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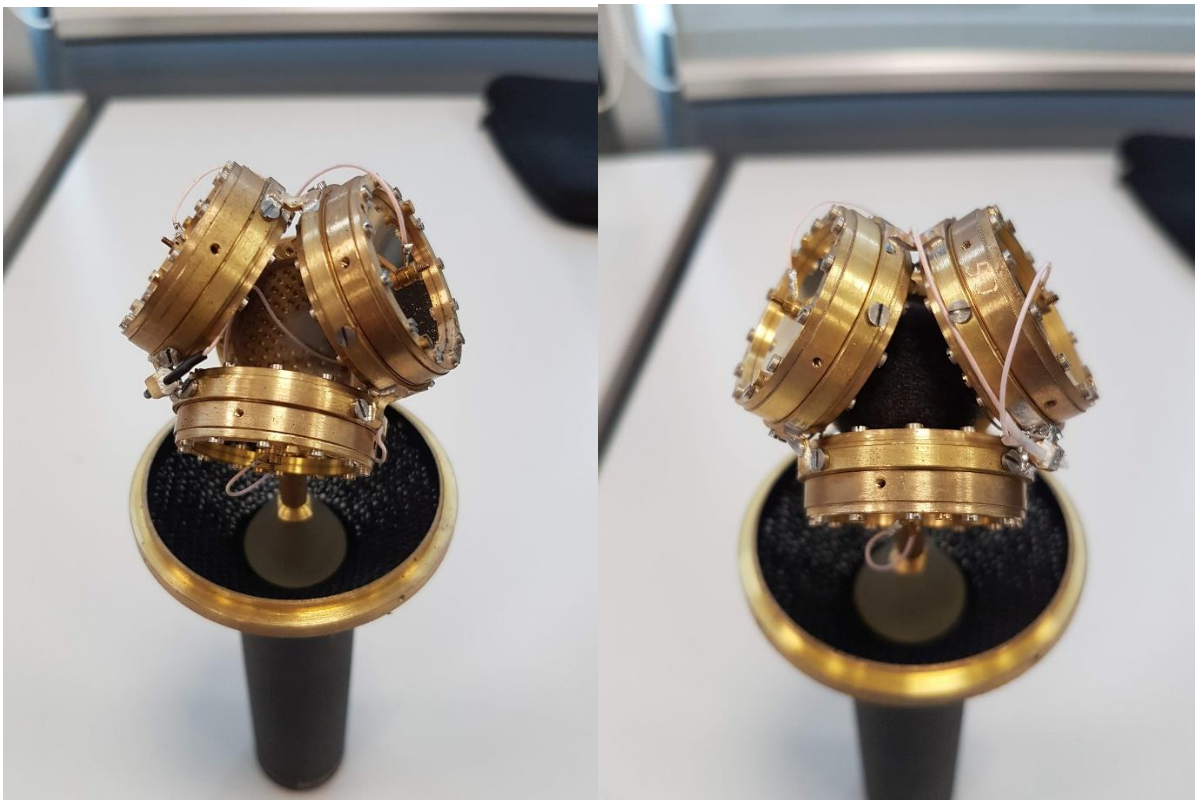
Anecoic measurements and A2B filter calculation for Nevaton VR microphones
Report by Angelo Farina – 19 August 2019

1. Microphones

We received two samples of Nevaton VR microphones, which were labelled as Nevaton1 and Nevaton2. Their only difference is the presence, in Nevaton2, of a small black sphere of absorbing material inserted at the center of the array, as shown in the following photos:



Nevaton1 (left) and Nevaton2 (right)

As it will be shown later, the presence of the absorbing material improves the flatness of the frequency response of the capsules and extendes the usable frequency range of the microphone.

Here you see the two microphones inside their wooden box:

The two Nevaton VR microphones under test

2. Measurements in anechoic room

The anechoic measurements were performed inside the anechoic room of the Poltyechnic of Turin on days 25-26 June 2019.
The equipment employed was the following:

- Macbook Pro 15.4” laptop
- Matlab v. 2019A
- Antelope Audio Orion 32 audio interface
- Antelope Audio MP-32 mic preamp with digital gain control
- Genelec studio monitor (8350A - SAM – three-way concentric)
- Bruel & Kjaer type 4189 reference class 1 microphone (for equalizing the loudspeaker)
- Bruel & Kjaer type 3921 turntable (modified with a secondary horizontal rotator)

The following photos show the equipment during the measurements:

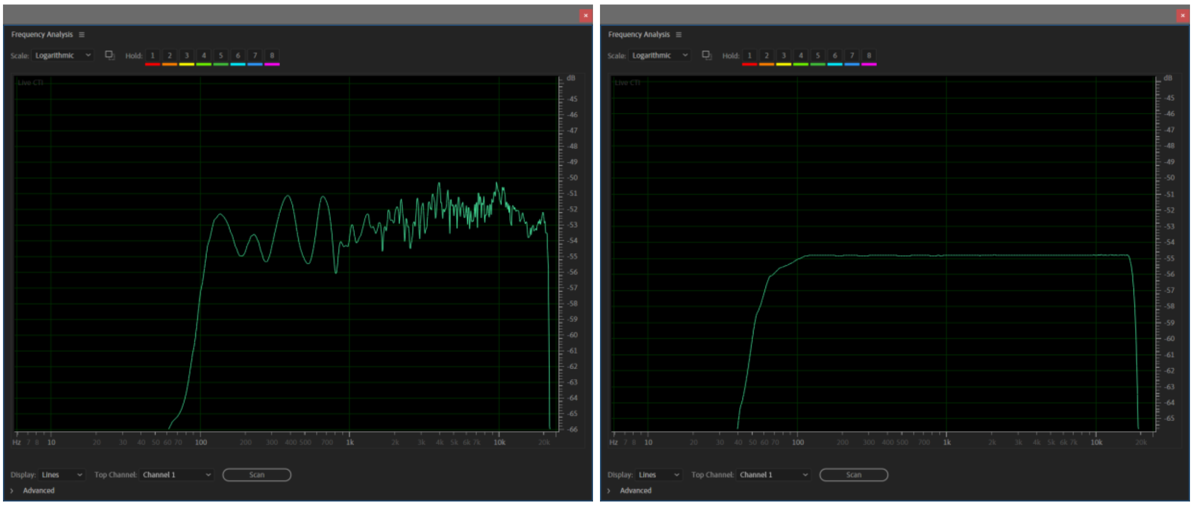
Genelec 8350A loudspeaker

Nevaton VR microphone over the two-axes turntable

Detail of the secondary axis and reference B&K type 4189 microphone

The Antelope Audio Orion 32 and MP-32 mic preamp.

The following figure shows how well the spectrum of the loudspeaker has been flattened, by generating a proper pre-equalized exponential sine sweep (ESS) and a proper post-equalized Inverse Filter (IF):



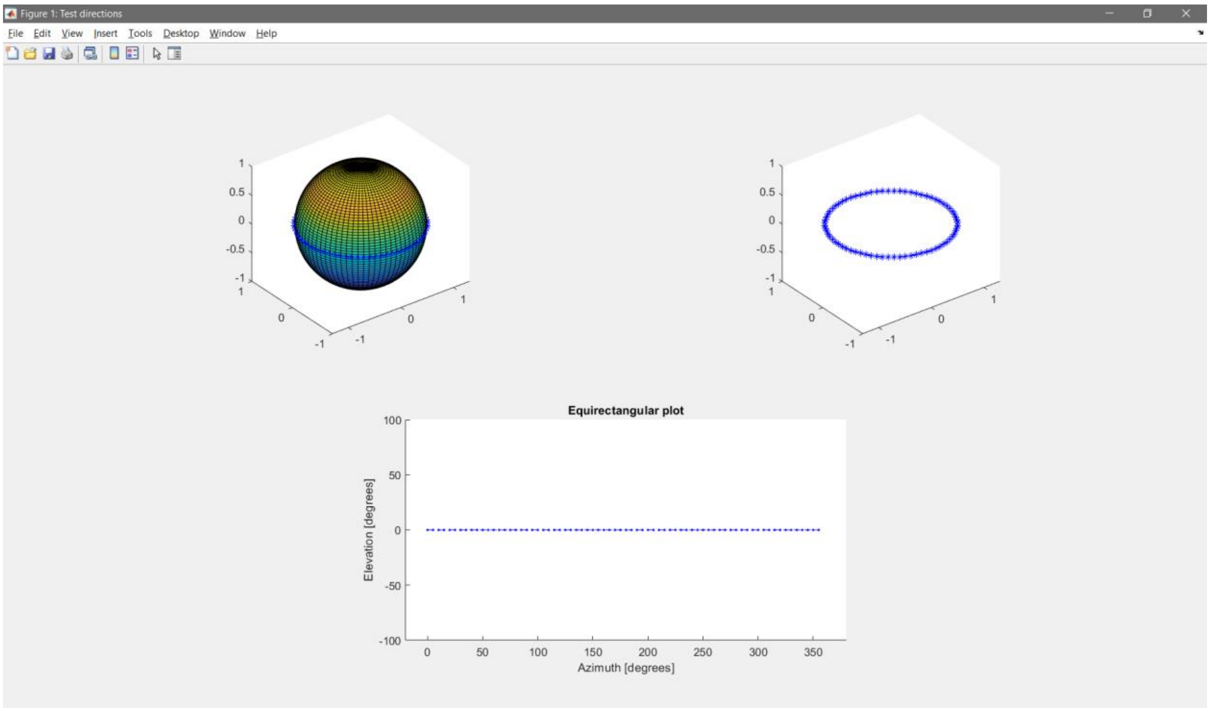
Loudspeaker's frequency response without (left) and with (right) equalization

3. Measurements

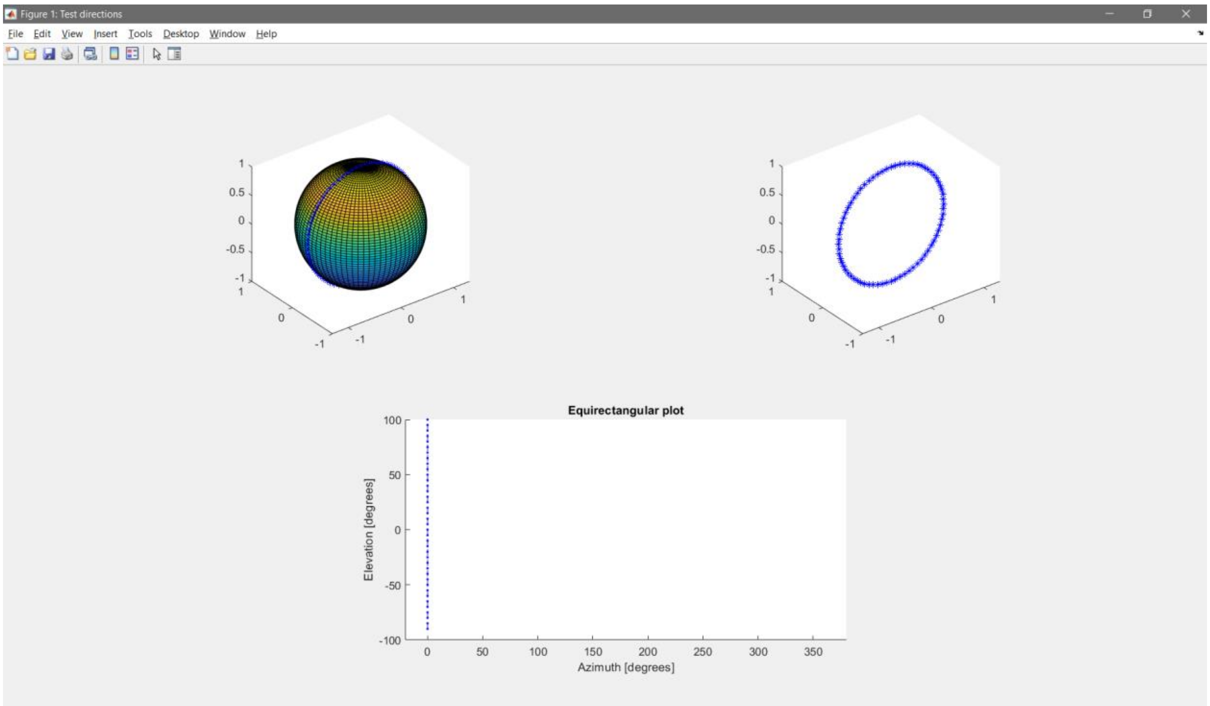
On each microphone 3 sets of measurmeents have been perfoment sequantially:

- HIR (Horizontal Impulse Responses)
- VIR (Vertical Impulse Responses)
- SIR (Spherical Impulse Responses)

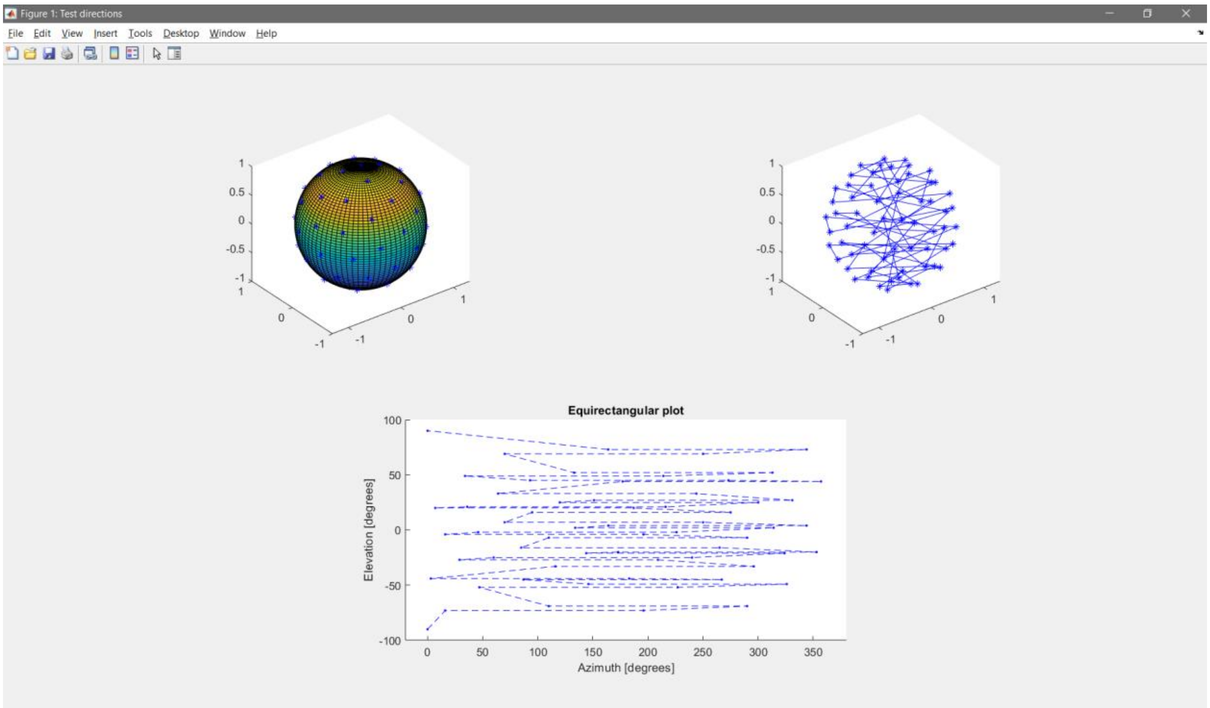
The first two are made of a ring of measurmenet positions rotating the microphone around its X and Y axes, with 5° spacing, hence 72 measurements for the complete circle.
SIR has been measured with 62 positions uniformy distributed on the spherical surface according to a T-design geometry.
The following figures show the direction of measurmenets of HIR, VIR and SIR setups:



HIR setup

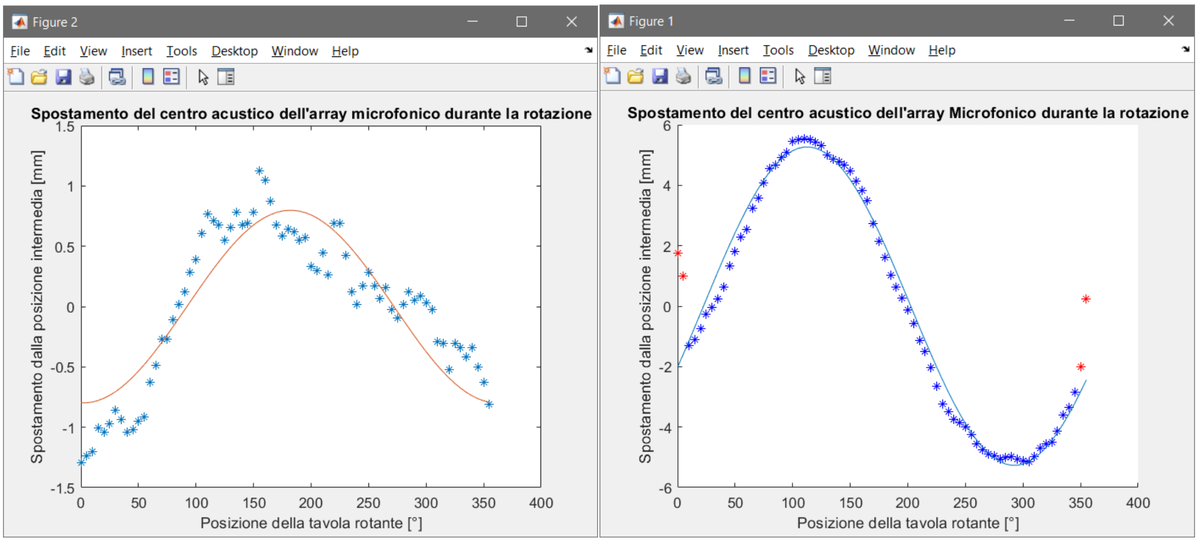


VIR setup



SIR setup

It can be noted how in the SIR setup the turntable trajectory is optimized for minimizing the rotations along elevation, as this is the less-accurate rotation axis of the turntable.
Despite the mounting of the microphone has been carefully aligned, there is always some small eccentricity. This can be corrected in post, analyzing the variation of the time-of-flight as a function of the angle of the turntable, and fitting a sinusoidal correction to it.
The following pictures show such a correction for the mounting eccentricty performed in the HIR and VIR measurements:



Correction for eccentricity in HIR (left) and VIR (right) measurements

It can be seen as the HIR measurement, making use of the very precise mounting on the secondary axis of the turntable, is affected by a very small (almost negligible) eccentricity error of less than 1 mm.
Instead the VIR measurement, operating on the main turntable, is affected by a much larger eccentricity error, more than 5 mm. This definitely needs to be corrected, for avoiding phase errors in the calculation of the inverse filters.
Hence during the SIR measurmeent no correction has been applied for the secondar-axis eccentricty, and instead the eccentricity correction has been applied as a function of the elevation angle, based on the VIR measurements. Here the values of correction applied for Nevaton1 and Nevaton2 microphones:

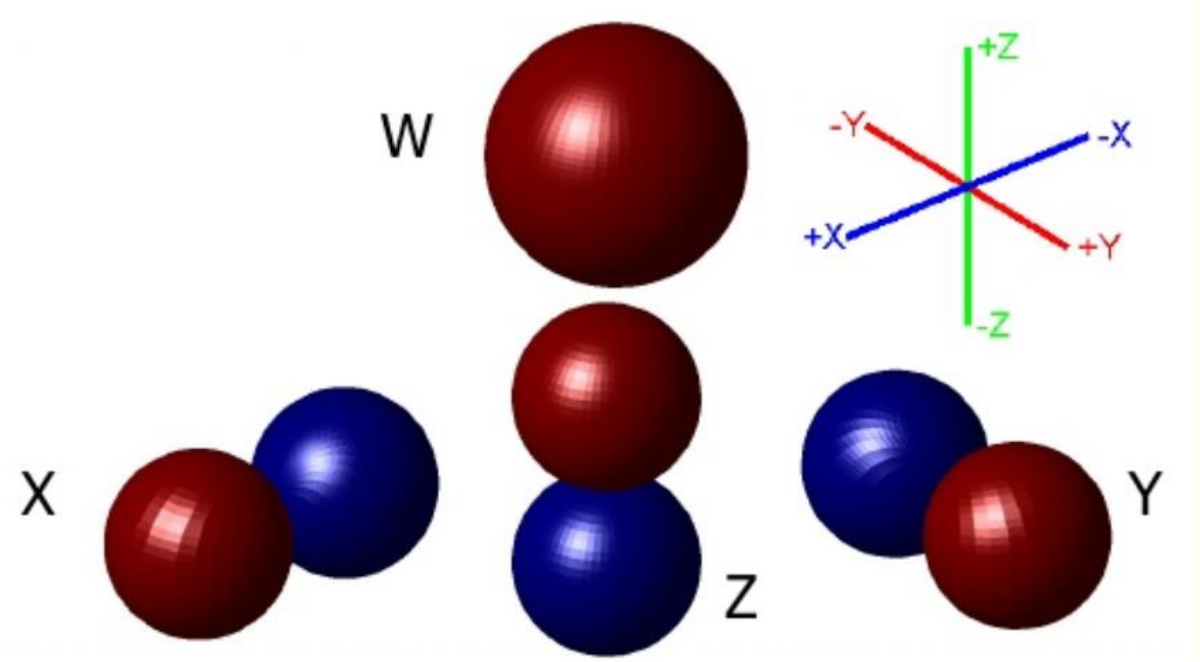
Nevaton1:
Radius: 0.737424 [sample], 5.269507 [mm]
Phase: -0.393111 [rad], -22.523624 [deg]
Position - x= 4.867557 [mm], z= -2.018560 [mm]

Nevaton2:
Radius: 0.947882 [sample], 6.773406 [mm]
Phase: -0.465198 [rad], -26.653868 [deg]
Position - x= 6.053615 [mm], z= -3.038547 [mm]

4. Calculation of the A2B filter matrices

After applying proper temporal corrections to HIR, VIR and SIR as explained before, these data sets have been employed for snthesizing a 4x4 FIR filter matrix, converting the raw microphone signals (A-format – where 1=FLU, 2=FRD, 3=BLD, 4=BRU) into Ambix signals (B-format), with ACN channel ordering (WYZX) and SN3D amplitude scaling (0 dB gain for all channels).
The filters have been computed using the method described in our paper[1]. In practice, a set of 4 “target functions” are defined, fixing the gain and phase of 4 virtual microphones possessing the required polar patterns in each direction of measurement.
Of course in this case the 4 virtual microphones have the directivities represented by the spherical harmonics of order 0 and 1, as shown in the following figure:

[1] Angelo Farina, Andrea Capra, Lorenzo Chiesi, Leonardo Scopece – “A Spherical Microphone Array For Synthesizing Virtual Directive Microphones In Live Broadcasting And In Post Production” - 40th AES Conference "Spatial Audio - Sense the Sound of Space", Tokyo, Japan, 8-10 October 2010



The 4 target polar patterns (W, Y, Z, X) for Ambix output

For each virtual microphone, a set of 4 filters f is computed, capable of transforming the measured impulse responses h from the D directions into a delayed Dirac's Delta function, with amplitude and phase described by the above-shown target functions t:

$$h * f = t \cdot \delta$$

The problem is solved employing the well known Kirkeby inversion formula, which yields the wanted filters f, in frequency domain, and employing a frequency-dependent regularization parameter β:

f = conj(h)./(conj(h).*h+beta);

The calculation of the inverse filters has been performed, for each of the two Nevaton VR microphones, using 4 different data sets:

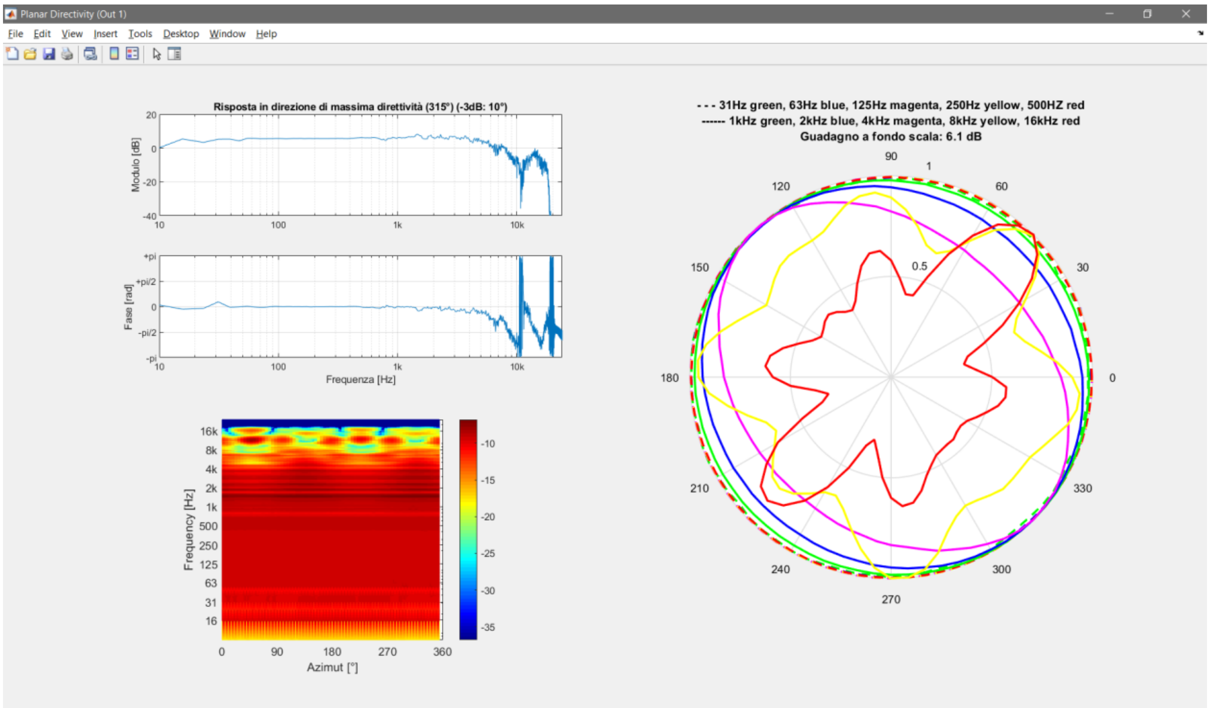
- A set of just 8 directions in the horizontal plane, with 45° spacing
- The complete set of HIR and VIR
- The set of SIR
- The total set of HIR + SIR
- The total set of HIR + VIR + SIR

The first approach corresponds to the method currently employed by competitors, such as the Core Sound Tetramic and Octamic, and the Brahma. It is fast and robust, but of course in not very accurate, in particular it does not take into account the shielding effect of the base of the microphone, hence there is some significant error in the polar patterns in terms of elevation sensitivity.
The second method favours accuracy where the measurements have been perfomed, that is in the XY plane and in the XZ plane. For directions away form these two planes the error increases.
The third method. Instead, does not favour any direction, as a set of measurements uniformly distributed along the sphere is being employed. This is the preferred method when measuring high-order microphones, such as the Eigenmike.

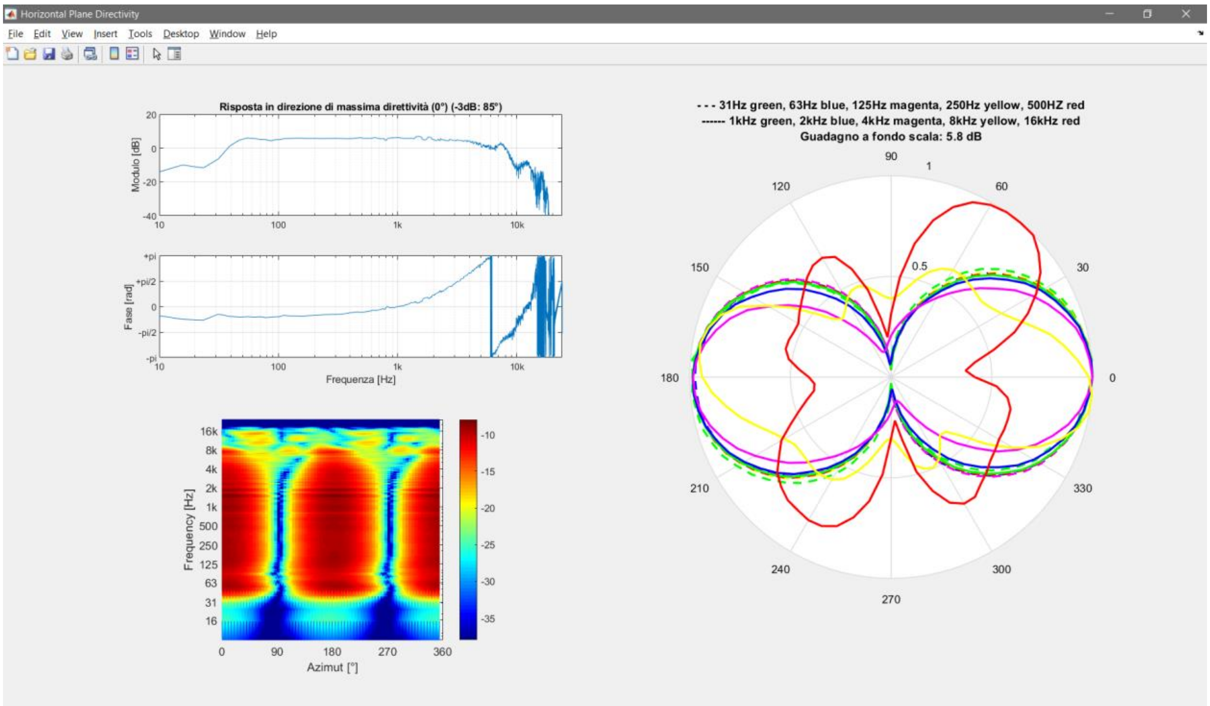
It also has the adavantage of using HIR and VIR as independent verification of the filters calculated from SIR, so we have better confidence on the results, as they are coming form two sets of measurements which were not employed for computing the filters.
Finally, the last two methods are some sort of superposition of the previous ones: the usage of SIR guarantees that the error is always controlled in every direction, but including in the calculation also HIR (and optionally VIR) ensures to get more accurate results in directions close to the most important plane(s). But doing so we loose the independency of the verification measurements from the data employed for computing the filters. So the results may look nice when re-analyzing HIR (and VIR), but this is in some way a positive bias.
Of course, it is left to the user to choose the FIR filter matrix he prefers, also depending on the application. My own preference is for method 3 (SIR only).

5. Analysis of the results

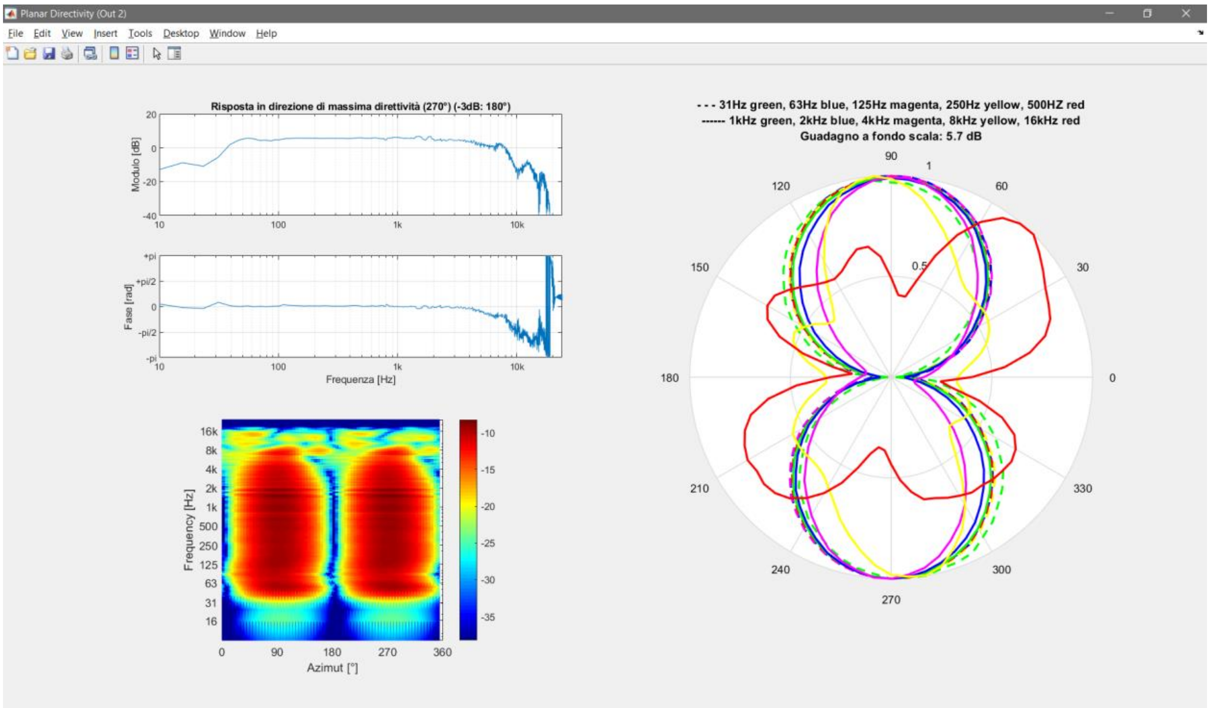
The following figures show the polar patterns of virtual mcirophones computed with the third method (SIR only) for each of the two microphones:



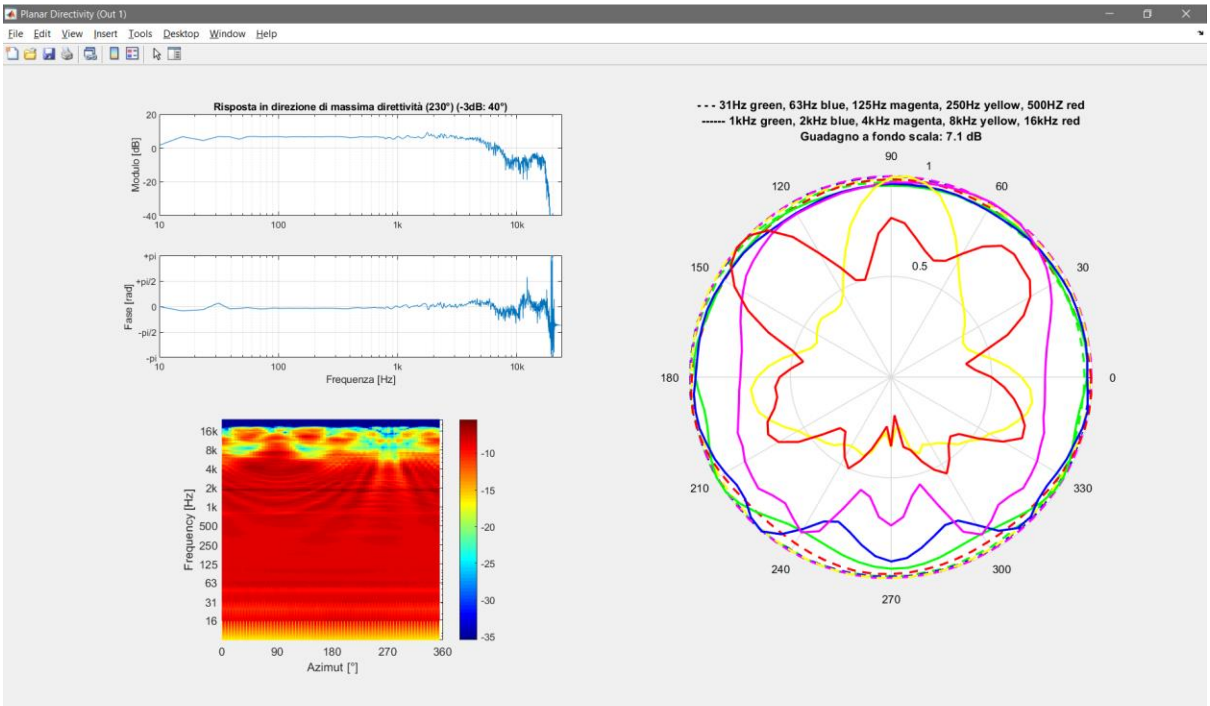
W – verification from HIR – Nevaton1



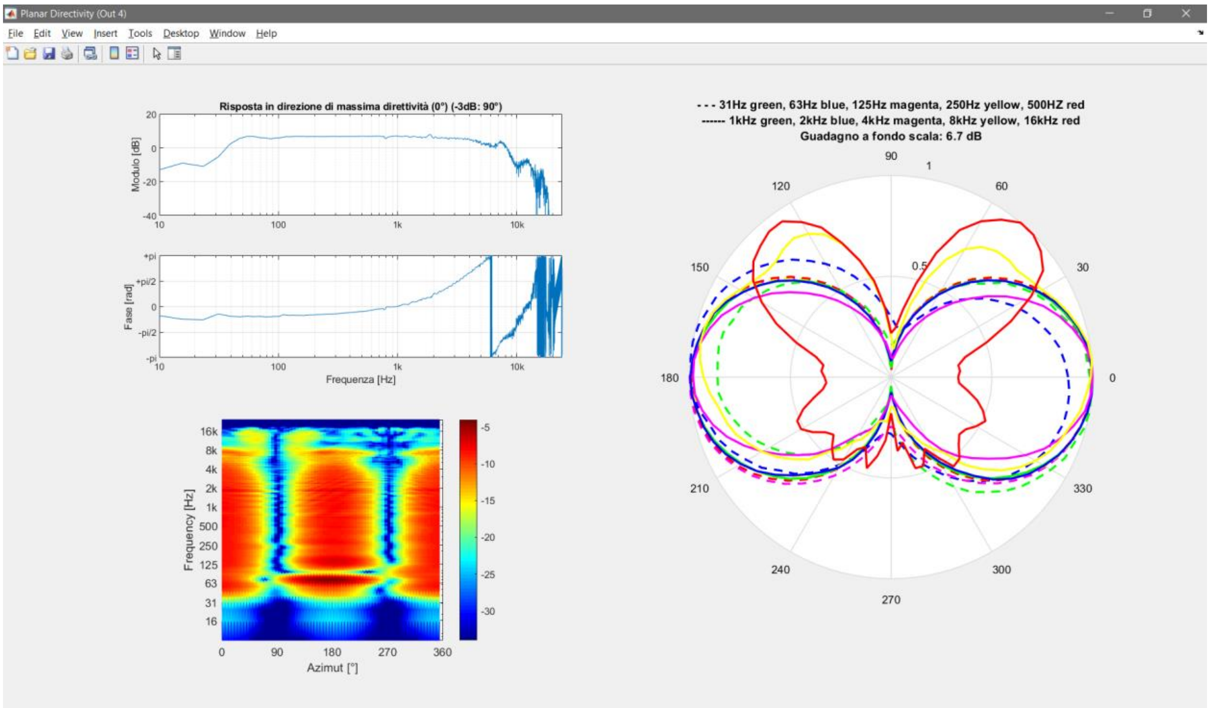
X – verification from HIR – Nevaton1



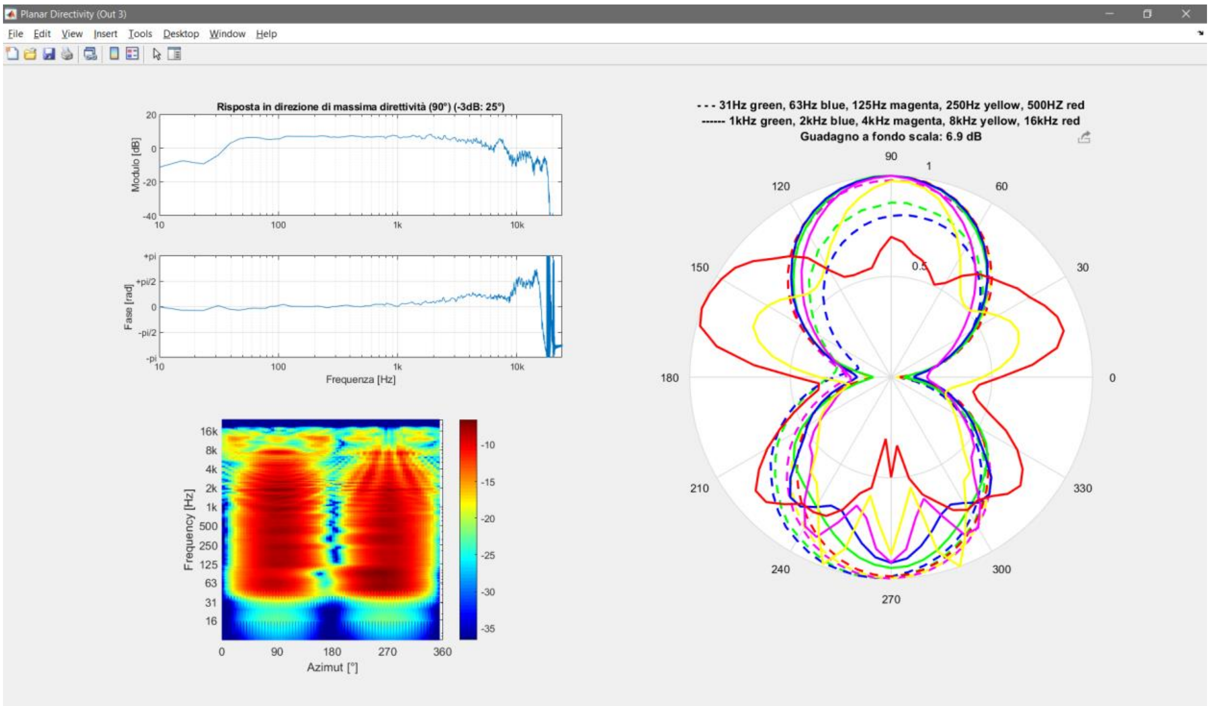
Y – verification from HIR – Nevaton1



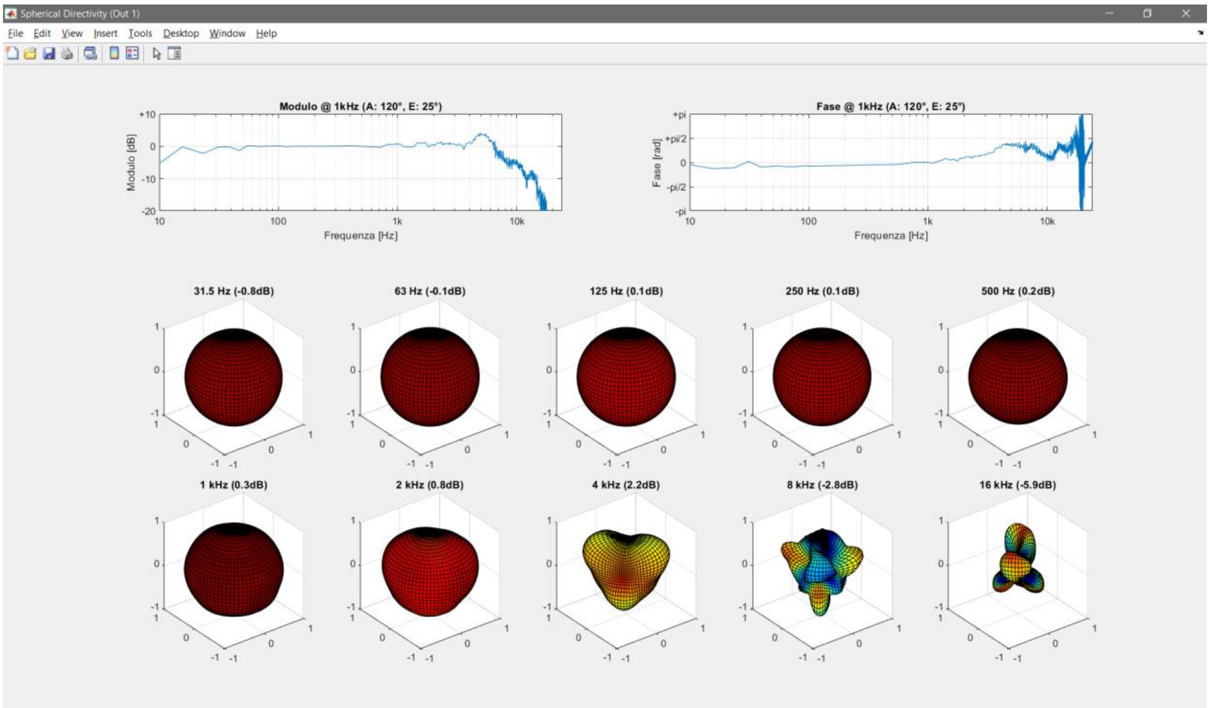
W – verification from VIR – Nevaton1



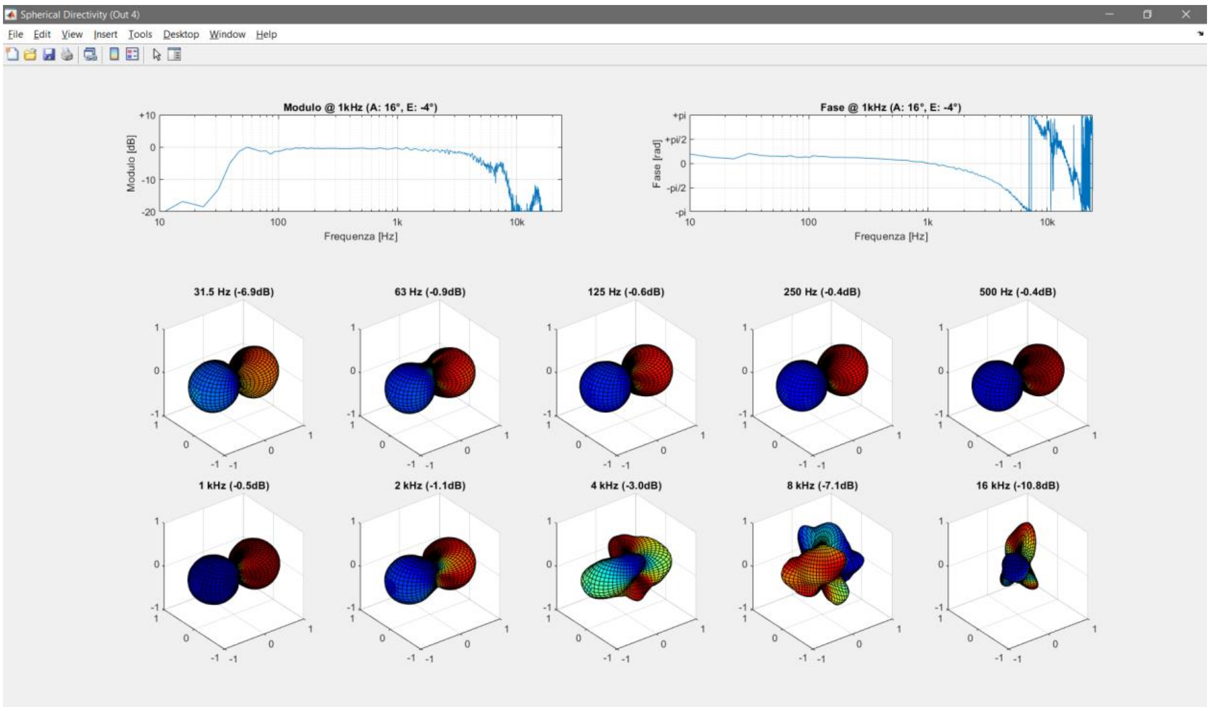
X – verification from VIR – Nevaton1



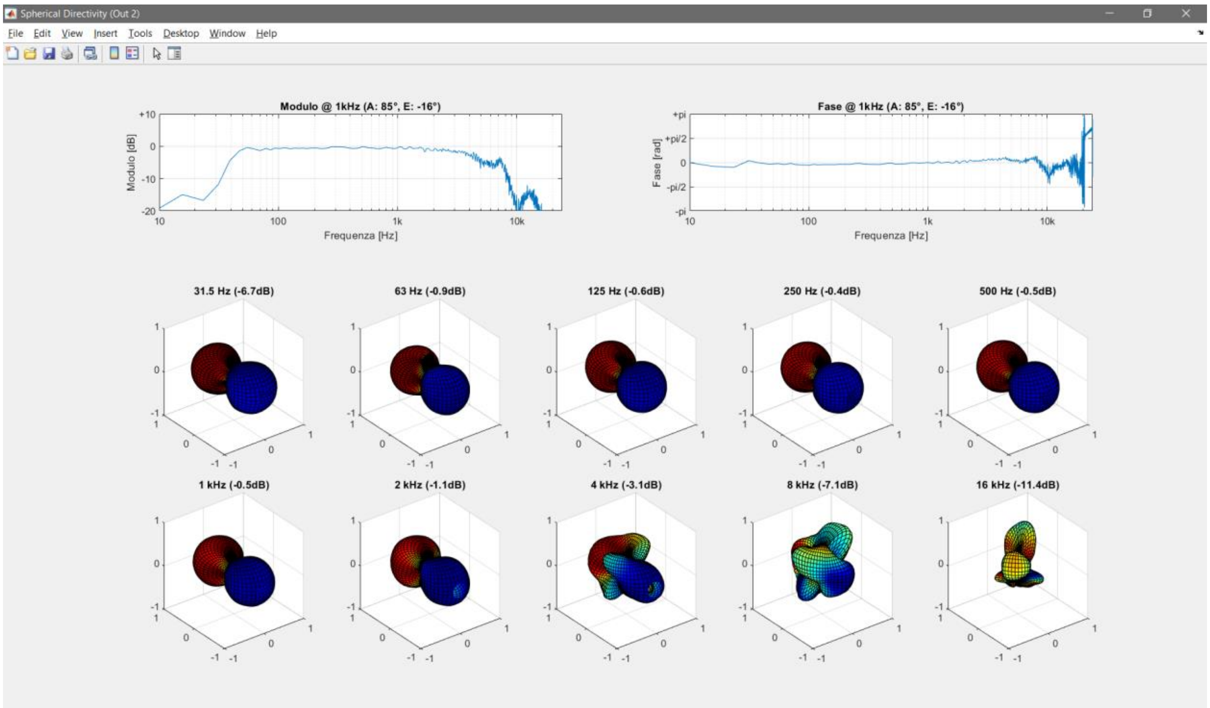
Z – verification from VIR – Nevaton1



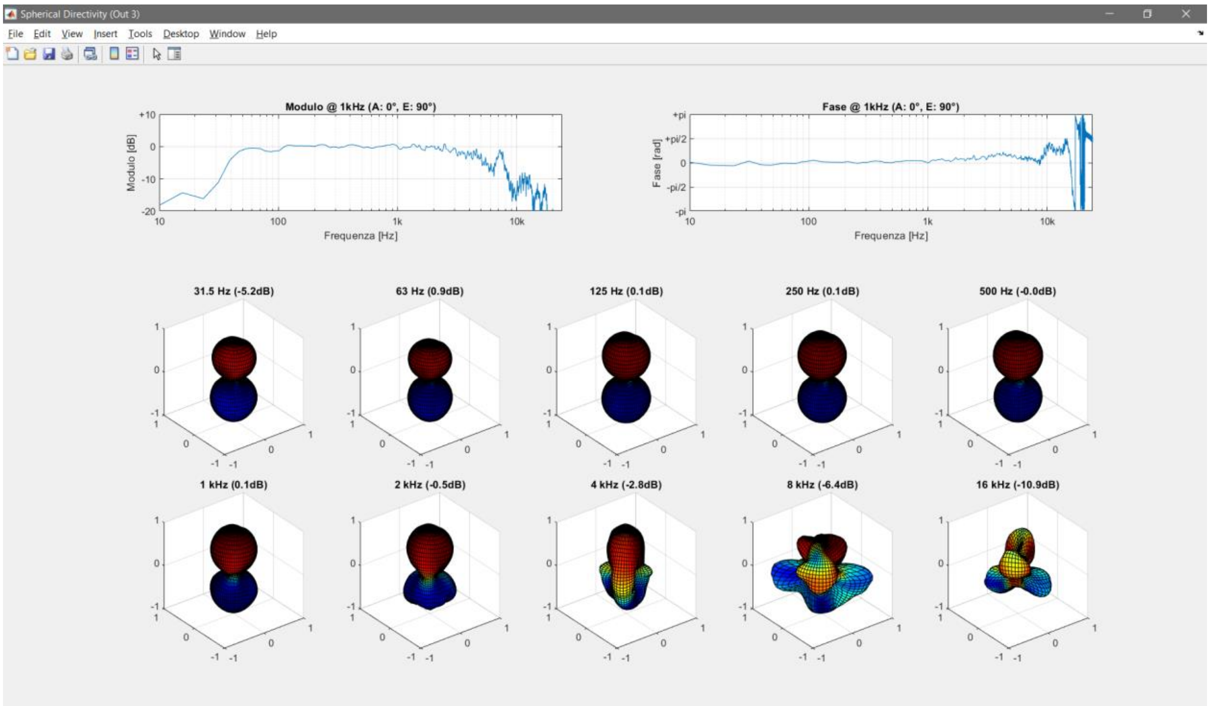
W – verification from SIR – Nevaton1



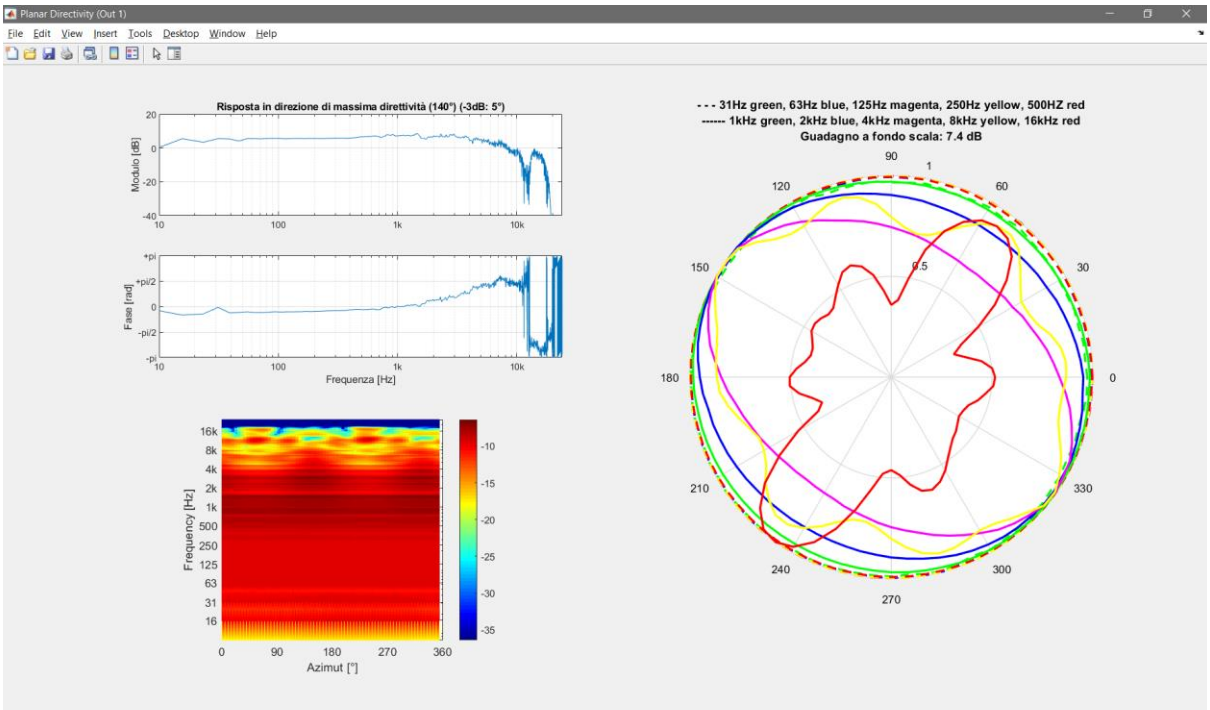
X – verification from SIR – Nevaton1



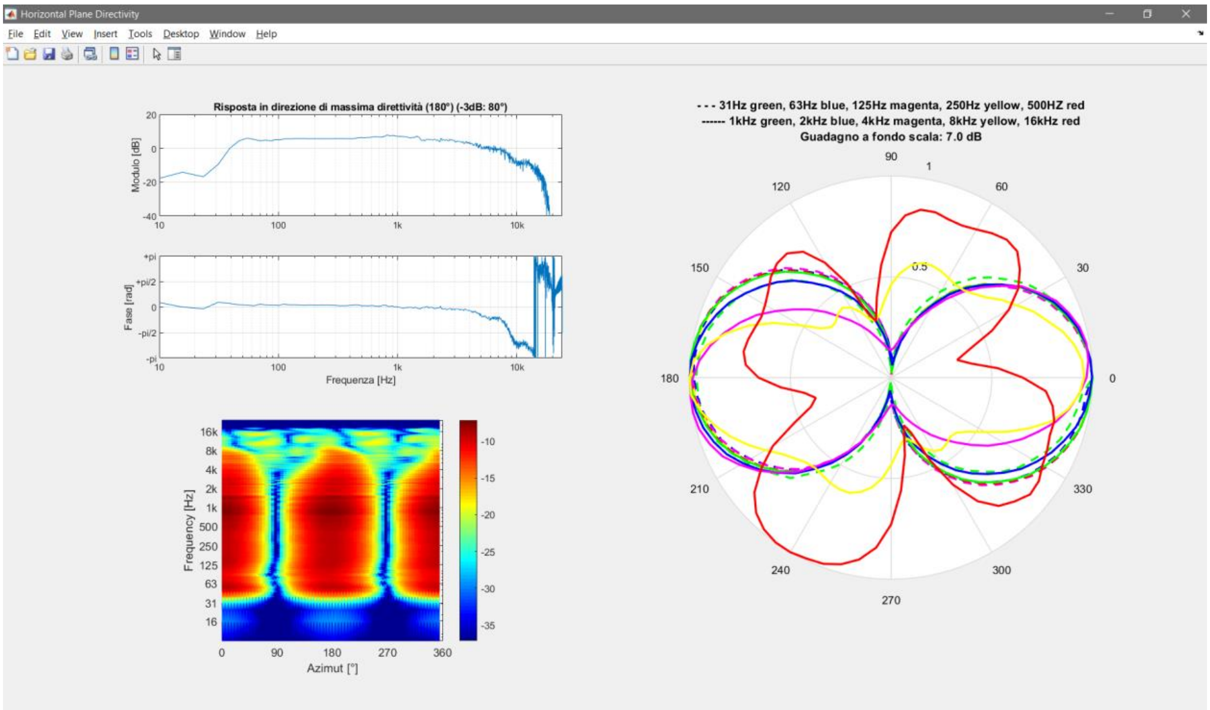
Y – verification from SIR – Nevaton1



