IONOS SIM HF/VHF Channel Simulator

BUSY DETECT Busy Channel Detector

Instructions, Basic Documentation, and Specifications

Ref: Software Beta revision 0.9.14   Rick Muething, KN6KB May 8, 2020

1.0 Introduction: The Teensy **IONOS SIM** is an audio processing 1-4 path (ray) simulator that models standard HF and VHF propagation channels. It is intended primarily for modem and protocol design, analysis, optimization and comparison. It allows non-radio testing of protocols and modems using statistically standardized channels that would be almost impossible to achieve with normal "over the air" RF testing. The simulator is based on the well-documented Watterson model [1] used by many laboratory grade instruments costing many thousands of dollars.

2.0 Basic Description: The **IONOS SIM** Simulator is based on the low-cost but powerful Teensy 4.0 processor (https://www.pjrc.com/store/teensy40.html) and was developed using the Arduino platform and makes extensive use of the Teensy Audio DSP library https://www.pjrc.com/teensy/gui/index.html . The IONOS SIM software is released under the MIT Open Source License (see appendix). A simplified block diagram of the simulator is shown below in Fig 1.

Fig 1. Teensy IONOS HF/VHF Channel Simulator block diagram.

[1] Watterson, C.C., J.R. Juroshek, & W.D. Bensema. 1970 Experimental confirmation of an HF channel model IEEE Transaction of Communication. Technology. Vol COM-18. Pp 792-803 Dec 1970

3.0 Basic Layout: The Basic layout of the Simulator is shown in Figs 2 & 3. The simplified user interface consists of just 2 rotary encoders (each with push switch) and a small color graphics TFT display mounted in an ~ 4" x 6" customized PolyCase enclosure. The simulator is powered through its micro USB connector which also provides optional USB serial I/O for computer-controlled operation if desired. Audio input (2 mono channels) and audio output (2 mono channels) connections are made using standard 1/8" (3.5 mm) stereo phone jacks.

Fig 2. Basic control/display layout (Rev 2 prototype) Schematic, PCB design, layout assembly and test by Tom Lafleur KA6IQA
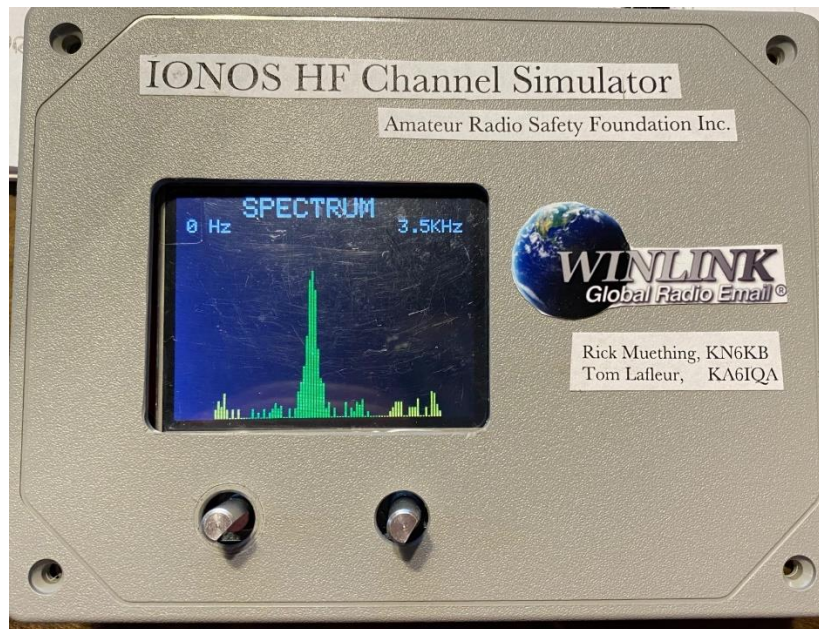
Fig 3. Revision 2 in Protype Case

3.1 Power on Automated self test. There is a simple mechanism for automated self-test and calibration verification. First connect the output jack to the input jack with a standard Stereo 1/8" (3.5 mm) 3 conductor male patch cord.   This jumpers the CH1 and CH2 output amplifiers to the CH1 and CH2 input buffers. The self-test software will block the normal in to out loop to avoid oscillations and accurately measure the response of the precision internally generated test signal and the injection of that signal into the inputs. This verifies: a) Connections and wiring to the output and input jacks, b) proper amplifier resistor values/tolerance, c) proper low frequency coupling capacitors, d) All Teensy Audio processing and DSP FIR filtering, e) Frequency response on both 3KHz and 6KHz bandwidths (Flat +/- .5dB). The self-test is also useful in setting up initial modem output levels.

