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Wind Noise Reduction Systems in the International Monitoring System Infrasound Network

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CTBTO PREPARATORY COMMISSION

Introduction

The infrasound component of the International Monitoring System (IMS) consists of sixty stations, among which forty-nine are already certified and continuously transmit data to the International Data Center (IDC) in Vienna, Austria. Each infrasound station is composed of an array of infrasound sensors capable of measuring micro-pressure changes produced at ground level by infrasonic waves. Wind generated micro-pressure fluctuations is the primary sources of background noise at the infrasound stations. Such noise may prevent the detection of infrasonic signals from atmospheric explosions. Wind Noise Reduction Systems (WNRS) are being used to reduce pressure fluctuations produced by wind generated noise.

Assessment of IMS WNRS performance

WNRS are being installed since 2001 at IMS infrasound stations. In the framework of station reengineering the performance of the WNRS were assessed and several areas of improvement were identified.

Key WNRS improvement areas:

- ❑ **The WNRS used at all array elements of an IMS infrasound station must have an identical response in IMS frequency band**
- ❑ **The WNRS should minimize distortion of the response (amplitude and phase) to pressure fluctuations produced by acoustic waves in the IMS frequency band of interest [0.02 Hz – 4 Hz] in any environmental condition**
- ❑ **Vegetation is the best noise reduction system at stations and should be preserved as much as possible**
- ❑ **Need of software that can model the response (frequency, amplitude, phase) of WNRS to find the optimum design**

Preservation of vegetation at stations

Development of flexible WNRS that can adapt to the environment:

- Reinforced heavy duty rubber hoses with industrial stainless steel fittings that can be used for stations located in very dense vegetation
- Stainless steel pipes which can be bent around trees by the use of a pipe bender and therefore adapted to the vegetation
- Pipes installed on flexible supports above the ground to minimize ground preparation works

Figures 1, 2 and 3. Pictures of recent installed 18 meter WNRS. The upper left picture shows the first installation of flexible hoses in Galapagos. The upper right picture shows stainless steel pipes installed in Tunisia. The pipes were bend around trees and installed on supports to adapt to the uneven terrain. The third picture shows a installation of stainless steel pipes on flexible wooded supports in Greenland.

Development and validation of WNRS frequency response models

Several institutes have developed and are using models to estimate pipe array frequency responses. Benchmarking and validation of these models was carried out and a standard model was developed that can be used in IMS infrasound station design and performance assessment.
In order to validate the models, a field experiment was performed with an infrasound generator that is able to produce stable infrasonic waves in the entire IMS frequency band. The infrasonic waves were recorded by sensors linked to a pipe array system and a set of opened reference sensors. The waveform data recorded with both systems was compared afterwards.

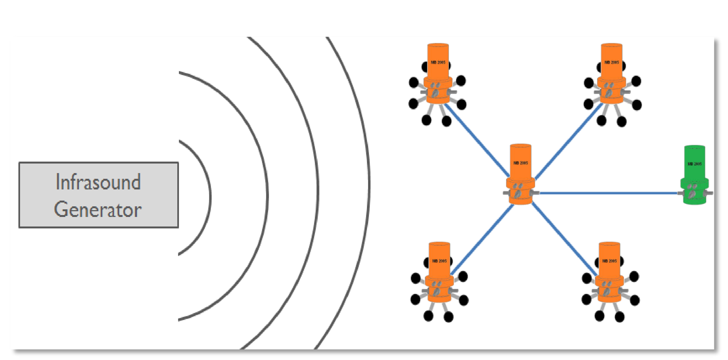

Figure 4. Experimental setup in which a comparison between recordings of the sensor linked to the pipe array system and a set of opened reference sensors was carried out

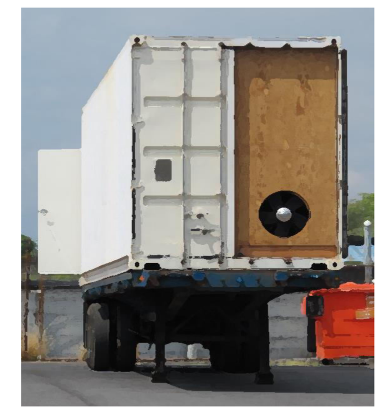

Figure 5. Infrasound generator installed in a 20 foot container produces an acoustic wavefield in the 0.4 Hz – 20 Hz bandwidth

