FastRanger

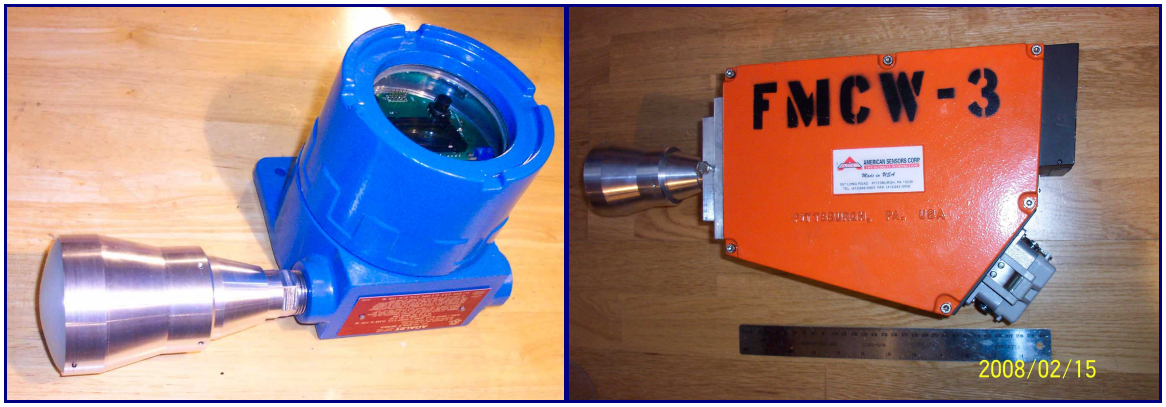
User Instruction Manual

Distance/level gauge and beam intrusion detector

Millimeter microwave FMCW Radar 77GHz (available also in ISM bands 62 or 122GHz)

3-Mar-2009
Draft revision 10

Stan Bleszynski
+1-705-6572419



Adalet's housing (left) and American Sensors' cooling jacket enclosure (right). 3" lens horn antenna, 4^0 beam width.

LIST OF CONTENTS

1. Product description.

"FastRanger" is millimeter microwave FMCW radar sensor designed as fast distance ranger (can also simultaneous read target velocity). It can be installed in various industrial applications requiring fast response time high robustness, narrow beam and high penetration power against environmental obstructions such as snow, rain, spray, mist, dust, smoke etc. Due to a very narrow beam it's application characteristics resemble that of a laser gauge - without the vulnerability to dust, moisture, dirt or to safety issues. It can be set up to detect targets through plaster or wooden walls, behind plastic or glass windows, see through plastic tanks etc. Unlike typical industrial radar level gauges, "FastRanger" is not vulnerable to spurious echo problem.

2. Specifications (preliminary, subject to changes).

Distance range: 0.5 – 30m standard tuning,
3 - 150+ m (requires re-tuning, lower accuracy, large targets or larger diameter antenna)

Distance accuracy: +/-2cm or +/-0.3% whichever greater

Response time: about 60ms

Housing: cast aluminum cylindrical enclosure by Adalet, with a screwed-on lid with glass window; explosion-proof approval ratings. Weight: 3.5kg. External diameter 5 inch (12.5cm), height 6 inch (15cm). Two threaded conduit ports, ¾ inch NPT. One port is used for antenna mount and one is free for cable connection.

Antenna: 3" diameter lens-horn (standard) or 8" diameter lens-horn (optional). Hermetically sealed aluminum horn with polypropylene (low temperature applications) or PTFE lens (high temperature applications, special order). Standard horn length is 5.75" (14.5 cm), 3" diameter (7.5cm), The lens holding part of the antenna can be moved or removed in the axial direction for tuning the beam focus and to allow swapping of the standard lens for the larger optional 8" lens-horn for long distance ranging or for special applications requiring ultra-narrow beam spread.

Environmental protection: water tight to 3 bar[1] similar to Nema-4. Operating temperature –10C to +45C.

Housing approvals: class I group B,C,D, class II group E,F,G, class III type 4X, class I zone 1 A Ex d IIC,
Exd IIC IEC 60529 IP66

[1] This is estimated theoretically upon design but not tested. A sealed cable conduit must be used.

Housing cable port: ¾" NPT (conduit entry)

Power Supply: 24V DC (19-29V) / 0.5A, fuse 2A /250V (BUSS 225, 14mm)

Transmitter Output: <50mW continuous wave, frequency swept in 76-78GHz range (adjustable sweep span from 0.3 to 2.5GHz[2])

Process Variable Output: 4-20mA current loop, quadrature tacho pulses or serial digital data link.

Analog output consists of a 4-20mA source supplied internally from the sensor's 24V supply line (default) or configured as an opto-isolated floating current sink. Voltage burden = 8V. Max load resistance 640 ohm. Full current span is 3.5-25mA.

A special tacho output option (for velocity measuring applications only) requires an optional quadrature differential pulse output board. It provides ground-isolated frequency-modulated pulses, two phase output, 5V or 24V, 0-100kHz span. Pulse frequency is proportional to velocity. Each tacho pulse corresponds to an incremental distance movement of the target in the direction towards of the antenna axis (incrementing count), or away from the antenna (decrementing count)

The third option of outputting the measured values consists of using the serial data link to a PC host controller, to a network gateway or to PLC. The host can poll the output using 'V' command (distance) and 'Q' commands (status) with ~60ms latency.

Digital Data Port: pseudo-RS232 with 3V TTL levels. 9.2-115kbaud(software configurable), no handshaking.

Only RX/TX and GND connections are needed. Since the levels are TTL (not RS232 standard) it is recommended to use a generic TTL-to-RS232 level translator dongle, for example "232LPTTL33" from http://www.bb-elec.com

It is recommended to use a USB and/or RS485 gateway interface (not included), for digital cable length beyond 10m.

Data port can be used for sensor diagnostics, setup and calibration, as well as for transferring measured values (process variables). Commands are described in chapter 5.

[2] Sweep span above 1GHz can only be used in testing! 2.5GHz violates 77GHz automotive band FCC approval. 0.5GHz sweep is permitted in the 61-61.5GHz ISM band, while 1GHz sweep in 122-123GHz ISM band. It is believed that the current design can easily be retuned to work in any mm microwave band (not yet tested). Lower span allows longer range, higher span allows higher accuracy.

Configuration: Manual – direct parameter entry using a 2 lines by 8 characters backlit LCD and two push-buttons (requires opening the enclosure). Remote – using serial data link and 'snnvvvvvv' commands in ASCII format (see chapter 5). VelTerm.exe utility (WinXP) can be also used for configuration and diagnostics by providing graphic user interface to the sensor. Remote configuration does not require enclosure opening.

Distance calibration: calibration procedure consists of placing a calibration reference target at a known distance to the transmitter (placed inside the enclosure at the bottom narrow end of the horn antenna). Use Config screen in VelTerm.exe) or manually using push-buttons and LCD: first enter the known calibration distance as the configuration parameter "CalDist", then execute calibration procedure by clicking "Calib" (VelTerm.exe), typing "c008" command or manually from "Calibrate" LCD screen.

Temperature range: -10C .. +45C (estimate, not fully tested)

3. Quick Installation Guide

Power and signal output cables (24V DC power and for example 4-20mA current loop or optional quadrature pulse output) are passed through the cable conduit port in the enclosure. +24Vdc power, ground and loop current connections are available on the 5 way detachable terminal block on the bottom board (see Fig.3). Pulse output terminals and relay terminals are mounted on different boards of the stack (refer to a separate manual for pulse output board and silkscreen marking on the boards). Power the sensor up and set up the configuration parameters while the enclosure is open, using UP and DOWN push-buttons, and observe the LCD screen.

The sensor is configured by default to work straight out of the box, with the fastest response time (no averaging and no output damping).

In the simplest case, connect only "+24V SUPP" and "GND SUPP" lines and observe readings on the LCD.

To verify the operation, point antenna towards some artificial target such as a wall or a wall corner etc and read the distance from the LCD. Observe signal "quality" index on "Dist Syy" screen. Value of yy should typically be higher than 85 for typical perpendicular flat targets from 2 to 20m distance. To stabilize noisy readings, increase "Damping" parameter (see chapter 4). Quality of the echo depends on the target material properties, inclination, surface structure and the distance, see Chapter 7 for more detailed description.

Operation of the sensor can be further verified using Digital Data Link. Connect TTL to RS232 interface ("232LPTTL33" from http://www.bb-elec.com) to the sensor data link (see chapter 6) then connect an RS232-to-USB cable interface and connect it to a USB port on a PC.

Digital data can be transmitted, downloaded, uploaded and graphically visualized with a VelTerm.exe program[3] under Windows (98,2000,XP). Download VelTerm from the website: http://www.velsensor.com/VelTermSetup.zip or use an installation CD. Unzip to a temporary directory, for example c:\temp\ and run installation program setup.exe.

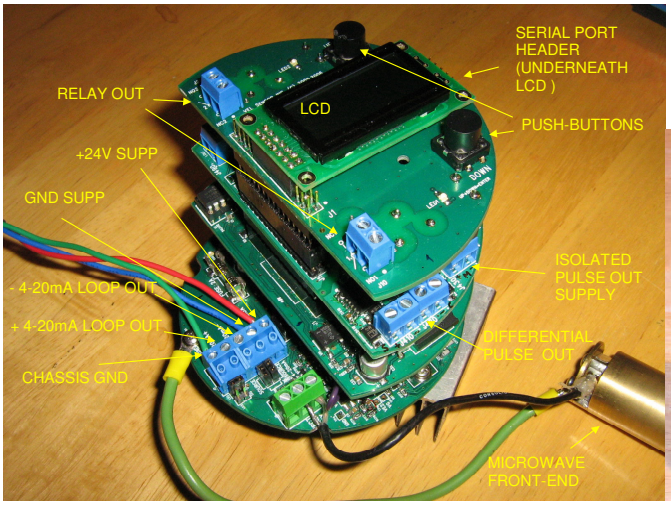
Start VelTerm, make sure that the correct com port ("Port" pull-down menu on top) is open and that the port data speed is 38400 baud[4]. Click on command buttons or type commands "F" or "[" to view the target peak (in FFT domain). Verify the raw signal waveform with "D" command that should look as a uniform sinus-like waveform with as little distorsion and noise as possible.

