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IMS Equipment Challenges for Waveform Technologies

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CTBTO PREPARATORY COMMISSION

1. IMS digitizers

The DM24EAM current IMS digitizers are aimed to be used for the International Monitoring System (IMS) waveform technologies stations for CTBT verification.
Optional set up of sampling rates and output data formats (including cd1.1) as well as compliance with IMS minimum technical specifications expands the range of potential applications of the digitizers for 3C seismic, T-phase hydroacoustic stations as well as for existing and new IMS seismic and infrasound arrays in combinations with other high resolution digitizers previously installed there.
Flexible set up of the front end gaining allows matching system calibration factors without significant impact on the digitizer noise floor. The units were tested under extreme temperature conditions potentially relevant for field applications over the entire IMS Network.
In addition to compliant performance within IMS specifications for generic tests like DC accuracy, input terminated noise, harmonic distortion, timing accuracy and channels cross-talk the digitizers have about 2-5W power consumption measured with embedded authentication card.

General Digitizer Specifications

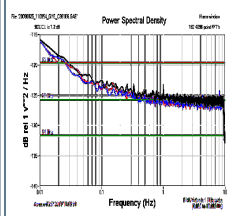
General Specifications (GS)	Description	Manufacturer Specifications	Requirements (IMS)
General DWR Inputs			
Number of Channels	Number of channels and groups of channels.	4	3 Channels
Sample Rates	Sample rates in samples per second, individual channel sample rates, grouped channel sample rates, multiple sample rates per channel.	1-1000	1, 20, 40, 80, 100
General Mechanical			
Size	Overall size, borehole capable, vault capable.	0.15X0.3 Cylinder	0.3X.3X.3 M
General Power			
Operational Input Power Supply Voltage	Input power supply voltage that DWR can operate over and maintain 100% operational capability including the ability to survive power system instabilities; Power on/off hysteresis.	10-28 V 2.75 W Continuous 5 W Peak	11-30 V @ 5W
General Environmental			
Fully Operational Temperature Range	Temperature range that DWR can operate over and maintain 100% operational capability, continuous power or cycled power.	-20 to +60 C	-20 to +45 C
Operational Temperature Range	Temperature range that DWR can operate over with reduced capability.	-40 to +80 C	
Watertight Capability	Splash Resistant or Submersible.	IP68	IP67

Digitizer Analog Specifications

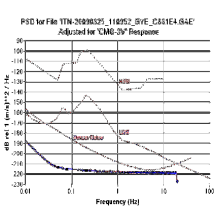
High Resolution Analog Input Subcomponent	Description	Manufacturer Specs	Requirements (IMS)
Input Type	Single-ended (V p-p) or differential input (2x V p-p).	Differential	Compatible with IMS Sensors
Input Impedance	In K or M ohms and capacitance.	>100K Ohms	>100K Ohms
Bit-Weight/Resolution	Value of least significant bit in volts.	2.84	N. S.
Input Voltage Range	Peak to peak signal voltage that DWR can operate over and maintain 100% operational capability. Input voltage clip or destructive threshold.	+/-10V on each Differential Output	Input Compatible with IMS Sensor Outputs
Data Word Length	In bits; 16, 20, 24, 32, etc.	24 bit	24-bit Resolution
Input Gain (Digital)	Software multiplier to normalize channel gains or use of digital multiplier to achieve gain or attenuation.	1.0	N. S.
Input Gain (Analog)	Generic preamplifier gain or attenuation, jumper or programmable selected; description of DWR input to HRD or A/D input.	1, 2, 4, 8	Selectable Gain to Signal Match Digitizer Noise to IMS Sensor Noise
Broadband Accuracy (gain=1.0 +/- %)	Percentage accuracy from DC to 1-dB including digital filter ripple.	0.1% est.	N. S.
Analog/Digital Offset	The part of dc offset that is related to the DWR analog preamp that can not be easily removed; this will cause loss of symmetry between positive and negative signals.	Factory Trim	Not Affect Dynamic Range
	The part of dc offset that is related to the DWR analog preamp and HRD that can be removed in the digital domain.	Yes	Field Removal of Offset
Digital/Analog Filter	Passband ripple, 3-dB point, attenuation at Nyquist, IIR, FIR.	-3 dB at 0.8 Nyquist	Bandwidth to Accommodate IMS Application Bandwidth
	Supplement to digital filter.	no	
GPS Synchronization Method	PLL to GPS, disciplined oscillator.	Software PLL	
Static/Dynamic Self-Noise	The terminated noise of the digitizer input expressed in counts RMS or volts RMS, can be indicated as a time domain number or a frequency domain PDS plot.		Based on IMS Application
Multi-Channel Crosstalk	The amount of signal from all channels coupled to any single channel.	-130 dB	-120 dB
Common-Mode Rejection Ratio	The amount of common signal that can be removed from the differential inputs of a DWR; the level of common mode signal that will affect operational capability.	-80 dB	N.S.
Linearity	Reflects the ability of the DWR to record signals without distorting them, IMD, THD.		0.01% (80 dB)
Dynamic Range/Signal to Noise Ratio	Reflects the maximum ability of the DWR to record small to large signals with out clipping, SNR, SINAD.	>130 dB @40 S/S	120 dB

