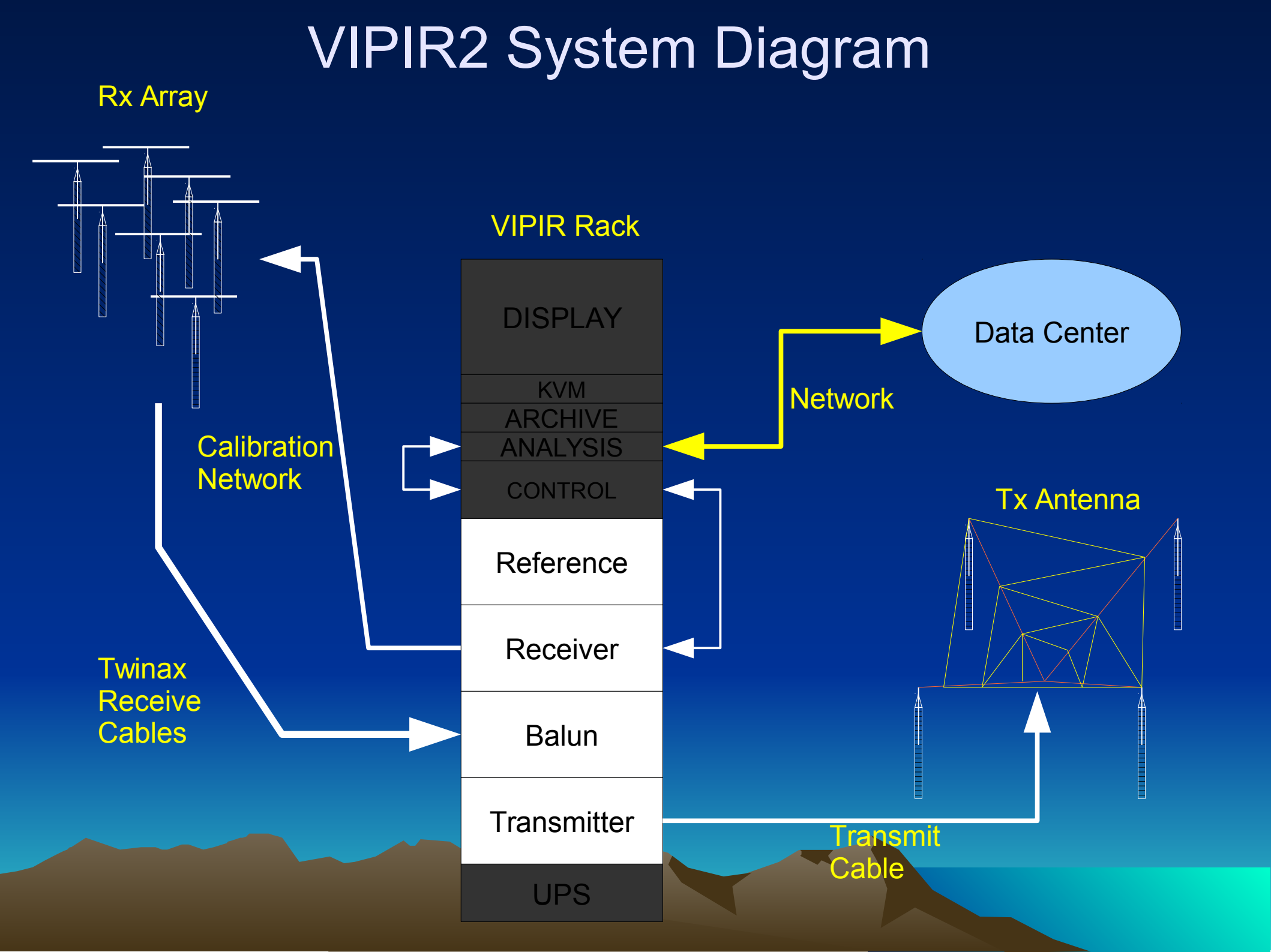
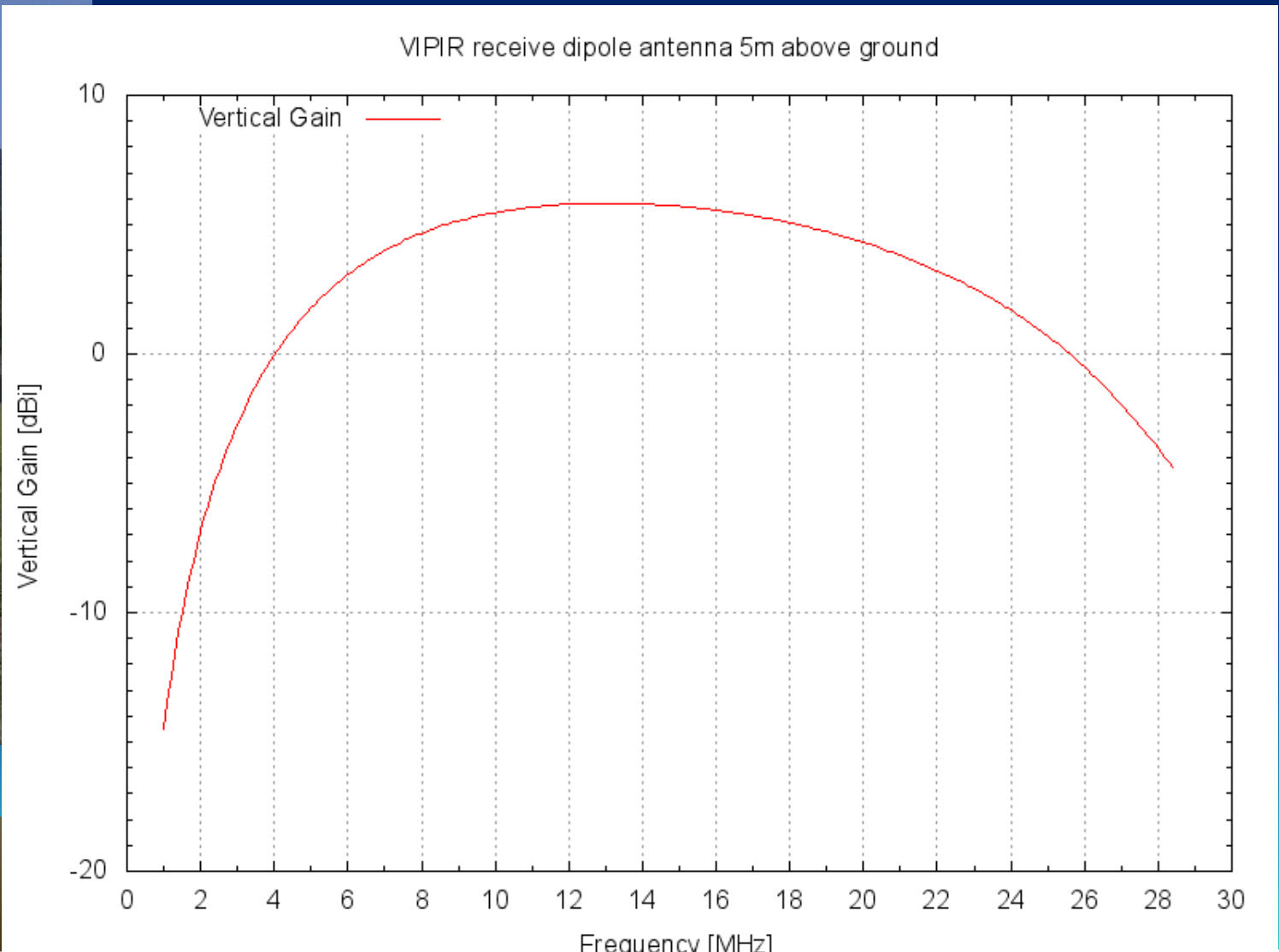
VIPIR2 System Diagram