3.1.1 Running the Self Test. With the patch jumper above in place, power on the IONOS Simulator by plugging in the USB port. The software and self-test software are already loaded. After the power on display of the current code revision (e.g. IONOS SIM 0.9.7 etc.) the display will enter the normal power on mode (WGN mode with S:N = 40 dB). Rotate the Mode (left hand encoder) knob 16 clicks CW to activate the TEST3K Sine: selftest. This will set up a 1548 Hz test sine wave at a specific amplitude and begin averaging the p-p (peak to peak) voltage readings at the input buffers (Ch1 in, Ch2 in) and output Amps (Ch1 Out, Ch2 Out). Averaging is used to increase accuracy and after about 5 seconds the average measurements should stabilize to stable values (all values in p-p mv). If the values displayed are all green text, the measurements are with +/- .5 dB…the basic accuracy of the simulator. Any values in red text are outside the +/- .5 dB limit above. Different levels for Ch1 and Ch2 are used to verify no cross-coupling. The entire range of frequencies for the 3 KHz bandwidth can be tested by rotating the right hand (parameter) knob. Frequency range for the TEST3K will range from 86 Hz to 3182 Hz. During the test you can toggle to the Spectrum display by pushing down on the Mode (left hand) encoder. Pushing again will toggle back to the TEST3K display.

In a similar way rotating the mode knob CW one additional click (17 clicks from Power on WGN position) will enable the TEST6K test. It works exactly the same as the TEST3K but the frequency range spans 172 Hz to 6192 Hz. It exercises different FIR filters used in the 6 KHz bandwidth mode. Again, you may have to wait a few seconds for reading averages to stabilize. The 6 KHz mode swaps the Ch1/Ch2 amplitudes from the 3 KHz test insuring all paths are independent and work at full amplitude.

Fig 4.   Example Screens for TEST3K   an TEST6K self-test and calibration.

Green text indicates parameter within +/- .5 dB and values can vary about 5% from those shown above.

3.2 Getting Familiar with the controls and displays of IONOS SIM. You can gain familiarity with the simulator without hooking it up to any modems or TNCs. An earphone (mono or stereo) plugged into the Ch1,2 output jack will be helpful. Upon power-up after plugging in to a +5 v powered micro USB port the TFT display will Activate and show IONOS SIM version xxxxx for three seconds before going to the *Basic Mode* display. There it will show the current mode "WGN:" in blue text and the current parameter value for that mode which will be "S:N= 40 dB" in green text. WGN (White Gaussian Noise) is the most basic mode and one that will be used often for setup and initial testing runs. Rotate the right hand encoder (parameter) CW or CCW to roll through the S:N options (-40 to +40 dB). The display of mode settings/parameters and text colors are similar for the 14 other modes shown in Fig 7. (The self-test modes TEST3K and TEST6K are shown in magenta to distinguish them from normal operating modes) Most modes and settings can be left at their power on defaults for basic testing. For modes WGN-MPP pushing down on the right encoder until it clicks will toggle the internal 1500 Hz test tone on/off. You should hear the tone in the earphone and adjusting the S:N lower should increase the noise. Most people can still hear the signal down to about -10 to -15 dB below the noise (all dB measurements and calculation are based on the operational bandwidth (3000/6000 Hz). In other modes pushing down on the right encoder will save the current mode parameter to EEPROM as the power on default value. For modes WGN-MPD pushing on the left encoder knob should switch the display to the *Spectrum* mode (3.5 or 6.5 KHz). There you should see the test tone and the background
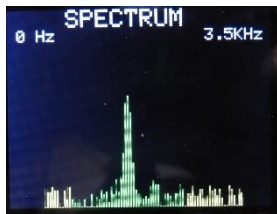
noise (white noise filtered to bandwidth) displayed. The vertical plotting scale of the spectrum analyzer is logarithmic and covers approx. 60 dB dynamic range. Each spectrum line (2 pixels wide for 0 to 3500 Hz) represents one ~43 Hz frequency bin. Toggle off the spectrum display with another push of the mode knob) to return to the *Basic Mode* display. Now select a multipath mode (say MPP for Multi Path Poor). Push the Mode (left) encoder once to switch back to the spectrum display. There you will see the impact the 4 ray multipath distortion created by the simulator has on the 1500 Hz test tone. MPP is a rather poor channel and HF digital communications on this path are often marginal. Another push of the Mode (left) encoder will toggle