IMS digitizer Test Results at Sandia National Labs. NM.

ITN (Input Terminated Noise)

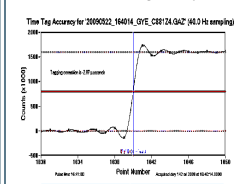


Test: SSN (Seismic Subsystem Noise)



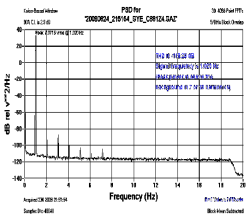
DM24 Gain X1 with CMG3-V 20000 V/M/S

Test: TTA (Time-Tag Accuracy)



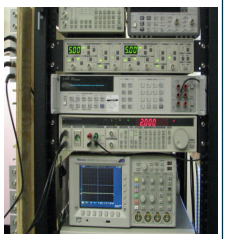
Absolute Accuracy	Accuracy Drift
-6 µs	3.4ms/min

Test: THD (Total Harmonic Distortion)



Digitizer Testing Based on Sandia National Laboratories:
SANDIA REPORT SAND2007-5037, Unlimited Release
Test Definitions for the Evaluation of Digital Waveform Recorders Version 1.0
Richard P. Kromer, Darren M. Hart and James M. Harris

SMAD digitizer CEA



Affinity new digitizer Guralp, UK

Measuring equipment rack

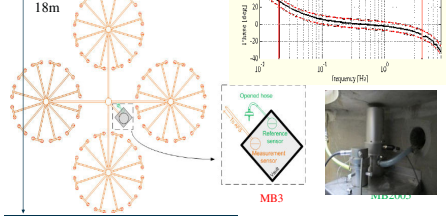
Guralp Systems and CEA digitizers under the testing

Abstract

The poster is focused on equipment challenges for IMS seismic and infrasound networks. As per Operational Manuals, stations of both networks must meet requirements for data authentication, data buffering, data availability with less than five minutes transmission delay to the IDC, and accurate control of absolute and relative timing for data samples. Developed Standard Station Interface (SSI) solution provides the compliance with these requirements.
It is known that verification seismology is concerned with searching of reliable methods of signal detections at high frequencies whilst IDC M_S/m_b screening criteria relies on reliable surface waves detection at low frequencies. To achieve that the requirements for instrumental noises are defined as certain dBs below minimum background within the whole required frequency band. Therefore the compliance with them introduces challenging task when close to NLNM conditions are recorded at the site. The experience has shown that hybrid response seismometers provide optimal solution for utilization of system dynamic range and assuring the compliance with instrumental noise requirements.
Results were achieved in infrasound technology to optimize the response of the WNRS within the required infrasound passband. To obey the requirement for infrasound system calibration the reference sensor technique was developed and validated at several stations.

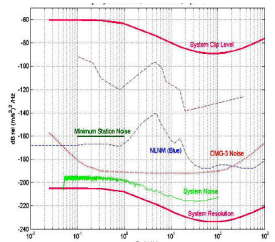
4. Standardization of WNRS and calibration with reference infrasound sensor

The purpose of WNRS standardization is to avoid within the IMS passband the impact of the pipe system on the infrasound channels acoustic frequency response presented by the sensor P&Z and digitizer FIR. The 18-m rosette system (depicted below) has been found to be the optimal choice.
Passive calibration of the full system (sensor + WNRS) response using side-by-side comparison implemented at I26DE, IS18DK and I37NO. Reference equipment linked to an opened hose was installed at each array element.
The eight infrasound array elements of station I26DE were successfully calibrated in full compliance with IMS requirements. The measured amplitude responses were within 5% of the theoretical amplitude responses. The measured phase responses were within 5° of the theoretical phase responses
Long term testing at IS26 also provided unique feedback on response stability of infrasound measurement systems.