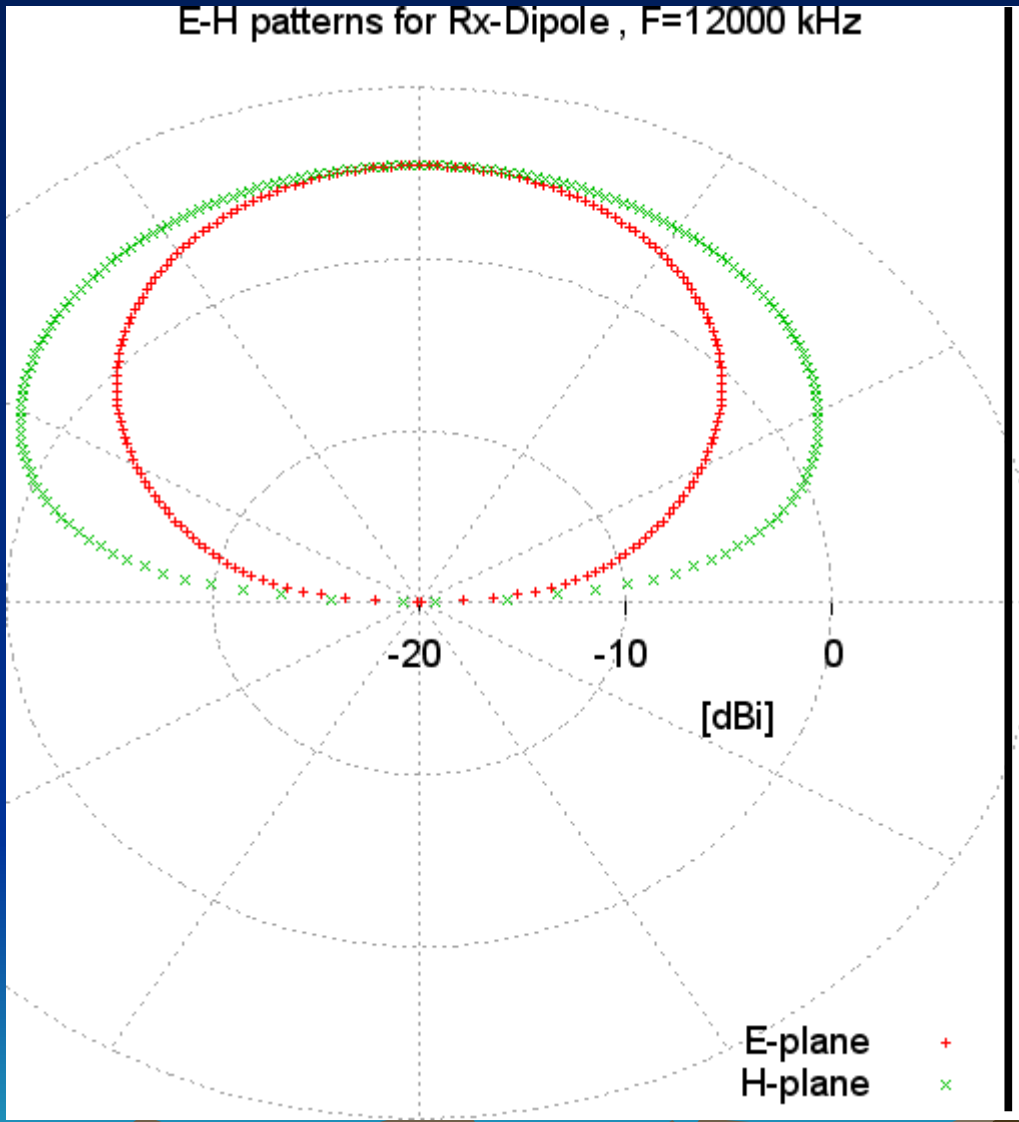


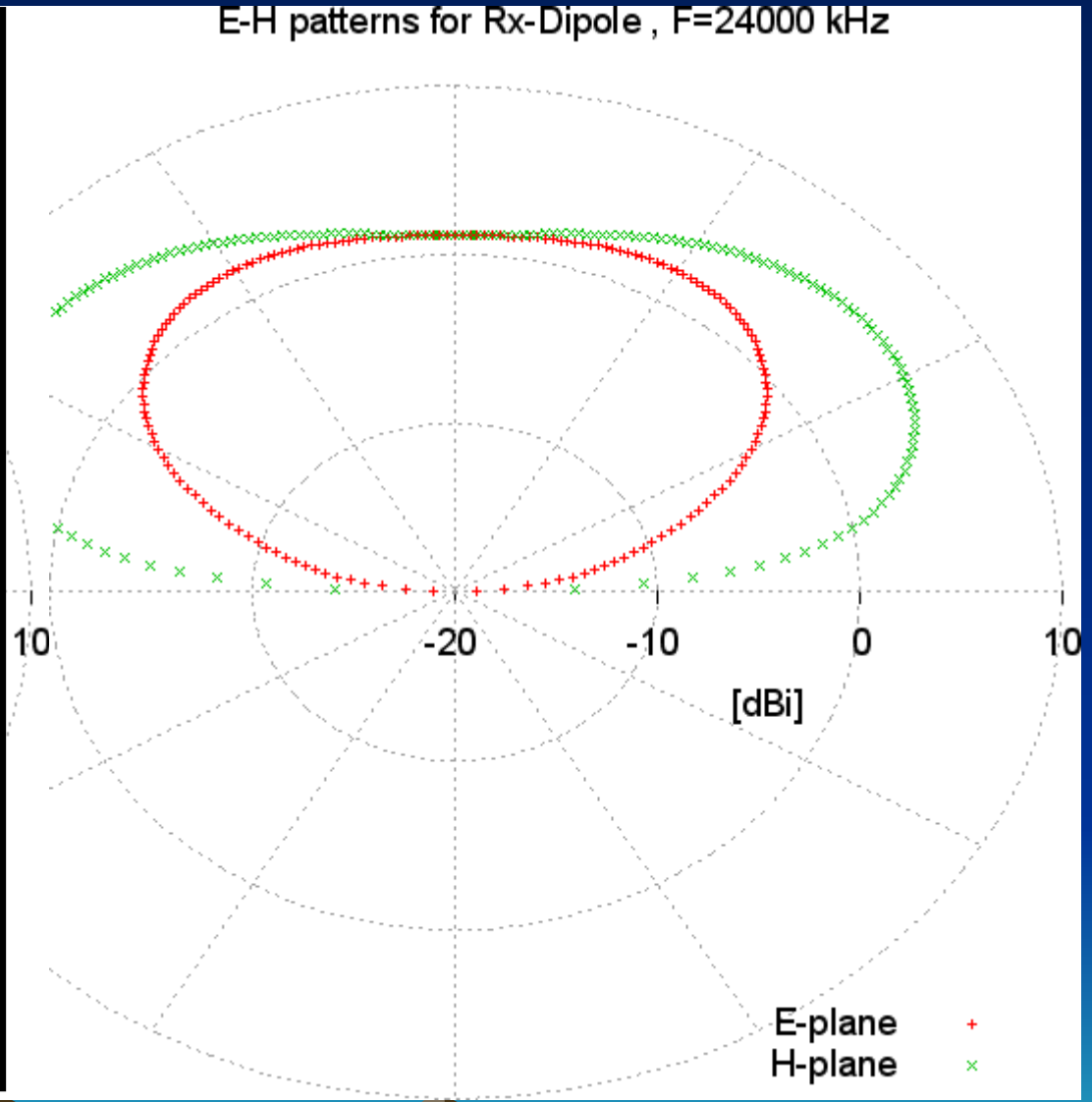
Receive Antennas

4m dipoles , 5m high



Rx Dipole E-H patterns: 12 & 24 MHz





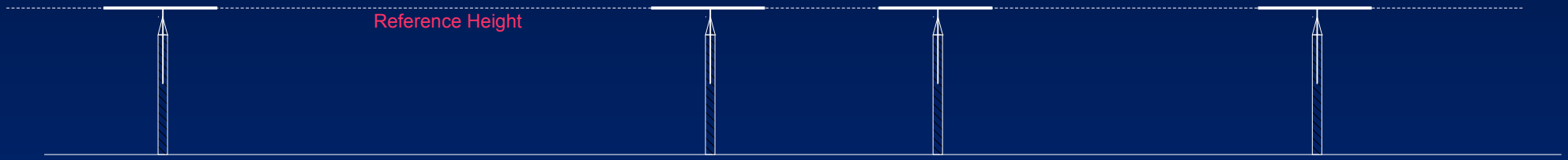
Polarization

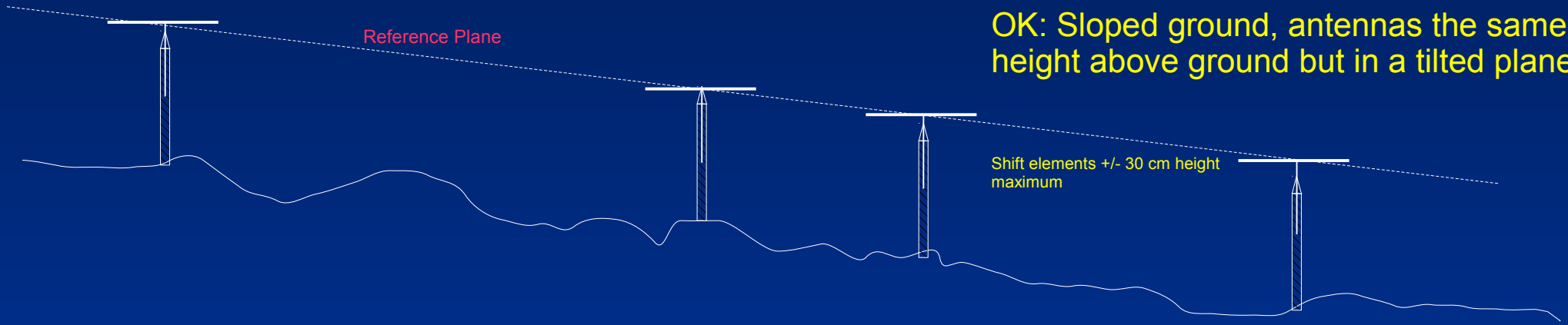
- Ordinary and eXtraordinary polarizations are circular and of opposite rotation
    - Except very near the magnetic equator, it is linear
- Two orthogonal, linearly polarized antennas can form a circularly polarized antenna
    - Digisondes do this in hardware at the antenna
    - VIPIR and Dynasonde do this in the analysis software