---

[3] Any ASCII text terminal program can be used to communicate with FastRngr. Data and commands are always transmitted as standard ASCII codes (32-127) and can be viewed on screen or saved as text files. However, data visualization in graphics mode can only be done by VelTerm.exe program.

[4] Higher speeds such as 115kbaud are recommended on faster laptops (>2GHz CPU, Win XP, Linux/Wine, but not Vista) with USB interfaces. On slow laptops and with direct RS232 connection, 38400 or 19200 baud should be set instead. Baud rate should be first configured from the push-button and LCD screens on the sensor, and then set up on VelTerm accordingly, from the program "Port" pull-down menu.

3.a. Wiring of the circuit board stack mounted in Adalet enclosure



Connector J3: 5-way single in-line connector header for power and sensor outputs.

1) “+24V/0.5A” : wire to DC positive supply 19-29V, average current 0.5A, startup current 1A.

2) “GND” : power ground, internally connected to the enclosure ground!

3) “4-20mA+/(+24V)” : when LK1 is off - external positive 4-20mA loop supply. +10 .. +29V, 25mA max. When LK1 is on, the loop is internally powered from 24V and this pin should be left unconnected.

4) “4-20mA-” : return terminal for the 4-20mA current loop output. When LK1 is off this pin should be connected to the negative input of the current loop host, while the “4-20mA+/(+24V)” should be connected to the positive terminal of the current loop host. When LK1 is on the loop is internally powered and “4-20mA-” pin should be connected to ground through an external ammeter or a stable resistance 0-500ohm (typically 100 ohm).

5) “SIG/GND” : test signal output or ground (power ground), depending on the links LK3 and LK5. When LK3 is OFF and LK5 is ON, the pin provides raw signal output 0..0.3V, 200 ohm source impedance. When LK3 is ON and LK5 is OFF, the pin is grounded and can function as the second ground terminal. The test signal output can be wired for the purpose of monitoring the radar raw signal on an oscilloscope. It is recommended to use a coaxial cable

Connector J4: 3 way connector for the microwave front end.

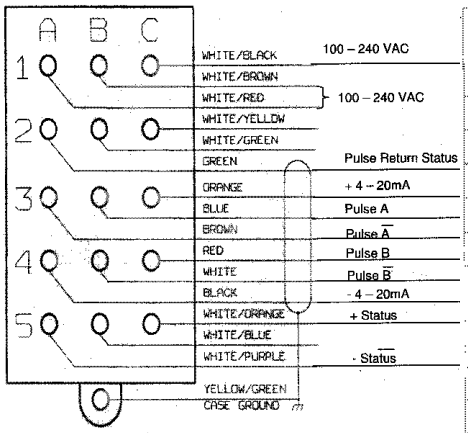
“TX” : transmitter signal and power connection. Warning: this line is static-sensitive!

“GND” : transmitter ground connection.

“VARACT” : frequency sweep control line. Warning: this line is very static-sensitive!

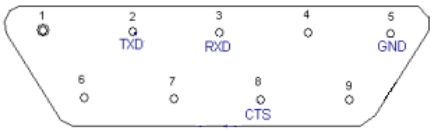
Note: microwave front end power ground is connected to the front end and antenna enclosure. If the sensor ground needs to be isolated from the enclosure/mounting ground, the microwave front end also would have to be isolated from the mounting ground. In such a case it is important that the GND connection between J4 and the front end is thick, for example a coaxial braided shield etc. In addition in such a case it is recommended to conduct a second ground strap between the grounding lug on the VEL-DRV-3 board and the microwave front end. If the front end is connected to the sensor enclosure through a metal pipe conduit, a second ground strap is not necessary.

3.b. Wiring with American Sensor Corp. enclosure



Harting Pin #	Wire Color	Function
C1	White / Black	110 / 220 VAC
A1	White / Red	110 / 220 VAC
C3	Orange	+4 – 20mA
B3	Blue	Pulse A
A3	Brown	Pulse $\overline{A}$
C4	Red	Pulse B
B4	White	Pulse $\overline{B}$
A4	Black	-4 – 20mA
A2	Green	pulse return status isolated
C5	White / Orange	+ Status
A5	White / Purple	- Status

All connections (except serial data port, see below) go through a proprietary rectangular socket at the back of the enclosure. When quadrature pulse output board is not installed then +STATUS and -STATUS lines (see above) are connected to RELAY1 (N.O.) contacts. Serial data port pinout (3V TTL) is shown below:



SERIAL DATA PORT
DB-9 socket (F)

3.c. Power up.

Power the sensor up, verify that the current draw is 0.4-0.5A at 24V. Set up the configuration parameters while the enclosure is open, using UP and DOWN push-buttons, and the LCD screen. See Chapter 4 for the explanations of the parameters. Test the radar by pointing it to various target such as a wall etc. Let it warm up for at least 30minutes before running calibration or linearization procedures.

4. LCD & Push-button User Interface (only with Adalet enclosure). Configuration screens and information screens.

The unit is equipped with a 2 lines by 8 character LCD module. Two (UP and DOWN) push-buttons allow scrolling through a number of screens, and executing edit (ENTER) function by simultaneous pressing of UP and DOWN buttons. Some screens may require a 3-digit password number **(password number is hard-coded = 008)** to be entered before ENTER operation and parameter modification is executed. Any modified parameter is automatically saved in EEPROM within one measurement cycle (about 60ms).

The following list of screens is implemented as of the current version of the firmware

FastRngr
Rel. x.xx - Displays the product name and the firmware revision number x.xx[5]. Displays additional product information or options in the bottom screen line (scrollable) when ENTER is pressed.

Note: Additional function of this parameter is selection of "FullMenu" which causes un-hiding of some hidden screens marked as (H), on the list below. Default screens that scroll (rotate) automatically after power up (or timeout) are in black, additional screens that scroll in when manually pressing up or down buttons are in blue, while the hidden screens (H) are in red[6].

Dist Syy
x.xxx uu - Displays distance x.xxx in units indicated by characters uu = mm,cm,in,ft or m, depending on the setting of the "Unit" screen. yy is the signal to noise ratio (00..99) in logarithmic scale yy = 73.2*log10(S/N). This is the main and most important screen displaying the primary sensor output variable.

Loop
x.xxx mA - Displays the loop current in milliampers. Note: the loop current is a linear function of velocity (see above) determined by two set points by screens "Set 4mA" and "Set 20mA" and can be fine-tuned and calibrated to a high accuracy by two other screens "Trim 4" and "Trim 20". Note: this screen shows the current value that is internally set, not the actual current in the output loop circuit.

Status
…….. - Displays system status messages. The messages are scrolling automatically once every 2 seconds, and are automatically cleared (unless underlying condition reoccurs) every 10 seconds. The list of all abbreviated error messages that can appear in the bottom line, and their full expanded explanation is listed in Appendix A.

[5] Current firmware revision is 0.48.
[6] Red (hidden) screens should be modified only with great caution - they are meant for factory adjust; blue screens are designed for application specific configuration by a user; black screens contain default display of sensor output variables and the status.

Note: the above 3 screens (Dist,Loop and Status) will normally be displayed automatically after power up and would rotate every 2 seconds, for example "Dist Qyy" followed by "Loop" followed by "Status" (if there are messages to be displayed, otherwise the "Status" is skipped) and then again "Dist Qyy" and so on.

Diagnost (H)

…….. - Displays diagnostic messages. The messages are scrolling automatically once every 2 seconds, and are accumulating ("sticky"). The messages persist and are not cleared automatically even if the underlying condition that caused them ceases to occur. The message list is the same as for "Status" screen above. Messages can be cleared manually by executing ENTER [7] twice.

TotAmpPP (H)

x.xxx V - Displays total peak-to-peak voltage over the entire spectrum integrated over all frequencies excluding DC. Note: the peak-to-peak voltage is approximately equal to RMS voltage multiplied by 2.8.

SigAmp

x.xxx V - Displays peak-to-peak amplitude of the main target peak signal (the peak amplitude of the target peak as seen in the FFT plot, see for example the 'F' command in the section 5 below)

Noise

x.xxx V - Displays peak-to-peak baseline noise amplitude in the spectrum, calculated around the base of the target peak. It corresponds to the height of the baseline noise curve around the target peak excluding the peak itself.

Min Amp

x.xxx V - Set the minimum signal amplitude (in peak-to-peak volts) for the target peaks to be detected. Signals that are smaller than MinAmp are to be ignored. Note: this parameter has the most important impact upon the target peak selection. Gain should be set such that the target signal amplitudes on the spectrum are typically within 0.5-2.5V, for the targets within the required application constraints and distance range. Baseline noise amplitudes (as per "Noise" screen) should typically be about 0.02-0.08V. Typical useful MinAmp value should therefore be set to between 0.03V (for high sensitivity and long distance target detection) and 0.15V for robust operation when targets are very strong. Setting MinAmp too high may cause weak

[7] ENTER function is triggered by pressing UP and DOWN buttons simultaneously. The top right character on the screen changes to "!" to indicate a pending ENTER condition. During a pending ENTER, a parameter value may be incremented or decremented or a list of selections may be scrolled (on some screens) using UP or DOWN keys. Subsequent execution of ENTER completes the sequence, and the exclamation character is cleared.

targets to be missed by the radar and results in Loss-of-Echo (LOE) condition. Setting it too low may case the radar to latch onto some spurious noise generated spectral peak in the absence of a target in view (or with very weak distant target), instead of reporting the Loss of Echo condition. Too low MinAmp setting may prevent a correct operation under PeakSel = "First" or "Amp/Dist"

Gain

x - Set receiver gain 0-10, such that the signal amplitude from flat plane target at 20m is typically 1.5 to 2.5V. Default gain = 8. Optimum Gain setup is done in factory and is hardware-dependent. Typical values are 5-9.

TX volt (H)

x.xxx V - Displays a voltage applied to the microwave transceiver circuit. The voltage is set by a potentiometer P5 (beside the fuse) on the bottom board, for the maximum signal strength and clean uniform signal waveform. Typically it should be within tha range of 2.8-5.3V. Note: Changing the TX voltage affects calibration and linearization! Adjustment of P5 is for factory configuration only!

TX curr (H)

xxx.x mA - Displays the microwave transceiver current (for diagnostics).

Temperat

xx C - Displays temperature inside the unit (Celsius)
Note: temperature reading is used internally to raise a "Temperature out of range" system fault (see SysFault). The preset fault limit is 70C.