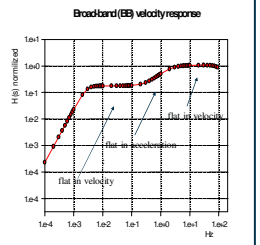


Layout of IS measurements and reference sensor calibration

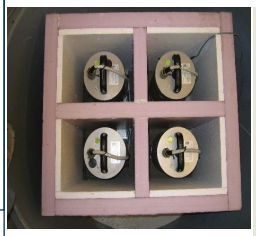
2. Utilization of hybrid frequency response for IMS applications



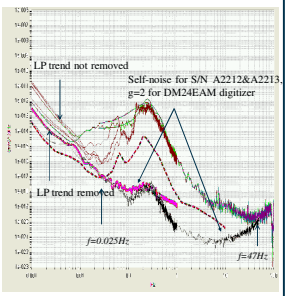
Noise study for single component Z elements of AS104 EKA UK (Güralp Ltd, UK)



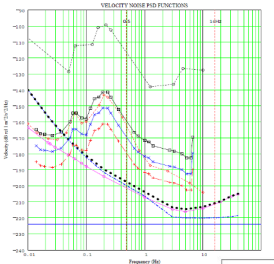
Frequency response of hybrid sensors at IMS arrays PS27 NOA, and PS28 ARCES both Norway



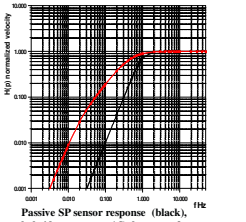
Hybrid response sensors at the test vault, PS27 NOA Norway



Channel noise study for hybrid response 1C elements at PS27 NOA Norway (IMS/ED)



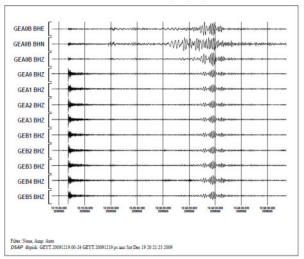
Noise study for hybrid response elements of PS44, GEYT (Nanometrics, CA)



Passive SP sensor response (black), hybrid response at 1C elements of Turkmenistan array (red)

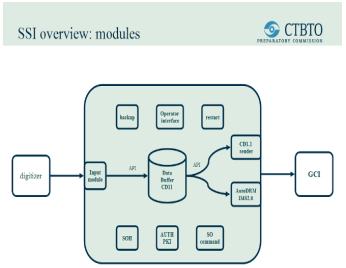
PS44 Turkmenistan, 9 elements regional IMS array.

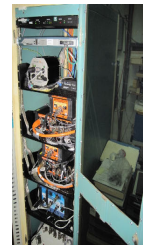
After installation Ms=6.4 event 19.12.2009 in Taiwan



3. Standard Station Interface (SSI)

- **Designed to meet unique IMS requirements**
  - 14+ days buffer
  - Data authentication/PKI
  - Tamper switches (ADI) monitoring
  - Timing status monitoring (both central and individual GPS)
  - Remote Command and Control
  - Calibration capability (full frequency RB or "white" noise and sin waves)
- **Designed to use IDC formats and protocols**
  - CD 1.0/CD1.1
  - AutoDRM
  - CSF subformat (signed, DSA, ECDSA is pending)
- **Multiple Input Modules**
  - Quanterra/Comserv, Guralp GCF, IDA NRTS, Nanometrics, DASE, SHI, Geotech,
  - CDrecv with at least 7-days buffering
- **Runs under Linux (Centos 6.5)** will work under Centos 5,3 or later version.
- **Development of mini SSI solution (*Raspberry Pi3 ModelB, TS7970 Technologic Systems*).** Applicable for meteorological channels and provides authentication solution.





SSI equipment rack at A105, GUMO Guam, USA.

Hardware solutions

Raspberry Pi3-ModelB

PrioComP
Industrial computers for rough conditions
alpha 2000