San Juan, Puerto Rico

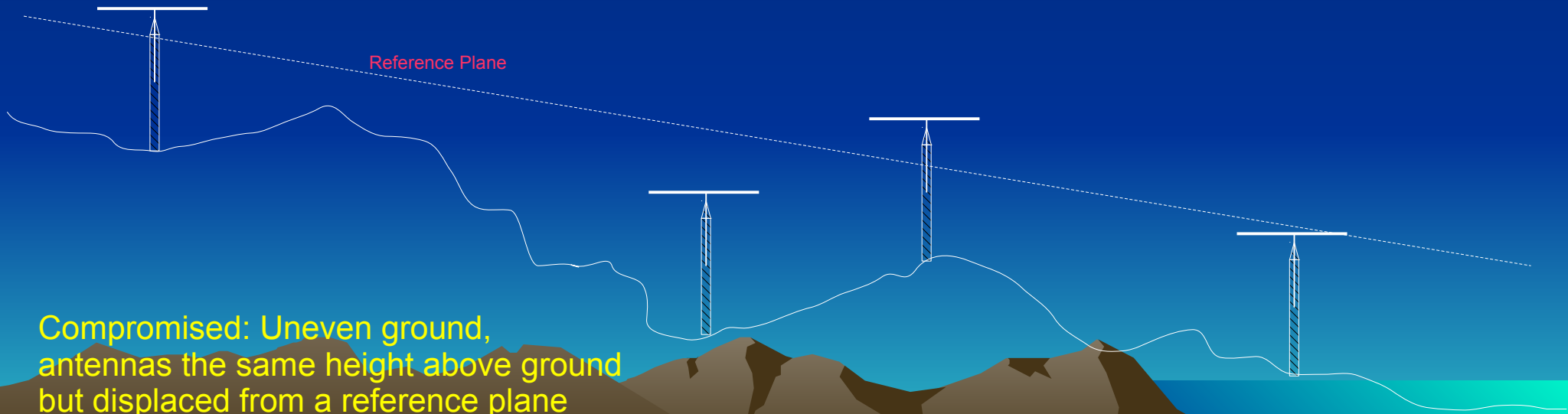
Uneven Ground

Ideal: Uniform, Horizontal ground, antennas the same height above ground





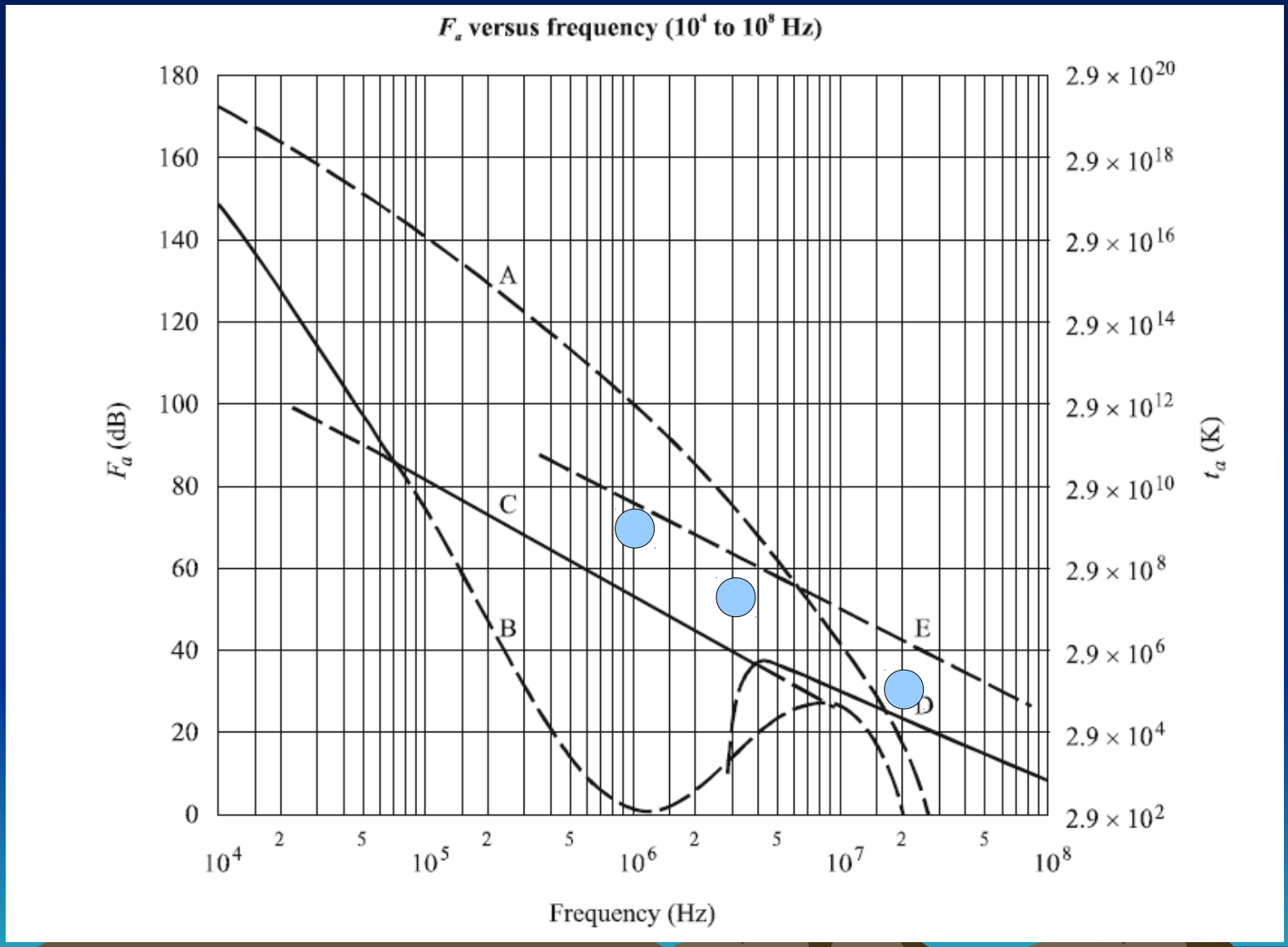
OK: Sloped ground, antennas the same height above ground but in a tilted plane



Compromised: Uneven ground, antennas the same height above ground but displaced from a reference plane

Atmospheric Noise Factor at HF

- Noise below 30 MHz is dominated by atmosphere and man-made sources



A) Atmospheric 99.5%tile

B) Atmospheric 0.5%tile

C) Man-made (Quiet)

D) Galactic

E) Man-made (City)

$At\ \lambda = 300\text{m}$

$F_a \cong 70\text{dB}$

$At\ \lambda = 100\text{m}$

$F_a \cong 50\text{dB}$

$At\ \lambda = 15\text{m}$

$F_a \cong 30\text{dB}$

Source:ITU-R P.372-10 (2009)

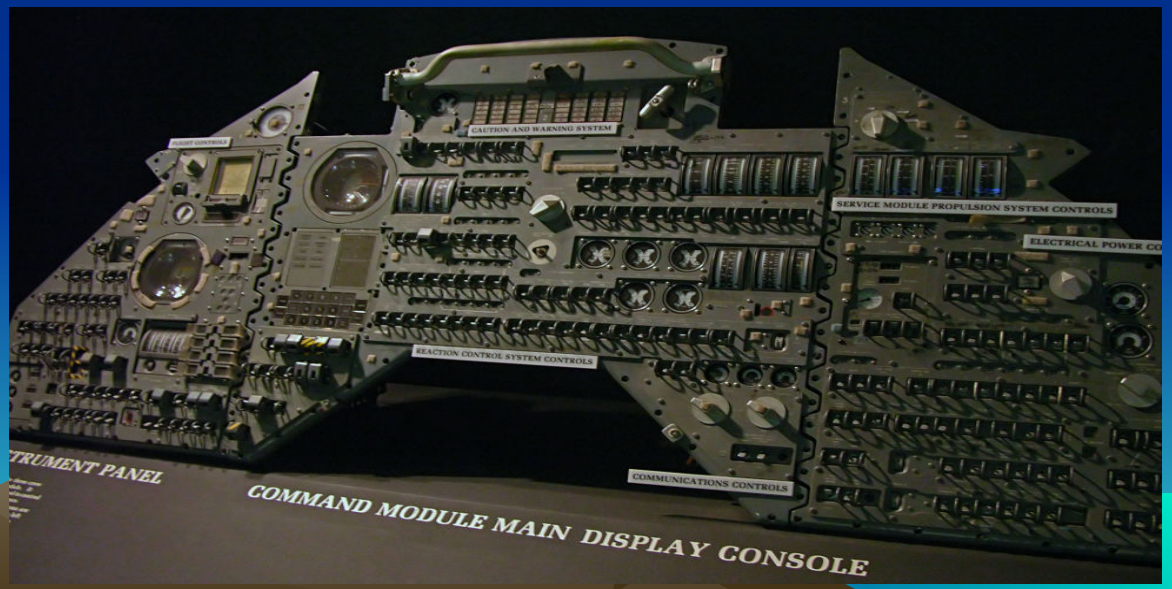
VIPIR Operation

- Operating the VIPIR radar involves editing text files and loading these files into the radar.
  - station.txt – Site specific information
  - freq_settings.txt – Frequency settings
  - timing.txt – Timing settings
  - frequency_table.txt – Arbitrary frequency table
  - ddc_setting.txt – Receiver filter settings
  - duc_settings.txt – Transmitter filter settings
- The continents of these files fill the SCT
- Changing these will break the system

Instead, start looking at the data!

Analysis Software

- There are a number of programs in the riq_ionogram version 2.08 package on analysis
- This software is open source. Install it anywhere!
- There are lots of switches and settings to control the analysis process
- Each code has a -h options to explain the options
- riq_ionogram
- powerplot-ox.sh
- spectrumplot.sh
- calplot.sh



"Use the Source, Luke"

