohelp.html for more information.

4. **Python Code for K4LED Automated Calibrator,** The Python code for the automated calibrator is available for free from K4LED upon request.

## SECTION VI: Station Test Equipment

Tektronix MDO 3022 Oscilloscope features six integrated instruments, including a spectrum analyzer.  Rigol 4102 Arbitrary Waveform Generator. Comet Antenna Analyzer CAA-500 Mark II. HP-8640B Signal Generator. HP-5335A Frequency Counter. Fluke 287 True RMS Logging Multi-meter. Micronetics Noise Generator, HP461, Kay Attenuator, and many, many more.
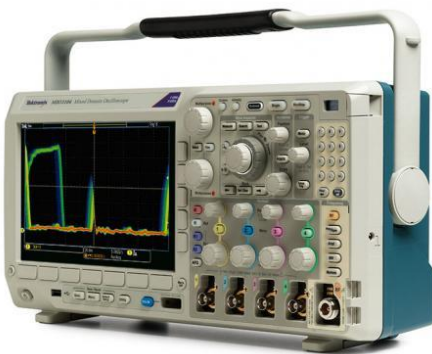
# SECTION VII: Implementation of a K4LED Stratum 1, PTP, GPS Time Server for near zero microsecond accuracy based on the GPS system.



## TIME SERVER FEATURES and SPECIFICATIONS:

- Receive time information from GPS satellites anywhere on the surface of the earth.
- RFC1119/1305 NTP Protocol to serve time (Network Time Protocol).
- RFC1769/2030/4330 SNTP Protocol (Simple Network Time Protocol).
- IEEE 1588 2002/2008 PTP Protocol.
- Server Time Level: Stratum 1.
- NTP Server Time Precision: Better than 1mS + network jitter.
- PTP Server Time Precision: Better than 3uS + network jitter.
- Holdover time: PTP: 1.25+ hrs  NTP: 48+ hrs.
- 10M/100M auto sensing network interface.
- Unit is capable of serving 750+ NTP synchronizations per second. That provides support for over 600,000+ devices updating every 15 minutes on the network.
- Compliant with FCC Part 15B and CE marked for radiated emissions and is a lead free product.
- Power Requirements: 5W at startup and 2.5W continuous at 12V DC.
- Environmental: Commercial temperature range, 0-70C, 95% humidity non-condensing. Altitude -304m to 18,000m.
- Networking: Static or DHCP IPv4 addressing. Standard browser interface for setup.
- Indications: Power, GPS Signal Lock, and 1PPS indications.
- Rear Connections:  Power, Cat5 Ethernet, Serial, Dual USB, and GPS antenna via SMA connection.
- Supports +3.3V and 5V active GPS antennas with internal jumper setting.
- Mechanical Dimensions: 5" x 4.2" x 1.3".

## GPS SPECIFICATIONS:

- Based on MediaTek MT3339 Chipset.
- 22 channel low power receiver module.
- Sensitivity: -165dBm.
- GPS Time Precision: +/- 10ns RMS jitter.
- Antenna Connection: 1575.42MHz (L1 Band).
- TTFF (Time To First Fix).
- Cold start @-125dBm typically 33 seconds.
- Re-acquisition (<10s obstruction) typically 1 second.

## ANTENNA SPECIFICATIONS:

- Active patch antenna with magnetic base.
- Size: 1.57" x 1.89" x 0.51", 43 grams.
- Amplifier: LNA +20dB, Noise: 1.5dB, VSWR: 2.0, Voltage: 2.7-6.0V.
- Cable: RG174, 5m length, SMA male.
- Environmental: -40 to +85C.
- Waterproof to IPx6.

The TimeMachines GPS NTP+PTP Network Time Server represents a major step forward in capabilities at a breakthrough price point. It will supply accurate time for all computers and time keeping devices on the network. Supporting both Precision Time Protocol (PTP) and Network Time Protocol (NTP), a Stratum 1 time source can now be available on the local network with no need for an internet connection. The TM2000A system uses an active GPS antenna to maintain the current time as broadcast by United States GPS satellites planet wide. In addition, a high stability OCXO reference clock is included that allows the unit to serve time if GPS lock is lost for periods of time. The unit is small and can be placed anywhere within the network layout. Outdoor antennas are available from TimeMachines including custom length cables and accessories.