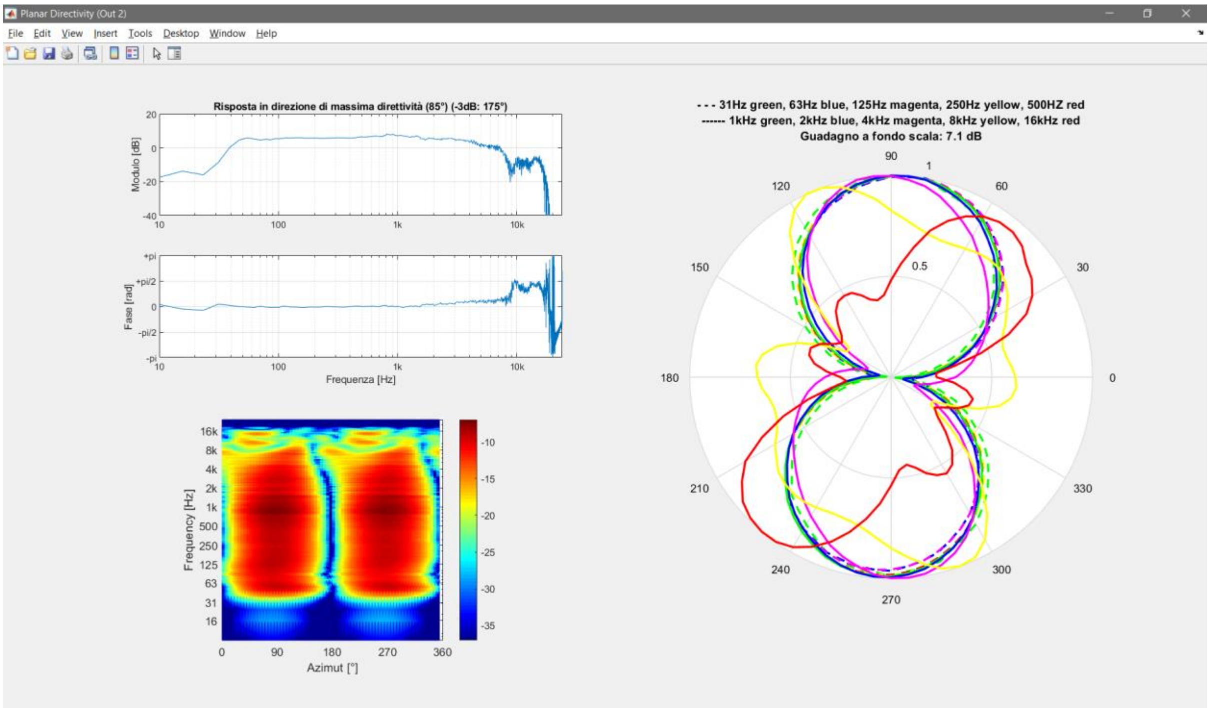
Z - verification from SIR – Nevaton1



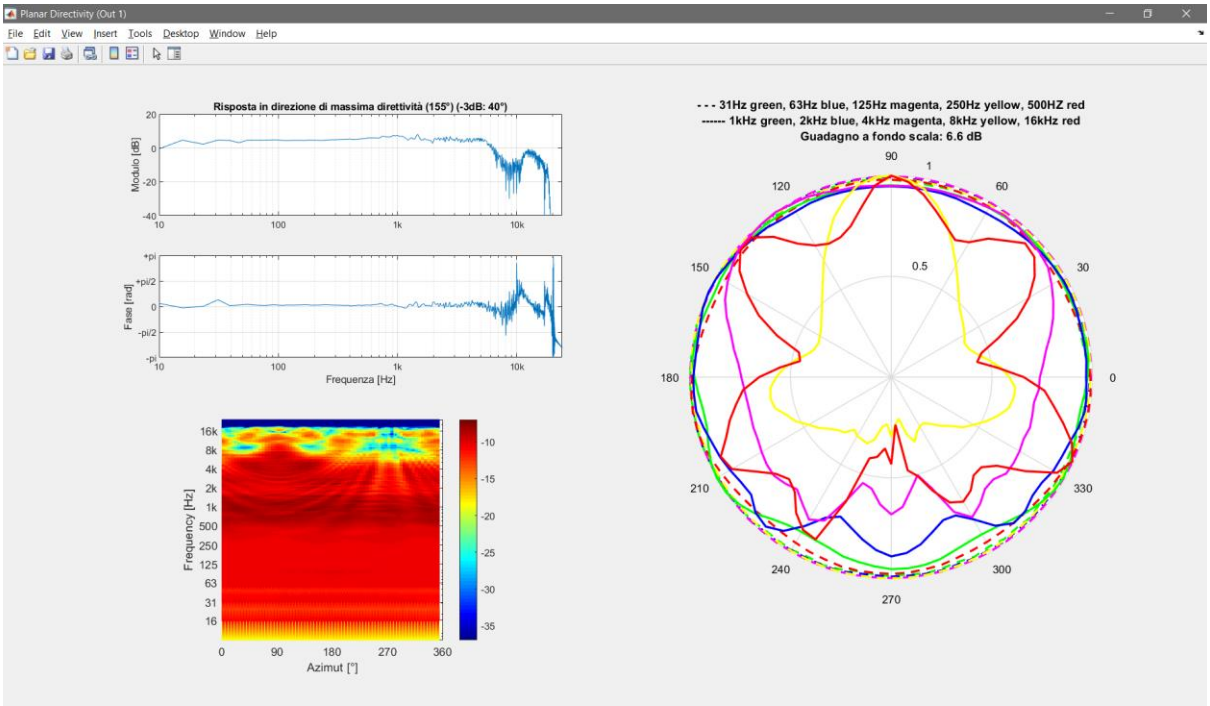
W verification from IR – Nevaton 2



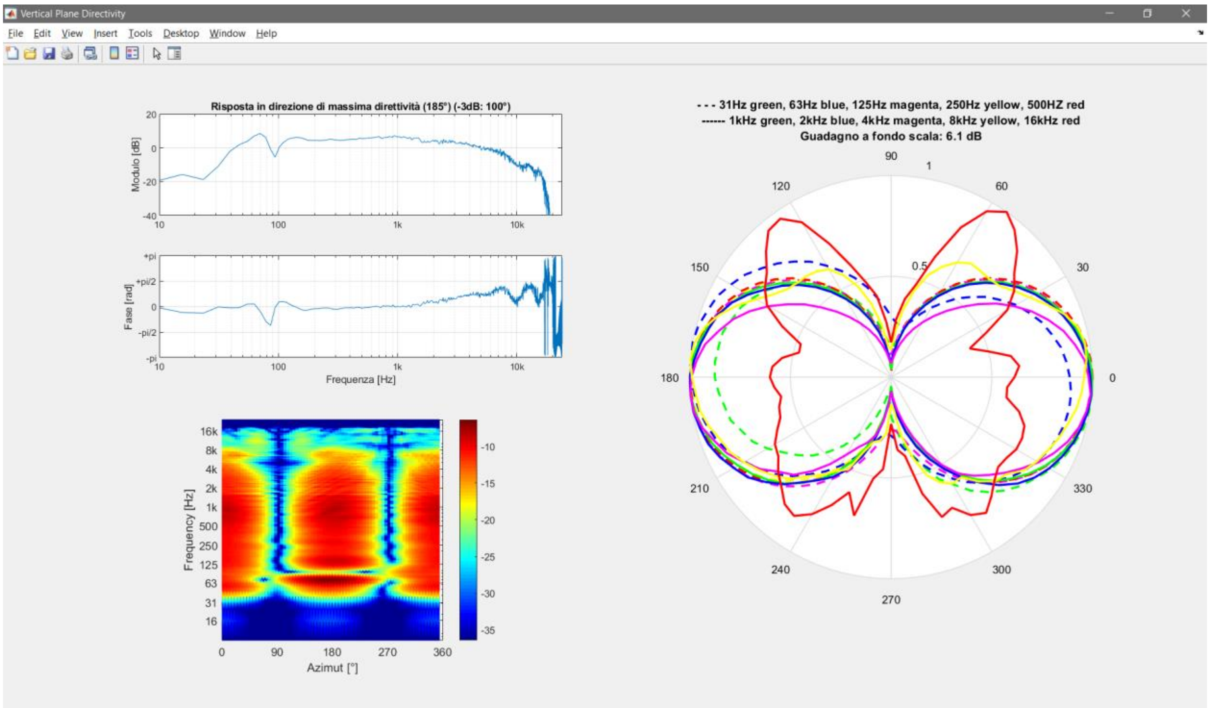
X verification from HIR – Nevaton 2



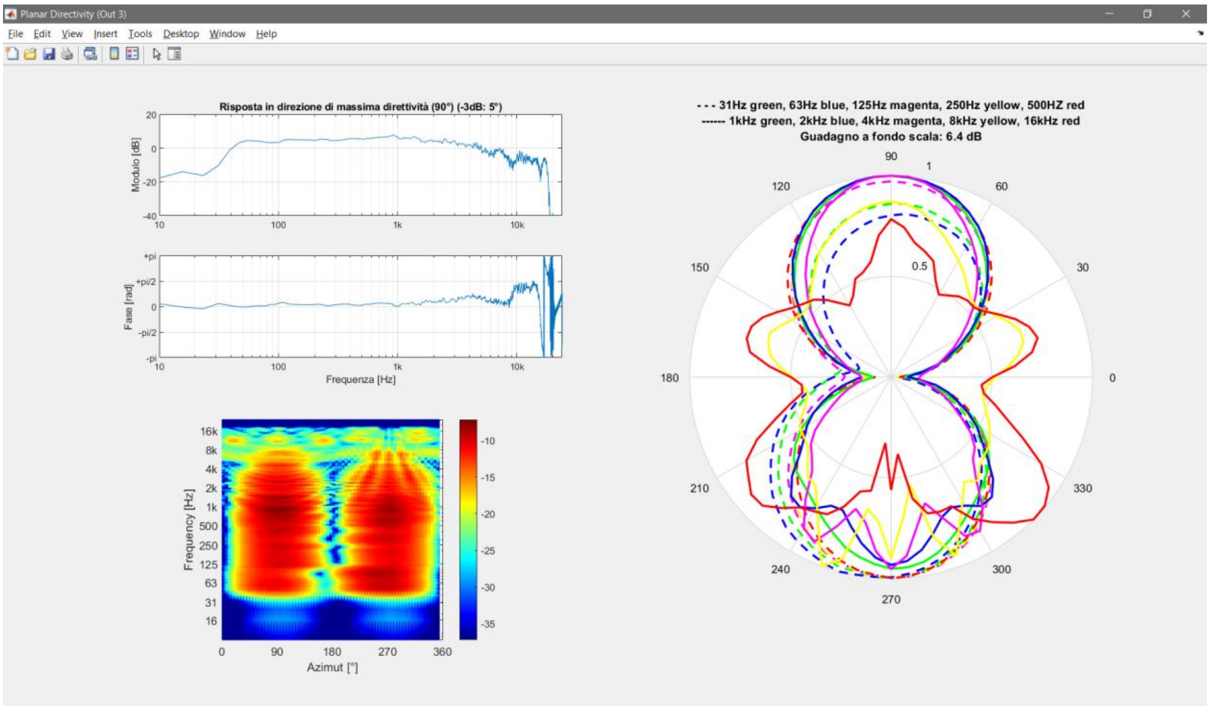
Y verification from HIR – Nevaton 2



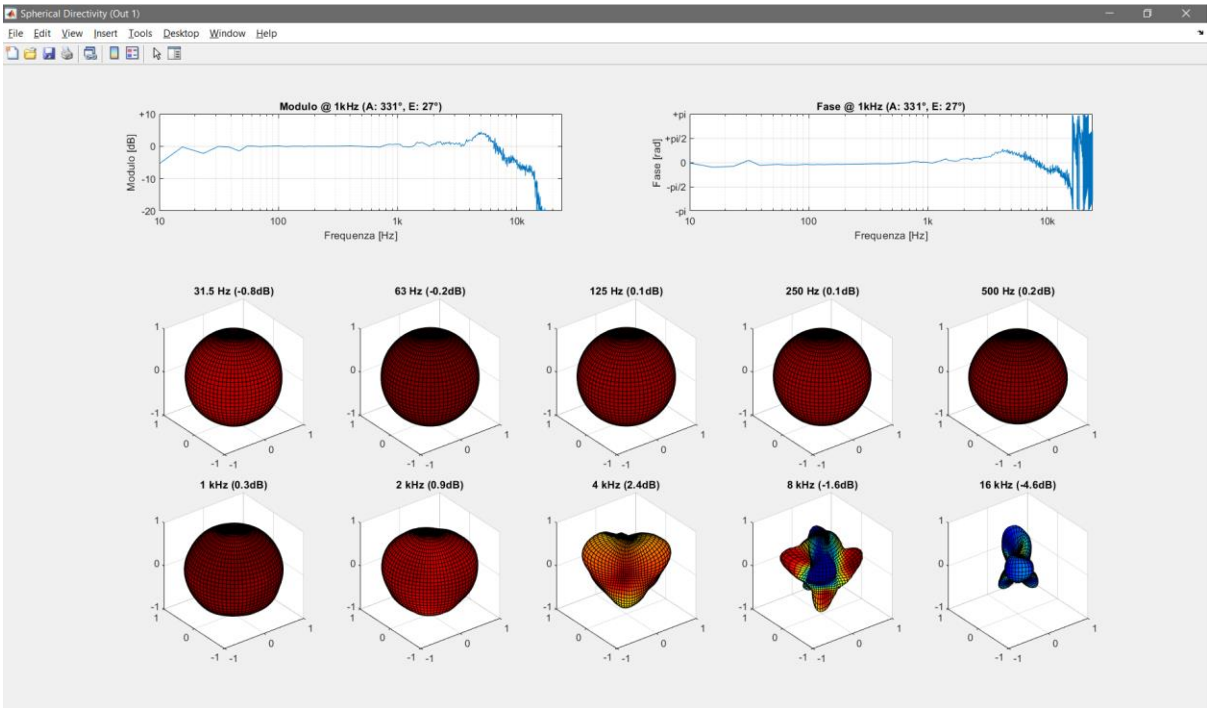
W verification from VIR – Nevaton 2



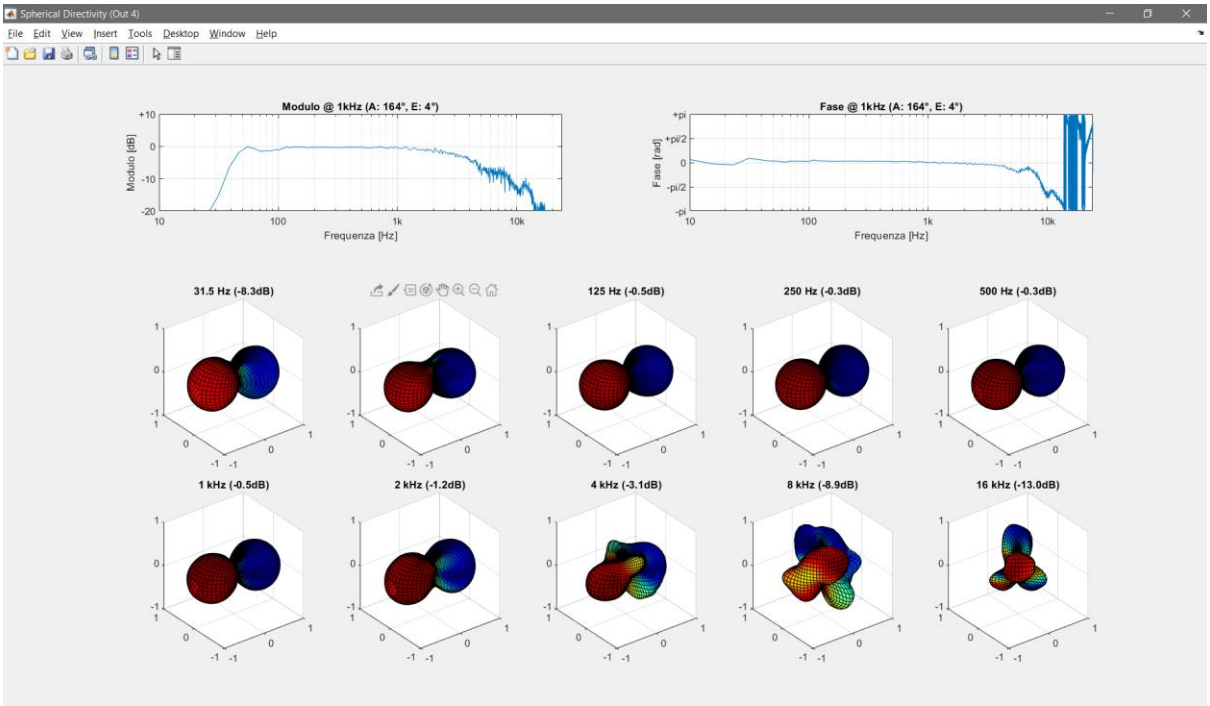
X verification from VIR – Nevaton 2



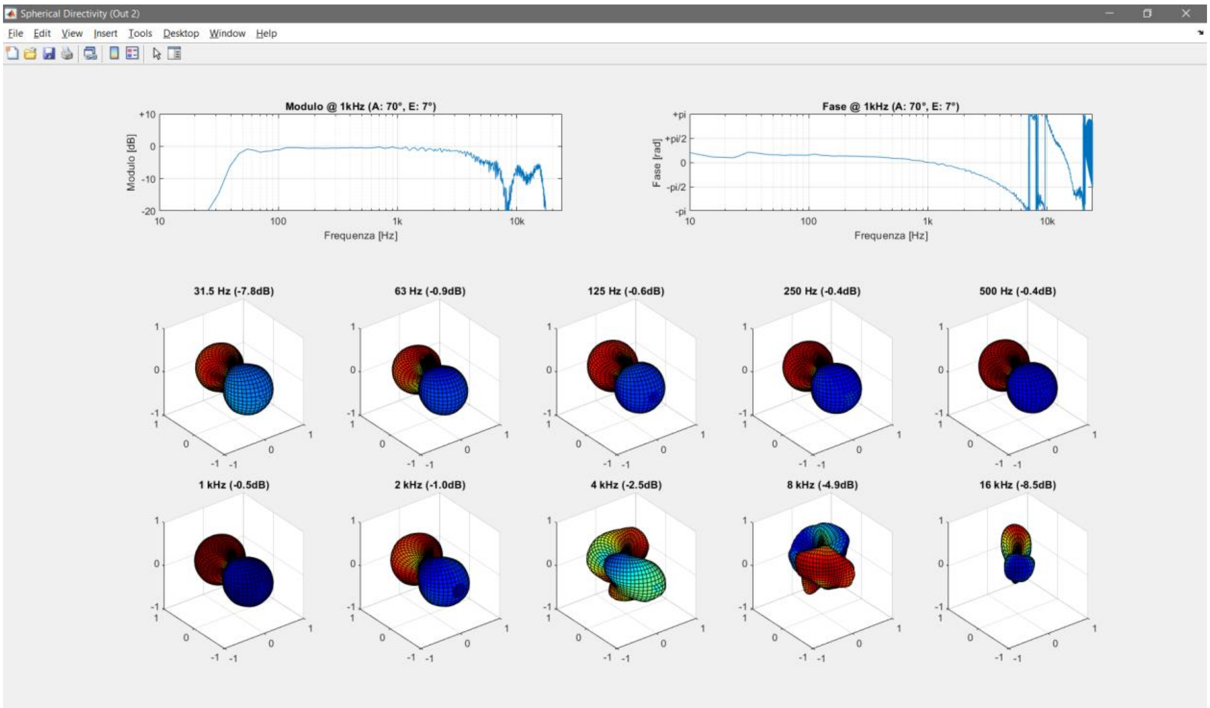
Z verification from VIR – Nevaton 2



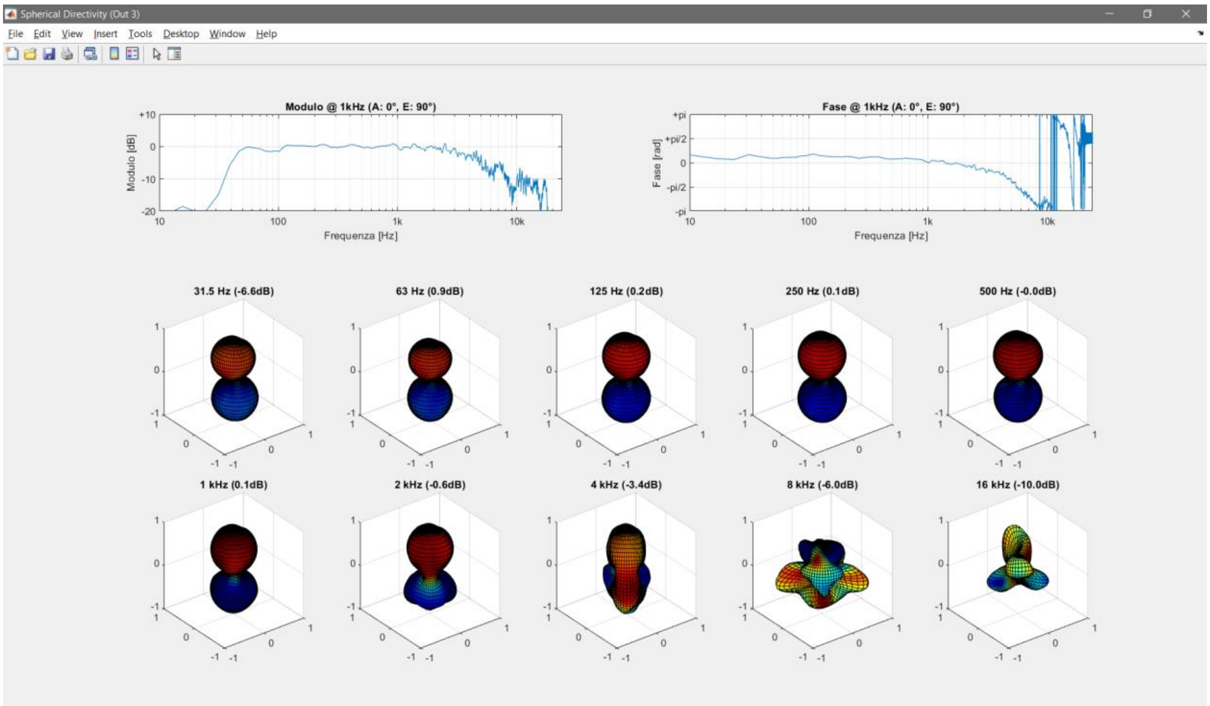
W verification from SIR – Nevaton 2



X verification from SIR – Nevaton 2



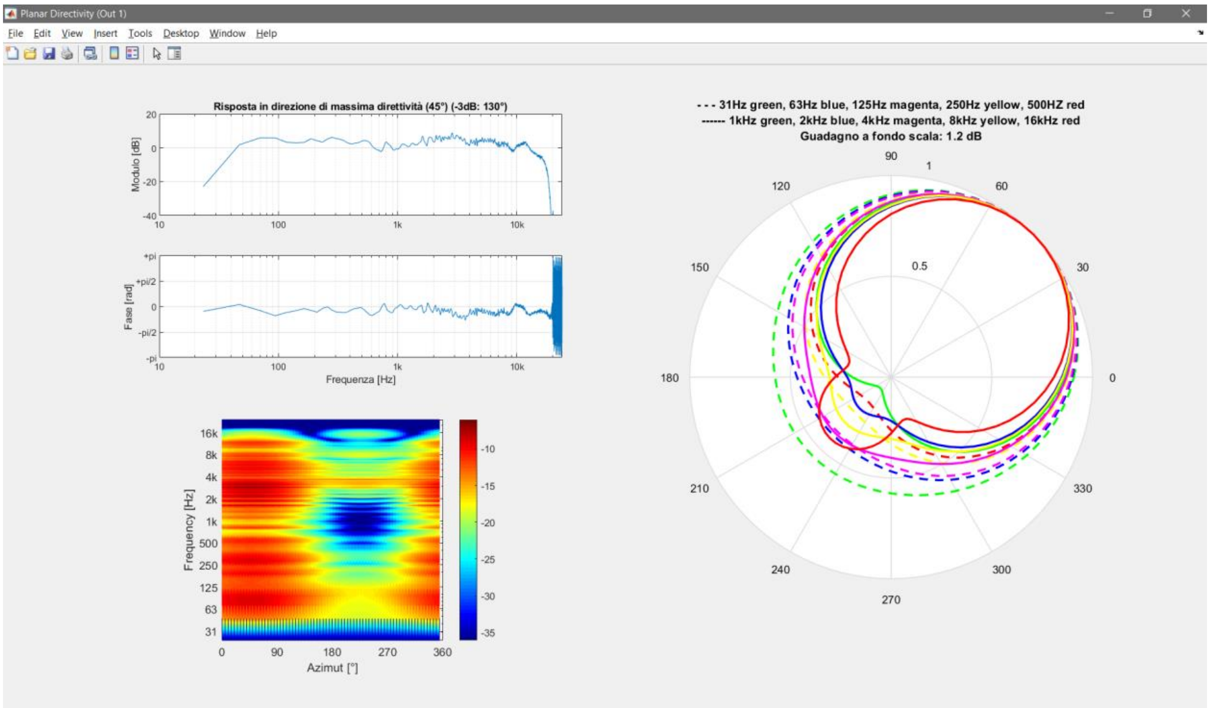
Y verification from SIR – Nevaton 2



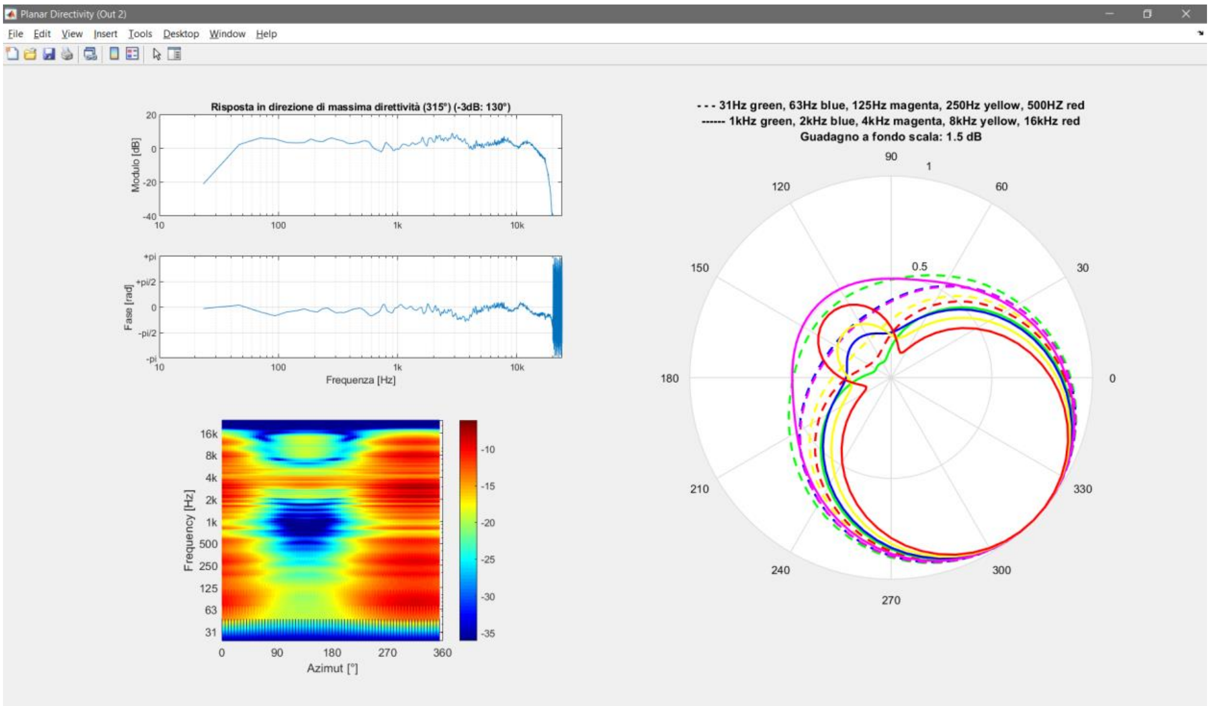
Z verification from SIR – Nevaton 2

6. Discussion

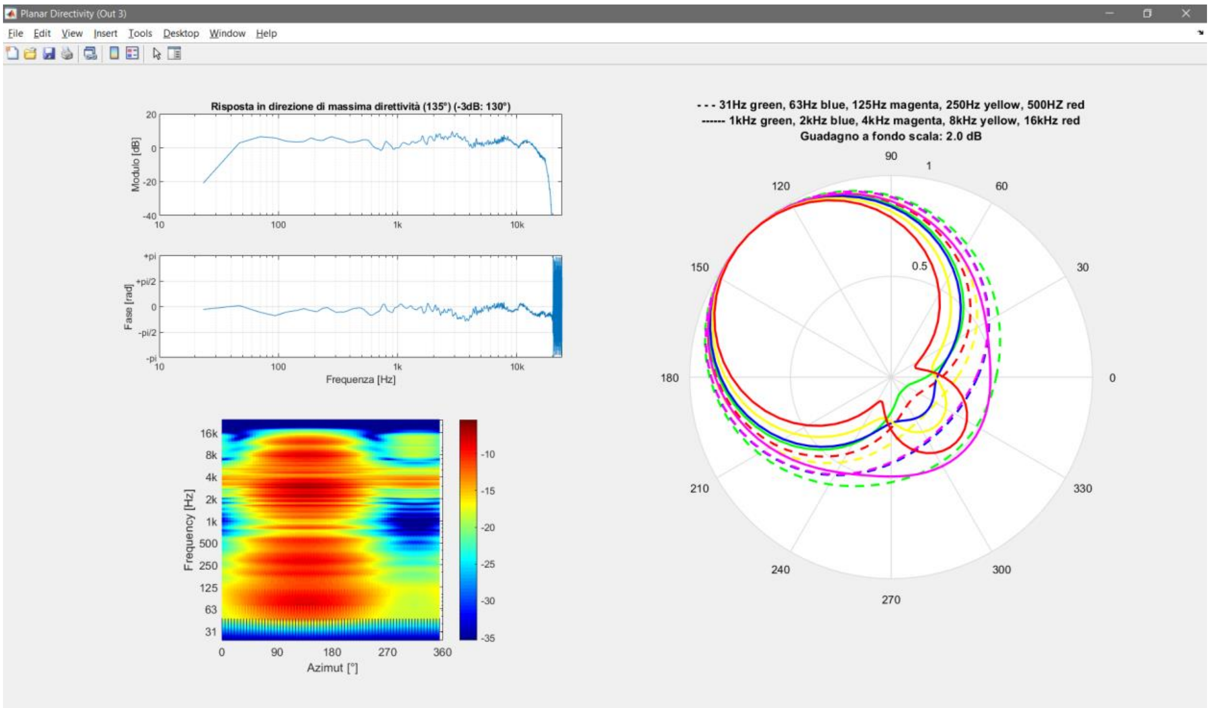
Looking at the results, it can be seen that due to the size of this huge Nevaton VR microphone the limit frequency for getting correct polar patterns is 2 kHz. At 4 kHz the patterns are already significantly distorted.
Analyzing the temporal delay of the 4 single capsules during the horizontal rotation (HIR), it was measured that the acoustical radius of this microphone array is approximately 24mm, which is approximntaley twice the radious of a Sennheiser Ambeo. And considering that the spatial aliasing frequency limit of the Ambeo is around 6 kHz, it appears obvious that such a limit is halved to 3 kHz for the Nevaton VR.