SuppVolt

xx.xx V - Displays the supply voltage value. Should be 19-29V DC. System fault is raised (see SysFault) if the voltage is outside of this range.

Units

uu - Selects the distance display unit, one from the list of: uu = m , cm , in, ft and "m(ldist)". The last one means "long distance" meter. The long distance meter selection produce similar display as "m" except that the resolution of the distance variables is two decimal digits rather than 3 (cm as opposed to mm). It allows displaying very large distance values up to 999 m.

Damping

xxx - Selects the strength of the damping filter for the output velocity variable. The selection is: 1,2,4,8,16,32,…4096. Setting of a very high value makes the sensor response very slow but less noisy. Setting it to a low value makes the response fast but may make the distance reading and loop current output more noisy (if the target

distance fluctuates or if the signal is unstable due to obstructions, process variability, tank filling etc). Default value is 1.

SmplFreq (H)
xxxxxxxx - Selects internal A/D sampling range (=Nyquist Frequency, which is related to ramp length) from the list of:

1) " 11kHz" - ramp length=45ms
2) " 26kHz" - ramp length=19ms
3) " 54kHz" - ramp length=9ms (default)[8]

Dist Max
xxx.xx uu - Displays calculated minimal measurable distance. Function of the calibration coefficient CalFact, RawFmin,. Units uu as per "Units" screen.

Dist Max
xxx.xx uu - Displays calculated maximal distance range, depending on the calibration coefficient and other system settings such as CalFact and RawFmax. Units uu as per "Units" screen. It should be verified at installation time that the maximum range given covers the application requirement. If the distance range is insufficient, RawFmax should be set at 511 and if that is still insufficient then the span between RampMax and RampMin should be reduced[9] .

Set 4mA
x.xxx uu - Set distance point for 4.00mA loop current. Units uu depend on the setting of the "Units" screen.

Set 20mA
x.xxx uu - Set distance point corresponding to 20.00mA loop current. Units uu depend on the setting of the "Unit" screen.

Trim 4 (H)
xxxxx - Setup of the current loop trimming parameter to calibrate the 4.000 mA point. Typical value is about 3300 (range 0-65534). While this screen is in the entry mode, the current loop is forced to output 4.000mA. The actual current should be measured with an ammeter and the parameter value has to be adjusted so that the current is exactly 4.000mA.

Trim 20 (H)
xxxxx - Setup of the current loop trimming parameter to calibrate the 20.000 mA point. Typical value is 59000 (range 0-65534). While this screen is in the entry mode, the current loop is forced to output 20mA that can be measured and verified. The actual current should be

[8] Selection of the 54KHz produces the shortest ramp and results in fastest sensor response time although the accuracy may be reduced. MargStart parameter should be increased to at least 10% with the 54kHz setting.
[9] Maximum sensor range is inversely related to the min-max ramp voltage span. **Changing of the ramp span requires a subsequent re-linearization and re-calibration!**

measured with an ammeter and the parameter value should be adjusted so that the current is exactly 20.00mA.

Note: "Trim 4" and "Trim 20" screens are meant for fine-tuning the accuracy of the current loop output circuit using an ammeter connected through the loop, such that when the LCD screen shows a certain current value, the actual loop current is exactly equal to that. To verify the output for other currents, the "LoopTest" screen can be used. This is not meant for setting the 4 and 20mA set points versus distance. For setting the 4 and 20mA span, use "Set 4mA" and "Set 20mA" screens.

Raw Fmin (H)

xxx - Set lower window boundary for spectral frequencies in 0..512 units (spectral frequency bin). The purpose of this variable is to limit the low frequency range (= low distance) to prevent detecting low frequency artifacts as valid target peaks. Note: permitted range is 1-510.

Raw Fmax (H)

xxx - Set upper window boundary for spectral frequencies in 0..512 units (spectral frequency bin). Note: permitted range is 1-511 (512=Nyquist freq). The main purpose of Raw Fmin and Fmax setting is to prevent detecting spurious peaks. In particular, Fmax can be set to eliminate the target peaks beyond the maximal expected target range.

Note(1): when the target echo falls beyond Raw Fmax or below Raw Fmin, and at the same time the signal within the range is below “Min Amp” value, the Loss Of Echo condition (LOE) is flagged.

Note (2): Reduction of the Raw Fmin to Raw Fmax window length speeds up the sensor response time.

(3) It is recommended to use Config screen from VelTerm.exe to set Raw Fmax and Fmin since that screen uses physical distance units rather than dimesionless 0..512.

SysFault (H)

xxx - Select exception-handling method (behavior) for the 4-20mA output, in case of system fault (except Loss of Echo). The choice is:

"22mA" – set current loop output on 22.00mA (default)
"3.6mA" – set current loop output on 3.6mA
"Hold" – hold a last good value on the current loop output

Note: system fault event may be triggered by any number of errors such as self-check circuit failure, processor error, front end fault or by some external condition such as temperature or supply voltage out of range. Precise nature of the fault can be determined by polling the sensor with 'e' or 'E' command through the RS232 port.

LOEFault

xxx - Select the exception-handling behavior for 4-20mA output, in case of the Loss-Of-Echo situation. The choice is:

"22mA" – set current loop output to 22.00mA
"3.6mA" – set current loop output to 3.6mA
"Hold" – hold last good loop current value (default)

LoopTst

xx.x - Current loop test. Press ENTER (UP&DOWN) and set a current value in 0.1mA resolution. Press ENTER again to exit. This is diagnostic feature to help calibrating the current loop receiver, to test chart-recorder or wiring connections.

Data Log (H)

xxx - Select data logging frequency. The choices are: 2s, 10s[10], 1m, 10m(default), 1h, 3h and "Never". Each data record contains measured distance value, time stamp and some internal variables and flags. History log can be downloaded through RS232 diagnostic port and displayed with VelTerm.exe (utility program provided by http://www.velsensor.com), Windows' Hyperterm or similar. See 'H' and 'h' commands. Maximum number of data records is 1008, beyond which the history file will scroll out the oldest data and put new one in (exception when 2s is selected, it will stop logging after 1008 data and will preserve the file). Note: wipe out the old records before letting the unit log new data (see "WipeLog" screen or 'W' command). To preserve the already logged data in memory, set "Data Log" to "Never". Data is saved in a removable EEPROM chip 24LC256 or 24LC512 in DIL 8 socket, located in the middle board (VEL-CPU-3). If necessary, the chip can be removed from the socket and placed in a different unit to read the data off-site[11].

WipeLog (H)

xxx - Select xxx="Proceed" to erase all history memory (with logged distance data versus time). Select "Esc" to return to abandon the action and return to main menu.

BaudRate (H)

xxxxxx - Select the baud rate for RS232 port. The choices are:

"9.6k NoH" – 9600 bit/s (legacy devices)
"19.2k NoH" – 19.2 kbit/s
"38.4k NoH" – 38.4 kbit/s (default)
"57.6k NoH" – 57.6 kbit/s
"115.2k NoH" – 115.2 kbit/s
"230.4 NoH" – 230.4 kbit/s (use only with fast USB/RS232 interfaces)

---

[10] Sensor should not be left with 10s or 1m settings selected permanently on since it may lead to a possibility of EEPROM wear damage after several years.

[11] Since configuration parameters are also saved in this chip, the unit will have to be reconfigured if a new blank chip was put in the socket. The unit would not work reliably without the EEPROM chip in the socket (it could only use default configuration parameters). To avoid having to reconfigure the unit, contact the company to obtain preconfigured EEPROMs.

Note: the protocol is always no handshaking, no parity, 8 bits and 1 stop. Only TXD, RXD and GND lines need to be connected.

CalOffs (H)
xx.x mm - Calibration offset in mm distance units. That parameter is used in the linear formula that converts the signal frequency obtained from the FFT power spectrum to the target distance. Normally =0, except when a fine-adjustment of the zero point is necessary under a two-point calibration procedure. This parameter should not be used for trimming the current loop (use "Trim 4" and "Trim 20").

CalFac (H)
xxxx mm - Calibration factor in mm/kHz units. It is a multiplicative factor used in the linear formula that converts the signal frequency obtained from the FFT power spectrum to the target distance. (see also "Calibrate" screen). It can be used for manually correcting the distance calibration.

LoopTime (H)
xxx.x ms - Displays the actual sensor cycle time (main loop time) in ms. This represents the fastest possible sensor response time (for Damping=1). This is provided for system diagnostic purpose.

Tsmp us (H)
xxx.xx - Displays the actual A/D sampling time in microseconds for system testing purpose (The FMCW sweep ramp time equals that value multiplied by 1024). This is provided for system diagnostic purpose.

PeakSel (H)
xxxxxxx - Choose target peak selection and interpolation method:

"by Amp" - select target peak of the highest amplitude, if multiple echo peaks are present. This selection is best for applications with very weak or distant targets (above 20m). Correct adjustment of Min Amp parameter towards lower voltage may be necessary .

"First" - select the very first peak, of the shortest distance to the sensor (above MinAmp threshold) as the target. Adjustment of MinAmp towards higher voltage may be necessary when this method is selected. This option may be more useful in some close range applications (below 1m)

"Amp/Dist" - select a peak of the highest amplitude divided by distance ratio (default). This option should give good results for the majority of applications.

Dither (H)
xxxxxx - Select ramp dither magnitude
"None" - no dither (frequency sweep ramp is fixed)
"1/16 T" - ramp wobbles by 1/16-th of the target frequency period (T)
"1/8 T" - ramp wobbles by 1/8-th of the target frequency period
"1/4 T" - ramp wobbles by 1/4 of the target frequency period

"1/2 T" - ramp wobbles by 1/2-th of the target frequency period(default)
"Full T" - ramp wobbles by the length of the target frequency period

Setting Dither too high may cause higher output signal fluctuations.

Note: Dither should be normally set to “None”, except when higher accuracy is required and response time is not critical. In such cases, set Dither to 1/4 and set also Damping parameter to above 4 (the response time will naturally slow down).

ReBoot (H)
--- - Restart the firmware, equivalent to power reset. Note: it is a good idea to reboot after running “Lineariz” , “Calibrat” or after setting “SmplFreq”.

Set T (H)
xxx.x C - Set known temperature (factory calibration of temperature sensor offset). Must enter the actual (independently measured) temperature inside the enclosure. Factory setup only.

