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# Improvement project for the infrasound station I17CI (Cote d'Ivoire) detections: increase from 4 to 8 sensors

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***Abstract*** In CTBTO monitoring system (IMS), Côte d'Ivoire benefits from two (2) primary stations: seismic (PS15) and infrasound (I17CI) respectively for monitoring underground and airborne nuclear tests. Upgrading the infrasound station I17CI from 4 to 8 sensors is part of the CTBTO's medium-term objectives, which include upgrading the world's other infrasound stations. Thus, this research project is part of the preliminary studies prior to the implementation of this major CTBTO project.


## 1- Introduction

- Infrasound detection has proven to be importance in the study of various fields (nuclear test monitoring, air safety, atmospheric dynamics, etc. (Andry, 2019).
- However, the detection capabilities of an infrasound network are strongly impacted, not only by the geometry of the sensors, but also by the inter-sensor distance (Blandford, 1997).
- The I17CI infrasound network in Côte d'Ivoire, and in general all networks of this configuration, see their performance reduced by the large distance between sensors (3 km), especially for the detection of high-frequency waves (> 1Hz) (Bowman and Lees, 2008).
- This study proposes to optimize the I17CI network by adding additional fictitious sensors, taking into account the geometry of the initial network.

## 2- Methods

- Two (2) methods were used: the loss-of-coherence method and the network coverage method:
  - Coherence is a parameter that measures the similarity of signals across all sensors (Nouvellet, 2016). It contains all the necessary information such as phase, amplitude and attenuation due to inter-sensor distance and frequency:

$coherence = \left|\frac{1}{n}\sum_{i=1}^{n} S_i\right|$ (1)

$S_i = A_i . e^{-d_i . f} . e^{j\phi}$ (2) : Signal received by i the sensor

$A_i = e^{-\alpha \, d_i}$ (3) : $S_i$ signal amplitude

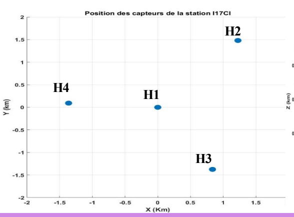
$\alpha = f^2 . \left(\frac{T_0}{T}\right) . \left(\frac{H_0}{H}\right)$ (4) : absorption due to frequency and weather conditions

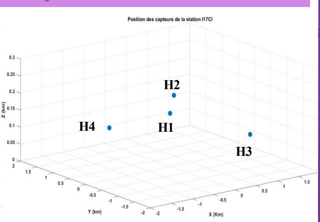
  - The coverage of an infrasound network measures its sensitivity to event detection. Anderson (2010) proposes the following formula for calculating coverage :

$P_i = \sum_{i=1}^{n} e^{-0.5 . d_i}$ (5)

$d_i = \sqrt{(x_i - x_p)^2 + (y_i - y_p)^2 + (z_i - z_p)^2}$ (6) : distance form i and each grid point p.

## I17CI sensors position




## 3- Results

### 3-1- Local atmospheric absorption

| Fréquence (Hz) | Absorption @ Tmin, Hmin (dB/km) | Absorption @ Tmoy, Hmoy (dB/km) | Absorption @ Tmax, Hmax (dB/km) |
|---|---|---|---|
| 0.10 Hz | 0.00774 dB/km | 0.00619 dB/km | 0.00568 dB/km |
| 0.20 Hz | 0.03097 dB/km | 0.02475 dB/km | 0.02274 dB/km |
| 0.30 Hz | 0.06968 dB/km | 0.05569 dB/km | 0.05116 dB/km |
| 0.40 Hz | 0.12387 dB/km | 0.09901 dB/km | 0.09095 dB/km |
| 0.50 Hz | 0.19355 dB/km | 0.15470 dB/km | 0.14212 dB/km |
| 0.60 Hz | 0.27871 dB/km | 0.22276 dB/km | 0.20465 dB/km |
| 0.80 Hz | 0.49548 dB/km | 0.39602 dB/km | 0.36382 dB/km |
| 1.00 Hz | 0.77419 dB/km | 0.61879 dB/km | 0.56847 dB/km |
| 1.50 Hz | 1.74192 dB/km | 1.39227 dB/km | 1.27905 dB/km |
| 2.00 Hz | 3.09675 dB/km | 2.47514 dB/km | 2.27387 dB/km |
| 3.00 Hz | 6.96769 dB/km | 5.56907 dB/km | 5.11620 dB/km |
| 4.00 Hz | 12.38701 dB/km | 9.90056 dB/km | 9.09547 dB/km |

**Table 1** : Absorption coefficient (α) above I17CIstation

- Infrasound wave absorption becomes very important for frequencies above 1Hz;
- For a given frequency, absorption is greater when the temperature-humidity couple (T; H) is low;
- This parameter has a major influence on infrasound detection in a sensor network.