to the *IQ Plane* display. This display shows dynamically how the 4 audio channels (In phase or *I* and quadrature or *Q*) for two audio paths (4 total "rays") are dynamically altered by the simulator. The display plots white and green "dots" corresponding to the calculated I & Q delay shifts for 4 audio rays on the IQ delay plane. The speed of the update is 32 x the delay spread for the channel modeled which meets the recommendation established by the CCIR.
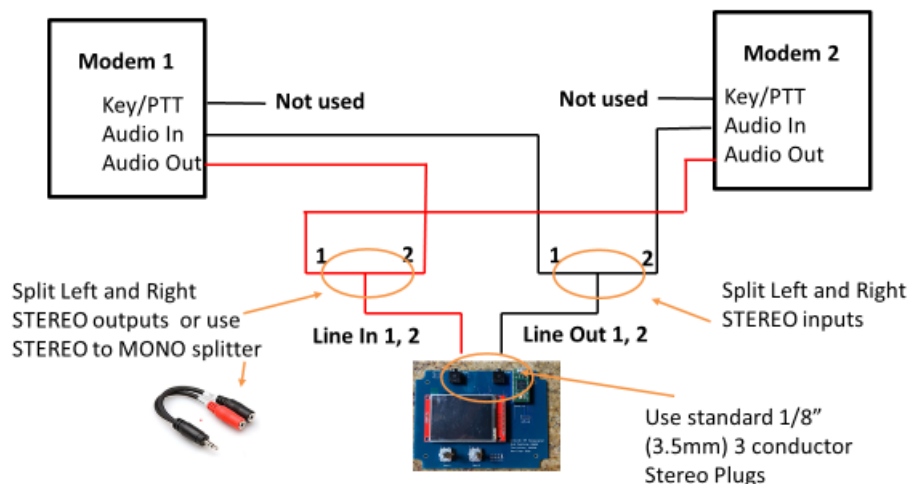

The IQ Plane plot *scale* remains constant at +/- 5 ms for all multipath modes. The values calculated by the simulator are based on a +/- 1 sigma normal (gaussian) distribution of the modeled channel's delay spread. Pushing the mode (left) encoder once more should return you to the *Basic Mode* display. For most parameters (except S:N on WGN-MPD) you can push the parameter (right) knob to set the displayed value as the power on default (stored in EEPROM). You can explore the various other mode and parameter settings. There are no settings that will damage the Simulator but care should be taken when advancing the output volumes (CH1, CH2 OUT) levels which could result in loud levels to some earphones.

3.3 Exploring the other modes and parameters for other testing. While the WGN and Multipath channels are primarily used in HF Path simulation the simulator also supports functions useful in VHF/UHF path simulation. This testing is usually done using the standard WGN channel (across a range of S:N range of interest) modified with functions for VHF/UHF simulation. The primary ones of these are **FLAT fade** caused by multipath signal reception on FM and **FM Deviation** caused by transmitter/receiver drift or doppler shift.   Figure 7 shows these modes and the parameter range of each. Again the 1500 Hz test tone can be used as a basic signal source and the Spectrum analyzer display to observe these effects just as was done in the basic HF modes.   The fixed **OFFSET** mode can also be used to supply a small (+/- 200 Hz range) frequency offset to the audio input and this is helpful in testing/evaluating the ability of the modem to handle frequency tuning offsets primarily on HF SSB transmission. Finally, the simulator also supports a 6 KHz bandwidth mode. Though not normally used on amateur HF transmissions this can be used in modeling wider band audio channels used on VHF and UHF such as 9600 baud packet or VARA VHF. In 6 KHz bandwidth mode the simulator's internal FIR filters are all switched to a 6300 Hz range and the Spectrum display is modified to cover the full range 0 to 6500 Hz. In the 6500 Hz spectrum mode each ~43 Hz bin is represented by a one-pixel-wide vertical rectangle spaced by 1 pixel of black.

4.0 Basic Setup and Connections for using the Simulator. The simulator can be used to model the paths for half-duplex or full duplex connections. With its' internal audio CH1 and CH2 mixing a *single* **IONOS SIM** can handle *both* directions of a half-duplex connection providing symmetric channel modeling (same channel for Modem 1 to Modem 2 and Modem 2 to Modem 1). Figs. 5 and 6 show the basic connections between modems (or sound cards for sound card protocols) and the simulator for both half duplex and full duplex channel modeling.
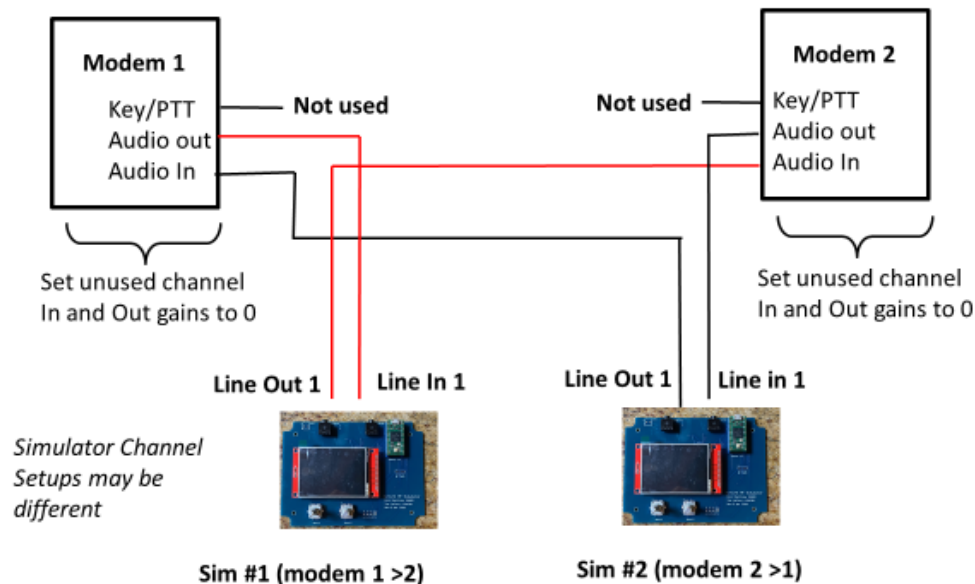

Fig 5. Basic Half Duplex, symmetric channel setup with one IONOS SIM.