A Stratum 1 GPS PTP network time server, Time Machines TM2000A (~$499) plus (Domain Time II Client $39.99 per computer) PTP client software is installed at this station providing near zero microsecond time accuracy. This network time server attaches to a dedicated Ethernet switched port. A PTP client is implemented on each computer for accurate time corrections. The higher accuracy provides support for highly detailed and specialized scientific studies. – TM2000A PTP Server Time Precision: ~+-5 $\mu$sec or better plus delay, offset, and jitter. (See actual results of the near zero $\mu$sec average deviation from the Stratum 1 Time server obtained at the K4LED Observatory below.)

**The chart below is an actual example of the computer clock drift corrections to maintain a near zero microsecond accuracy at the K4LED Observatory on an RCP SDRPlay2PRO Radio Jove receiver.**

**The center green line indicates the "average" clock deviation from the Stratum 1 Time Server – In this case near zero microseconds.**
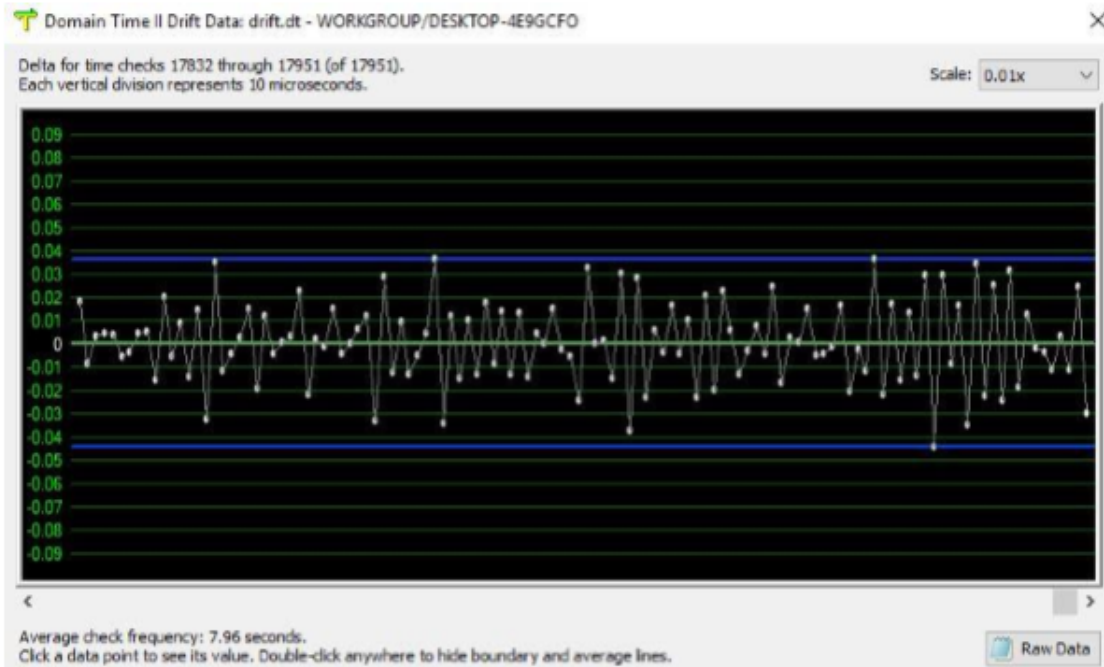
The chart above is an actual example of the computer clock drift corrections to maintain a near zero average microsecond accuracy at the K4LED observatory feeding three Windows 10 computers.

IMPLEMENTING FULL PTP: The "Precision" Time Protocol (PTP) is a protocol used to synchronize clocks throughout a computer network. On a local area network, it achieves high clock accuracy in the microsecond range, making it suitable for precise measurements. This level of precision is further improved with PTP specific software, hardware, network switch and NIC especially designed for PTP precision time. This can become very expensive. The TM2000A is capable of PTP microsecond time with the proper PTP network software and hardware. Even without the proper "hardware" (PTP NIC, PTP Switch, etc.) timing in the microsecond range (5 - 30 microseconds or better) is easily possible.

NOTES: Be aware that only the (TN2000A) solution Level 4, Sub Level C, provides a built in holdover capability. Without a holdover capability the SkyPipe chart or Spectrograph could become corrupted due to poor timing data. The software can be configures to use internet NTP timing during GPS outages. Holdover keeps the clock stable based on the last GPS time data received during periods of satellite outages as experienced during heavy rain storms or heavy cloud cover. Estimated average time accuracy is highly dependent upon local characteristics, computer speed, network configuration, router specifications, cable length, cable type and many other conditions. Other solutions may perform as well or even better but keeping costs to a reasonable level is a consideration. Standardization is desired to facilitate comparison of science investigations from observatories at various locations. Notice in the example below the Ethernet switch is "not" your LAN router but a separate dedicated unmanaged switch dedicate for time distribution.