### 3-2- before optimization (4 sensors)

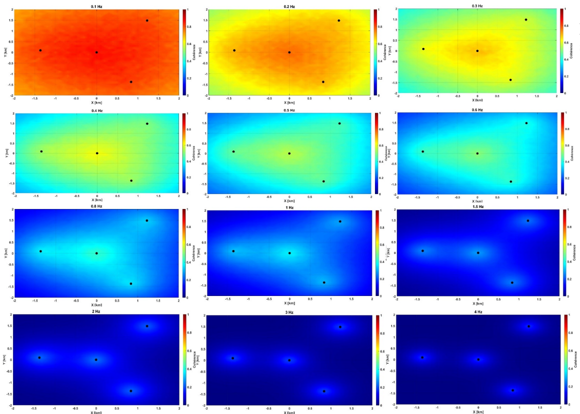


**Figure 1a**: Loss of signal coherence of I17CI station before optimization.

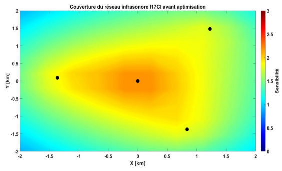



**Figure 1b**: I17CI network coverage before optimization.

- Events with frequencies below 0.8 Hz are detected with great similarity between sensors. But they are often marked by ambient noise and also by interference between waves (Brown and Assink, 2018). These effects are caused by the excessive distance between sensors, which has a major impact on network capacity;
- Signals with frequencies above 0.8 Hz see their coherence significantly reduced. This is due to their sensitivity to weather conditions and atmospheric interference (Bowman and Lees, 2008);
- In this configuration, the network shows concentrated coverage in the central zone (2.5 sensitivity), while remote zones remain under-covered (0.5 at the extremities) (**Fig. 1b**). This reflects the existence of shadow zones within the sensor network: signals arriving in these zones cannot be detected by the network, thus reducing its performance.

### 3-3- After optimization with 4 dummy sensors (8 sensors)

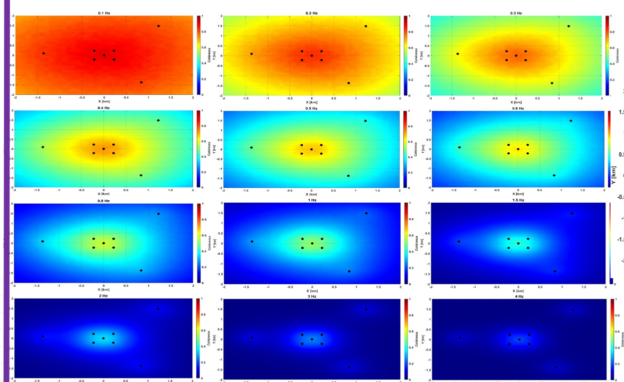


**Figure 2a**: Loss of signal coherence of I17CI station after optimization with 4 dummy sensors.

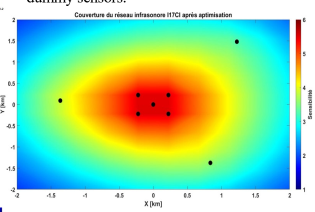



**Figure 2b**: I17CI network coverage after optimization with 4 dummy sensors. The Blue dots represent the geometry and positions of dummy sensors to optimize overall network performance.

- Improved network consistency and coverage as shown in **Figures 2a and 2b**.
- The impact of optimization on coherence is most pronounced at frequencies > 0.8Hz. This improves signal detection and source localization (Bowman, 2005);
- Low-frequency signals (< 0.8 Hz) are less affected by background noise and inter-signal interference, as the inter-sensor distance is reduced;
- Lhe optimized network offers more sensitive coverage. The minimum sensitivity is 2, whereas the initial network offered a maximum sensitivity of 2.5.
- This network optimization reduces shadowing and localization errors, and enables signals to be captured with greater precision (Le Pichon et al., 2010).

## 4- Conclusion and perspectives

- Optimization of I17CI network by adding additional dummy sensors provides enhanced and more accurate detection capability. The network's full capabilities are enhanced, which is very useful for detecting signals from various sources at several frequencies.
- For the future, it may be useful to consider dynamic optimization methods that adjust the position of sensors according to the events detected.

## 5- Bibliographical references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