0.001%/K (H)
xxxxx - Temperature correction factor in 0.001%/K units, the range is -32768 to +32767. This parameter allows correcting the temperature drift. It acts upon the display variable "Distance", and also affects the primary sensor variable returned through all output channels such as 4-20mA and digital data. Default value is zero.

Set Vref (H)
xxxx mV - Set internal voltage reference value (factory calibration only). Should be measured by a voltmeter on pin 1 of the 30-way header (versus chassis GND). Typically 3680-3720mV . Factory setup.

SetR6/R3 (H)
xx.xxx - set resistor ratio R6 /R3 for calibrating the ramp voltage scale. Resistor R6 is on VEL-DRV-3 board, R3 is on VEL-CPU-3 board. Typical ratio is 33k/5.6k = 6. This factor affects the operation of the Ramp Min, Max, Ramp1/8, 1/4 etc screens. If this parameter is off then the values RampMin and Max would not correspond to actual sweep voltages. Factory setup.

Rly1Mode (H)
xxxxxxxx - Select relay 1 mode of operation from the list of:

1) “DistSwi” - switching on distance threshold as set by **SetRly1** screen
2) “ LOE ” – switch ON on Loss Of Echo condition
3) “No LOE” – switch OFF on Loss Of Echo condition
4) “ Fault ” – switch ON when any fault occurs that may invalidate sensor output (including LOE condition).
5) “No Fault” – switch OFF on fault (including LOE)
6) “ ON ” – always on

7) “ OFF ” – always off

Note: typical use of relay 1 to flag the LOE condition. It can also be used to flag events of target falling outside the measuring range (RawFmin , RawFmax)

Rly2Mode (H)

xxxxxxxx - Select relay 2 mode of operation from the list of:

1) “DistSwi” -switching on distance threshold as set by **SetRly2** screen
2) “ LOE ” – switch ON on Loss Of Echo condition
3) “No LOE” – switch OFF on Loss Of Echo condition
4) “ Fault ” – switch ON when any fault occurs that may invalidate sensor output (including LOE condition).
5) “No Fault” – switch OFF on fault (including LOE)
6) “ ON ” – always on
7) “ OFF ” – always off

Set Rly1 (H)

x.xxx uu - Set the switching point for relay 1, in distance units, for “Dist Swi” selection (below). Units uu depend on the setting of the "Units" screen. Setting a positive value causes relay 1 to switch ON when distance goes above the set value. Setting a negative value allows inverting the logic. If the set value is negative, relay stays ON when the distance is lower, and switches OFF when the distance is higher than the absolute value. When the value is exactly zero then the relay is always OFF. This parameter is ignored when Rly1Mode is not “DistSwi”.

Set Rly2 (H)

x.xxx uu - Set the switching point for relay 2, in distance units, for “DistSwi” selection (below). Units uu depend on the setting of the "Unit" screen. Setting a positive value causes relay 2 to switch ON when distance goes above the set value. Setting a negative value allows inverting the logic. If the set value is negative, the relay stays on when the distance is lower, and switches OFF when the distance is higher than the absolute value set in. When the value is exactly zero then the relay is always OFF. This parameter is ignored when Rly2Mode is not “DistSwi”.

Note: typical use of relay 2 is to trigger beam interruption alarm in applications that require it. For example, set the “Rly2Mode” to “DistSwi” and set up “Set Rly2” parameter to a distance shorter than a default target seen by the sensor with the uninterrupted beam.

TestFlgs (H)

0 - Binary flags alowing activation of self-test options (factory use only). Must be 0 to ensure normal operation.

bit 0 : 0=normal operation, 1=enable software generation of artificial cosine signal and noise (CPU diagnostics).
bit 1 : sets amplitude of the artificial cosine signal, 0=25.6, 1=512.0
bit 2 : sets amplitude of random noise added to artificial cosine signal, 0=0.0, 1=51.2
bit 3 : lock/unlock certain features. Factory use only.
bit 4 : reserved (1=same as "Reboot", do not use)
bit 5 : reserved (1=same as "LoadDflt", do not use)
bit 6 : reserved (1=same as "WipeLog", do not use)
bit 7 : 1 = resets the time count on "T(days)" screen, clears the 64-bit internal non-volatile time count.
Note: bit 7 option can be and should be used to initialize a newly plugged blank memory chip 24LC512 or 256.

T(days) (H)
xxx.x - Displays the total working time in days, from the first factory power up.

MargStrt (H)
xxx % - Set the starting margin for data within the sweep ramp, in % of the ramp length. Range 0-45%. Data is sampled only to the right of the starting margin and to the left of the end margin zone. Factory set. Typically 8% (reasonable selection is 5-15%). The purpose of the margin zone at the start is to blank out some switching artifacts that may appear when SmplTime=54kHz.

MargEnd (H)
xxx % - Set the ending margin for data within the sweep ramp, in % of the ramp length. Rage 0-45%. Factory set. Typically 0% (reasonable selection is 0-5%). Normally, when transmitter tuning is done correctly, there should be no artifacts on the signal at the end of the ramp thus this parameter should be set to 0.

Ramp Max (H)
xx.xxx v - Set the maximum voltage level for FMCW ramp (frequency sweep ramp). Must be less than the TX voltage. Typical value is -4V to +3V. Setting it too high (too close too TX Volt) makes the frequency sweep ramp less linear. Setting it too low reduces the sweep span thus spoils the overall accuracy of the sensor.

Ramp 1/8 (H)
xx.xxx v - Set the ramp voltage offset (from the linear) at 1/8 distance from the ramp start.

Ramp 1/4 (H)
xx.xxx v - Set the ramp voltage offset (from the linear) at 1/4 distance from the ramp start.

Ramp 2/4 (H)
xx.xxx v - Set the ramp voltage offset (from the linear) at 1/2 distance from the ramp start.

Ramp 3/4 (H)

xx.xxx v - Set the ramp voltage offset (from the linear) at 3/4 distance from the ramp start.

Ramp 7/8 (H)

xx.xxx v - Set the ramp voltage offset (from the linear) at 7/8 distance from the ramp start.

Notes: the distances expressed as 1/8,1/4 etc are fractions of the total ramp length (typ 9ms at SmplFreq=54kHz). The purpose of the above offset values is to make the ramp profile non-linear to correct for the frequency characteristics of the tunning element. The ramp is defined in terms of piecewise linear subsections but the actual ramp profile is additionaly smoothed out using a digital filter of 1/4 ramp length plus a low pass RC filter (3-pole 0.5kHz). Whenever trasmitter voltage is adjusted by a potentiometer "Vtx P5" on the VEL-DRV-3 board, the ramp profile must be regenerated by re-booting the sensor, re-powering or re-entering one of the offsets (or Ramp Min, Max).

Ramp Min (H)

xx.xxx v - Set the minimum voltage level for FMCW ramp (frequency sweep ramp). Typical value is -11 to -5V. Setting it too low could make the frequency sweep ramp less linear on some units. This voltage cannot or should not be set below the negative supply of -11V. Setting it too high (too close to Ramp Max) reduces the sweep span thus spoils the overall accuracy of the sensor, but narrows down the emitted bandwidth of the microwave signal and allows longer range.

Note: RampMin and RampMax are factory-configurable parameters. Changing any of the above parameters from MargStrt to RampMin is by the user is not recommended. Doing so would require a re-linearization and re-calibration.

Note2: adjustment of “Ramp Max” and “Ramp Min” parameters is essential for ensuring that the device emission falls within the prescribed frequency band, as per the automotive standard (76.00-77.00GHz) or ISM band (62-62.5GHz, 122-123GHz, FCC Part 18).

Lineariz (H)

xxxxxx Performs automatic sweep ramp linearization procedure. A good strong target should be present within the radar range (preferably between 4 and 15m). For example an empty tank bottom. Wait few seconds until it displays "Done". Optimal values of parameters "Ramp 1/8" to "Ramp 7/8" are automatically calculated and stored. Select one of the following xxxxx =:

"Escape" - abandon procedure
"Incremnt" - perform incremental linearization starting with the existing values of "Ramp 1/8" to "Ramp 7/8" parameters.

"Clr&Go" - first zero the parameters "Ramp 1/8" to "Ramp 7/8" then run linearization.
"Restore" - restore the previous values of "Ramp 1/8" to "Ramp 7/8" (possible only if the unit was not powered off or rebooted in between).

After linearization: - check the accuracy (displayed on the separate screen "LinrzAcc", see below) . Accuracy should normally be 2% or less. 1% or less is best. If it is higher than 2% repeat the procedure using "Incremnt" selection a couple of times until accuracy is as low as possible.

Notes:

Linearization procedure does not work very well if RawFreq is below 20 or above 200. Test target distance should be adjusted such that the RawFreq is in the middle of that range, say 50-150. It may also fail or return poor accuracy if the signal is too small. It works best if the target strength yy>70, the higher the better (see screen "Dist Syy "). Not every transmitter linearizes with default parameters of "RampMax" and "RampMin". In some units, RampMax has to be reduced and RampMin increased to linearize the ramp to desired accuracy (or even to make the linearization algorithm converge at all). Some transmitters have to have the tuning screw[12] adjusted (#10-32 slotted screw). Transmitter supply voltage may also need to be adjusted in the range 2.9-4.9V by potentiometer "Vtx" on the bottom board.

Note it is recommended to "ReBoot" after linearization. Dither should be set to “None” before “Linearize” procedure is run.

LinrzAcc (H)

xx.x % - Displays accuracy (in %) of the most recent sweep ramp linearization procedure. This is the square average of the peak frequencies deviation over the four subintervals of the ramp. Ideally, after the linearization, all subintervals ought to show the same frequency thus xx.x should be very close to zero. LinrzAcc parameter shows how much on average they differ from each other.

Calibrate

Escape/Proceed - Start calibration procedure (when Proceed is selected). “Cal Dist” parameter is used as the actual known distance to calibration target. A calibration target could be for example a tank bottom if the tank is empty. The result of the calibration are calculated

[12] Do not to turn that screw deeper in than the head sticking out by two threads, and always turn it very gently. Otherwise it may impinge against internal resonator structure. Forcing the screw too deep may break the internal parts. When adjusting, observe the raw signal from the target on the oscilloscope (connector J3 pin "SIG/GND") or use D command over RS232 connection. The signal should be as high in amplitude and as uniform as possible, and should have as high a frequency (for a given distance) as possible.

automatically and recorded as new value of "CalFac" parameter. Make sure that the correct value of the "Cal Dist" (see below) that corresponds to the tactual target distance, is keyed-in.