Time Server Features and Specifications • Receive time information from GPS satellites anywhere on the surface of the earth • RFC1119/1305 NTP Protocol to serve time (Network Time Protocol) • RFC1769/2030/4330 SNTP Protocol (Simple Network Time Protocol) • IEEE 1588:2002/2008 Version 1 and 2 PTP protocol • Server Time Level: Stratum 1 • NTP Server Time Precision: better than 1mS + network jitter. • PTP Server Time Precision: better than 3uS + network jitter. • All networked computing platforms support time synchronization either natively or with add on drivers including: Windows, Macintosh, and Linux. Many other devices can access the device as well including VoIP phones and digital clocks. • 10M/100M adaptive network interface • Unit is capable of serving 750+ NTP synchronizations per second. That provides support for over 600,000+ devices updating every 15 minutes on the network. • Active Patch GPS antenna included. Magnetic base. • Indications: Power, GPS Signal Lock, and 1PPS indications • Rear Connections: Power, Cat5 Ethernet, Serial (NOT FOR CUSTOMER USE), and GPS antenna via SMA connection. Supports +3.3V and 5V active GPS antennas with internal jumper setting. • Serial port outputs data every two seconds, including the following items: - IP, Time, GPS fix, Time known, ptpClockClass, ptpClockAccuracy, ntpStratum. • Mechanical Dimensions: 5 in. x 4.2 in. x 1.3in.

# Example: Ultimate Network Time Configuration

(Skypipe and an FSX11 spectrograph are also on this time server but not shown.)