(note: Stereo isolation transformers can be used if ground loops affect audio quality)

Connecting the simulator: 2 Simulators Full Duplex, non symmetric channels:

Fig 6. Full Duplex, non-symmetric channel setup using two IONOS SIMs
(note: Stereo isolation transformers can be used if ground loops affect audio quality)

4.1 Audio Levels. For proper operation the simulator must supply non-saturated, undistorted audio *to* the modems and receive correct level audio *from* the modems. The Simulator has 4 audio gain/output level controls that allow a wide independent adjustment for CH1 and CH2 input and CH1 and CH2 Outputs. There are probably also other gain adjustments (hardware or software) on the *modem* in and out audio. The optimum settings are those output levels that allow modem to be driven with the required signal without overdriving or clipping *and* with input levels and gain settings that allow the simulator to process audio in its normal range (200 – 1800 mv p-p). Take time to adjust and note the settings [Modems 1 and 2 inputs and outputs, Simulator CH1 and CH2 Inputs and Simulator CH1 and CH2 outputs] so they can be easily setup again. *(Simulator gain settings can be saved to EEPROM by pushing on the right (parameter) encoder when the gain setting is displayed).* Input gains and output levels are adjustable over a wide logarithmic range (0,.1,.2,.5,1,2,5,10,20,50,100). If an input gain or output level is too large for the dynamic range of the simulator it will cause clipping and distortion of the audio signal. One suggested mechanism for setting the proper level signal into the simulator is:

1)Connect the modem outputs to the simulator. If there is any noise or hum introduced by ground loops using a stereo line isolator (transformer) in the audio to/from the simulator has been shown to help.

2) Set the simulator up for TEST3K mode. This will show the input signal p-p readings on the Ch1 In and Ch2 in lines of the TEST3K display.

3) Adjust the output of the *modem* to fall within a range of 500 – 1500 (mv p-p) if possible. Operation with inputs at 200 to 1800 mv p-p is the normal minimum to maximum range. The simulator In and Out gain settings can then be used to make simulator *output* adjustments as desired but care should be used to insure the gain settings selected do not cause saturation of the simulator or the modem.

4) Make test runs using the WGN mode with 10 or 30 dB S:N to verify proper setup and operation before making any extensive measurement runs. Document all the levels used to make repeated setups easier and consistent.

5.0 Manual User Interface. The primary user interface consists of 2 rotary encoders with push capability and a 320x240 pixel color graphics display. The Encoders allow selection of basic Modes (left encoder) and parameters (right encoder). The left push function toggles less used functions on/off : (**Spectrum Plot**, **IQ Plane** delay plots). The right encoder push function togles a built in 1.5 KHz oscillator on/off for testing or saves power on default parameter values to EEPROM.

Manual User Interface

Left Encoder (large knob)   Right Encoder (small knob)

MODE		Parameter / Range /Power On Default*
WGN		S:N /-40 to +40 ,1 dB steps/ +40
MPG		S:N /-40 to +40 ,1 dB steps/ +40
MPM	Common	S:N /-40 to +40 ,1 dB steps/ +40
MPP		S:N /-40 to +40 ,1 dB steps/ +40
MPD		S:N /-40 to +40 ,1 dB steps/ +40
MULTIPATHS		# of Multipaths used/ 2, 3, or 4/ 4
FADE DEPTH (dB)		Depth of Fade dB/ 0 to 40 dB/ 0
FADE FREQ (Hz)		Fade Frequency/0,.1,.2,.5,1,2,5,10,20,50,100/0
OFFSET (Hz)		Freq Offset/-200 to +200 Hz, 10 Hz steps/0
FM DEVIATION(p-p, Hz)		FM Deviation/ 0,.1,.2,.5,1,2,5,10,20,50,100/0
FM RATE (Hz)	Less used	FM Rate/ 0,.1,.2,.5,1,2,5,10,20,50,100/0
CH1 IN (Gain)		Ch1 Input Gain/ 0, .1,.2,.5,1,2,5,10,20,50,100/2
CH2 IN (Gain)		Ch2 Input Gain/ 0, .1,.2,.5,1,2,5,10,20,50,100/2
CH1 OUT (Level)		Ch1 Output Level/ 0,.1,.2,.5,1,2,5,10,20,50,100/2
CH2 OUT (Level)		Ch2 Output Level/ 0, .1,.2,.5,1,2,5,10,20,50,100/2
BANDWIDTH		Audio bandwidth/3 KHz or 6 KHz/3
TEST3K Sine	Built in Test	Test/Cal Measure Ch1,2, In p-p, Out p-p 3KHz BW
TEST6K Sine		Test/Cal Measure Ch1,2, In p-p, Out p-p 6KHz BW

* Except for Path S:N, power on default may be saved to EEPROM with push of right encoder

Fig. 7 . Manual User Interface Encoders 1 and 2.