Analysis Computer

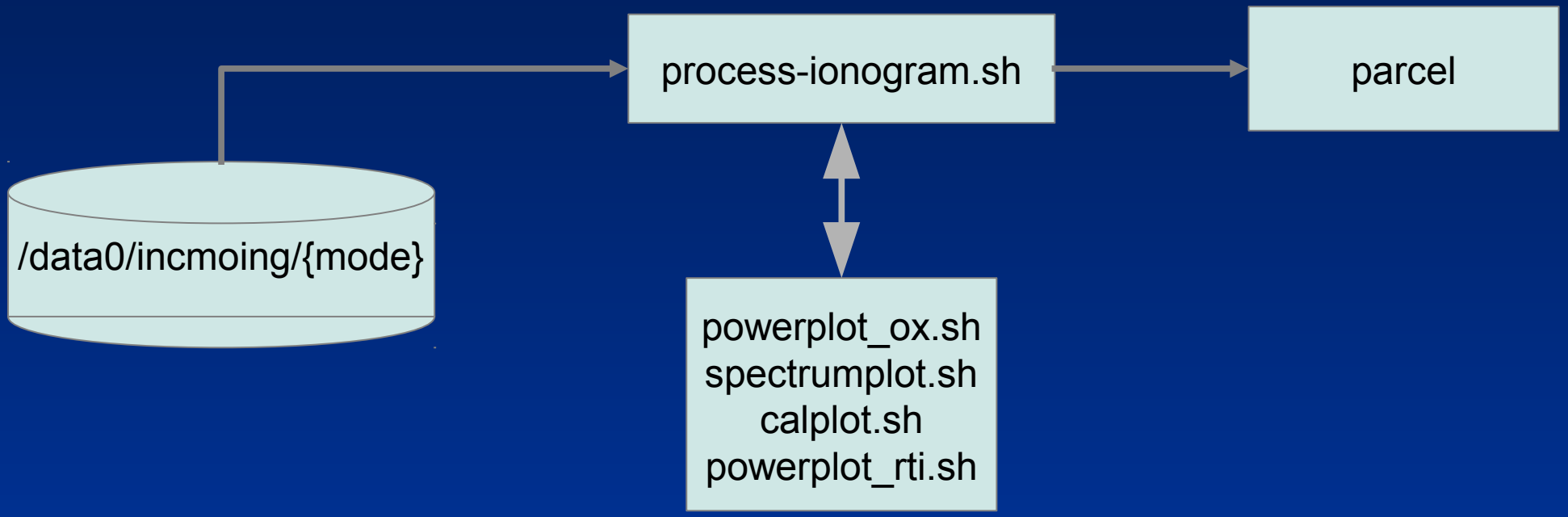
- Receives RIQ files from control
- Generates:
  - NetCDF Grid Ionogram (NGI) File
  - Ionogram Images
  - Spectral Images
  - Calibration Plots
  - Daily SNR plots
- Web server for latest data
- Deliver FTP to remote sites
- Local Archive
- Bash, Fortran, Gnuplot

Analysis Computer Maintenance

- Change the data archive disk when full
  - Data will be backed up onto /data0 and when that is full the system stops working
- Look into log files in /home/analysis/log
  - They tell everything about what is going on
- Read the logwatch emails everyday
  - Who should get these?
-

PROCESS-IONOGRAM

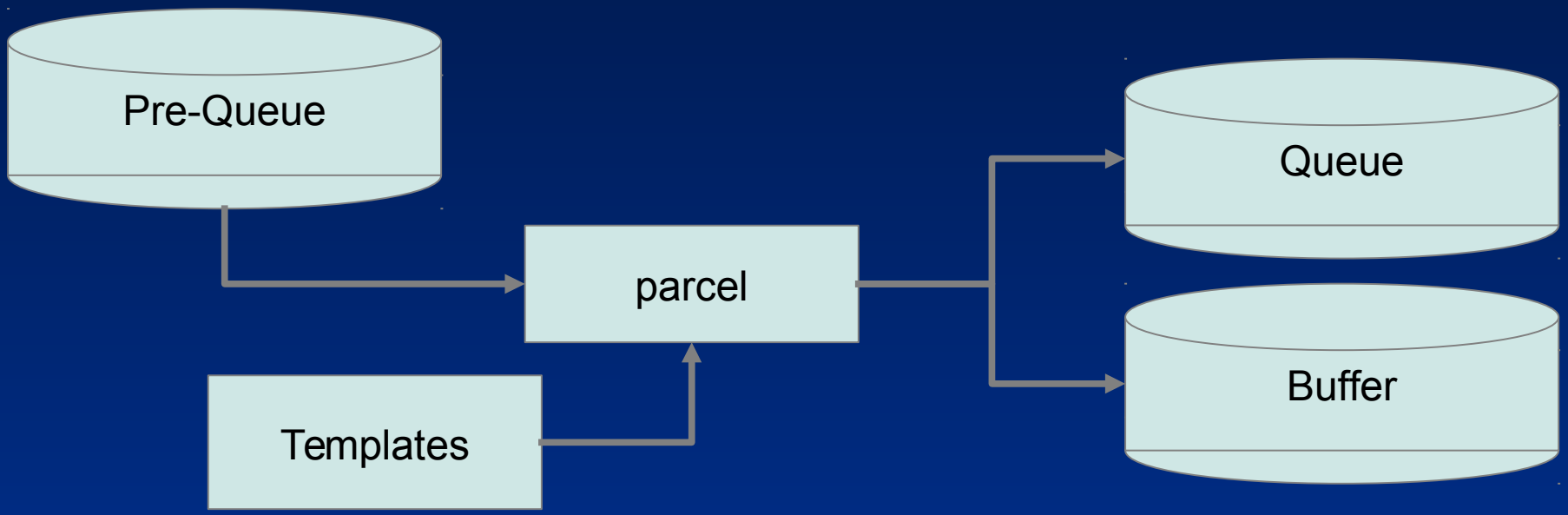
"The Boss"



- Watches for RIQ files in /data0/incoming/{mode}
- Calls scripts to process the data
- Hands results off to "parcel" for further processing

PARCEL

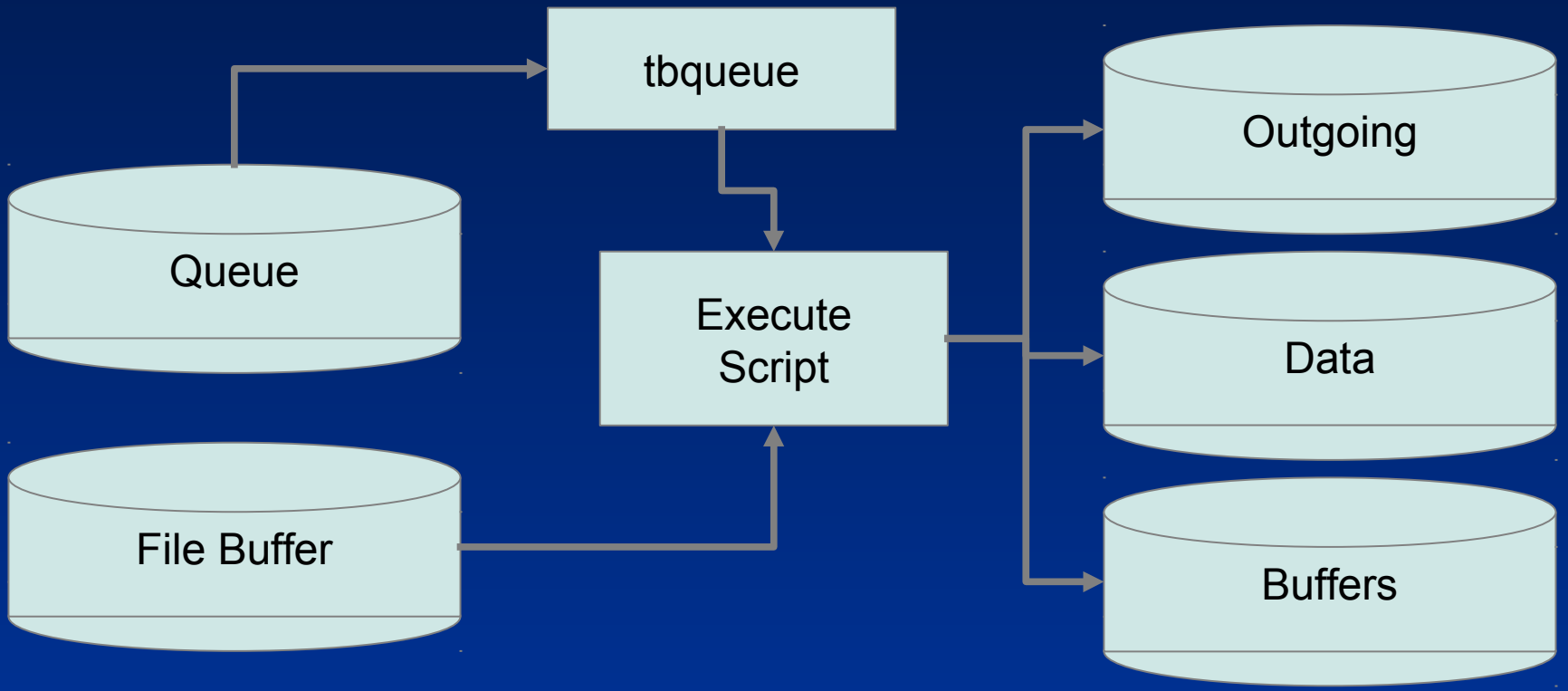
"Middle Manager"