The microphone can still be used in full bandwidth, thanks to the excellent frequency response of these large diaphragm capsules, accepting some spatial blur and colouration at high frequency.
Analysing the polar response in the horizontal plane (HIR) it was also possible to obtain the polar patterns of the 4 capsules, which is shown here below:



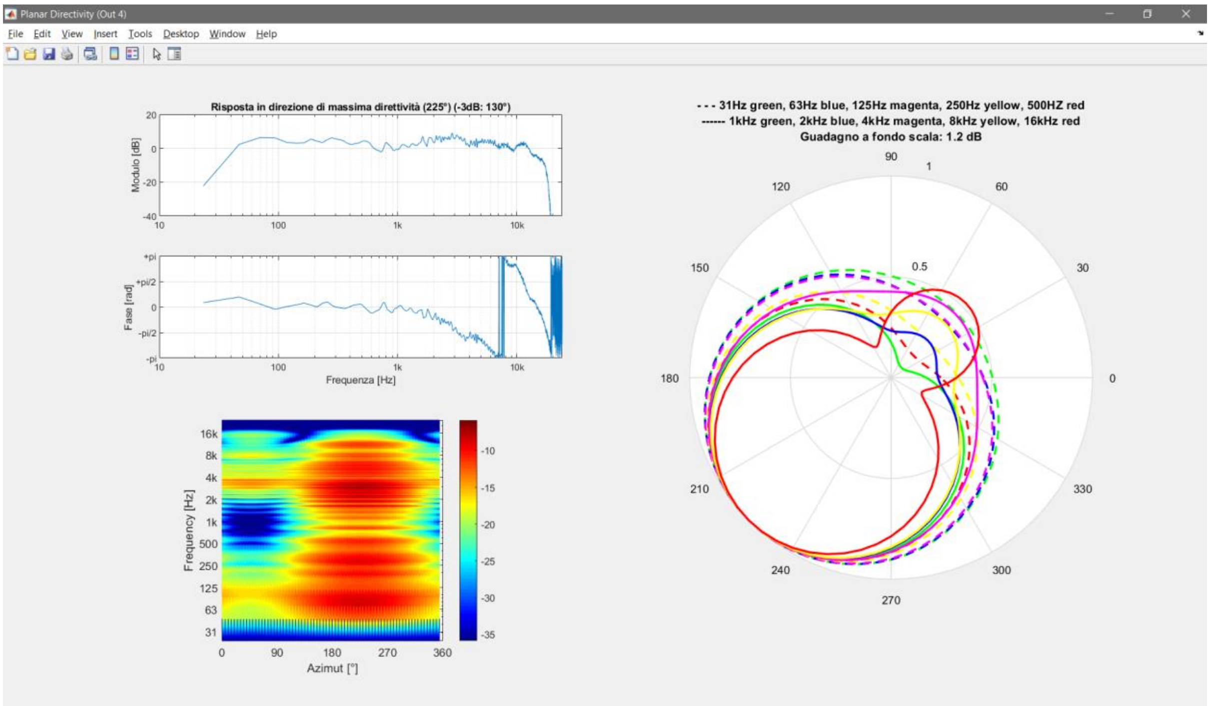
Capsule #1 – FLU



Capsule #2 - FRD



Capsule #3 - BLD



Capsule #4 - BRU

Knowing the radius of the microphone array (24 mm) we also employed the Sparta Array2SH software for generating a further “generic” filter matrix, which should work with any Nevaton VR microphone.