6.0 Computer interface. Although most users will find the encoder interface above simpler and easier to use an alternative USB serial interface (9600 baud) is included that can allow more sophisticated and automated testing using short ASCII commands through the Simulator's serial USB port. This will require some user supplied control program that sets up the simulator and modem, runs a session for a specific path type and S:N, and computes and saves performance data (e.g. average net bytes/minute transferred). This can save much time if a large number of simulations are to be run. Each command sent by the computer to the simulator must be sequenced by the correct response [OK(Cr)] from the simulator. The commands are case insensitive standard ASCII as shown in Fig 8. If a syntax, spelling error, or parameter out of range is received by the simulator a ["?" (Cr)] is returned. The BUSY command is used for a busy detector function (section 7). The commands in Fig 8 correspond to mode and parameter settings of rotary encoders 1 and 2.

Simulator USB Serial User Interface
USB Serial Commands and Responses for automated testing
(Mimic manual commands from Mode and Parameter Encoders)

Command (case insensitive, End with Cr)	Acknowledge Response/ Interpretation
WGN:20	OK(Cr) or ?(Cr) / WGN +20dB S:N
MPG:20	OK(Cr) or ?(Cr) / MPG +20dB S:N
MPM:-10	OK(Cr) or ?(Cr) / MPM -10dB S:N
MPP:+20	OK(Cr) or ?(Cr) / MPP +20dB S:N
MPD:20	OK(Cr) or ?(Cr) / MPD +20dB S:N
MULTIPATH: 4	OK(Cr) or ?(Cr) / # or multipaths used
FADE DEPTH:10	OK(Cr) or ?(Cr) / FADE DEPTH:10 dB
FADE FREQ:10	OK(Cr) or ?(Cr) / FADE FREQ:(log)7 Hz
OFFSET:100	OK(Cr) or ?(Cr) / OFFSET: 100 Hz
FM DEVIATION:10	OK(Cr) or ?(Cr) / FM DEVIATION:(log)7Hz
FM RATE:.1	OK(Cr) or ?(Cr) / FM RATE:(log)7 Hz
CH1 IN:0-10	OK(Cr) or ?(Cr) / CH1 IN gain,(log)7
CH2 IN:0-10	OK(Cr) or ?(Cr) / CH2 IN gain,(log)7
CH1 OUT:0-10	OK(Cr) or ?(Cr) / CH1 OUT gain,(log)7
CH2 OUT:0-10	OK(Cr) or ?(Cr) / CH2 OUT gain,(log)7
BANDWIDTH:3000	OK(Cr) or ?(Cr) / BANDWIDTH = 3KHz
BUSY:	OK(Cr) or ?(Cr) / ENABLE BUSY DETECT

Note: 1. All commands case insensitive. "+" signs ignored.
2. All commands and replies terminate with (Cr).
3. "OK" reply indicates command was interpreted OK and executed.
4. "?" reply indicates command was not understood, corrupted or out of range.
5. Commands must be sequenced by sender using Acknowledge Response
6. Successful commands will update Mode/Parameter display
7.Values 0 to 10 correspond to log gain/level values of 0.0, .1, .2, .5, 1, 2, 5, 10, 20. 50, 100

Fig 8. Serial Commands for Simulator Control

(note: Command "**BUSY:**") is normally not used with the Simulator. It switches the **IONOS SIM** to a **BUSY DETECT** mode. See section 7.0)

7.0 Basic Application of the Simulator for HF and VHF/UHF use

The use of the IONOS Sim is relatively straight forward but some care is required in setting up test to get consistent and representative test results.

7.1 Test Parameters. Most Simulation runs compare/plot net throughput (after all retries for ARQ modes) vs a specific path type and range of S:N (e.g MPG over +20 to – 10 dB). For comparison several graphs are often shown on one chart. To obtain accurate and repeatable results requires sending sufficient data over a fairly long session (at least 5 minutes and often over 10.). This is because of the nature and designed randomness of the channel modeling and the adaptation to changing channels used by adaptive modems. White Noise and channel delay values are standardized random or normal (gaussian) distributions so successive runs with the same test data and parameter values normally will vary somewhat.