- Templates are partial shell scripts with all file handling commands
- Parcel selects template by file name
- Actual execute script is generated using sed to replace keywords
- Queue shell scripts are prioritized by data age
- Buffer contains the file to be handled

TBQUEUE

"The Secretary"



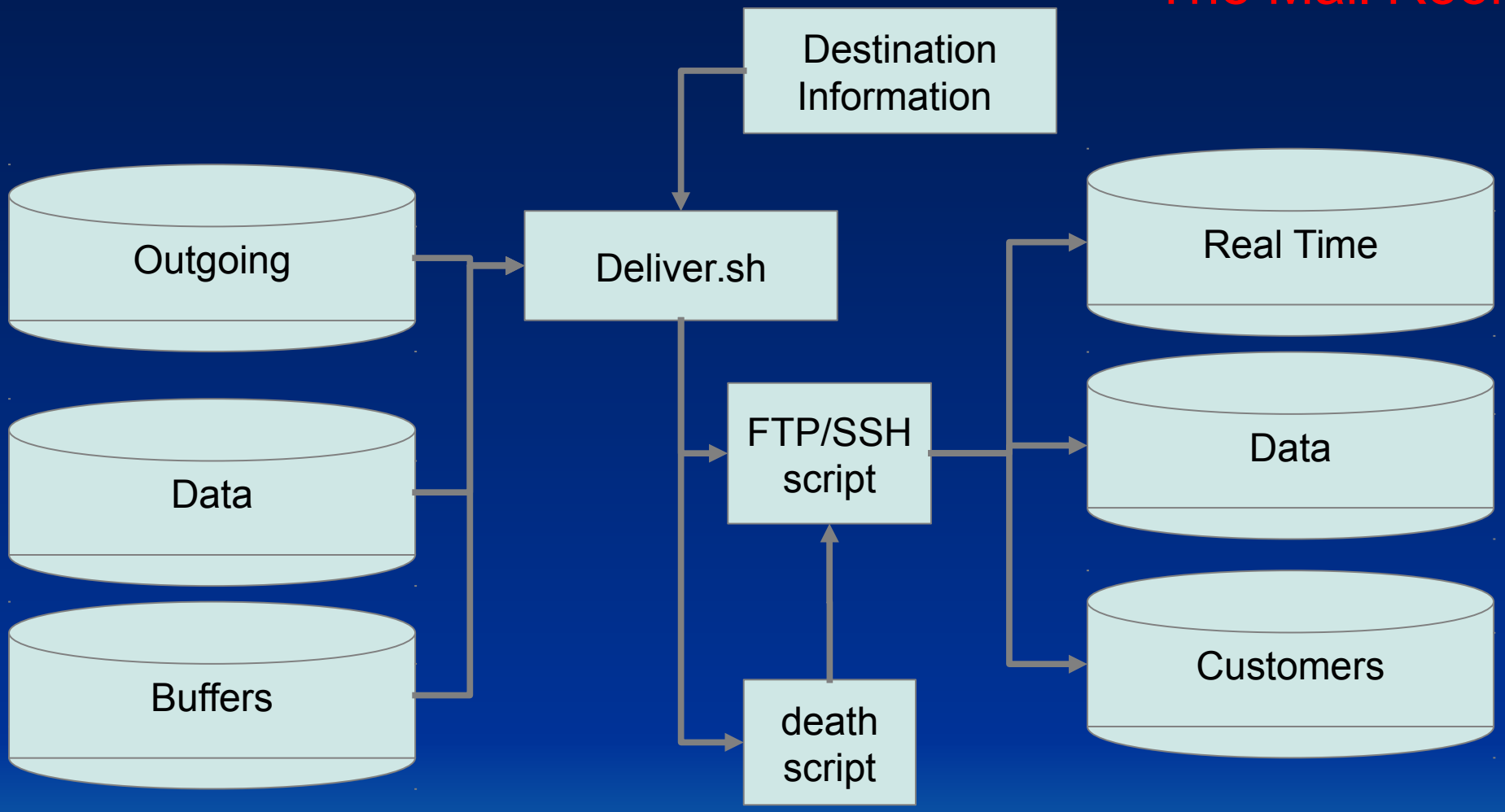
- Extremely simple queue processor just runs execute scripts in order
- Scripts do all the work:
  - Format check
  - QC
  - Fillbuffer.sh --> Local and Remote Archives
  - Highly Extensible
  - Thread safe

FILLBUFFER

- fillbuffer.sh knows how to place files in outgoing buffers
- Multiple destinations possible
- Uses destination.sh for the details

DELIVER

"The Mail Room"



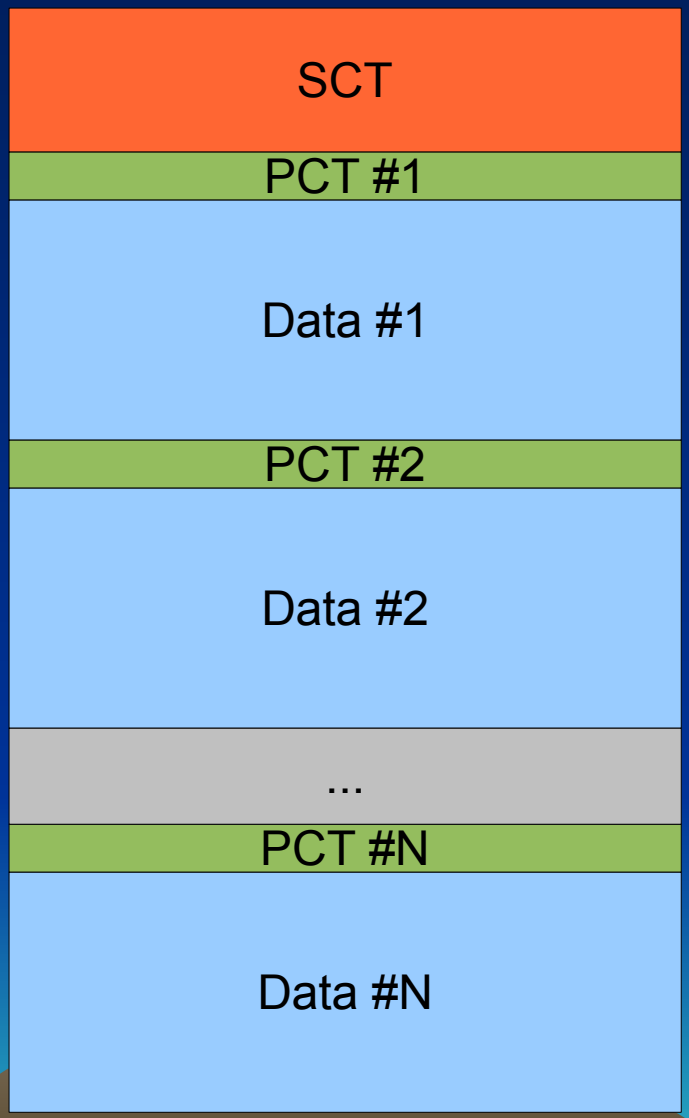
- Takes data from outgoing buffers and delivers to remote data customers
- Robust to FTP and SSH errors and network problems