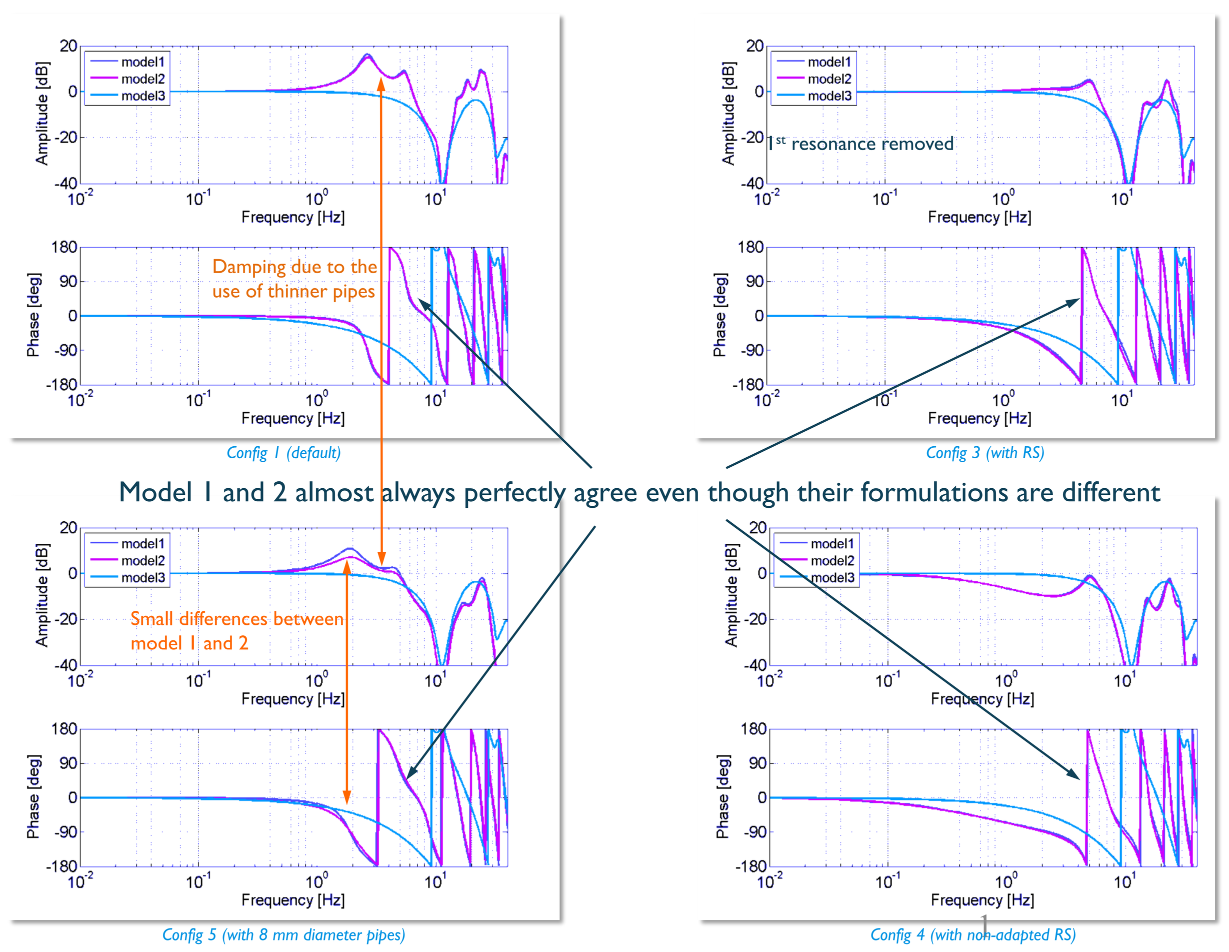

Figure 6. Response model validation on configurations with several low-frequency resonances and different pipe lengths and diameters

Modelling results:

- ✓ Impressive match of the phase response between the field measurements and the two models
- ✓ Models can reliably be used to predict the frequency response of IMS pipe array systems
- ✓ Model improvement (options added, parameterization, etc.)

