



*Institute of Radio Astronomy
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Serge Yerin

GURT Subarray: Structure and Characteristics

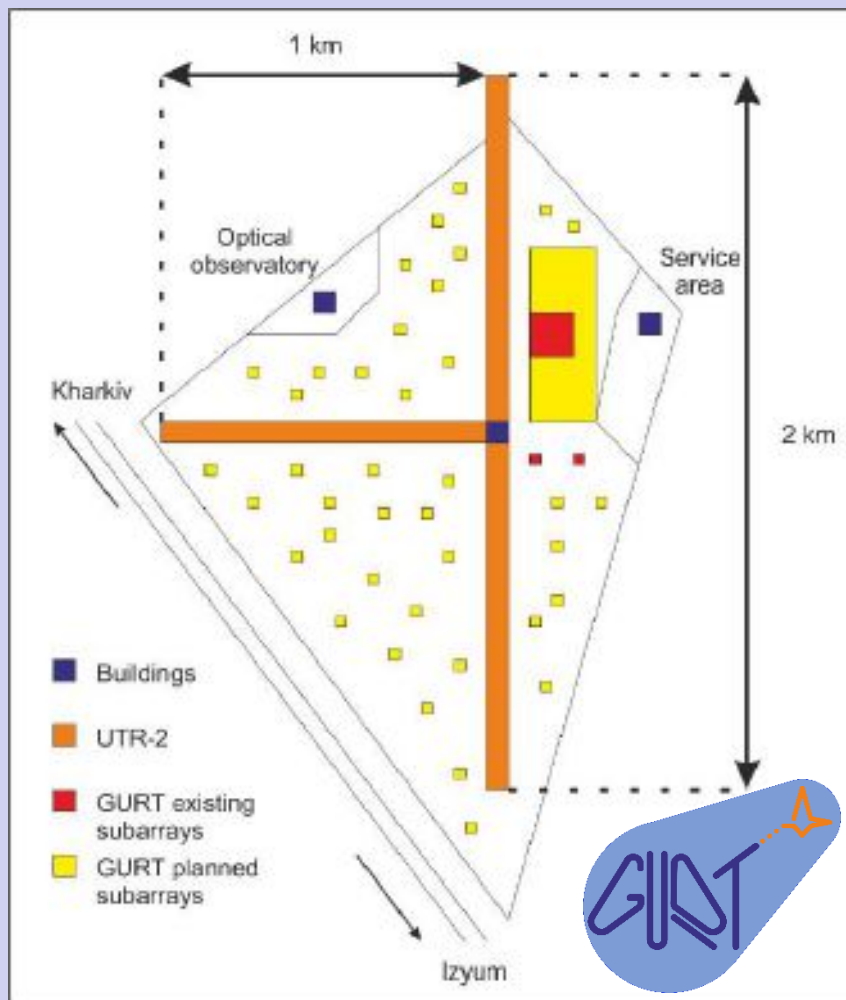


**BUILDING ON ADVANCED LOFAR
TECHNOLOGY FOR INNOVATION,
COLLABORATION, AND SUSTAINABILITY**



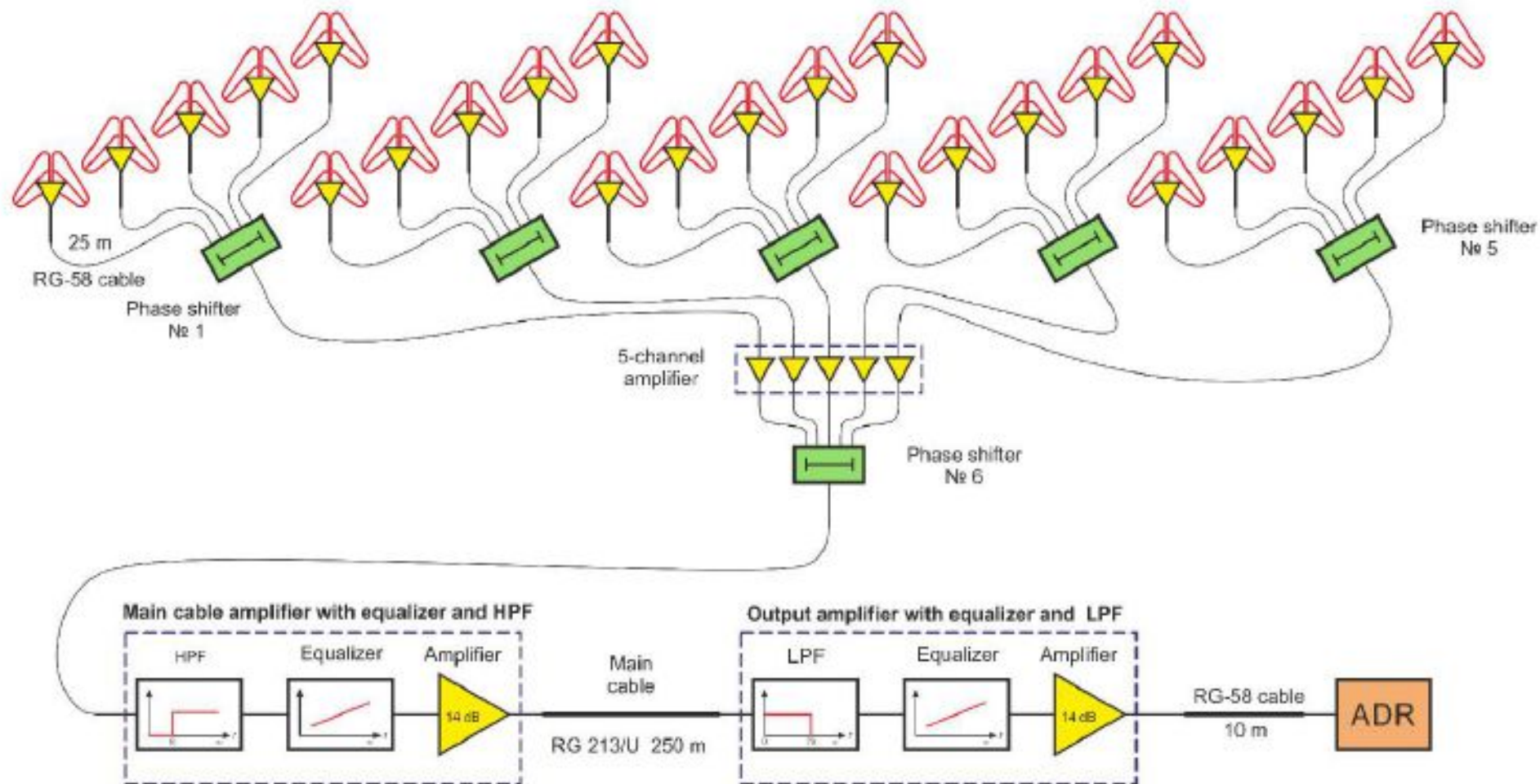
*Latvia, Jūrmala - Ventspils - Irbene
December 5-6, 2018*

Giant Ukrainian Radio Telescope (GURT)

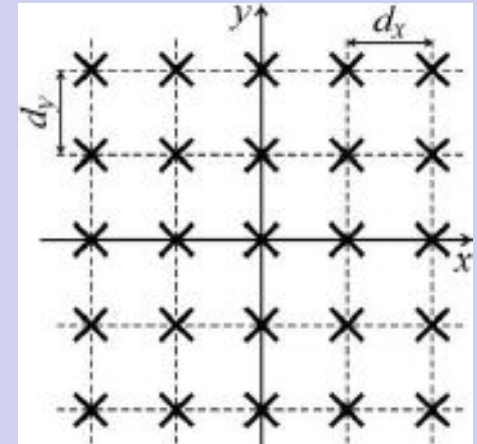


- **Frequency range: 8 - 80 MHz.**
- **Up to several hundreds of subarrays.**
- **5×5 element subarrays.**
- **Subarray dimensions 15×15 m.**
- **Interelement spacing 3.75 m.**
- **Subarray elements – active dipoles.**
- **Total area up to 2 sq. km.**
- **2 orthogonal polarizations of incoming waves.**
- **Analog beamforming at subarray stage.**
- **Digital beamforming at entire antenna array stage.**
- **Digital signal processing.**
- **Low cost of dipoles and subarrays.**
- **Easy radio telescope extension.**
- **Construction in UTR-2 territory.**





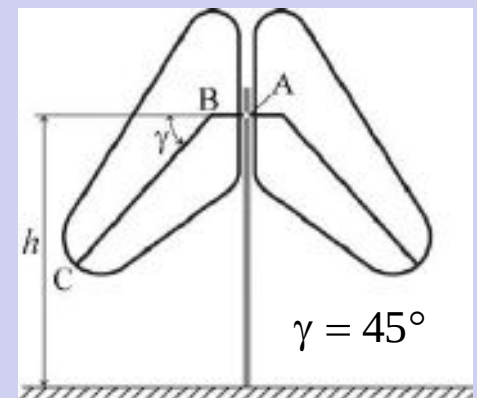
GURT Real Subarray



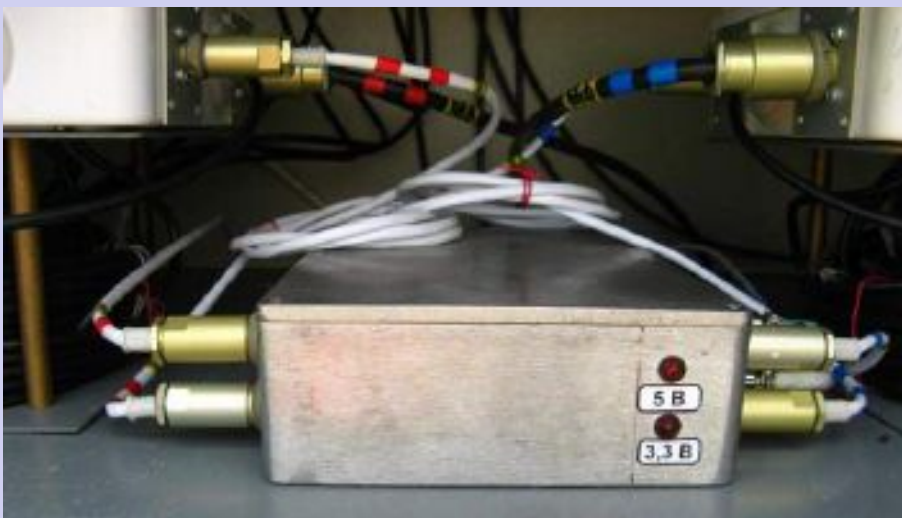
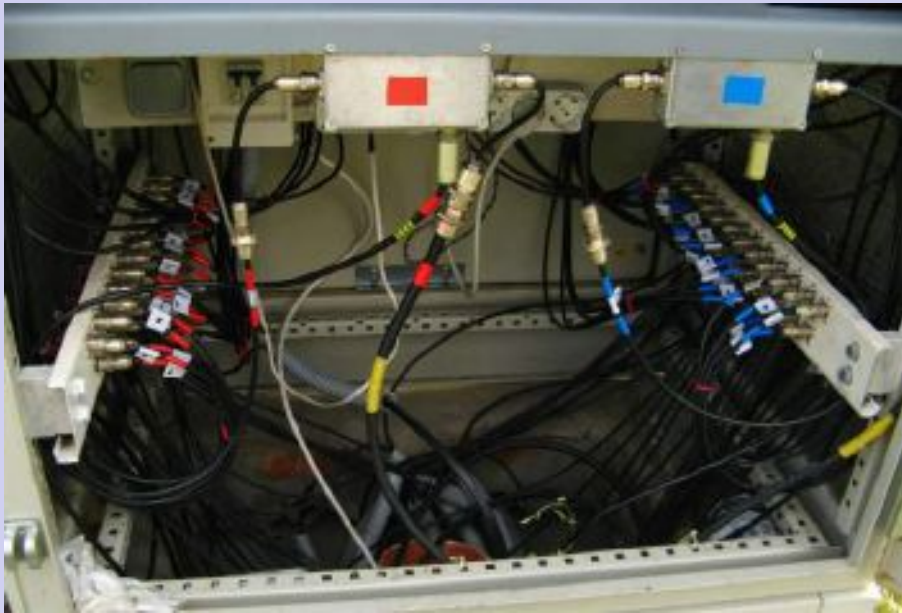
$$d_x = d_y = 3.75 \text{ m}$$

$$h = 1.6 \text{ m}$$

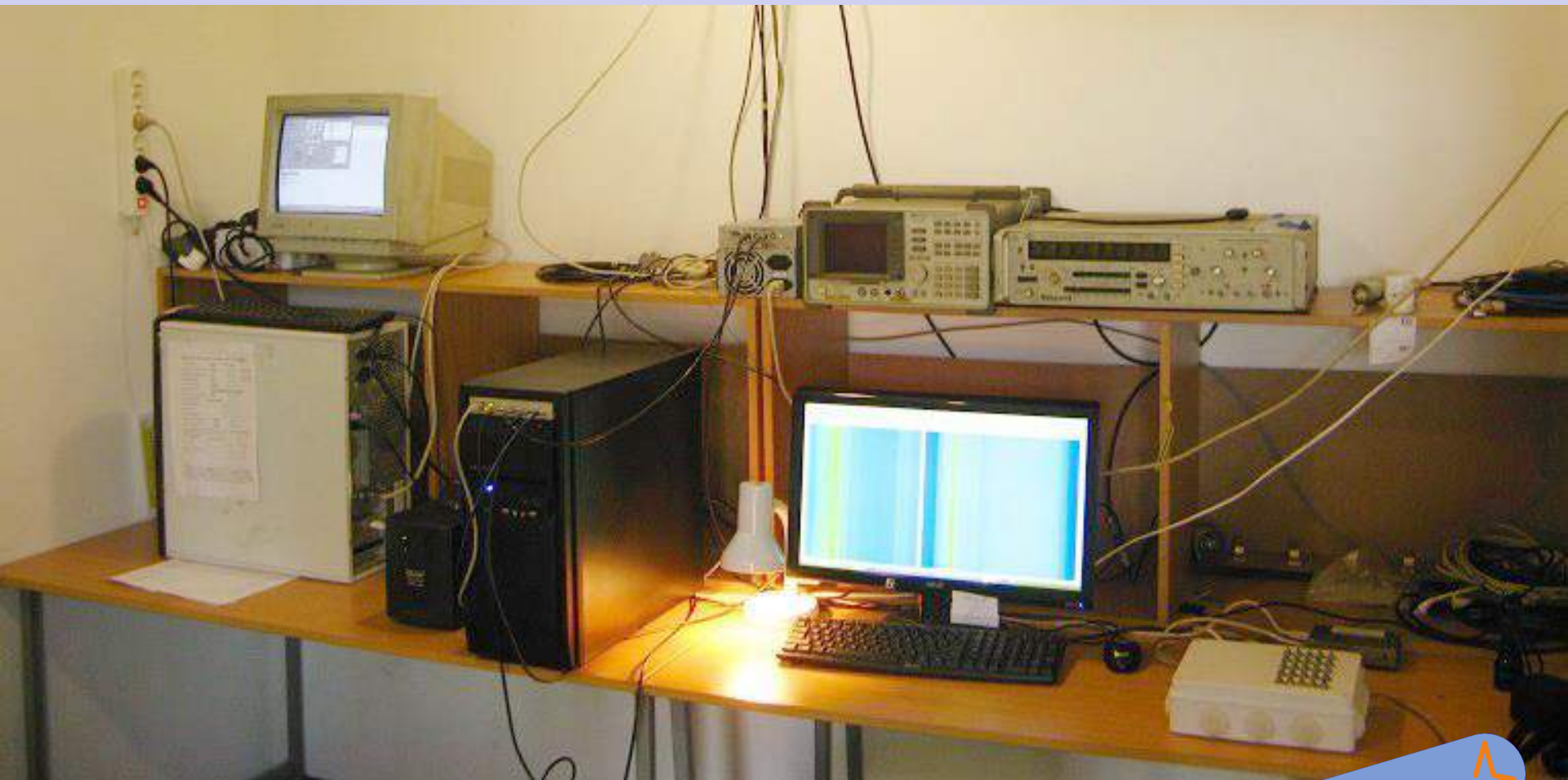
$$ABC = 1.4 \text{ m}$$



GURT equipment box



GURT Advanced Digital Receiver (ADR)

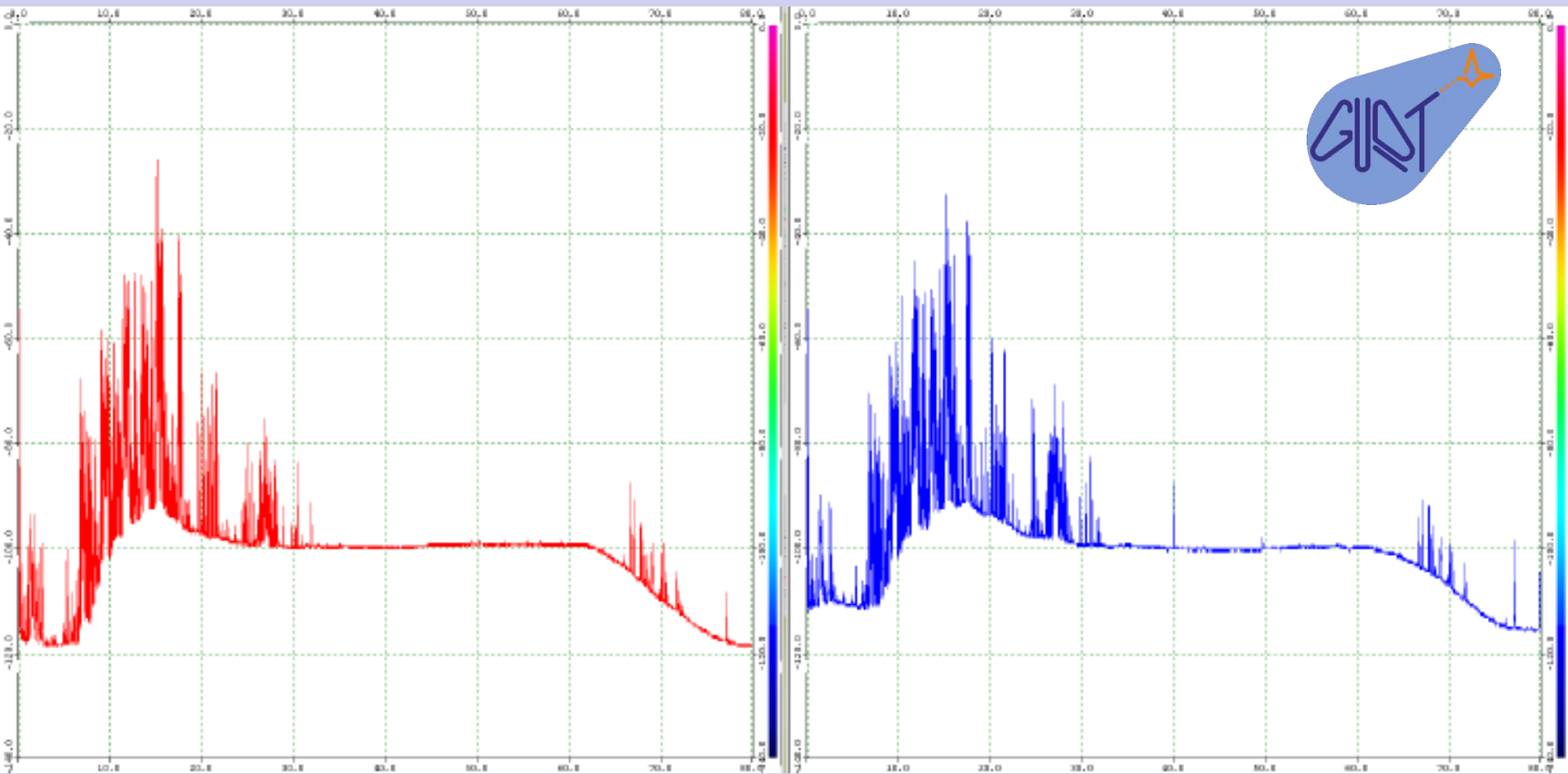


GURT Advanced Digital Receiver (ADR)



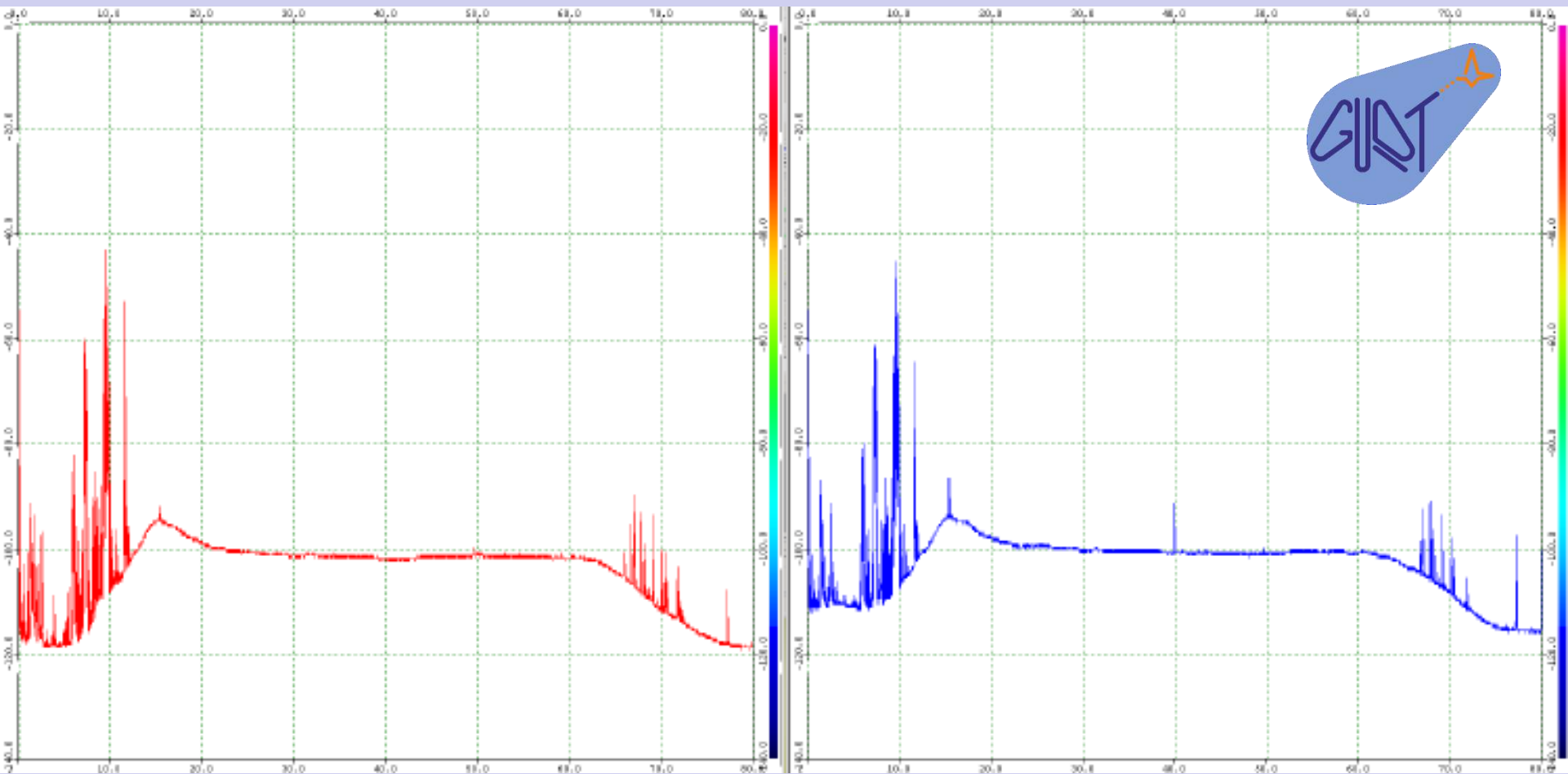
Parameters	ADR – GURT
Frequency band (MHz)	80
Number of freq. channels	16 384 (tunable)
Frequency resolution (kHz)	4,8
Time resolution (ms)	2
ADC resolution (bits)	16
Dynamic range (dB)	90
Input channels	2
On-line real-time possibilities	
Fast Fourier transform	Yes
Wave-form	Yes
Auto- and complex cross-spectra	Yes
Sum-Subtraction mode	Yes
Signals normalization	yes
Signals delay	yes

GURT spectrum (day)



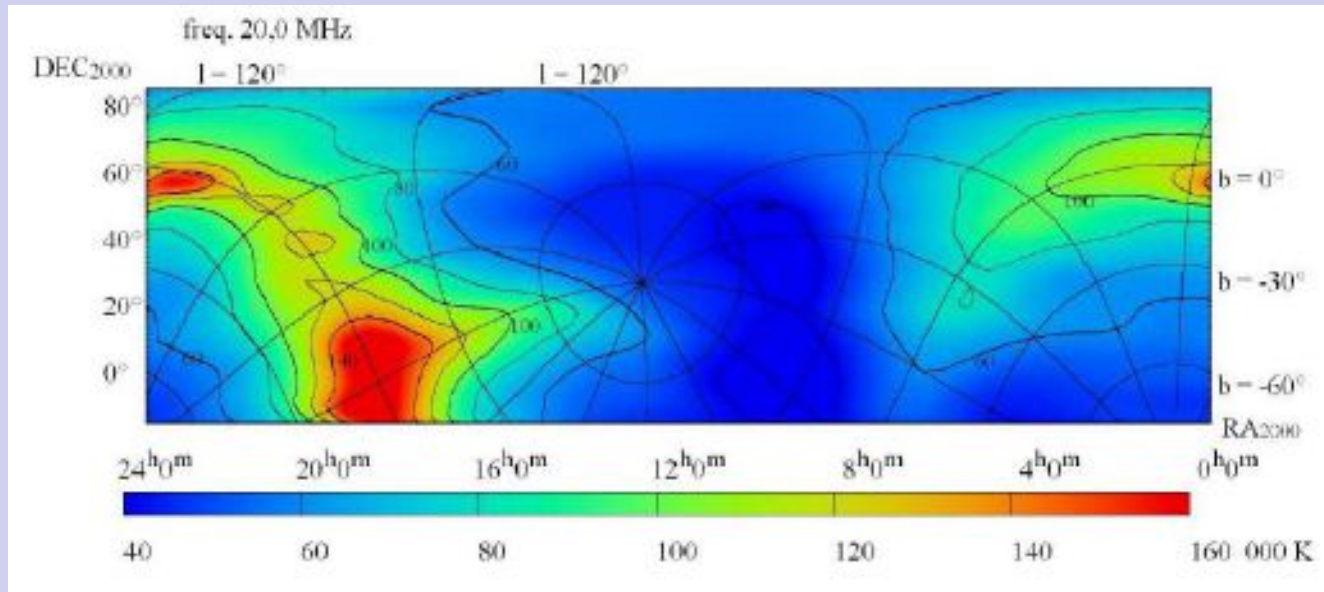
***RFI and galactic background of GURT subarray phased to zenith direction
(December 11, 2014 at 13-43 Local time)***

GURT spectrum (night)



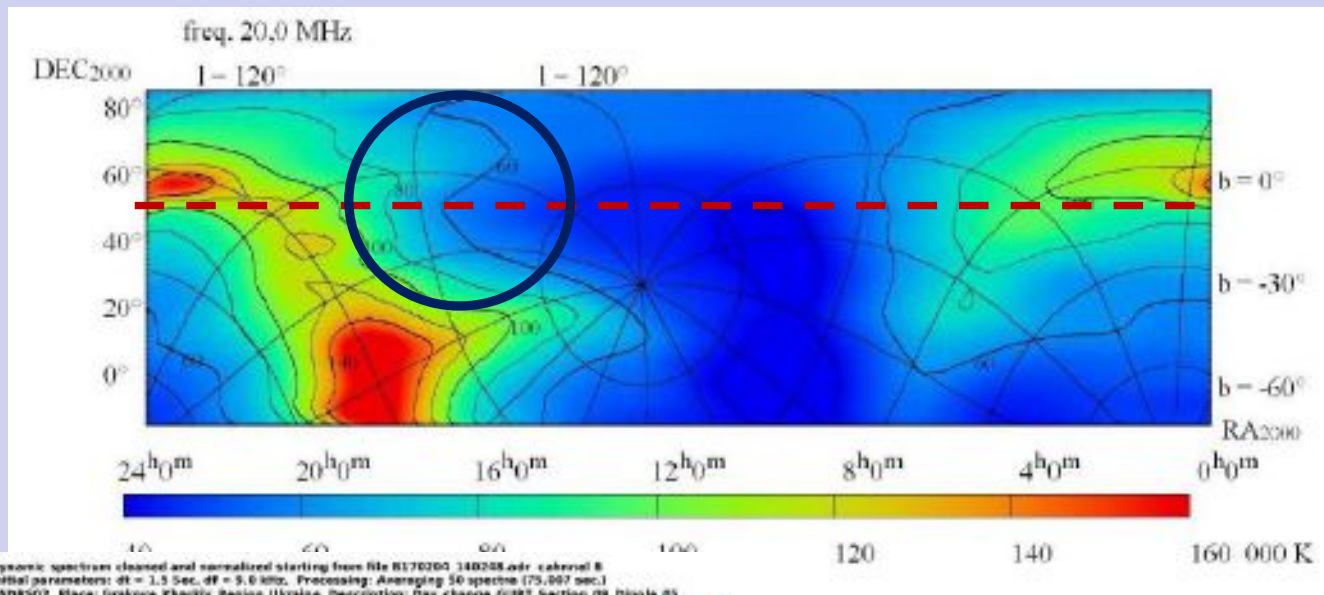
***RFI and galactic background of GURT subarray phased to zenith direction
(December 11, 2014 at 23-20 Local time)***

Galactic background diurnal change

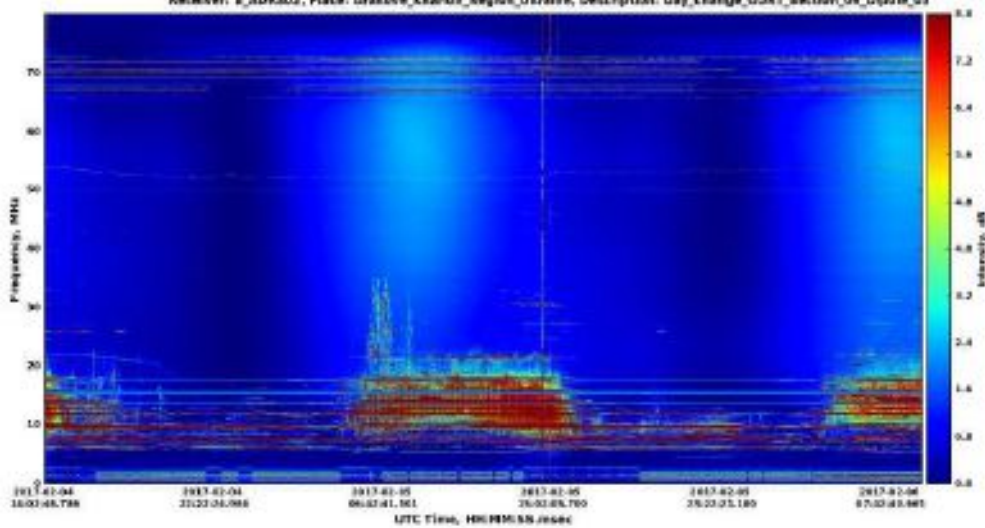


Galactic
background
distribution
map

Galactic background diurnal change

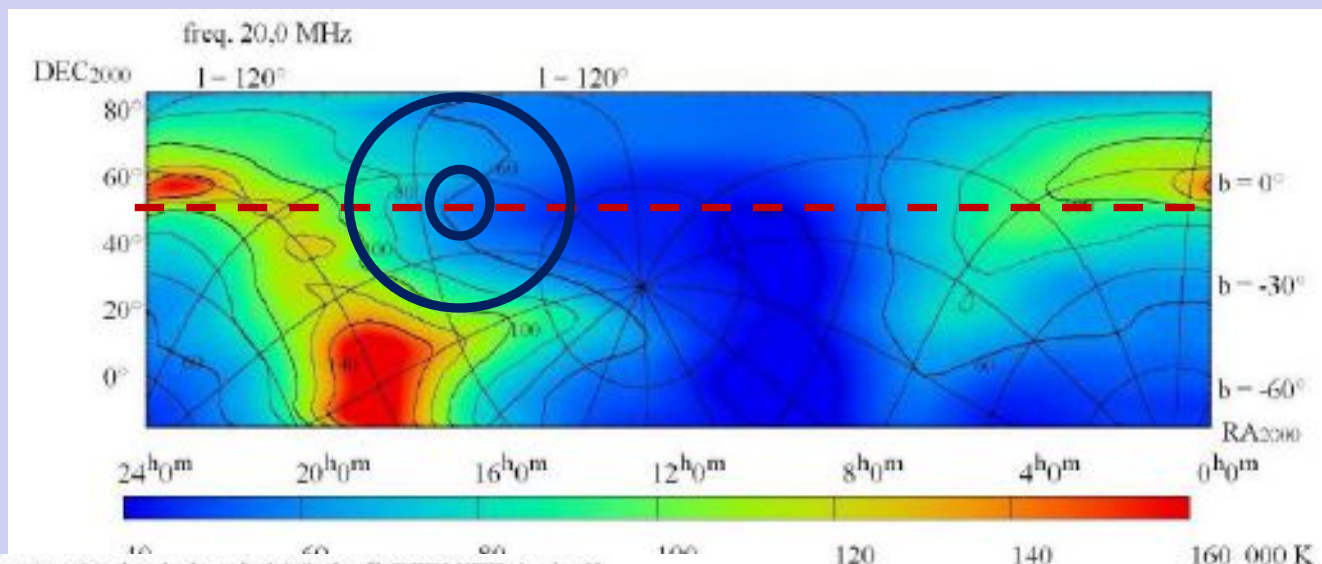


Galactic
background
distribution
map

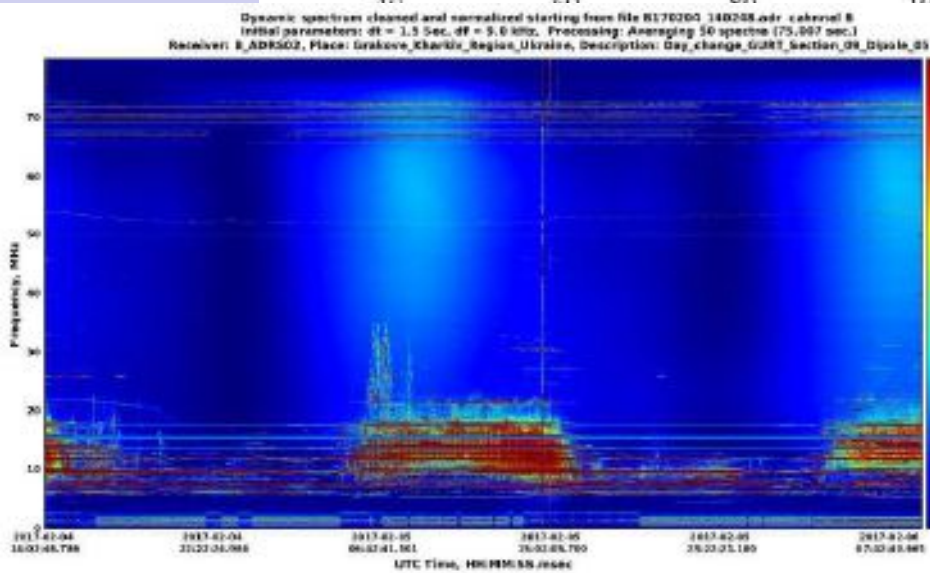


as seen by single GURT dipole

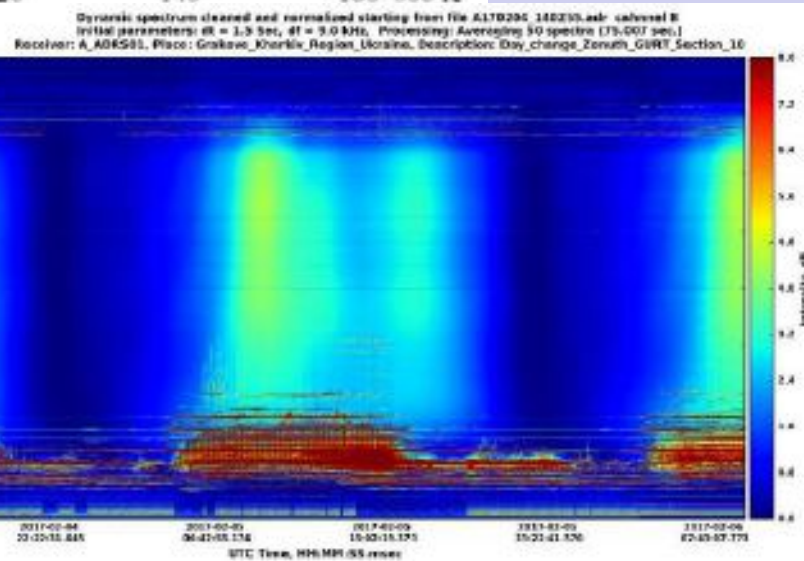
Galactic background diurnal change



Galactic
background
distribution
map

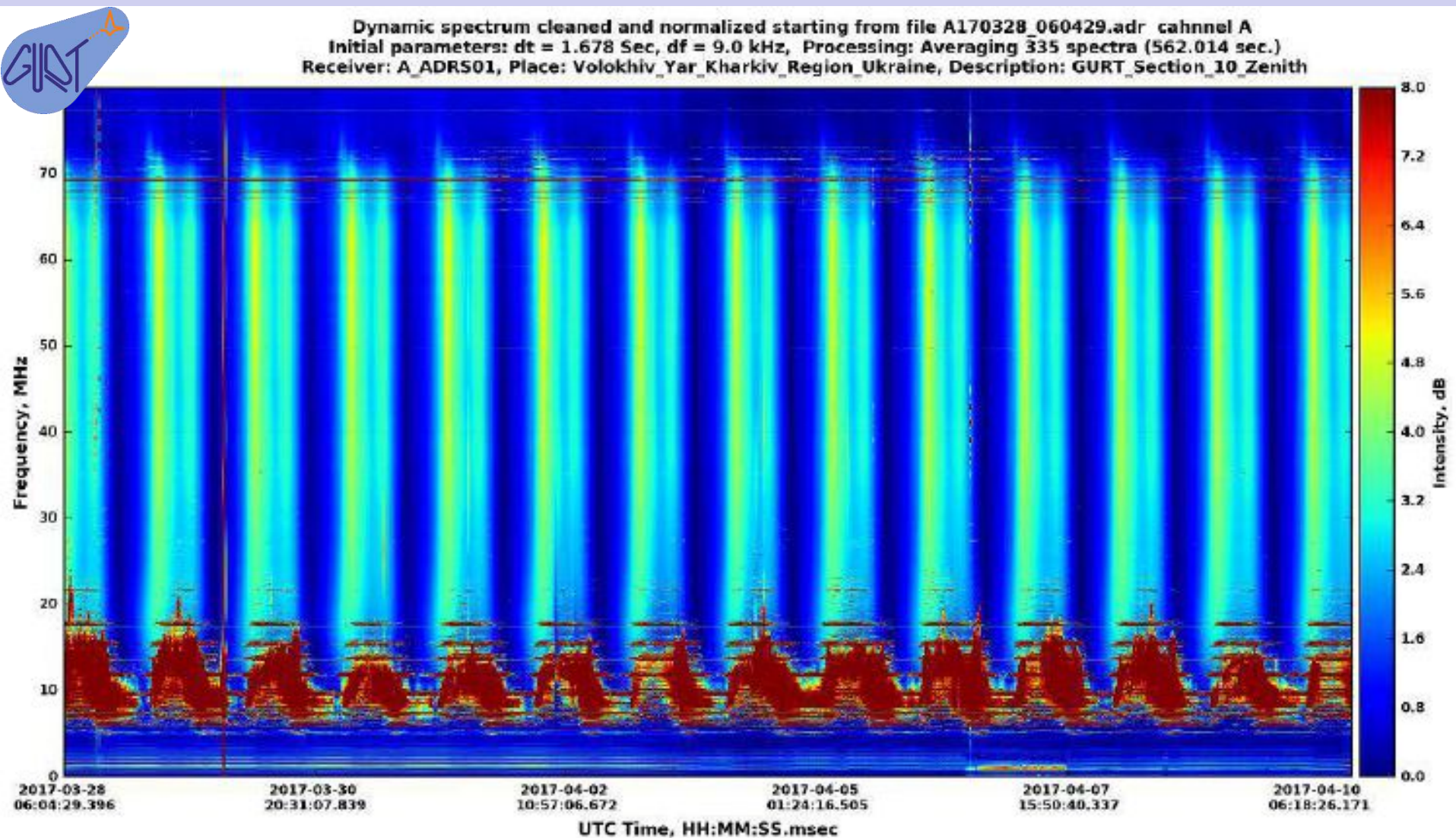


as seen by single GURT dipole

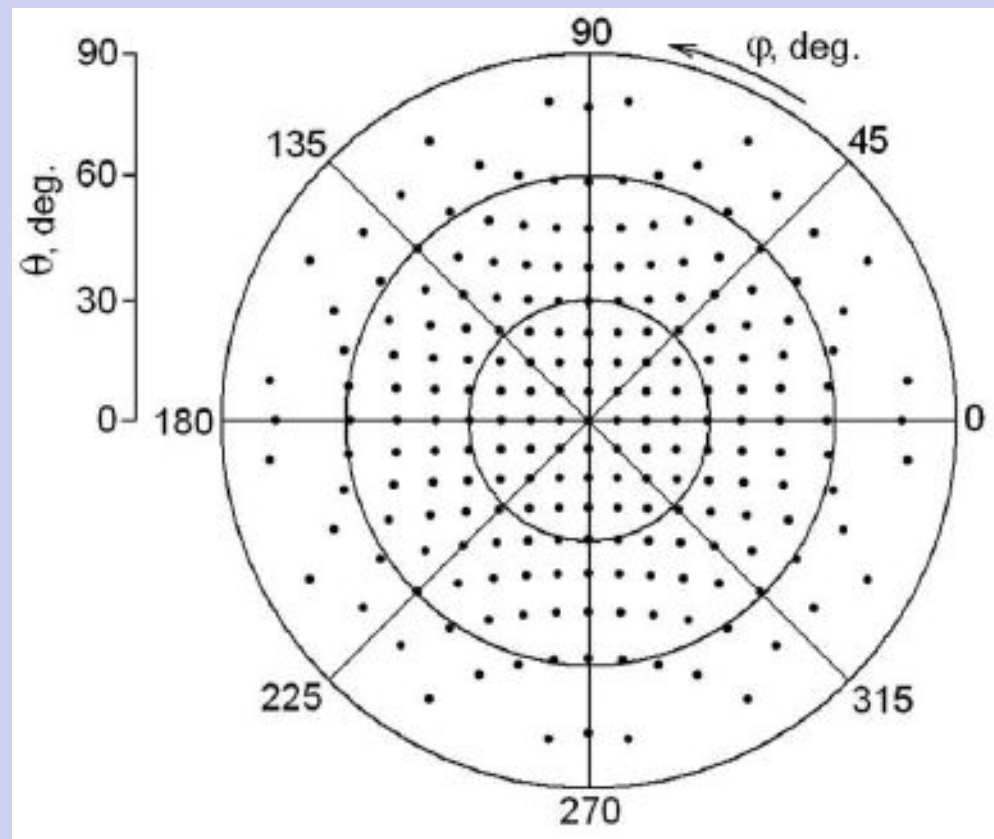
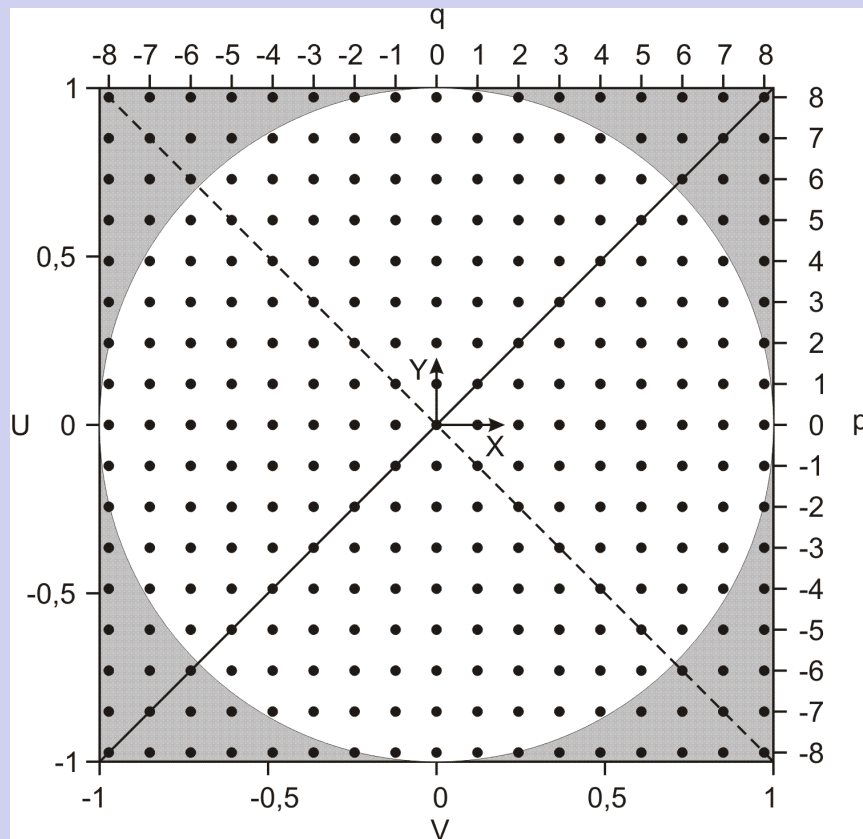


and by GURT subarray of 25 dipoles

GURT long term observations (zenith)



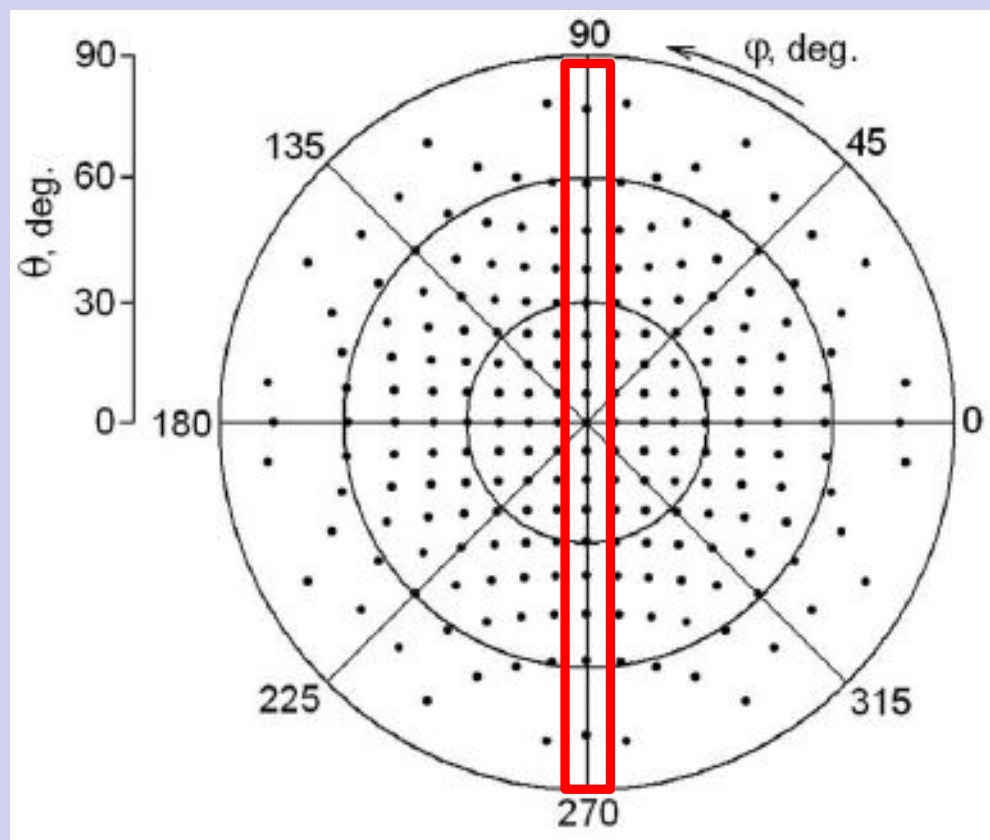
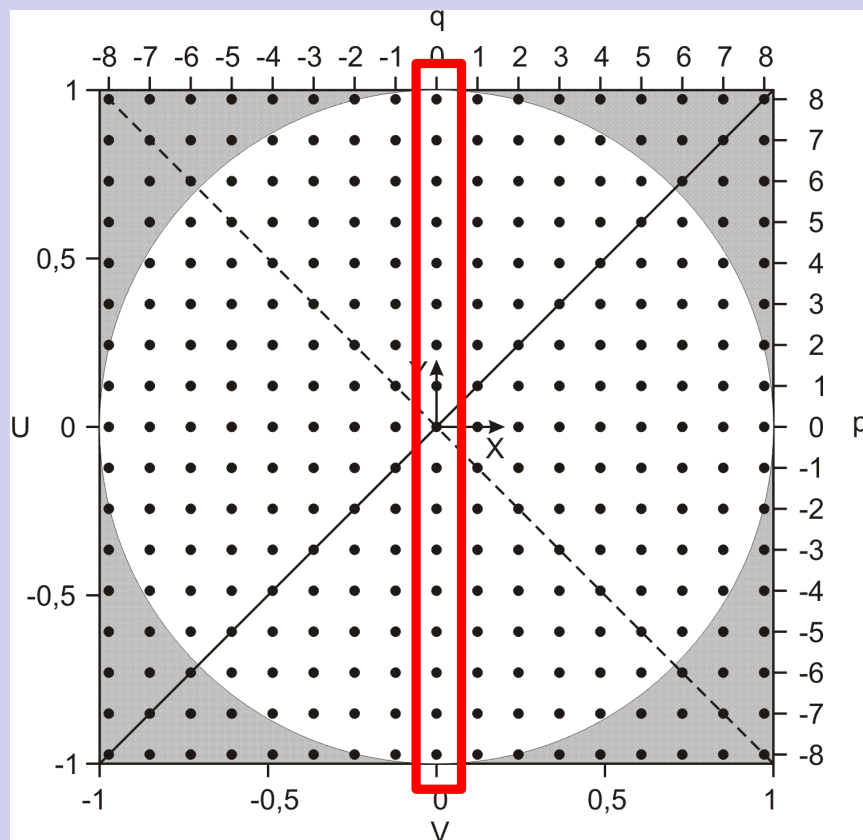
Phasing directions of GURT subarray



$$U = \sin \theta \sin \varphi$$

$$V = \sin \theta \cos \varphi$$

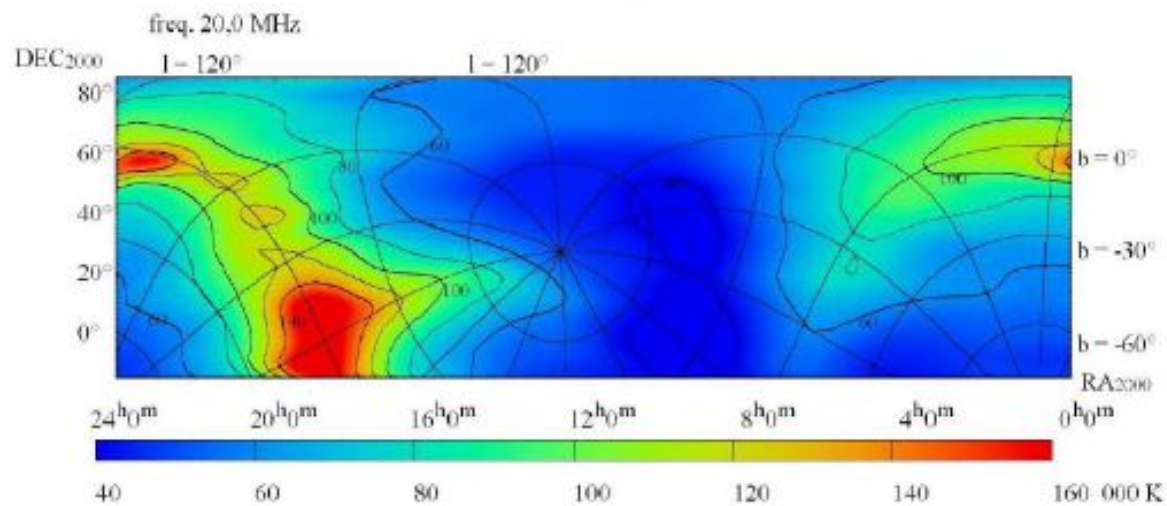
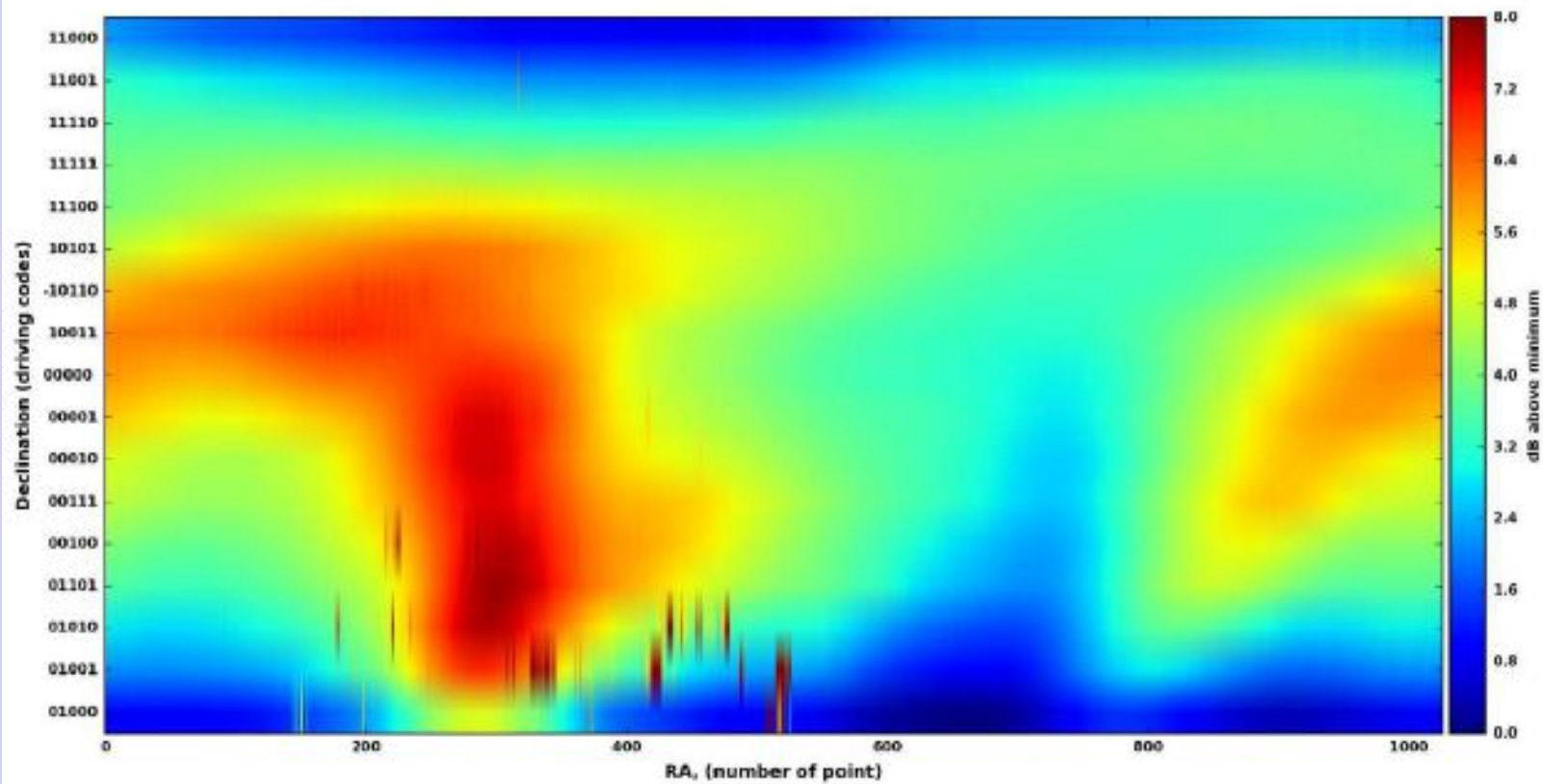
Phasing directions of GURT subarray



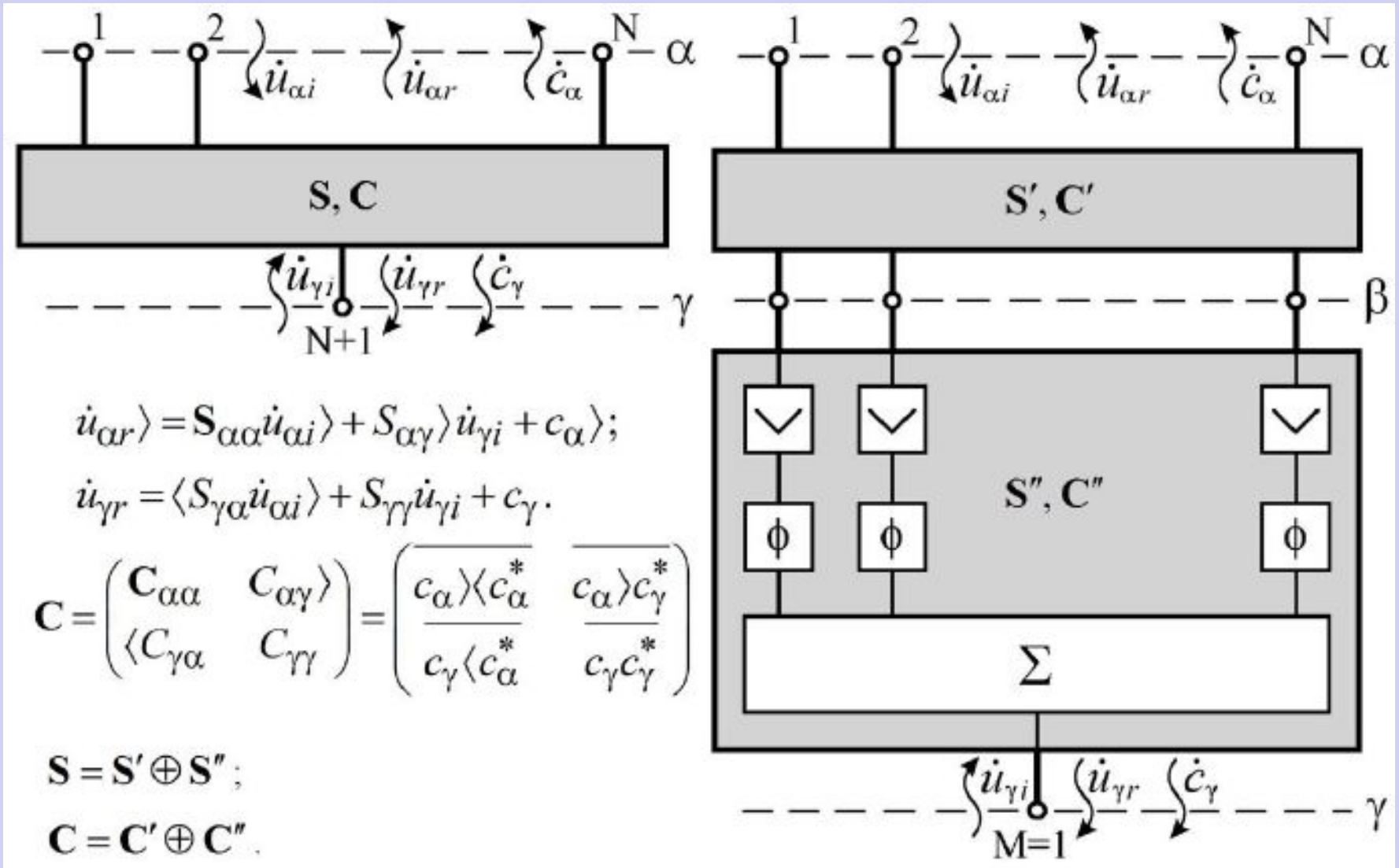
$$U = \sin \theta \sin \varphi$$

$$V = \sin \theta \cos \varphi$$

GURT background map at 35.008 MHz



GURT subarray mathematical model



Model of antenna array

- partial radiation patterns of the antenna array $f_n(\theta, \varphi)$, $n = 1, \dots, N$
- normalized matrix of self and mutual impedances

$$\mathbf{z} = \mathbf{r} + j\mathbf{x} = \mathbf{r}_\Sigma + \mathbf{r}_d + j\mathbf{x}$$

where $\mathbf{r}_\Sigma$ and $\mathbf{r}_d$ are normalized matrices of radiation and loss resistances

Scattering matrix

$$\mathbf{S}' = \begin{pmatrix} \mathbf{S}'_{\alpha\alpha} & \mathbf{S}'_{\alpha\beta} \\ \mathbf{S}'_{\beta\alpha} & \mathbf{S}'_{\beta\beta} \end{pmatrix} = \begin{pmatrix} -\mathbf{J}^{-1}\mathbf{A}\mathbf{J}_t^{-1} + \mathbf{J}_t^*\mathbf{J}_t^{-1} & \mathbf{J}^{-1}\mathbf{A} \\ \mathbf{A}\mathbf{J}_t^{-1} & \mathbf{E} - \mathbf{A} \end{pmatrix}, \text{ where } \mathbf{A} = 2(\mathbf{z} + \mathbf{E})^{-1}$$

Covariation matrix of spectral densities of noise waves

$$\mathbf{C}' = k_B T_0 (1 - \mathbf{S}'\mathbf{S}_t'^*) = \begin{pmatrix} \mathbf{J}^{-1}\mathbf{V}(\mathbf{J}_t^*)^{-1} & \mathbf{J}^{-1}\mathbf{V} \\ \mathbf{V}(\mathbf{J}_t^*)^{-1} & \mathbf{V} \end{pmatrix}, \text{ where } \mathbf{V} = k_B T_0 \mathbf{A}\mathbf{r}_d \mathbf{A}_t^*$$

k_B is Boltzmann constant

Model of the GURT subarray

$$\langle i_e = -j \langle \Phi [\mathbf{E} - (\mathbf{E} - \mathbf{A}) S_{y11}]^{-1} \mathbf{A} S_{y21} / \sqrt{N} \rangle - \text{current distribution}$$

$$A_e = \lambda^2 |\langle i_e f(\theta_m, \varphi_m) \rangle|^2 / \langle i_e^* \mathbf{r}_\Sigma i_e \rangle - \text{effective area}$$

$$F(\theta_m, \varphi_m) = \langle i_e f(\theta, \varphi) \rangle / \langle i_e f(\theta_m, \varphi_m) \rangle - \text{normalized antenna pattern}$$

$$\eta = \langle i_e^* \mathbf{r}_\Sigma i_e \rangle / \langle i_e^* \mathbf{r} i_e \rangle - \text{efficiency}$$

$$T_{\gamma int} = C_{\gamma\gamma} / k_B - \text{temperature of internal noise}$$