7.2 Test Example for HF Testing of 3 different protocols. Fig 9 below plots the performance in net bytes/minute of 3 HF protocols over a S:N range +40 to -10 dB using a basic WGN (White Gaussian Noise) channel using an early revision of the IONOS SIM simulator. The drop off of throughput vs S:N is normal and gives a good indication of how the protocol can be expected to work at a given received S:N.
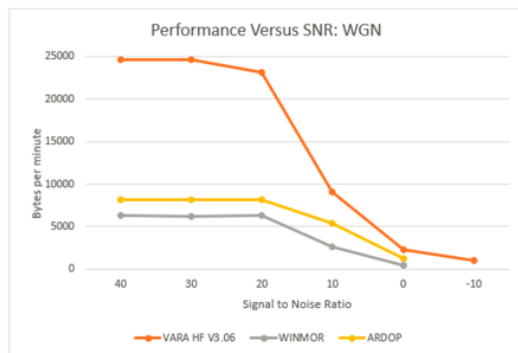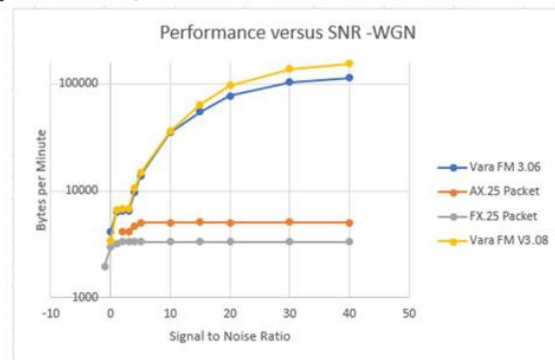
Fig 9: 3 HF Protocols over +40 to -10 dB S:N   **Fig 10: 4 VHF Protocols over -3 to + 40 dB S:N**

Figure 10 shows a similar simulation for 4 different VHF protocols. Since these protocols can use wider bandwidth "audio" to the FM Modulator the IONOS SIM simulator is set for its 6KHz bandwidth option. These basic simulations then are usually followed by similar sets of curves for different path types. For example for HF modes multipath channels (MPG, MPM, MPP, MPD) can be used over similar S:N ranges to show the affect of multipath propagation. VHF/UHF propagation usually is not modeled with the same multipath but instead often use FLAT FADING channels or FM Deviation which are also supported by the IONOS SIM simulator. Since each plotted "dot" in the above plots represents a typical simulator run of 5 -10 minutes these tests will take some time to complete and log. If extensive testing is anticipated using the computer commands shown in Fig 8 and custom designed simulator and modem control software for setup may be a more efficient use of time and the IONOS SIM simulator. These examples highlight why trying to obtain this kind of test accuracy and repeatability is so difficult using normal "over-the-air" radio testing.

8.0 Busy Channel Detector operation (experimental)

This function rewires (via software) the audio path flow and DSP processing of the **IONOS SIM** to perform a **BUSY DETECT** function. The purpose of this function is to provide improved automatic (computer controlled) busy channel detection capability for automated stations by performing accurate and rapid spectrum analysis over a specified frequency band of interest. This function is in development and optimization of the performance (speed and accuracy) of the busy detector algorithms continues. This function is NOT intended for manual user control so is totally commanded from serial commands sent between the simulator/busy detector from a host computer. Figure 9 summarized the basic commands of the **BUSY DETECTOR**.

Busy Detect USB Serial User Interface

USB Serial Commands and Responses for using busy detector
(note no encoder selection for these modes and parameters,
all control and reporting via USB serial)

Command (case insensitive, End with Cr)	Acknowledge Response/ Interpretation
ENB BUSY:1-50	OK(Cr) or ?(Cr) / Enable busy detect avg 1-50 7
DIS BUSY:0	OK(Cr) or ?(Cr) / Disable busy detect
LOW:500	OK(Cr) or ?(Cr) / FFT Low Limit 43-5000 Hz
HIGH:4000	OK(Cr) or ?(Cr) / FFT High Limit 500-6000 Hz 6
THRESH:10	OK(Cr) or ?(Cr) / dB Peak above avg (3-40 dB)
TONE ON:1500	OK(Cr) or ?(Cr) / Enable Test tone 43- 6300 Hz
TONE OFF:	OK(Cr) or ?(Cr) / Disable test tone (normal use)
CH1 IN:0-10	OK(Cr) or ? (Cr) / Set input CH1 Gain 0-100 (log)8
BANDWIDTH;3000/6000	OK(Cr) or ?(Cr) / Set bandwidth Hz
SPECTRUM:1/0	OK(Cr) or ?(Cr) / Enable/Disable spectrum disp.
SIM:	OK(Cr) or ?(Cr) / Switch to simulator mode

notifications to application FROM Busy Detector

DETECT:6	OK(Cr) or ?(Cr) /BUSY DETECT peak level in dB
DETECT:0	OK(Cr) or ?(Cr) / NON BUSY CONDITION DETECTED

Note: 1. All commands case insensitive. "+" signs ignored.
2. All commands and replies terminate with (Cr).
3. "OK" reply indicates command was interpreted OK and executed.
4. "?" reply indicates command was not understood, corrupted or out of range.
5. Commands must be sequenced by sender using Acknowledge Response
6. HIGH must be at least 260 Hz above LOW
7. # of Averages. Larger number reduces noise fluctuation at the cost of higher detection latency.
8. Values 0-10 correspond to Log gain steps 0.0, .1, .2, .5, 1, 2, 5, 10, 20, 50, 100 CH2 IN gain forced to 0.