Outdoor GPS Antenna Puck

Stratum 1 GPS

Receiver/Server

TM2000A    TIME MACHINES

GPS PTP Time Server

CAT7 Cables

tp-link  5-port Gigabit Desktop Switch    TL-SG105

Ethernet Switch

NTP Client software

DC 12V Power Jack    Mini DP    USB-C

Gigabit Ethernet    HDMI 1.4

3.5mm Audio Jack + S/PDIF

DC 12V Power Jack    Mini DP    USB-C

Gigabit Ethernet    HDMI 1.4

3.5mm Audio Jack + S/PDIF

Minix Computer/SDRplay 2 – RCP

Minix Computer/SDRplay 2 - LCP

TFD Antenna

TFD Antenna

**APPENDIX A (Station Images)**
**K4LED Complete station 2' x 4' – RSS - RCP/LCP and FSX11 and Skypipe.**
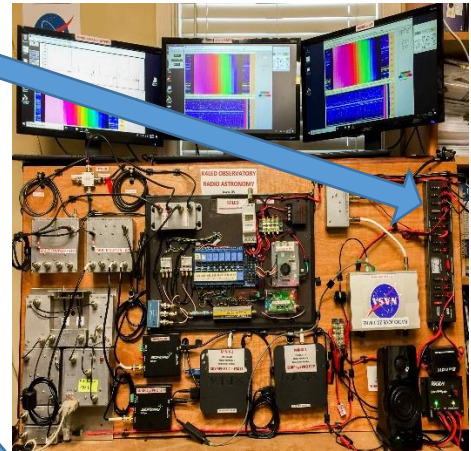**3@ Minix NEO N42C-4 computers and one FSX11 spectrograph.**
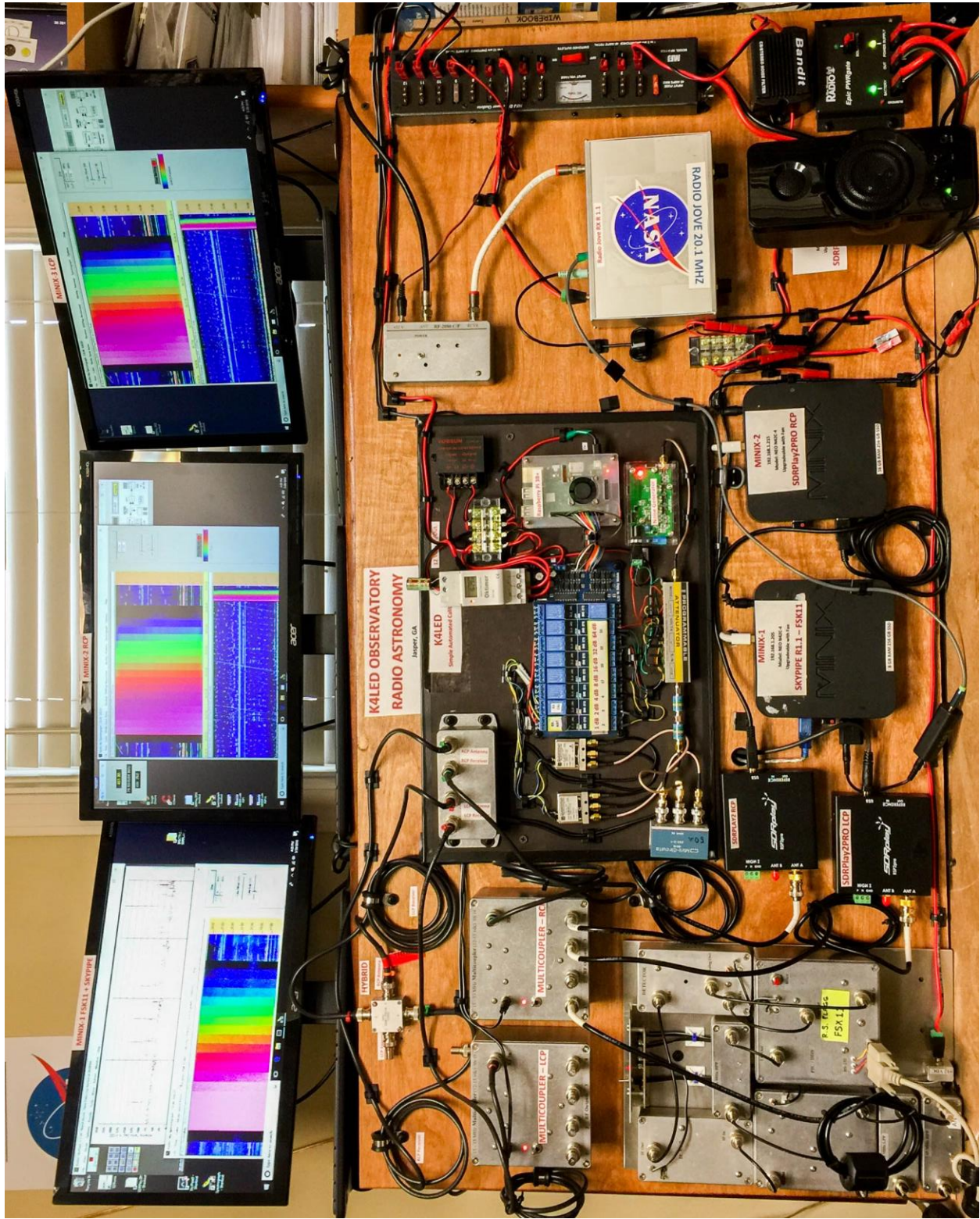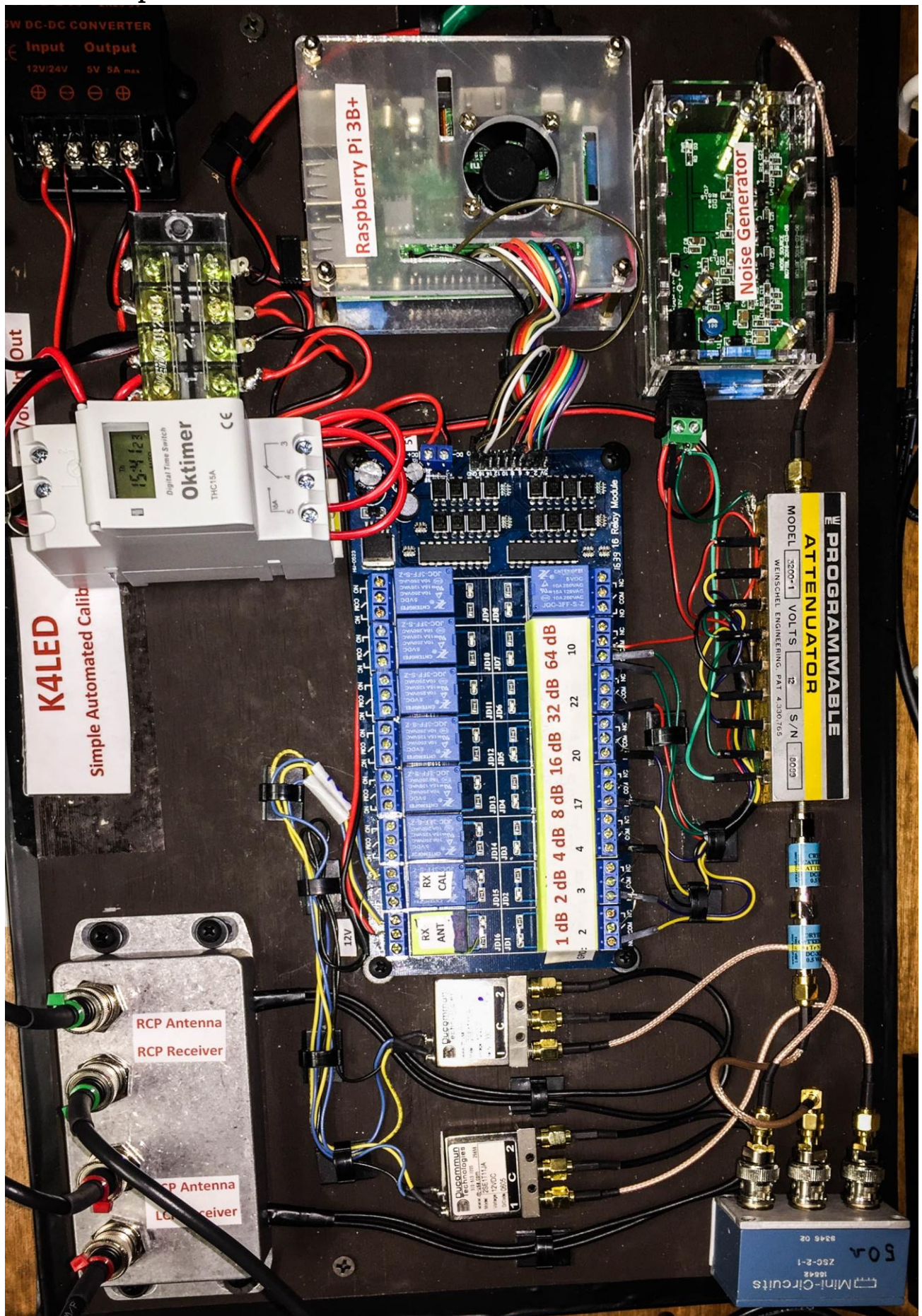
**MFJ-1126 Power Distribution fuse buss and Anderson Power Connectors**