Note: if two-point calibration is required (for example - to cancel out some near distance offset), CalOffs parameter has to be entered in manually, before the Calibration procedure is executed. The procedure will only calculate automatically and reassign CalFac preserving the CalOffs. CalFac value can also be manually fine-tuned after the procedure in order to refine the calibration. The target used for calibration should produce strong single echo peak (S>90). The target should be placed as far as reasonably possible. Avoid calibrating in situations when multiple targets may produce strong echos at different distances, avoid using weak targets. Inclined metal plates should also be avoided since they reflect the beam like a mirror causing some unexpected targets to be mistakenly registered.

It is recommended to "ReBoot" after calibration.

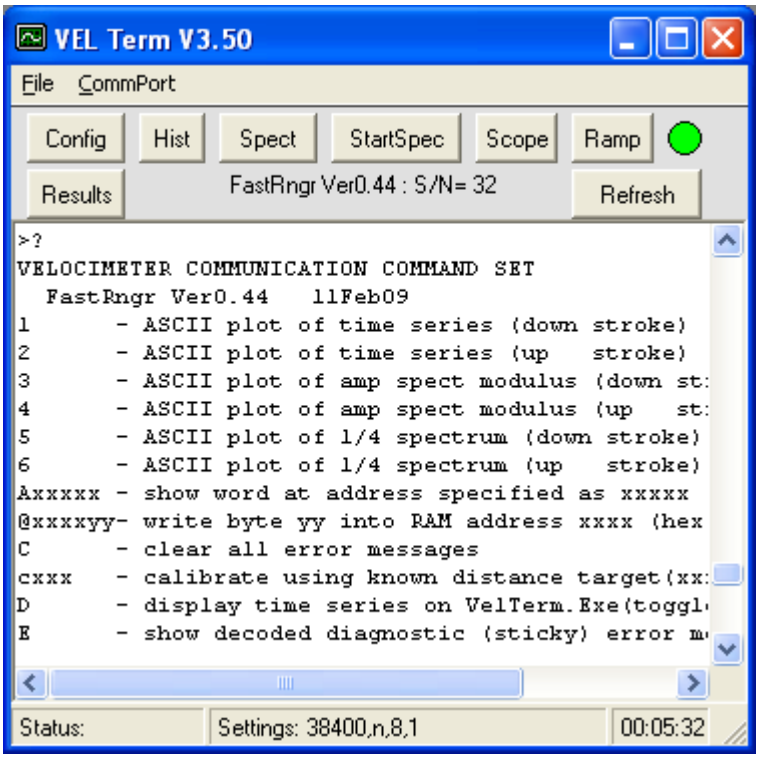
Cal Dist

xxxx uu - Calibration reference distance in uu units (see Units screen). This parameter has to be equal to the actual distance to the calibration target used during calibration procedure (see "Calibrate" screen). The distance should be measured and verified by a tape or other calibrated device, from the surface of the target to the narrow base (beginning) of the horn antenna. This parameter is used only during calibration in order to calculate the "CalFac" parameter. It is not relevant outside of the calibration procedure and changing it after calibration does not affect the unit calibration status.

5. Digital Data Link Commands
PC Host Application 'VelTerm.Exe'

VelTerm is a PC host based application which interfaces to the sensor via a serial data port (see a connection diagram at the end of this chapter).

The operation in principle is quite similar to commercially available terminal emulators such as Hyperterm however; VelTerm has some built in functionality for visualization and exporting of the data downloaded from the sensor. The main screen presented to the user is as follows.

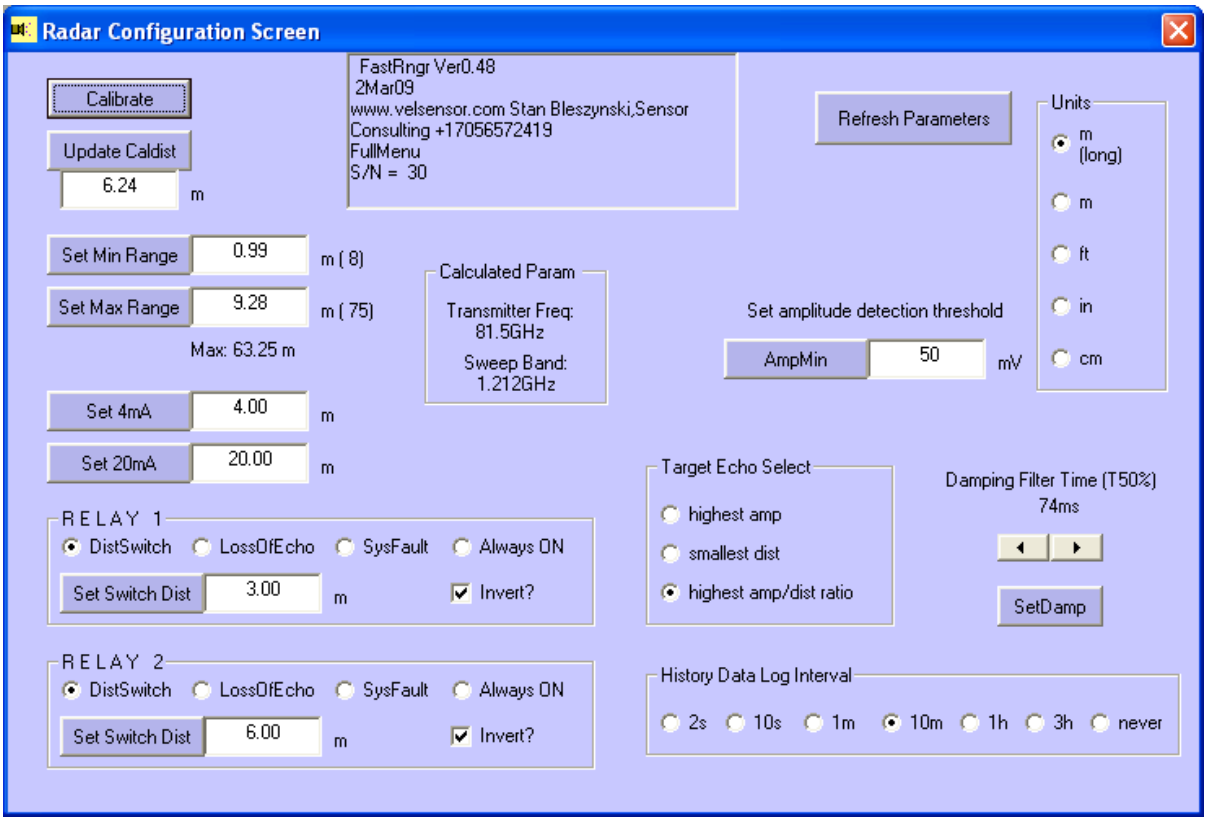


The easiest way to get an overview of VelTerm operation is by pressing the question mark **'?'** key. This will update the screen with a list of all available ASCII text commands that the sensor microcontroller will recognize.

Main menu bar (top) contains "File" submenu that allow opening/closing of a data log file, viewing of a saved history file (following 'h' command), as well as opening and executing a script file ("Transmit Text File…"). CommPort submenu allows enable/disable of the serial port and modification of the port parameters[13].

First task that the user may want to perform is verify or update configuration parameters to configure the application-specific settings. Easiest way to do it is by clicking on "Config" to open Configuration form screen:

[13] It is possible to open multiple VelTerms instances each talking to a different com port. When starting a second VelTerm, ignore initial warning message, change the COM port number and re-enable the new port.

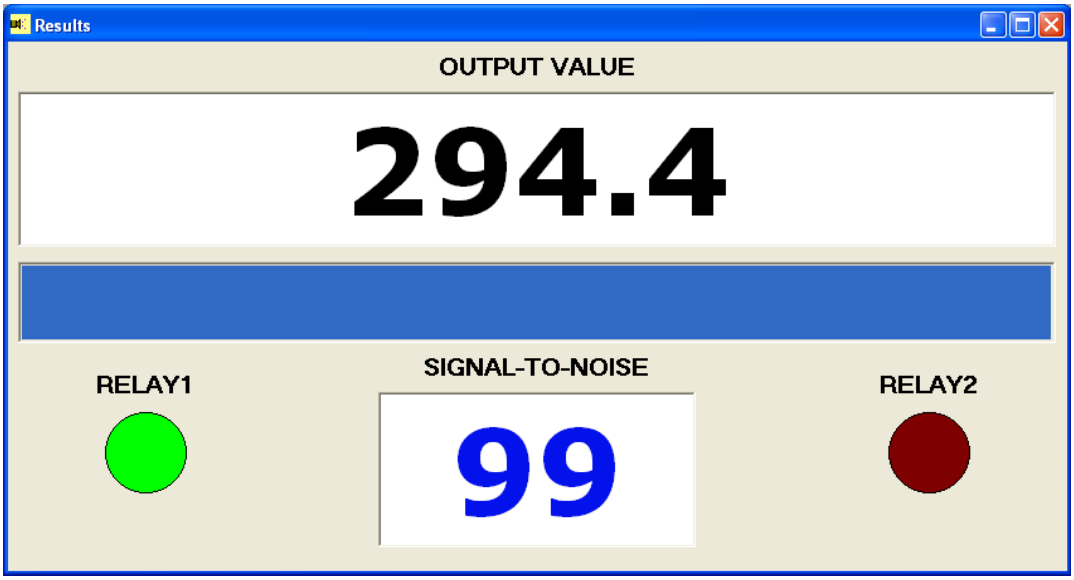


Select units, use m(long) when the maximum range is beyond 99m, otherwise use m,ft,in or cm selection. Type in Set Min and Max ranges limits (the nearest and the farthest target distance window, respectively). Set up 4 and 20mA values, and then set up the relay modes and tripping distance (if applicable). For tank level sensing applications, set up the "Damping" time constant to a suitably high value to slow down the output (5-30s is a typical value for tanks). For distance position sensing and beam-intrusion detection keep Damping at minimum to achieve the the fastest response (default).

If re-calibration is required, make sure that a reference target is placed at front of the sensor (preferably within 4 to 10m distance), then enter the actual tape-measured target distance[14] under the "Update CalDist" window then click on "Update CalDist" button to store the value. Click on "Calibrate" button to execute calibration routine (wait ~20 seconds).