Data Model Levels

- Level 0 – Raw Data Record
  - RIQ File – Raw radar data and meta-data in instrument specific formats
- Level 1 – Sensor Data Record
  - NetCDF Grid Ionogram (NGI) – Amplitude, polarization, Arrival angle, Doppler, etc as a function of Frequency and Time of Flight
- Level 2 – Environmental Data Record
  - Electron density profile
  - KASI to provide
- Browse Products – Ionogram Images
  - PNG format

RIQ Data Format

- VIPIR data: Raw In-phase and Quadrature



- SCT: Sounding Configuration Table
  - Instrument settings (output)
  - Instrument control (input)
- PCT: Pulse Configuration Table
  - Pulse-to-pulse variable settings
- Data Block
  - 16 or 32 bit values
  - In-phase and Quadrature
  - 8 receivers
  - Requested number of range gates

Sounding Configuration Table

- Binary object used to control the radar and record the instrument settings
- C or FORTRAN structure

```
! Top level Sounding Configuration Table, Version 1.2
!
TYPE :: SCTtype
INTEGER(KIND=4) :: magic                ! magic number 0x51495200
INTEGER(KIND=4) :: sounding_table_size  ! bytes in sounder configuration structure (this file)
INTEGER(KIND=4) :: pulse_table_size     ! bytes in pulse configuration structure
INTEGER(KIND=4) :: raw_data_size        ! bytes in raw data block (one PRI)
REAL(KIND=4)    :: struct_version       ! Format Version Number.  Currently 1.2
INTEGER(KIND=4) :: start_year           ! Start Time Elements of the ionogram (Universal Time)
INTEGER(KIND=4) :: start_daynumber      !
INTEGER(KIND=4) :: start_month          !
INTEGER(KIND=4) :: start_day            !
INTEGER(KIND=4) :: start_hour           !
INTEGER(KIND=4) :: start_minute         !
INTEGER(KIND=4) :: start_second         !
INTEGER(KIND=4) :: start_epoch          ! epoch time of the measurement start.
CHARACTER(128)  :: readme               ! Operator comment on this measurement
INTEGER(KIND=4) :: decimation_method    ! If processed, 0=no process (raw data)
REAL(KIND=4)    :: decimation_threshold ! If processed, the threshold value for the given method
CHARACTER(128)  :: user                 ! user-defined

TYPE(STATIONtype)   :: station      ! Station info substructure
TYPE(TIMINGtype)    :: timing       ! Radar timing substruture
TYPE(FREQUENCYtype) :: frequency    ! Frequency sweep substructure
TYPE(RECEIVERtype)  :: receiver     ! Receiver settings substructure
TYPE(EXCITERtype)   :: exciter      ! Exciter settings substructure
TYPE(MONITORtype)   :: monitor      ! Built In Test values substructure
```

SCT Station

```
TYPE :: STATIONtype
CHARACTER(64)    :: file_id      ! name of station settings file
CHARACTER( 8)    :: ursi_id      ! URSI standard station ID code
CHARACTER(32)    :: rx_name      ! Receiver Station Name
REAL(KIND=4)     :: rx_latitude  ! Position of the Receive array reference point [degrees North]
REAL(KIND=4)     :: rx_longitude !                                                [degrees East]
REAL(KIND=4)     :: rx_altitude  ! meters above mean sea level
INTEGER(KIND=4)  :: rx_count     ! Number of defined receive antennas
CHARACTER(32),DIMENSION(32)  :: rx_antenna_type ! Rx antenna type text descriptors
REAL(KIND=4),DIMENSION(3,32) :: rx_position     ! X,Y,Z = (East,North,Up) Positon [m] of each Rx
REAL(KIND=4),DIMENSION(3,32) :: rx_direction    ! X,Y,Z = (East,North,Up) Direction of each Rx
REAL(KIND=4),DIMENSION(32)   :: rx_height       ! Height above ground [m]
REAL(KIND=4),DIMENSION(32)   :: rx_cable_length ! physical length of receive cables [m]
REAL(KIND=4)     :: frontend_atten  ! Front End attenuator setting
CHARACTER(32)    :: tx_name         ! Transmitter Station Name
REAL(KIND=4)     :: tx_latitude     ! Position of the Transmit Antenna reference point [degrees North]
REAL(KIND=4)     :: tx_longitude    !                                                  [degrees East]
REAL(KIND=4)     :: tx_altitude     ! meters above mean sea level
CHARACTER(32)    :: tx_antenna_type ! Tx antenna type text descriptors
REAL(KIND=4),DIMENSION(3) :: tx_vector ! tx antenna direction vector [m]
REAL(KIND=4)     :: tx_height           ! antenna height above reference ground [m]
REAL(KIND=4)     :: tx_cable_length     ! physical length of transmit cables [m]
INTEGER(KIND=4)  :: drive_band_count    ! Number of antenna drive bands
REAL(KIND=4),DIMENSION(2,64) :: drive_band_bounds ! drive bands start/stop in kHz
REAL(KIND=4),DIMENSION(64)   :: drive_band_atten  ! antenna drive atteunuation in dB
INTEGER(KIND=4)  :: rf_control   ! -1 = none, 0 = drive/quiet, 1 = full, 2 = only quiet, 3 = only atten
CHARACTER(32)    :: ref_type     ! Type of reference oscillator
CHARACTER(32)    :: clock_type   ! Source of absoulte UT timing
CHARACTER(128)   :: user         ! Spare space for user-defined information
END TYPE STATIONtype
```

SCT Timing

```
! Timing of the measurement
TYPE :: TIMINGtype   ! Time values are in microseonds unless otherwise indicated
CHARACTER(64)   :: file_id           ! Name of the timing settings file
REAL(KIND=4)    :: pri               ! Pulse Repetition Interval (PRI) (microseconds)
INTEGER(KIND=4) :: pri_count         ! number of PRI's in the measurement
INTEGER(KIND=4) :: ionogram_count    ! repeat count for ionogram within same data file
REAL(KIND=4)    :: holdoff           ! time between GPS 1 pps and start
REAL(KIND=4)    :: range_gate_offset ! true range to gate 0
INTEGER(KIND=4) :: gate_count        ! Number of range gates, adjusted up for USB blocks
REAL(KIND=4)    :: gate_start        ! start gate placement [us], adjusted
REAL(KIND=4)    :: gate_end          ! end gate placement [us], adjusted
REAL(KIND=4)    :: gate_step         ! range delta [us]
REAL(KIND=4)    :: data_start        ! data range placement start [us]
REAL(KIND=4)    :: data_width        ! data pulse baud width [us]
INTEGER(KIND=4) :: data_baud_count   ! data pulse baud count
CHARACTER(64)   :: data_wave_file    ! data baud pattern file name
COMPLEX(KIND=4),DIMENSION(1024) :: data_baud ! data waveform baud pattern
INTEGER(KIND=4) :: data_pairs        ! number of IQ pairs in waveform memory
REAL(KIND=4)    :: cal_start         ! cal range placement start [us]
REAL(KIND=4)    :: cal_width         ! cal pulse baud width [us]
INTEGER(KIND=4) :: cal_baud_count    ! cal pulse baud count
CHARACTER(64)   :: cal_wave_file     ! alternative baud pattern file name
COMPLEX(KIND=4),DIMENSION(1024) :: cal_baud ! cal waveform baud pattern
INTEGER(KIND=4) :: cal_pairs         ! number of IQ pairs in waveform memory
CHARACTER(128)  :: user              ! Spare space for user-defined information
END TYPE TIMINGtype
!
```