Fig 11. BUSY DETECT serial commands and responses.

There is one serial command "**BUSY: (Cr)**" issued from the **IONOS SIM** serial interface to *enter* into the **BUSY DETECT** mode. Once this command is received the screen displays **BUSY DETECT** and the revision number for 3 seconds and acknowledges by an OK (Cr) response. Then the commands, responses and DETECT: notifications in Fig 9 are operational. Since all operation of the **BUSY DETECT** function are controlled by serial commands to/from to the host control program there is no encoder mode or manual entry parameters used in **BUSY DETECT** mode.

8.1 BUSY DETECT Command Details. This section documents the command function use in the busy detector.

ENB BUSY:n 1 <= n <= 50 Enable Busy detection using FFT averages. Each FFT acquisition and average takes approx. 11 ms. This allows trading off noise suppression by averaging (larger number of averages) vs decision time. Typical values range between 10 and 30 averages.

DIS BUSY:0 Disables busy detection

LOW: n 43 Hz <= n <= 5000Hz Sets the low frequency limit for the frequency band of interest.

HIGH: n 500Hz <= n <= 6000 Hz Sets the high frequency limit for frequency band of interest. Note: HIGH value must be at least 260 Hz above LOW value. **IMPORTANT:** *BOTH* the HIGH and LOW frequencies should pass to the busy detector without attenuation by any receiver filters. This is easily observed by looking at the spectrum display using the **SPECTRUM:1** command. There must be some yellow spectrum lines showing in the spectrum both at the high and low ends of the frequency band of interest. Signals in the yellow spectrum region *ARE NOT* considered by the busy detect algorithms.

THRESH: 3 to 40 (dB) Sets the detection threshold in dB above the averaged bins. A lower number (more sensitive) will usually require a higher number of averages in **ENB BUSY:n** above. Each average takes approximately 11 ms so there is a tradeoff in sensitivity vs response time. Typical thresholds are 5-20 dB. With moderate averaging (e.g. 15-20) it should be possible to detect a carrier at approximately -10 to -15 dB below the noise with few false detects. Note this will still be visible on the spectrum display since it displays S+N to N.

TONE ON: n Enable the test tone at frequency n Hz. 43 Hz <= n <= 6300 Hz

TONE OFF: Disable the test tone.

CH1 IN: n Set Input gain on Audio CH1 0 <= n <= 10. This corresponds to a gain factor of 0,.1,.2,.5,1,2,5,10,20,50,100. Audio CH2 Input Gain is forced to 0. Excessive gain will cause clipping and distortion inside the busy channel detector. **IMPORTANT:** The input level to the busy detector is a function of the audio output of the receiver *and* the **CH1 IN:** gain above. It is not critical as long as spectrum lines are showing at the bottom of the display and there is no clipping of the audio level. The Receiver AGC should normally be set to FAST to MEDIUM and the bottom level "grass" of the spectrum on a quiet channel should be set to approximately the lower 25% of the spectrum amplitude.

BANDWIDTH: n Set the Busy detector bandwidth. n = 3000 or 6000 Hz.

SPECTRUM: n Enable (n=1) or Disable (n=0) Spectrum Display. Note on the spectrum display: Signals outside the frequency band of interest (below LOW or above HIGH above) are plotted in yellow. Non-busy conditions will plot the frequency band of interest in green. A busy detection will plot the frequency band of interest in red. Note the spectrum display adds approximately 200 ms to the processing time so the spectrum display should be disabled (**SPECTRUM:0**) once levels have been set up when operating under computer control.

SIM: Normally not used. Leaves the **BUSY DETECT** mode and returns to the **IONOS SIM** mode.

8.2 BUSY DETECT automated responses. There are two automated responses from the BUSY DETECT that are issued automatically upon entering or leaving a channel busy condition. Responses are asynchronous and need not be acknowledged by the Host.

DETECT: n   3 <= n < 40. A busy condition is detected that identifies a signal within the range of LOW to HIGH (above) that is >= the threshold value set with **THRESH:n** (above). n is in dB. Signals outside the region of interest (LOW TO HIGH) are ignored.

DETECT: 0   Indicates a non-busy condition is detected (after appropriate averaging) There is a small hysteresis used that requires the **DETECT:0** to be sent *only* after the busy detector sense a level 2 dB or more *below* the programmed **THRESH:n** level.