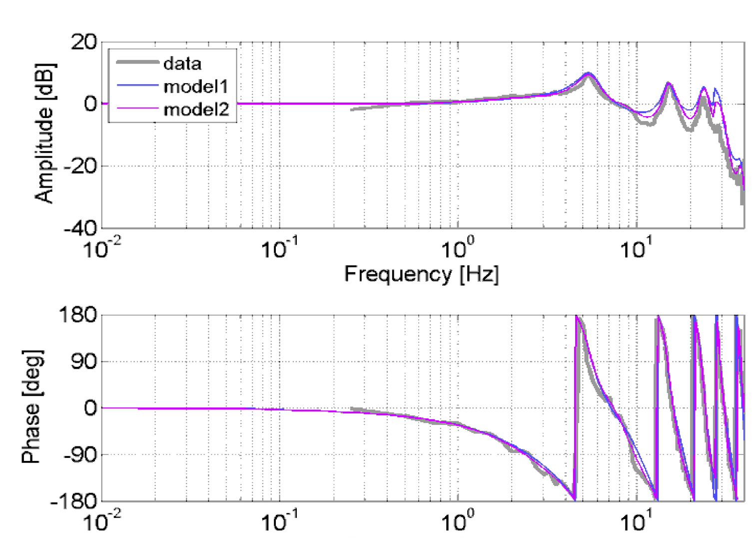

Figure 7. Comparison of modeled responses with empirical measurements show an almost perfect agreement in amplitude and phase

WNRS design with identical and stable response

The following improvements were identified to ensure an identical response of the WNRS :

1. Modelling of all parts of the WNRS to find optimum size of manifolds and length of pipes
2. Minimize hose length between primary manifold and microbarometer by installing the sensor on a platform above ground

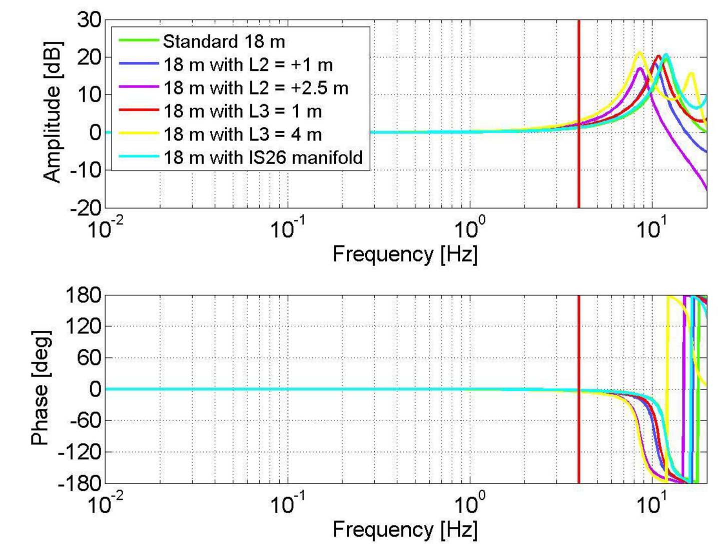

Figure 8. Amplitude and phase response of a 18 meter pipe array with different pipe length.
L2= pipe length secondary to primary manifold. L3= pipe length primary manifold to sensor.

3. Resonance suppressors should not be used in WNRS since they introduce phase shifts in the IMS band and created an unstable response
4. Homogenization of WNRS at 7 infrasound stations.

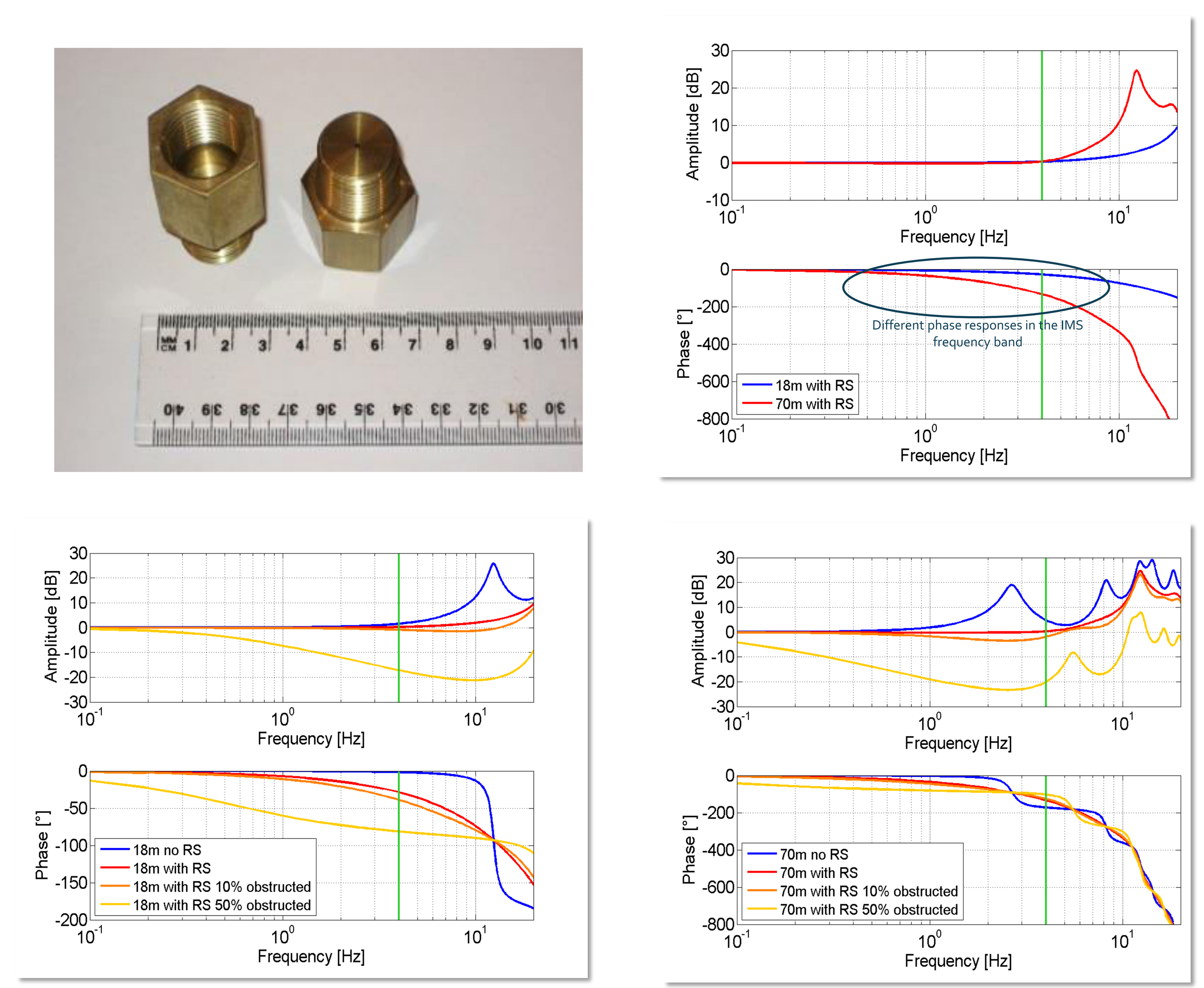

Figure 9. Resonance suppressor and its modeled impact on a 18 meter and a 70 meter WNRS. The resonance suppressors generates different phase shifts depending on the size of the WNRS. The phase shifts creates different time delays which is an issue in the IDC for the computation of the wave parameters.