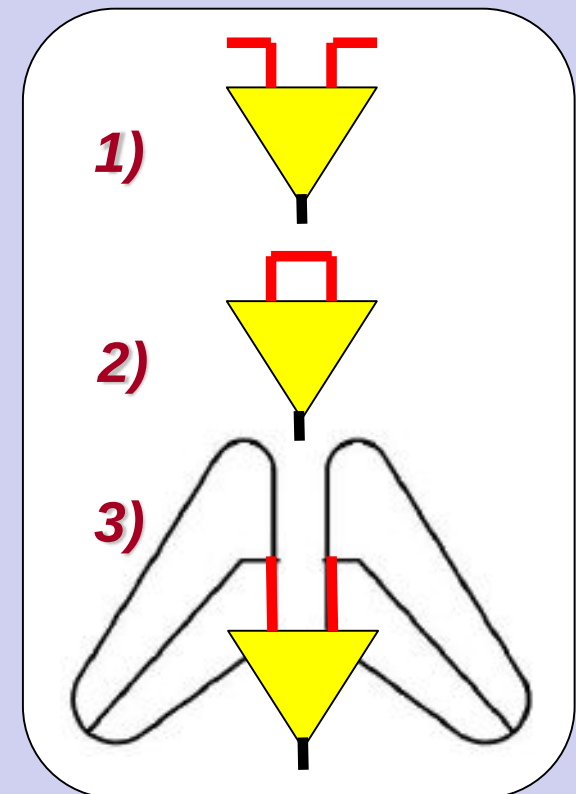
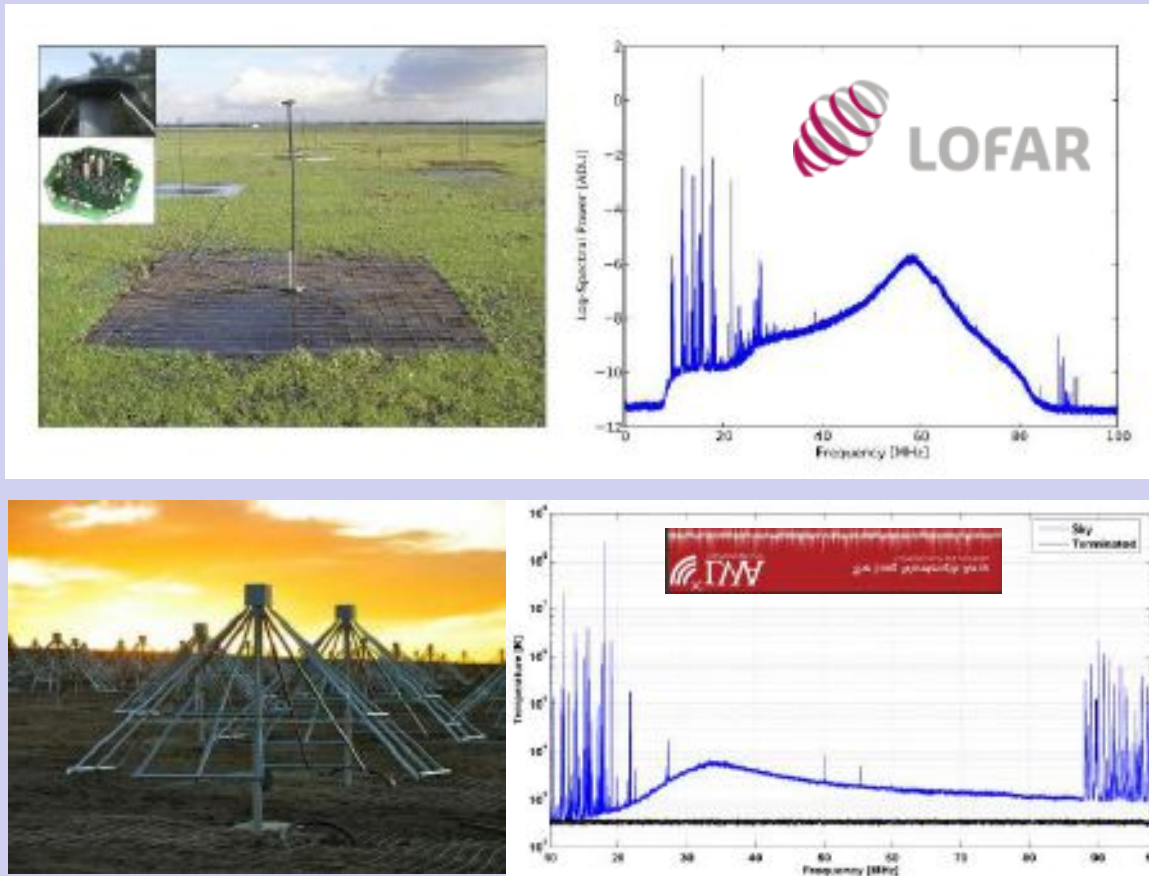
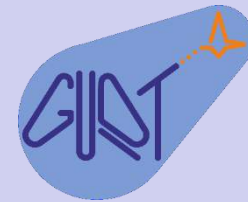
$$T_{\gamma ext} = T_B \langle i_e^* \mathbf{r}_\Sigma i_e \rangle - \text{temperature of external noise}$$

$$\text{SND} = T_{\gamma ext} / T_{\gamma int} - \text{SND (Sky Noise Dominance)}$$

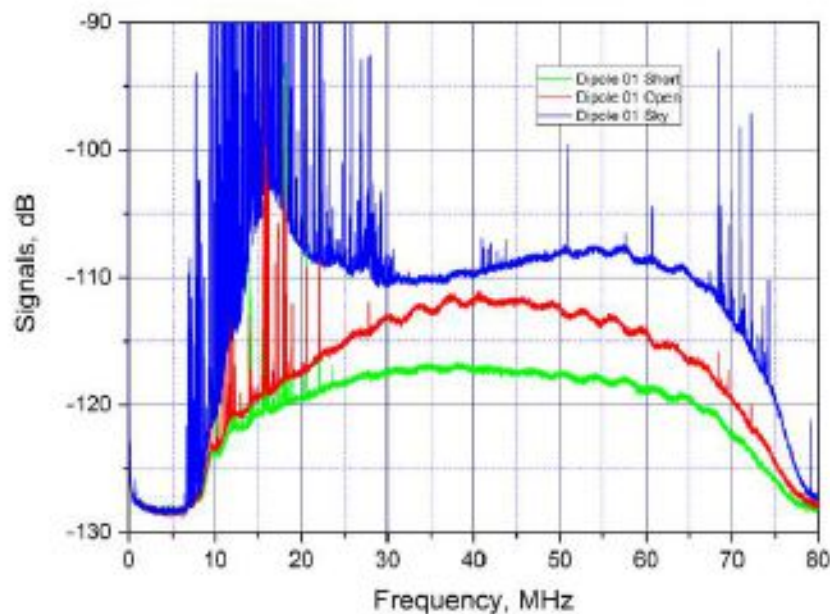
$$\text{SEFD} = \frac{k_B T_B}{A_e} \left(1 + \frac{1}{\text{SND}} \right) - \text{SEFD (System Equivalent Flux Density)}$$

$$T_B - \text{sky brightness temperature}$$

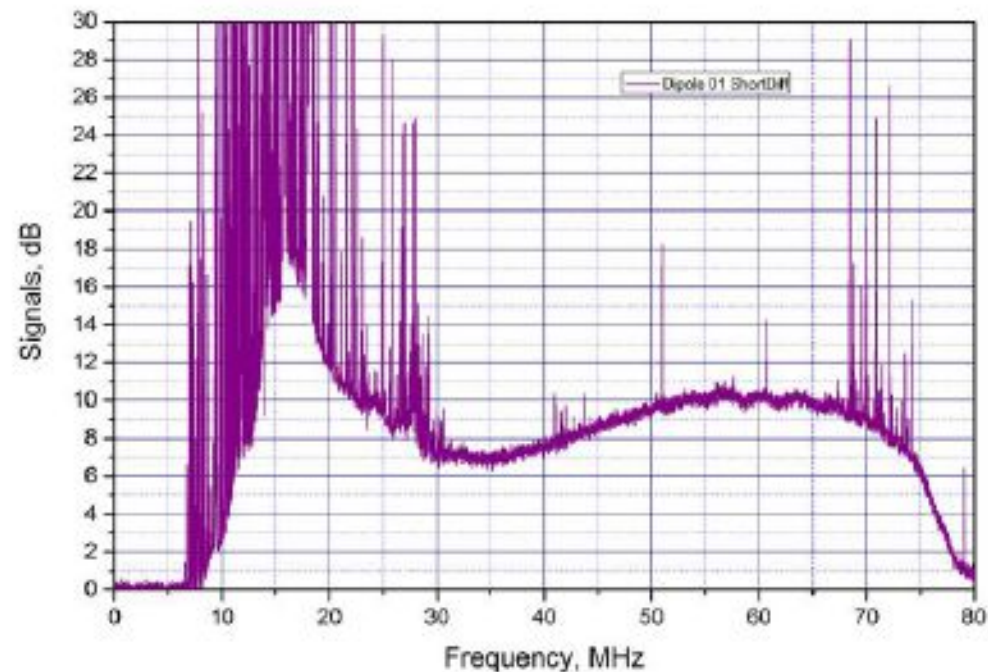
Noise tests



Dipole noise tests and its SND

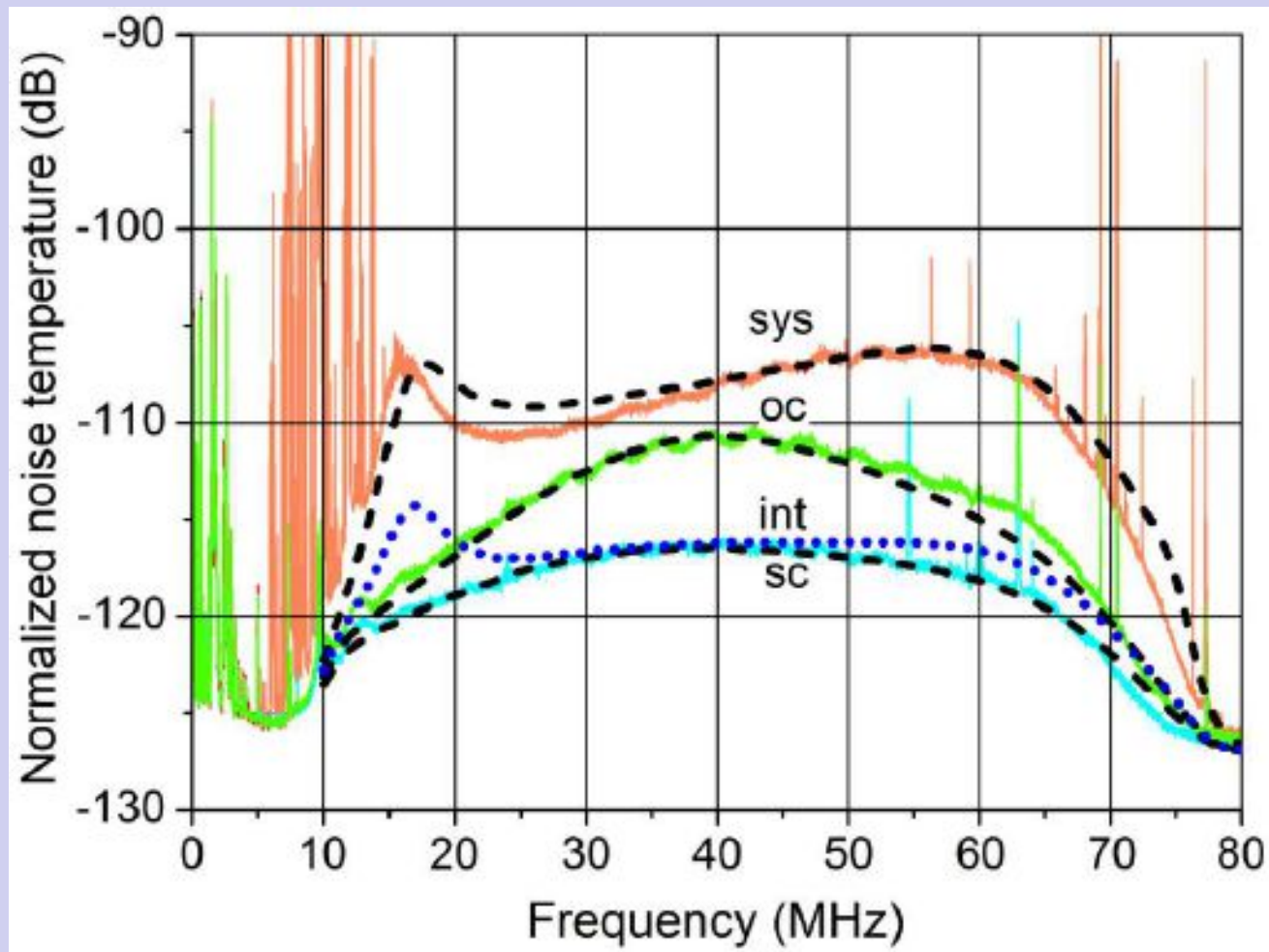


One array element with open-circuited amplifier input, short-circuited amplifier input and connected to dipole arms