8.3 Basic Description of the Busy Detector Algorithm. The busy detector does not try to interpret or in any way decode the signal in the band of interest. That would be a very complex task with significant DSP loading and complex decoding software. It would also limit sensitivity, require continual updating for new modes and significantly lengthen the detection time. Rather the algorithm relies (much like the human ear) on detection of the average energy received in each of the ~43 Hz FFT frequency bins within the spectrum of interest. (Between **LOW** and **HIGH** frequencies above). The algorithm averages each of the bins as received (rolling average implemented using IIR filters) to reduce the bin fluctuations due to noise. It then scans the frequency band of interest for narrow (~260Hz wide) *peaks* or *dips* in the spectrum lines. This mechanism allows detection of both narrow modes (e.g. CW, RTTY, PSK, JT etc.) and wider modes (e.g. SSB Voice, Pactor, VARA, FAX, WINMOR etc.) By allowing setup via commands (e.g. **ENB BUSY:n**,   **THRESH:n**, and frequency detection range **LOW:n**, **HIGH:n**) the bandwidth, sensitivity and response time can be quickly customized for frequency band and receiver bandwidth during scanning operations. As operating experience is gained improvement in the sensitivity and accuracy of the **BUSY DETECT** algorithms is anticipated.

IONOS SIM HF/VHF Channel Simulator Specifications   Rev 1.8 May 6, 2020

Description*: IONOS SIM* is a self-contained audio DSP based ionospheric simulator based on the Watterson Model [1]. It uses the Teensy 4.0 CPU (ARM Cortex-M7 processor at 600 MHz) and Teensy Audio DSP Library. The MIT open source licensed software (see appendix) was developed on the Arduino platform.

Primary Use: The development, characterization, maintenance and comparison of HF and VHF modems and protocols including "sound card" modems and protocols.

Channels Modeled: WGN (White Gaussian Noise: Spread 0 Hz, Delay:0ms); , MPG (CCIR Multipath Good) Spread .1 Hz, Delay .5ms ; MPM (CCIR Multipath Moderate) Spread .5Hz, Delay 1ms; , MPP (CCIR Multipath Poor) Spread 1 Hz, Delay 2ms; MPD (Multipath disturbed) Spread 2.5 Hz, Delay 5ms; Flat Fading 0-40 dB Fade, (Rate .1 to 100 Hz); Static Freq offset +/- 200 Hz; Slow FM deviation +/-.1 -100 Hz, FM Rate .1 to 100 Hz. Multipath: (2,3 or 4 channels) Delay update rate: 32x spread above. (CCIR recommendation)

Audio Paths: WGN: 1 path. Multipath: selectable 2,3 or 4 channels (rays). Input to Output Delay: ~4-16 ms.

Connections Modeled: 1 Simulator: Half duplex, both sides, symmetric channel models.
2 Simulators: Full Duplex both sides: symmetric or asymmetric channel models.

Bandwidths: 3KHzBW:40Hz - 3.3 KHz, 6KHzBW:40Hz - 6.3 KHz. Ripple < +/- .5dB   **Sampling rate:** 44.1 KHz

Noise modeling: WGN filtered to 3 KHz or 6 KHz bandwidth. S:N -40 to +40 dB, 1 dB steps.

Inputs: Ch1, Ch2 via standard Stereo 1/8" (3.5 mm) jack. AC coupled. Input protection.
Impedance > 50KOhms. Nominal input range: 200 – 1800 mv p-p.

Outputs: Ch1, Ch2 via standard Stereo 1/8" (3.5 mm) jack. AC Coupled. Short circuit protection.
Impedance 150 Ohms. Nominal output range 200-1800 mv p-p.

Power Required: Nominal 5 v (internally reg. to 3.3 V) via micro USB connector. ~ 200 ma.

Display: 320 x 240 pixel color TFT for Text and Graphics. 2.4"x 1.8" (60mm x 45mm)

Operating and Display Modes: Self-test and calibration verification; Set modes and parameters; Spectrum Display (3 & 6 KHz), ~60 dB dynamic range; Multipath dynamic IQ (2,3, or 4 channel) delay plot.

User Parameter and control: Two Incremental encoders (Mode, Parameter) each with push toggle functions. Parameter default values can be saved to EEPROM. USB serial ASCII commands for automated operation.

Size: 6.1" (155 mm) L x 4.7" (120 mm) W x 1.4" (36 mm) H (excluding knobs).

Built In Test: Built in Test (TEST3K, TEST6K) Tests and confirms Input to output continuity, Functions and Calibration accuracy +/- .5 dB in WGN mode across 3000 Hz or 6000 Hz spectrum.

Alternate Functions: Integrated Busy Channel Detector (experimental). Uses only serial USB ASCII command interface with host program.

 [1] Watterson, C.C., J.R. Juroshek, & W.D. Bensema. 1970 Experimental confirmation of an HF channel model IEEE Transaction of Communication. Technology. Vol COM-18. Pp 792-803 Dec 1970

APPENDIX: