Euro-Asian gravitational network: criteria of quality

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Abstract. We estimate efficiency of a conceivable Euro-Asian network (EAN) of gravitational wave (GW) interferometers that might be realized having in mind a plan of construction of third generation interferometer in Novosibirsk region. The quality of network in question is considered on the base of typical numerical criteria of efficiency for detecting GW signals of known structure - radiation of relativistic binary coalescence and rotational instabilities of proto-neutron stars during core collapse. We compare EAN efficiency with two reference networks and choose optimal orientation angle for Novosibirsk detector.

Criteria of efficiency.

To estimate the efficiency of the networks one needs to calculate antenna pattern functions $F_+, F_\times$ (they depend on location, orientation of the detector, time, location of a source and GW polarization angle), which define detectors response to GW, and antenna power pattern P:

$$h(t) = \frac{\delta L}{L} = F_+ h_+(t) + F_\times h_\times(t), \quad P = F_+^2 + F_\times^2.$$

We use the following criteria proposed in (Raffai et al., Class. Quantum Grav. **30** (2013) 155004).

1) Polarization criterion **I** defines ability of a network to assess the polarization of the received GW. Calculation of **I** is held in DPF, which provides $F_\times^N / F_+^N \gtrapprox 1$, where

$$I = \left(\frac{1}{4\pi} \oiint \left| F_+^N - F_\times^N \right|^2 d\Omega \right)^{-1/2}$$

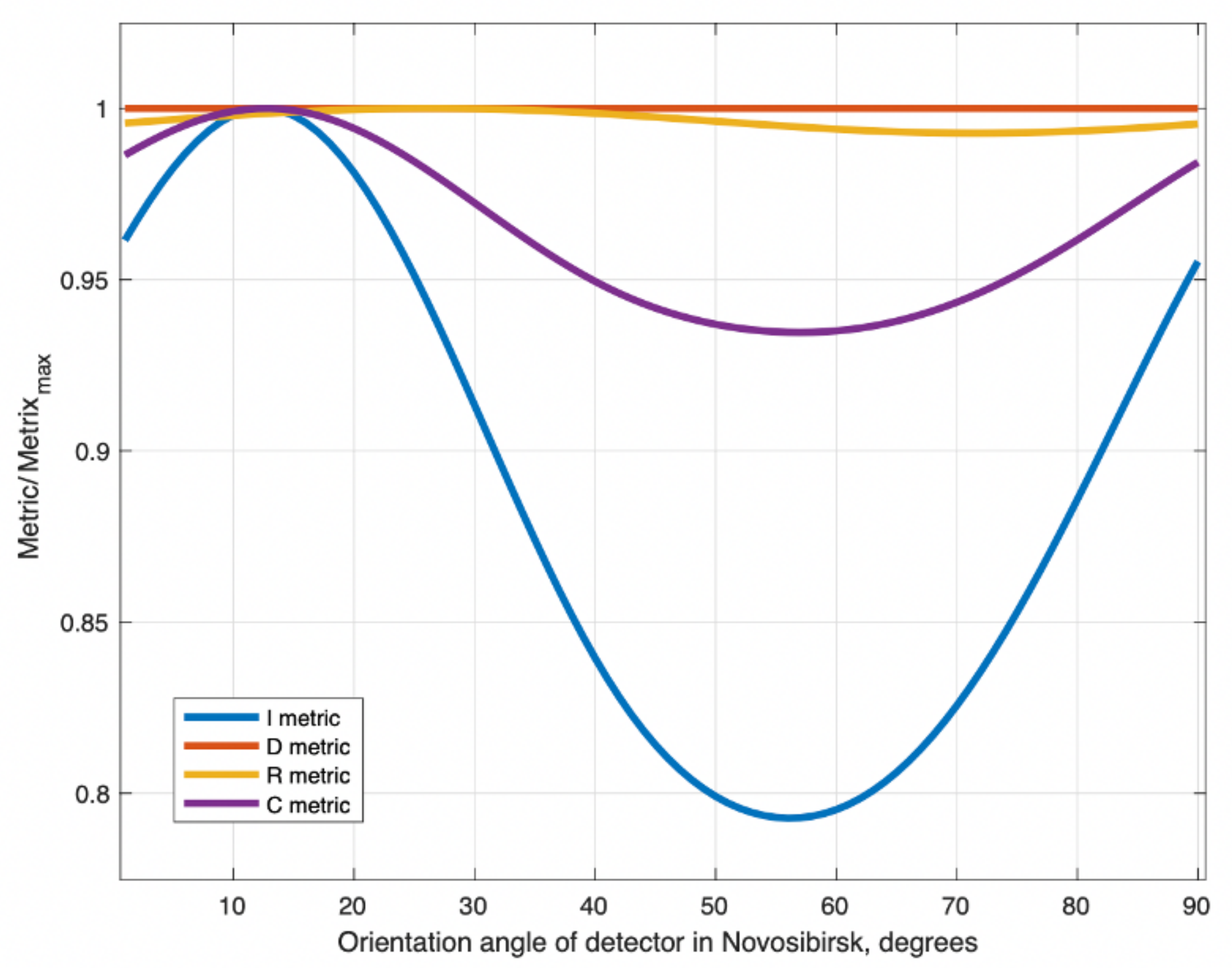
2) Localization criterion **D** defines ability to determine the angular position of a source. Localization is based on triangulation so the ability is proportional to distance between detectors. **D** is calculated as an area of a triangle formed by the three detectors of the network, which has the largest area of all possible detector combinations.
3) Parameter reconstruction criterion **R** defines the possibility to reconstruct parameter p of a signal with a known structure. It is calculated using Fisher matrix Γ_N of a network which takes into account detectors

$$R = \left(\frac{1}{4\pi} \oiint \frac{(\Gamma_N^{-1})_{pp}}{p^2} d\Omega \right)^{-1/2}$$

4) Integral criterion **C** allows us to evaluate and compare different detector network configurations (in our case $\gamma_{Novosibirsk}$ is the only degree of freedom).

$$C = \sqrt{\left(\frac{I}{I_{max}}\right)^2 + \left(\frac{D}{D_{max}}\right)^2 + \left(\frac{R}{R_{max}}\right)^2}$$

Dependence of EAN criteria on γ_{Nsk} for chirp



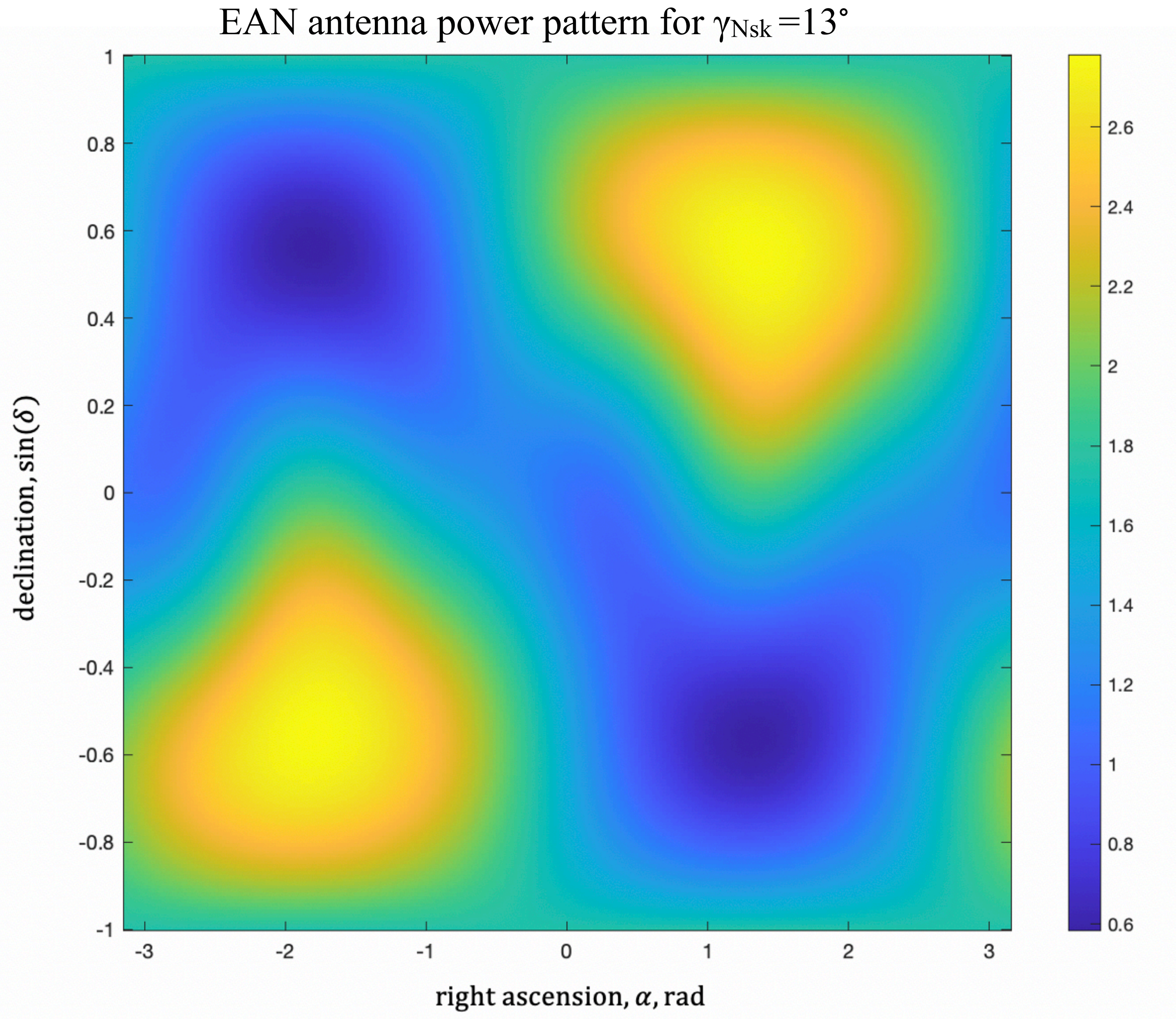
Networks in question.

- EAN - VIRGO, KAGRA, LIGO India, Novosibirsk
- HLVK - Hanford, Livingston, VIRGO, KAGRA
- HLVI - Hanford, Livingston, VIRGO, LIGO India

Orientation is an angle between the southward direction and the bisector of the angle formed by its arms, measured counterclockwise.

Detector	Latitude, Φ°	Longtitude, λ°	Orientation, γ°
LIGO Hanford	46.5	119.4	261.8
LIGO Livingston	30.6	90.8	333.0
VIRGO	43.6	-10.5	206.5
KAGRA	36.4	-137.3	163.3
LIGO India	19.6	-77.0	254.0
Novosibirsk	55.0	-82.9	to be defined

EAN antenna power pattern for γ_{Nsk}=13°



Results. In the table results of numerical integration are presented for two different sources as a ratio of criteria for EAN and for the reference network. EAN shows good results especially in **I** criterion for chirp signal. EAN copes with localization reconstruction worse than other networks because of location of all EAN detectors on the same continent.

Source	Ingration area	Network	I	D	R	Optimal γ_{Nsk}
Binary merger (chirp signal)	Whole celestial sphere (isotropic distribution of sources) at fixed arbitrary moment	HLVK	1.4	0.6	0.9	13°
		HLVI	1.2	0.7	1.0	
PNS rotational instability (core-collapse)	Milky Way galactic disk (LIGO/VIRGO sensitivity is insufficient to detect GW from supernovae core-collapse from distant galaxies); antenna power patterns are averaged over period 24 hours	HLVK	0.9	0.6	1.0	40°
		HLVI	0.7	0.7	1.0	

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