Sensor output may be monitored on-line with "Results" command button (or press "{" command from the terminal window). Data is refreshed on screen (see below) automatically every 2 seconds.

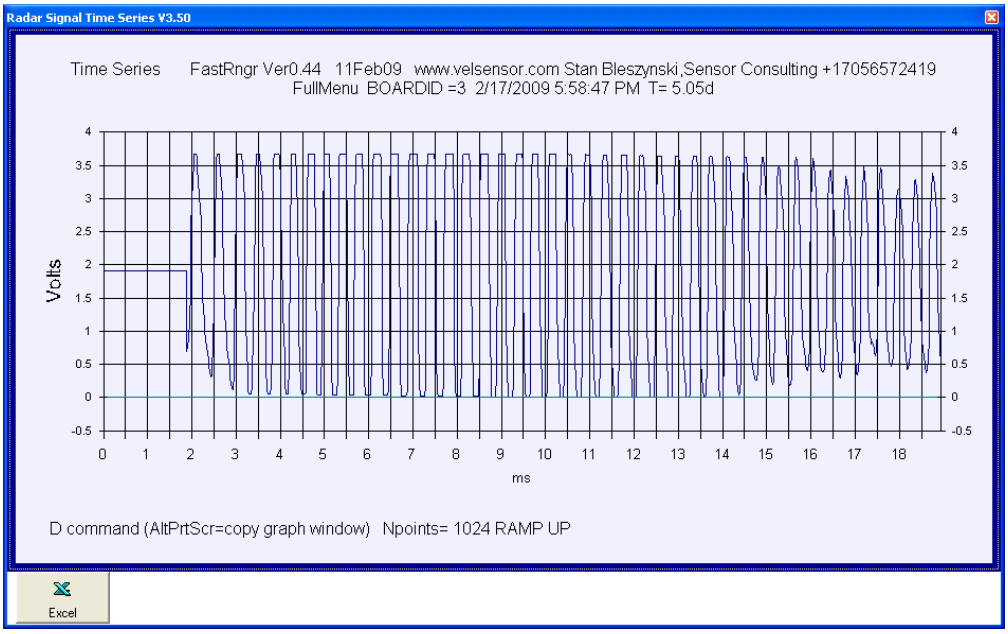
[14] Target distance is referenced to the bottom (narrow) end of the horn antenna, or the place on the enclosure where the 3/4" NPT threaded end of the horn is attached to.



The main data visualization commands, useful for diagnostic and data analysis are ‘D’, ‘F’ and ‘H’,available also as clickable screen buttons "Scope", "Spect" and "Hist" respectively.

‘D’ Command ("Scope" button)

The ‘D’ command downloads a raw time series data from the sensor and displays a chart of voltage vs. time. This feature is particularly useful for installation and adjustment of the unit and essentially emulates an oscilloscope. This can facilitate adjustment of the unit such as to maximize signal strength (voltage amplitude).



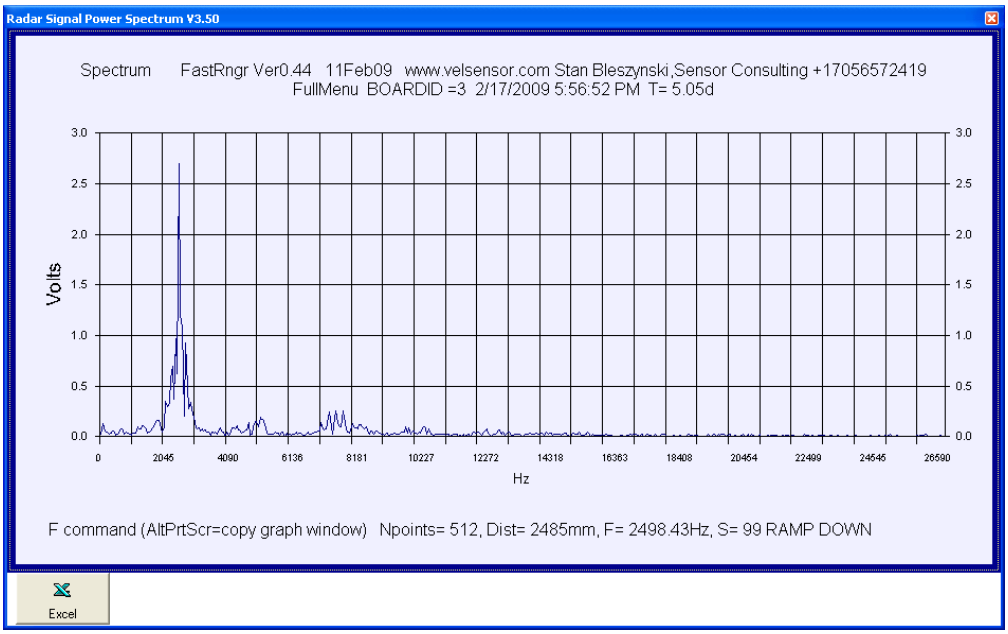
The ‘Excel’ button in the lower left hand corner of the screen launches Microsoft Excel[15], creates a new workbook and automatically populates two columns of data with time in ms as the independent variable and voltage as a function of time as the dependent variable. This feature allows the customer to use the features of Excel for further data analysis or visualization as per their own unique requirements.

Each time D command is executed, a buffer of 1024 data points collected during FMCW sweep ramp is displayed. Data gathered during the rising and the falling ramps are displayed alternatively, that is if first D displays the rising ramp data, a subsequent D will display falling ramp etc.

Note: down ramp data can be distinguished from the up ramp data by having the longer flat margin at the left (only when "FFT win" = "K30dB80%" or "Rect 80%")

‘F’ Command ("Spect" button).

The ‘F’ command provides the frequency domain equivalent of the ‘D’ command in that it is also a visualization tool to assist installation and troubleshooting but in this instance it displays a Fourier spectrum of the data and displays signal power as a function of frequency. In this regard it is basically like an on board Spectrum Analyzer.



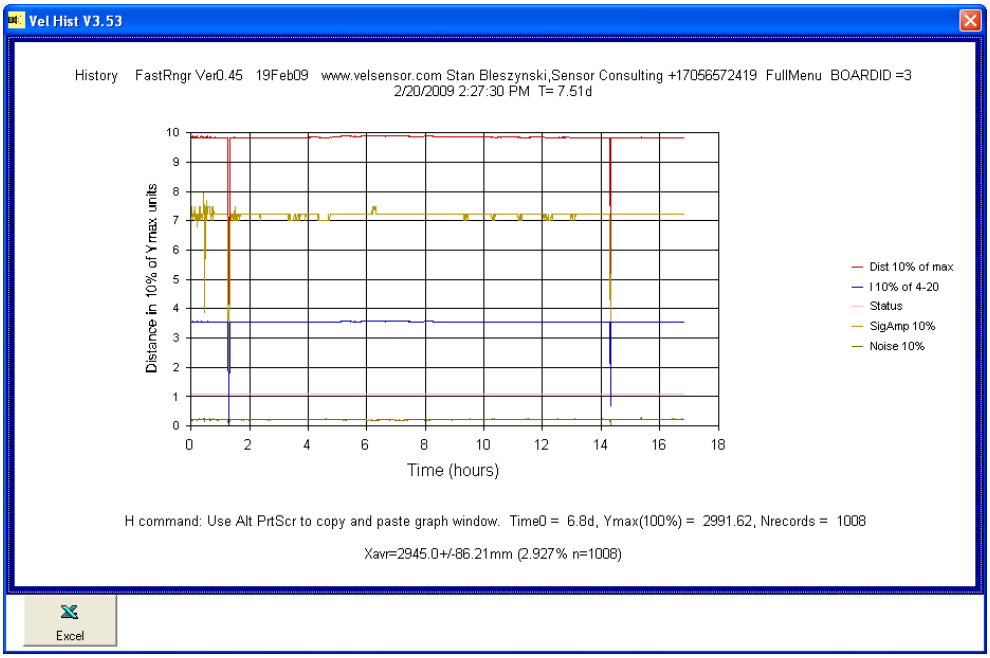
[15] Providing that it is already installed in the host PC (not included).

Again, the Spectral display screen contains a button to facilitate exporting the data to Excel. In this instance, two columns of data are populated on the spreadsheet, the independent variable is frequency in Hz and the dependant variable is in volts squared as a function of frequency i.e. V^2 per 1 bin (0..512 bins), in the units of spectral power density. The spectral peak in the plot above represents the frequency proportional to the distance to the target. The frequency peak is internally scaled filtered and converted to a distance in m, ft, inches or cm.

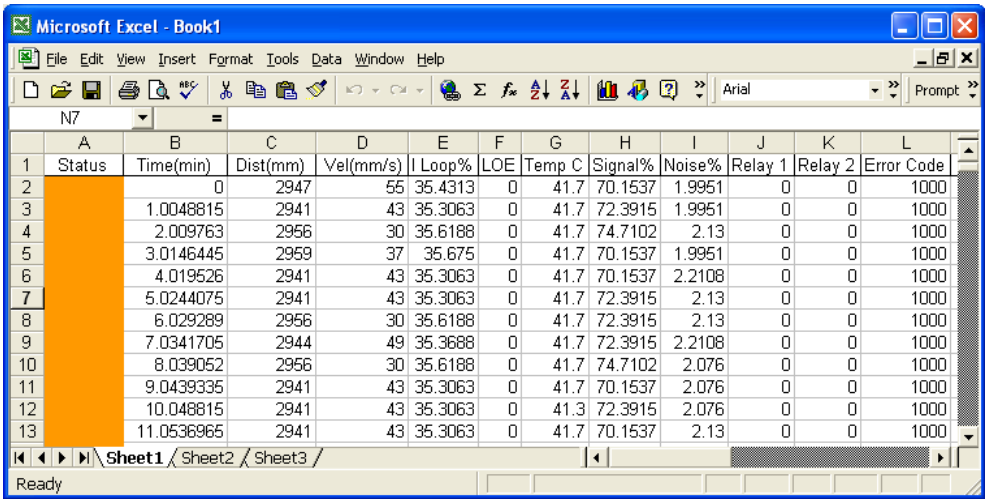
Each time F command is executed, a buffer of 1024 data points collected during FMCW sweep ramp is converted by Fast Fourrier Transfor (FFT) into power spectrum and displayed. The rising (up) and falling (down) ramp spectra are displayed alternatively, that is if first F displays the rising ramp spectrum, a next F will display the falling ramp spectrum etc. Note: the down ramp spectrum can be distinguished (from the up-ramp) by having its zero frequency component always zeroed. To autorepeat the same screen every 2 seconds, use "[" command or click "StartSpec" button.