SCT Frequency

```
TYPE :: FREQUENCYtype  ! Values are in kilohertz unless otherwise indicated
CHARACTER(64)  :: file_id      ! Frequency settings file
REAL(KIND=4)   :: base_start   ! Initial base frequency
REAL(KIND=4)   :: base_end     ! Final base frequency
INTEGER(KIND=4):: base_steps   ! Number of base frequencies
INTEGER(KIND=4):: tune_type    ! Tuning type flag:  1=log, 2=linear, 3=table, 4=ShuffleMode
REAL(KIND=4),DIMENSION(8192) :: base_table ! Nominal or Base frequency table
REAL(KIND=4)   :: linear_step   ! Linear frequency step [kHz]
REAL(KIND=4)   :: log_step      ! Log frequency step, [percent]
CHARACTER(64)  :: freq_table_id ! Manual tuning table filename
INTEGER(KIND=4):: tune_steps    ! all frequencies pre-ramp repeats
INTEGER(KIND=4):: pulse_count   ! pulset frequency vector length
INTEGER(KIND=4),DIMENSION(256) :: pulse_pattern ! pulset frequency vector
REAL(KIND=4)   :: pulse_offset  ! pulset offset [kHz]
INTEGER(KIND=4):: ramp_steps    ! pulsets per B-mode ramp (ramp length,base freqs per B-block)
INTEGER(KIND=4):: ramp_repeats  ! repeat count of B-mode ramps
REAL(KIND=4),DIMENSION(8192):: drive_table ! base frequencies attenuation/silent table
CHARACTER(128) :: user          ! Spare space for user-defined information
END TYPE FREQUENCYtype
```

SCT Receiver and Exciter

```
! Receiver Settings
TYPE :: RECEIVERtype
CHARACTER(64)    :: file_id        ! Frequency settings file
INTEGER(KIND=4) :: rx_chan         ! Number of receivers
INTEGER(KIND=4),DIMENSION(16) :: rx_map ! receiver-to-antenna mapping
INTEGER(KIND=4) :: word_format     ! 0=big endian fixed, 1=little endian, 2=floating_point
INTEGER(KIND=4) :: cic2_dec        ! DDC filter block
INTEGER(KIND=4) :: cic2_interp     ! DDC filter block
INTEGER(KIND=4) :: cic2_scale      ! DDC filter block
INTEGER(KIND=4) :: cic5_dec        ! DDC filter block
INTEGER(KIND=4) :: cic5_scale      ! DDC filter block
CHARACTER(32)    :: rcf_type       ! text descriptor of FIR filter block
INTEGER(KIND=4) :: rcf_dec         ! decimation factor for FIR filter block
INTEGER(KIND=4) :: rcf_taps        ! number of taps in FIR filter block
INTEGER(KIND=4), DIMENSION(160) :: coefficients   ! Receiver filter coefficients
REAL(KIND=4)     :: analog_delay   ! analog delay of receiver, us
CHARACTER(128)   :: user           ! Spare space for user-defined information
END TYPE RECEIVERtype
!
! Exciter Settings
TYPE :: EXCITERtype
CHARACTER(64)    :: file_id         ! Frequency settings file
INTEGER(KIND=4) :: cic_scale       ! DUC filter block
INTEGER(KIND=4) :: cic2_dec        ! DUC filter block
INTEGER(KIND=4) :: cic2_interp     ! DUC filter block
INTEGER(KIND=4) :: cic5_interp     ! DUC filter block
CHARACTER(32)    :: rcf_type       ! text descriptor of FIR filter block
INTEGER(KIND=4) :: rcf_taps        ! number of taps in FIR filter block
INTEGER(KIND=4) :: rcf_taps_phase ! number of taps in FIR filter block
INTEGER(KIND=4), DIMENSION(256) :: coefficients   ! Receiver filter coefficients
REAL(KIND=4)     :: analog_delay   ! analog delay of exciter/transmitter, us
CHARACTER(128)   :: user           ! Spare space for user-defined information
END TYPE EXCITERtype
```

SCT monitor and PCT

```
! System status and Built-In-Test info
TYPE :: MONITORtype
INTEGER(KIND=4),DIMENSION(8) :: balun_currents  ! As read prior to ionogram
INTEGER(KIND=4),DIMENSION(8) :: balun_status    ! As read prior to ionogram
INTEGER(KIND=4),DIMENSION(8) :: front_end_status! As read prior to ionogram
INTEGER(KIND=4),DIMENSION(8) :: receiver_status ! As read prior to ionogram
INTEGER(KIND=4),DIMENSION(2) :: exciter_status  ! As read prior to ionogram
CHARACTER(512) :: user                          ! Spare space for user-defined information
END TYPE MONITORtype

! Pulse Configuration Table   Version 1.2
TYPE :: PCTtype
INTEGER(KIND=4) :: record_id           ! Sequence number of this PCT
REAL(KIND=8)    :: pri_ut              ! UT of this pulse
REAL(KIND=8)    :: pri_time_offset     ! Time read from system clock, not precise.
INTEGER(KIND=4) :: base_id             ! Base Frequency counter
INTEGER(KIND=4) :: pulse_id            ! pulse set element for this PRI
INTEGER(KIND=4) :: ramp_id             ! ramp set element for this PRI
INTEGER(KIND=4) :: repeat_id           ! ramp repeat element for this PRI
INTEGER(KIND=4) :: loop_id             ! Outer loop element for this PRI
REAL(KIND=4)    :: frequency           ! Frequency of observation (kHz)
INTEGER(KIND=4) :: nco_tune_word       ! Tuning word sent to the receiver
REAL(KIND=4)    :: drive_attenuation   ! Low-level drive attenuation [dB]
INTEGER(KIND=4) :: pa_flags            ! Status flags from amplifier
REAL(KIND=4)    :: pa_forward_power    ! Forward power from amplifier
REAL(KIND=4)    :: pa_reflected_power  ! Reflected power from amplifier
REAL(KIND=4)    :: pa_vswr             ! Voltage Standing Wave Ratio from amplifier
REAL(KIND=4)    :: pa_temperature      ! Amplifier temperature
INTEGER(KIND=4) :: proc_range_count    ! Number of range gates kept this PRI
REAL(KIND=4)    :: proc_noise_level    ! Estimated noise level for this PRI
CHARACTER(64)   :: user                ! Spare space for user-defined information
END TYPE PCTtype
```

NetCDF Grid Ionogram

- *"NetCDF is a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data."* – UCAR/UniData
- The VIPIR NetCDF was based on NOAA weather radar data formats to meet NOAA archive requirements
- How to document a self-documenting file format?
  - ncdump
- This can not be done in a presentation format