**West Mountain Epic PWRGate**          **Optima BlueTop AGM Batteries – Spill Proof**

- Epic PWRgate is a 12 volt backup power system rated at 40 amperes continuous from either a Power Supply or a Battery.
- Connected equipment will instantly switch to battery during a power blackout or power supply failure.
- Low loss PWRgate provides forward voltage drop of only 0.05 volts.
- USB port access to monitor system or to change charge parameters.
- Program for specific battery types.
- Supports smart charging of either Lead Acid or Li-Ion battery charging up to 10A.
- Optional direct solar panel input for battery charging (all chemistries). Solar panel VOC must be <= 30V.
- Can be programmed for vehicle use to suspend charging when the alternator is off.
- Complete LED status indicators.
- Battery charge suspend button to eliminate current draw or charger noise for 30 minutes.
- Optional temperature probe to control charging based on battery temperature.
- Solid, durable construction in an aluminum case. Includes mounting holes for convenient and safe use in mobile units.
- Uses Anderson Powerpole connectors.
- Includes: Epic PWRgate Unit, USB-micro Cable, (4) Retention Clips, Owners Manual, Reference
- Maximum Voltage: PS 16V / Solar 30V
- Maximum Current: 40 Amperes
- Voltage Drop: 0.05VDC
- Connectors: Anderson Powerpole, 40A
- Size: 4.5 x 3.375 x 1.25 in
- Weight: 0.35 lbs
- Mounting Holes: Four - 0.175 d, #8 hardware