'H' Command ("Hist" button).

The sensor unit contains an internal non-volatile memory (socketed EEPROM chip 24LC256, U5 on VEL-CPU-3 board) which facilitates data logging. At user defined intervals, the unit will take a snapshot of primary process variables. These, together with some system data, environmental variables and error messages are time-stamped and logged in the EEPROM. 'H' command provides a means for the end user to read the contents of the EEPROM, display them in tabular and graphical format and also to export them to Microsoft Excel. After the data is read in from the system, VelTerm will launch the following graph. The graph contains various information relating to the primary process variables together with diagnostic information.



The graph has a button which exports the logging history to Excel. This appears as follows:



	A	B	C	D	E	F	G	H	I	J	K	L
1	Status	Time(min)	Dist(mm)	Vel(mm/s)	I Loop%	LOE	Temp C	Signal%	Noise%	Relay 1	Relay 2	Error Code
2		0	2947	55	35.4313	0	41.7	70.1537	1.9951	0	0	1000
3		1.0048815	2941	43	35.3063	0	41.7	72.3915	1.9951	0	0	1000
4		2.009763	2956	30	35.6188	0	41.7	74.7102	2.13	0	0	1000
5		3.0146445	2959	37	35.675	0	41.7	70.1537	1.9951	0	0	1000
6		4.019526	2941	43	35.3063	0	41.7	70.1537	2.2108	0	0	1000
7		5.0244075	2941	43	35.3063	0	41.7	72.3915	2.13	0	0	1000
8		6.029289	2956	30	35.6188	0	41.7	72.3915	2.13	0	0	1000
9		7.0341705	2944	49	35.3688	0	41.7	72.3915	2.2108	0	0	1000
10		8.039052	2956	30	35.6188	0	41.7	74.7102	2.076	0	0	1000
11		9.0439335	2941	43	35.3063	0	41.7	70.1537	2.076	0	0	1000
12		10.048815	2941	43	35.3063	0	41.3	72.3915	2.076	0	0	1000
13		11.0536965	2941	43	35.3063	0	41.7	70.1537	2.13	0	0	1000

The leftmost column ‘Status’ is color coded and represents a status flag for the current data sample, the legend is Red = Fatal Error, Orange = Warning, Yellow = System Information. The next column is the timestamp which is in units of the sensor system timer which is equal to 87.381 ms. The next column is Distance reported in mm units, followed by Velocity in mm/s. The I Loop % column contains the output current on the 4-20mA current loop in % of the full span (4mA→0%, 20mA→100%). The LOE column contains a flag variable which indicates ‘Loss of Echo’ condition associated with the current data sample. Temp C is the radar circuit internal temperature as measured by the on board temperature sensor. Signal and noise represent the instantaneous signal amplitude and spectral

background noise and are expressed in % of the reference voltage (3.7V). Relay1 and Relay2 are flags representing the status of the two relays (user-programmable to trip under predefined conditions). Finally the Error code column is a hexadecimal value where each bit is mapped to a specific error flags (bits 20-31), warning flags (bits 4-19) or process status flags (bits 0-3). The flags are described in details in the Appendix.

Other useful commands:

E - display decoded **non-volatile** system errors, warnings and process info messages in plain English. Use 'C' command to clear.

e - display decoded **volatile** system errors, warnings and process info messages in plain English. The difference between messages displayed by "E" versus "e" command is that the non-volatile flags are stored in EEPROM and persist through power down, while volatile flags are updated (set or cleared) automatically by the processor every 10 seconds.

C - clears all error, warning and status codes (clears both "E" and "e" commands)

V – displays sensor output variable in ASCII decimal format in 1 line, followed by <CR> and <LF>:
xxx.xxx, xxxx,xx , xxxxx.x or xxxxxxx - depending on the units selected (m,ft,in,cm)[16]

This command can be used by a host controller or a network master server to asynchronously poll the sensor output variables and the sensor status. The data packet is sent within the next measurement cycle time from the time of sending the command, resulting in typically about 60ms latency (=LoopTime).

Q - displays status flag word in ASCII, 32 bits in 8 hex digits. The flag bits are explained in the appendix. Q command can be used for polling the relay status (Relay1=bit0, Relay2=bit1). Commands V and Q are intended for fast data poll by a PLC or host PC with minimum latency (~60ms), when digital data link is to be used as the main process connection for the sensor.

{ - begins a continuous (auto-repeat) display of one line of sensor output values and status data, every 2.0 seconds., one datum per line. .

[16] Special version optimized for velocity measurement returns velocity instead of distance in the same units as above, per second.

} - ends the "}" command ('R' command or power reset also terminate it)

[- begins continuous (auto-refresh) graphic display of power spectrum, similar to "F" command, refreshing automatically every 2.0s. Note: the display alternates between falling and rising slopes of FMCW sweep ramp. Normally both slopes produce similar data and similar spectra but some small differences may be noticeable, especially if the target moves.

] - ends the "[" command ('R' command or power reset would also terminate it)

P - shows the list of all internal configuration parameters and values. This is important command that should be executed every time the sensor is reconfigured, in order to check it. It is recommended that every time the sensor is commissioned or reconfigured, the configuration data is retrieved using 'P' command, captured and saved using File-->Open Log/Close Log menu selections in VelTerm.exe.

S - list all configurable parameter numbers that can be accessed through "s" (lowercase s) command. Displays the command formats and parameter ranges.

s - assign a new value vvvvvv to a parameter number nn. The command format is: snnvvvvvv where nn is the parameter number nn=08..78 (use 'S' command to display the actual list of all the parameters, that can be modified), vvvvvv is a 6 digit decimal parameter value to be assigned. All 6 digits must be passed, the leading zeros must be inserted explicitly. If the value is negative the first v may be a minus sign for example -6 value is entered as 'snn-00006'. A modified parameter is automatically saved in EEPROM within one measurement cycle (typ ~60ms at SmplFreq=54kHz selection, or 75ms at SmplFreq=26kHz).

The 'snnvvvvvv' command allows configuring the sensor through the digital remote serial link rather than using push-buttons and LCD interface. For example s19000004 command causes the Damping filter to be assigned a value of 4 (which produces a 16 cycle long averaging16=2^4). Another example useful for installation testing is the loop test command such as: s29000iii whre iii is the forced loop current in 0.1mA units. For example s29000201 forces the loop output to 20.1mA current (and also forces the optional quadrature pulse output if installed). Issuing s29000000 ends the loop test and restores the normal

operation[17]. Note: the allowed range for loop current is 3.6..25.0mA (accuracy is +/-10uA within 4-20mA, degraded above 1mA). Many of the snnvvvvvv parameters can be also more conveniently entered from the "Config" screen, see above.

h - similar to H command but displays history data in ASCII text format without invoking graphics plot. It can be used to capture and save history file as text file (File→Open/Close Log menu). The file can be subsequently read from disk and displayed graphically using File->DispHistFile menu option.

N - number of data records logged in the built-in non-volatile memory, counted since the last power reset, 'W' command or reboot 'R'.

W - wipe (erase) all history log file from the sensor built-in non-volatile memory[18].

c008 - start distance calibration procedure (008 = password). The sensor must be pointed to a strong reference target at a known distance. The target distance has to be entered as s36xxxxxx parameter value (or use "Update CalDist" button from Config screen), prior to the execution.

l008 – (l=lowercase "L")
k008 start automatic linearization procedure in the "Incremental" mode (see "Lineariz" user menu selection) (008 = password) . The sensor must be pointed to a strong reference target at some distance, preferably within 3-15m distance range. Linearization procedure works best when the RawFreq is withn 20 to 200[19], preferably around 100. Linearization procedure is cumulative, every time l008 it improves (converges) to a more accurate ramp shape, controlled by the Vramp0..4 parameters (s66..s70). Typically, l008 command should be repeated several times to achieve linearization accuracy below 2%. To restart linearization from a default straight ramp, clear all Vramp0..4 values (send s66000000, s67000000,…,s70000000). Or use the "o008" command. Command k008 works the same as l008 except it automatically repeats 10 cycles.

[17] It times out automatically after 5 minutes, also 'R' command or power reset would cancels a pending loop test command.
[18] Fast Ranger has a built-in data logger that can store up to 1008 records in an on-board EEPROM memory chip 24LC256/512. Frequency of data logging can be set from the Config screen to: 2s, 10s, 1m, 10m, 1h, 3h and "never". Setting of 2s fills the log memory up and then stops when full. All the higher time settings cause the log records to roll over (circular), with new records overwriting the old ones.
[19] Linearization procedure may be inaccurate if Raw Freq<20 and may be unstable (non-converging) above 200 (Raw Freq is between 0 and 512). Optimum is about 100.

X - dump the buffer contents of consecutively measured (every 60ms) unfiltered distance values in internal units (0..51200).

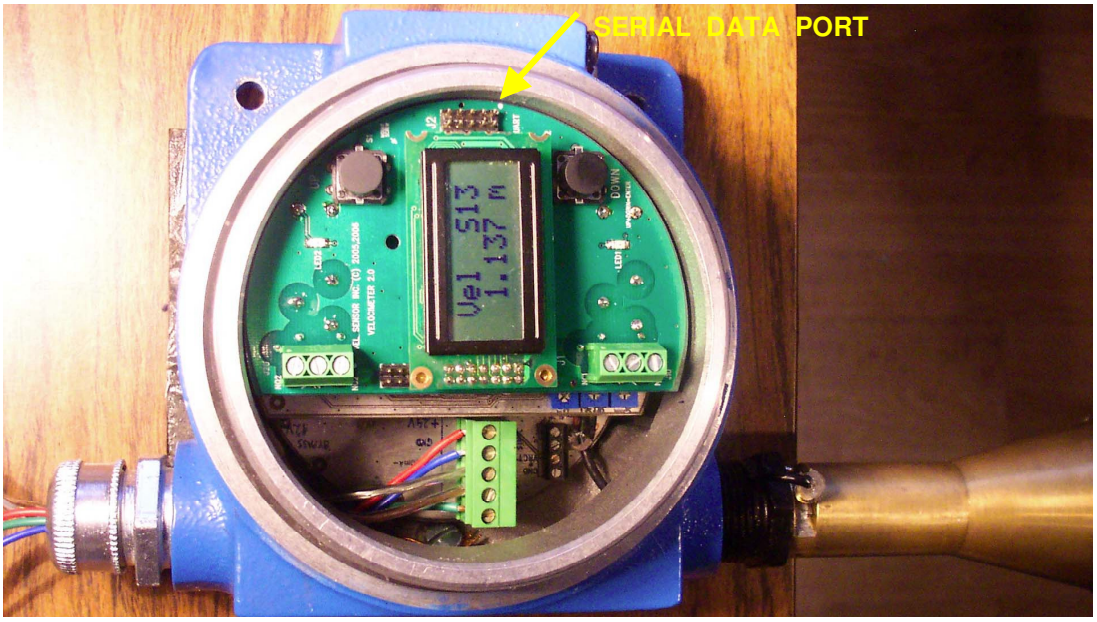
x - dump the buffer contents of consecutively measured (every 60ms) unfiltered velocity values in internal units (0..51200).