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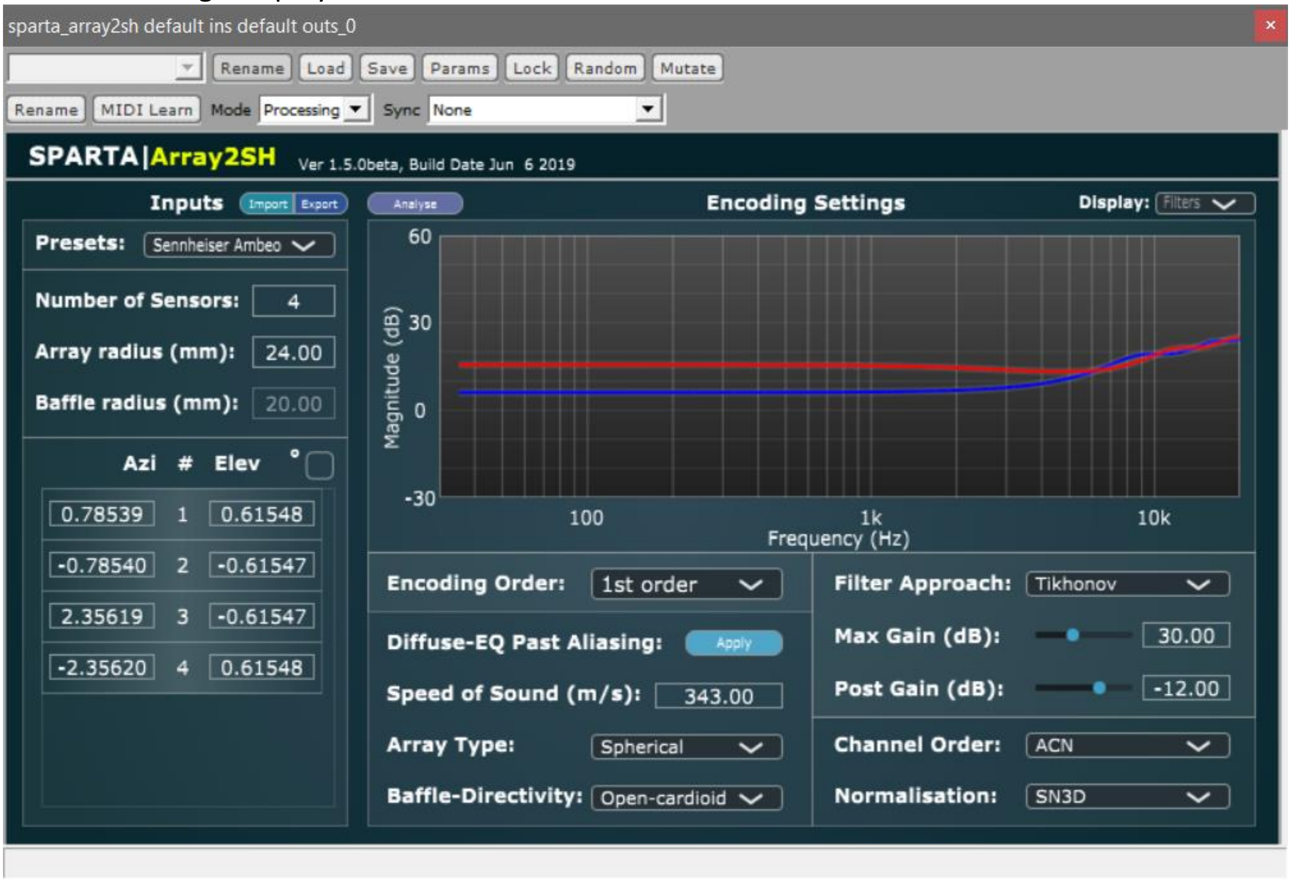
Here the settings employed:



The Array2SH plugin employed for computing a “generic” FIR filter matrix

And finally we generated a last “generic” filter matrix by using our Matlab script, starting from a “synthetic” SIR measurement matrix, obtained synthesizing the responses of 4 perfect cardioids, again with a radius of the array of 24mm.

All the computed filter matrices have been made available on Internet at the following address, alongside with this report:

http://www.angelofarina.it/Public/Xvolver/Filter-Matrices/Aformat-2-Bformat/Nevaton-VR/

Parma, Italy – 19 August 2019

Prof. Angelo Farina

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