**Canadian Solar
Monocrystalline 100 Watt Solar Panel**

**Astron AC Power Supply**

# APPENDIX C: Antenna Feed System Losses

## AN–TFD–24–4 Antenna and Feed System Losses, K4LED, Feb 2018

| Component: | TFD Elements | Baluns | Element Feeds | Combiners | Main Feeds | Surge Suppressors | Jumpers | Loss Between Element Feed Points and Hybrid Inputs (CAL PLANE) (dB) | Loss Between sky side of element wires and Hybrid Inputs (CAL PLANE) (dB) | Hybrid Ring | Jumpers | Jumpers |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sweep Date: | 27 Aug 2014 | 04 Feb 2018 | 17 Feb 2018 | 04 Feb 2018 | 03 Feb 2018 | 04 Feb 2018 | 17 Feb 2018 | | | 24 Jan 2018 | 17 Feb 2018 | 17 Feb 2018 |
| Mfgr: | AJ4CO | AJ4CO | Belden | Mini-Circuits | Times | PolyPhaser | Times | | | Synergy | Belden | Belden |
| P/N: | TFD-24 | BA-161 | 8259 RG-58 | ZSC-2-1+ | LMR-240DB | IS-50NX-C0 | LMR-240DB | | | DQK-701B | 8259 RG-58 | 8259 RG-58 |
| Descr: | 24' TFD element wire only | 16:1 Balun Two no S/N + S/N 9, 10 | Baluns to J-box | Combiners | J-box to surge suppressors | Surge suppressors | Surge suppressors to hybrid | | | 90° Hybrid S/N 13 | Hybrid to multi-couplers | Multi-couplers to receivers |
| Coax Length: | | | 26' | | 100' | | 22' | | | | 5' | 5' |
| Coax Color: | | | ORG / BLU | | ORG / BLU | | ORG / BLU | | | | GRN / RED | GRN / RED |
| Freq (MHz) | Inefficiency (dB) | Loss (dB) | Loss (dB) | Loss (dB) | Loss (dB) | Loss (dB) | Loss (dB) | (dB) | (dB) | Loss (dB) | Loss (dB) | Loss (dB) |
| 14 | ? | -0.48 | -0.43 | -0.10 | -1.05 | -0.01 | -0.23 | -2.3 | ? | -0.12 | -0.08 | -0.08 |
| 16 | ? | -0.49 | -0.46 | -0.10 | -1.12 | -0.01 | -0.25 | -2.4 | ? | -0.14 | -0.08 | -0.08 |
| 18 | ? | -0.50 | -0.49 | -0.11 | -1.17 | -0.01 | -0.26 | -2.5 | ? | -0.16 | -0.09 | -0.09 |
| 20 | -4.3 | -0.53 | -0.52 | -0.11 | -1.22 | -0.01 | -0.27 | -2.7 | -7.0 | -0.17 | -0.09 | -0.09 |
| 22 | ? | -0.54 | -0.55 | -0.11 | -1.28 | -0.01 | -0.28 | -2.8 | ? | -0.19 | -0.10 | -0.10 |
| 24 | ? | -0.56 | -0.58 | -0.12 | -1.33 | -0.01 | -0.29 | -2.9 | ? | -0.19 | -0.10 | -0.10 |
| 26 | ? | -0.58 | -0.60 | -0.12 | -1.37 | -0.01 | -0.31 | -3.0 | ? | -0.19 | -0.11 | -0.11 |
| 28 | ? | -0.60 | -0.62 | -0.12 | -1.42 | -0.01 | -0.32 | -3.1 | ? | -0.18 | -0.11 | -0.11 |
| 30 | ? | -0.61 | -0.64 | -0.13 | -1.46 | -0.01 | -0.33 | -3.2 | ? | -0.17 | -0.11 | -0.11 |
| 32 | ? | -0.63 | -0.67 | -0.13 | -1.51 | -0.01 | -0.34 | -3.3 | ? | -0.16 | -0.12 | -0.12 |

## Calculated Signal Levels, 20 MHz Galactic Backgorund, K4LED TFD Array, Feb 2018

| | | |
|---|---|---|
| 20 MHz GB (kK) | 50 | |
| BW (MHz) | 15 | |
| GB signal level @ sky (dBm) | -79.8 | |
| Wire element inefficiency (dB) | -4.3 | |
| Signal level @ feed point (balun binding posts) (dBm) | -84.1 | |
| 20 MHz Feed system loss (dB) | -2.7 | |
| Signal level @ hybrid inputs (CAL PLANE) (dBm) | -86.8 | |

| | |
|---|---|
| Hybrid + jumper loss (dB) | -0.3 |
| Signal level @ multicoupler input (dBm) | -87.1 |
| Multicoupler Gain (dB) | +10.0 |
| Signal level @ multicoupler output (dBm) | -77.1 |
| Jumper loss (dB) | -0.1 |
| Signal level @ receiver input (dBm) | -77.2 |