R - reboot the sensor CPU and restart firmware. Clears any pending command. The same effect as power reset.

y - display ramp profile

6. Digital Data Link Connection

UART port for diagnostics, data transfer and configuration are available through a 10-way 2.54mm DIL header[20] going through the entire board stack. It can be accessed from the top board. A photo below shows the 10 way header on the top above the LCD panel.



Sensor top board view (serial port shown by a yellow arrow)

+3.7V	1	2	CTS1/RTS1
CLK1	3	4	**RXD1**
CE	5	6	EPM
GND	7	8	-RST
CNVss	9	10	**TXD1**

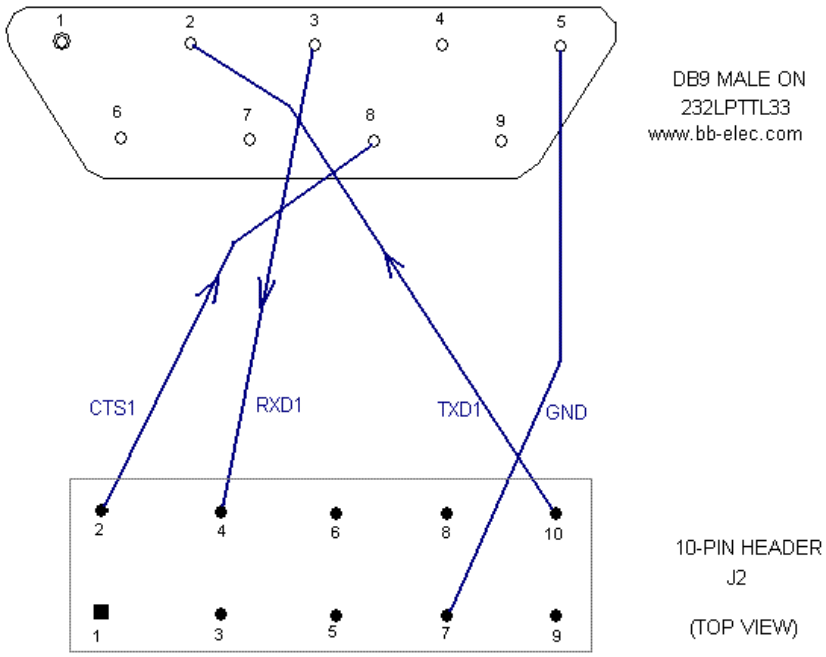
Table. Pin-out of 10-way serial port header. The serial port conforms to 0-3.7V signal levels (3V TTL UART).

[20] The header pinout and size is compatible with the Renesas "FoUSB" programmer and In-Circuit-Emulator

.

Wiring diagram for the serial port connection.

The serial port uses 0 to 3V digital signal levels. A TTL-to-RS232 level converter should be used to translate the digital sensor port to RS-232 standard, for example: product “232LPTTL33” from http://www.bb-elec.com .



Note: only RXD1, TXD1 and GND are required for RS232 data link, other pins are only used for in-circuit programming by Renesas tools. RS232 data format is 1 start bit, 8-bits, no parity, 1 stop bit and no handshaking, allways ASCII (32-127), byte values >127 are not used. Baud rate is software selectable from 9600 (legacy, for slow PC), 38400 (default) to 230kbaud (works only on fast PC’s with USB/RS232 cable interfaces).

Note 2: when data link cable has to be substantially longer than 10m, it is recommended to connect the 232LPT33 (TTL-to-RS232) interface on the cable within a few meters from the sensor and then connect another RS232-to-USB cable interface within a few meters from that. RS-485 interface may also be used for long distance connection or when high noise level is present.

7. Application Notes.

Sensor beam has approximately 4 degree angular width (full angle) with a 3" (75mm) diameter lens-horn antenna and ~1.5deg with a 8" lens-horn, at 77GHz band[21]. Reflection strength (i.e. target peak amplitude) is a function of the target distance, target inclination angle (if it is a flat surface), surface roughness, material properties (dielectric constant and absorption coefficient) and the presence of some environmental factors such as water, branches or other obstructions in the line of sight. There are following basic rules:

- flat perpendicular (to the antenna axis) surfaces produce the strongest echos
- rough[22], corrugated, rippled or irregular surfaces produce medium to good echos even when not perpendicular
- linear perpendicular targets such as wires, pipes etc produce weak but usable echos (reduced maximum range).
- smooth flat surfaces inclined by more than a few degrees (e.g. 4deg) produce very weak non-usable echo or no echo at all.[23]

In terms of material sensitivity, metallic surfaces and water (or wet surfaces) produce the strongest echos, non-metallic materials produce smaller echos. Water reflectivity at 77GHz is about 50%, metal ~100%, dry wood ~3-5%, wet wood ~10%, cement ~2%, plastic or glass sheets ~10%. Radar beam can penetrate and measure metallic targets behind double plaster board walls, wooden walls or behind glass windows.

In practice, material dielectric properties are much less important than the surface roughness/granularity and inclination angle. The most severe impact on the echo strength, more important than the material property, has the inclination angle of flat smooth targets.

Presence of droplets of water in the line of sight (mist or even heavy rain) does not visibly impact the signal quality even at 30m range. Presence of heavy water splashes and droplets on the lens surface (polypropylene) may weaken the signal but does not prevent it from working. Water splashes on most types of targets generally enhance the echo. Snow and ice have a much smaller impact than water, however heavy ice buildup on the antenna may disturb the lens focus and may deflect the beam from the target. Presence of dust or smoke does not affect the radar signal at all. It is not sensitive to infrared sources or light. Movement of the target (Doppler effect) is compensated (subtracted out) by means of data processing such that the distance reading should not normally be affected (for example up to +/-10m/s at 30m distance or +/-1m/s at 3m).

---

[21] With a given antenna, beam width is inversely proportional to the center frequency band,; at 122GHz the beam width is 2.5deg (3" antenna) and 1 degrees (8" antenna), respectively

[22] "rough" means granularity on the scale of 1 millimeter or larger.

[23] However, flat inclined metal surfaces can be used as beam reflectors to re-direct or re-route the beam to other targets .

The radar transceiver is mechanically sensitive to strong acoustic vibrations in the 50-500Hz range conducted through the enclosure mount (but not through air) and may potentially pick the noise instead of the signal[24]. When high intensity vibrations are present, the sensor must be mounted on shock-absorbing and vibration-damping rubber pads or soft fiber-composite pads.

[24] For instance, vibration level present around a cold rolling steel mill requires double 1/2" soft rubber mounting pads to isolate it.

Appendix A – Error Messages, status word bit flags.

The following list shows status flags reported by command 'Q', embedded in history file and other da ta outputs. These messages are also reported by 'e' and 'E' commands from serial data link. Firmware Release 0.48 (3-Mar-2009).

Bit #	**ScreenMsg**		Long message text
Bit 0	**Rly1 ON**	-	relay 1 is ON[25]
Bit 1	**Rly2 ON**	-	relay 2 is ON
Bit 2			(not used)
Bit 3			(not used)
Bit 4	**FFT Err**	-	FFT software error
Bit 5	**badTsmpl**	-	measured sample time calculation failed, over range
Bit 6	**CalibErr**	-	calibration inaccurate, out of range or failed
Bit 7	**Vel Hi**	-	target velocity too high to compensate (accuracy loss due to Doppler)
Bit 8	**TsensUnc**	-	temperature sensor is not calibrated
Bit 9	**TsensRng**	-	temperature sensor out of range (-30..+90C)
Bit 10	**Hi Noise**	-	high baseline noise
Bit 11	**Low Sig**	-	low signal
Bit 12	**Hi Sig**	-	high signal
Bit 13	**No Echo**	-	Loss Of Echo, target out of range or amp < MinAmp threshold
Bit 14	**Hist Cnt**	-	corrupt history record number (soft error or memory fault)
Bit 15			(not used)
Bit 16	**CrptPass**	-	corrupt password (corrupt memory)
Bit 17	**ScrError**	-	screen error, program configuration error[26]
Bit 18	**NotLinea**	-	linearization not done or error
Bit 19	**ArithOvr**	-	arithmetic long integer overflow error
Bit 20	**Eprom SW**	-	parameter group too long for EEPROM, software error",
Bit 21	**Vsupply**	-	supply voltage out of range (19-29V)
Bit 22	**TranFail**	-	transmitter failure - antenna lead shorted or disconnected
Bit 23	**Hi Temp**	-	temperature too high (70C)[27]
Bit 24	**SoftErr**	-	invalid argument, software error
Bit 25	**Eprom Wr**	-	EEPROM write data failure
Bit 26	**Eprom Rd**	-	EEPROM read data failure
Bit 27	**CPUFault**	-	CPU or A/D failure
Bit 28	**Lvl Zero**	-	circuit failure - signal DC level is zero
Bit 29	**LvlClipd**	-	circuit failure - signal DC level is clipped high
Bit 30	**StackOvf**	-	stack overflow, software error
Bit 31	**CorptPar**	-	corrupt param., EEPROM read inconsistent with hard-coded data[28]

----- End of file ------

[25] Bits 0..3 are process (not error) flags and are not displayed on Status and Diagnostic screens.
[26] Parameter out of range, examine parameter screens and re-enter a correct in-range value.
[27] Temperature measured by the sensor is typically 7-15C higher than the outside temperature
[28] If blank EEPROM was inserted - reinitialize all parameters manually, and also send s5400136 command to pre-format the EEPROM.