5. Development of a standard 18 meter WNRS that will be installed at new stations and existing stations and which is flexible enough to adapt to the local environment
6. Usage of stainless steel (grade 304 or 316) as basic material to ensure stable and identical response
7. Usage of standardized sealing techniques to ensure air tightness of the WNRS

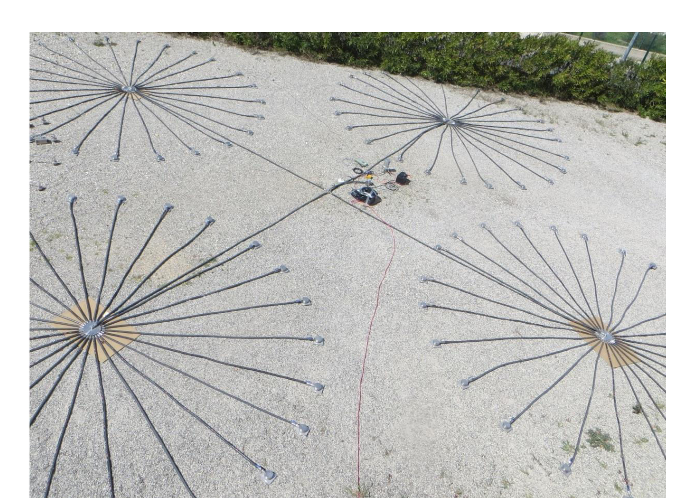

Figure 10. Response testing of a 18m WNRS that uses reinforced heavy duty rubber hoses at the manufacturer facility

Extended life-cycle and reduction of installation and maintenance costs of WNRS

Extended life-cycle:

- All parts of the WNRS are made of stainless steel or a combination of stainless steel parts and reinforced heavy duty rubber hoses
- Development of inlet ports, a 24-way one-row manifold and a 4-way manifold
- Reduction of the total number of fittings and the usage of Loctite glue sealing makes WNRS air tight
- Quality control during the production of WNRS to enhance reliability, precision and robustness
- Usage of high quality stainless steel fittings and valves

Figure 11. Stainless steel inlet port with valve, fixation plate and lateral hose access

Figure 12. Valve extension for inlet ports that are covered by gravel

Reduced installation and maintenance costs:

- Use of 24-way one row manifolds simplifies drastically the installation and the maintenance of the WNRS
- Installation of WNRS with reinforced heavy duty rubber hoses or stainless steel pipes on flexible supports reduces the need of terrain flattening and enhances its capability to adapt the WNRS to the local environment
- Replacement of pipe sealing tape by Loctite glue seal during production of WNRS minimizes assembling work during installation and reduces the time of searching for air leaks
- Create precise drawings to describe each part of the WNRS to allow the tracking parts and therefore improve the maintainability of the WNRS

Figure 13. Pressure testing of a WNRS without the need of removing the gravel from the inlet port

Figure 14. Reinforced (2 metal layers) heavy duty rubber hose

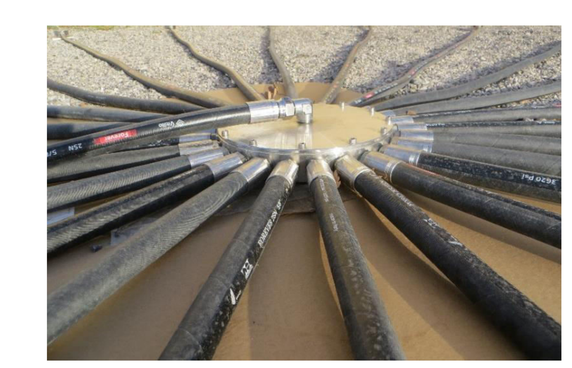

Figure 15. Detail of one rosette with reinforced rubber hoses connected to the single row secondary manifold

Conclusions

The Provisional Technical Secretariat (PTS) assessed and improved the robustness and efficiency of the WNRS used within the IMS infrasound network.

The major achievements are:

- ✓ **Design and production of WNRS with a stable response in amplitude and phase with minimum distortion in the 0.02-4 Hz band**
- ✓ **Design of WNRS that can be adapted to the environment preserving local vegetation**
- ✓ **Development and validation of WNRS frequency response models**
- ✓ **Extend WNRS lifetime, reduce installation cost and simplified maintenance**