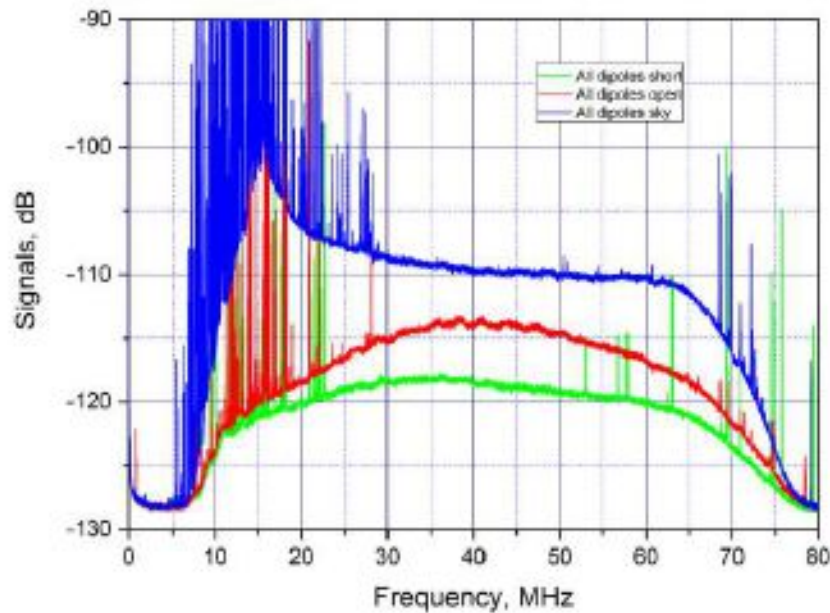
Sky-noise dominance (in short circuited mode) for one dipole

GURT dipole noise calculations and measurements

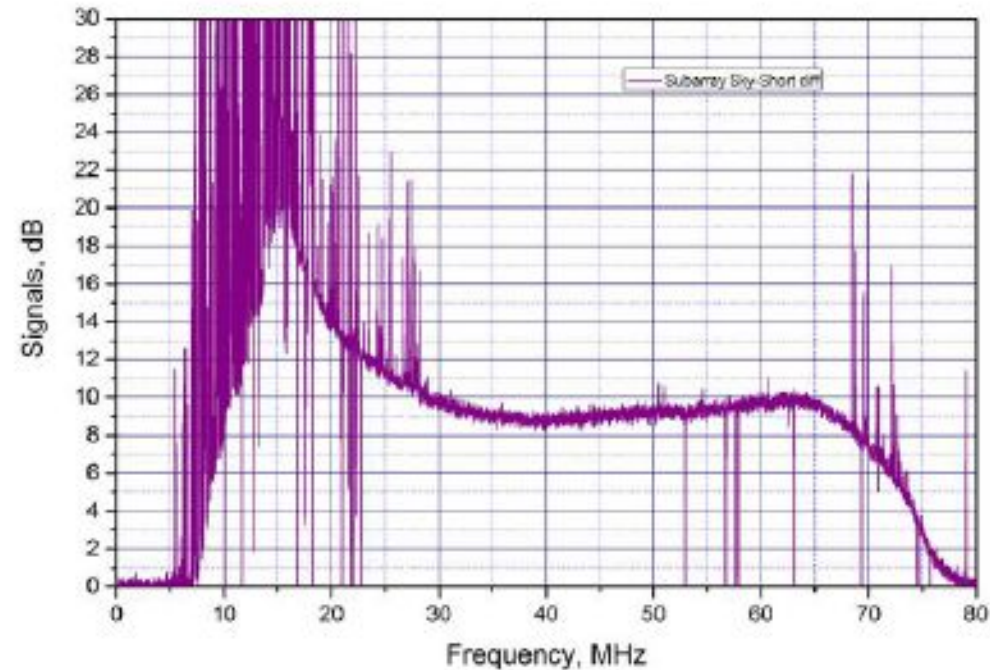


P. Tokarsky, A. Konovalenko, S. Yerin, "Sensitivity of an Active Antenna Array Element for the Low-Frequency Radio Telescope GURT," *IEEE Transactions on Antennas and Propagation*, vol. 65, is. 9, p. 4636–4644, 2017. DOI: 10.1109/TAP.2017.2730238

Subarray noise tests and its SND

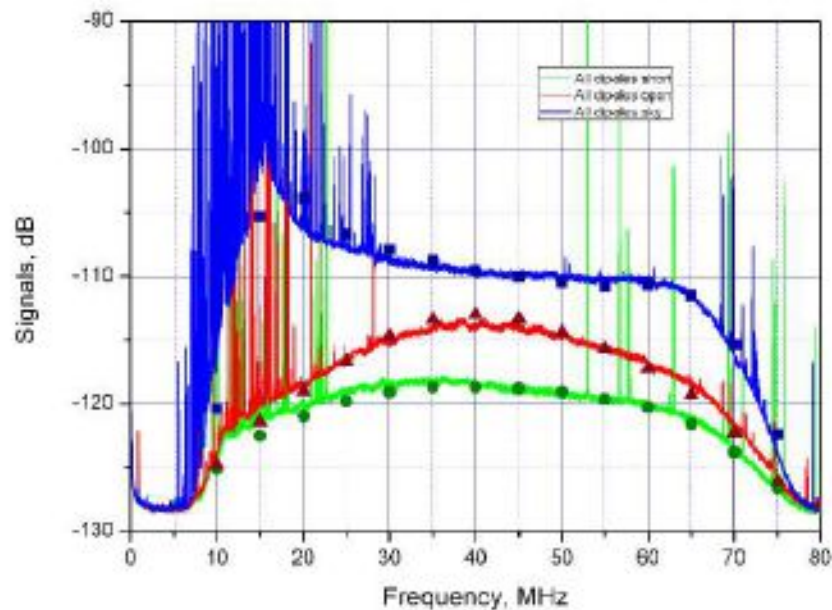


All array elements with open-circuited amplifiers inputs, short-circuited amplifiers inputs and connected to dipoles arms

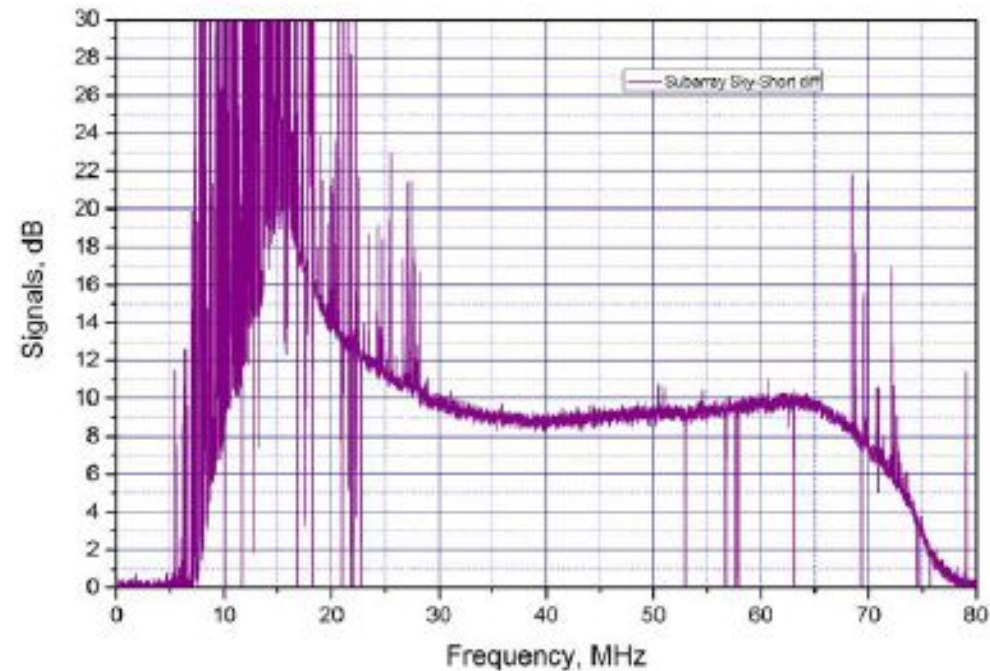


Sky-noise dominance (in short circuited mode) for the whole subarray

Subarray noise tests and its SND



All array elements with open-circuited amplifiers inputs, short-circuited amplifiers inputs and connected to dipoles arms



Sky-noise dominance (in short circuited mode) for the whole subarray

SND vs. SEFD

$$\Delta S_{\min} = K_{\text{rec}} \frac{2 \cdot k_B \cdot T_{\text{sys}}}{A_e \sqrt{\Delta t \cdot \Delta f}} = \frac{SEFD}{\sqrt{\Delta t \cdot \Delta f}} \quad SND = \frac{T_{\text{ext}}}{T_{\text{int}}}$$

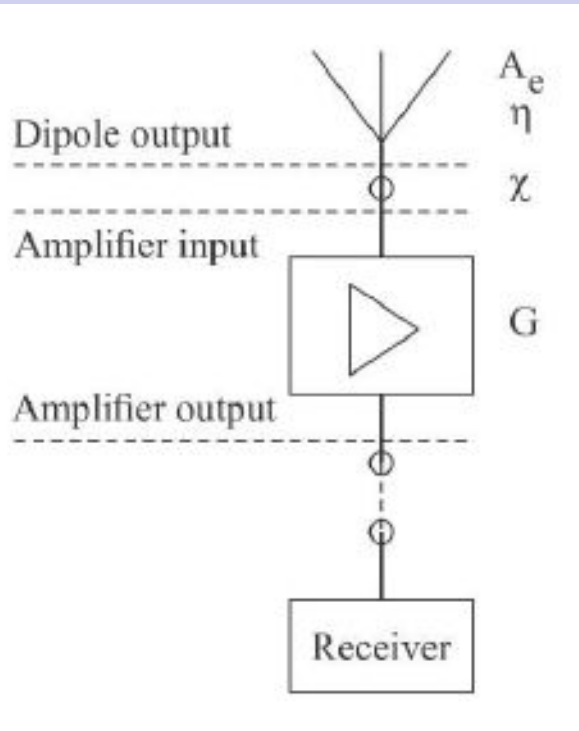
η – efficiency of passive dipole;

χ – mismatch coefficient of passive dipole and antenna amplifier;

G – amplifier transmission coefficient (of the whole consequent signal path).

T_{ext} – external noise temperature

T_{int} – internal system noise temperature

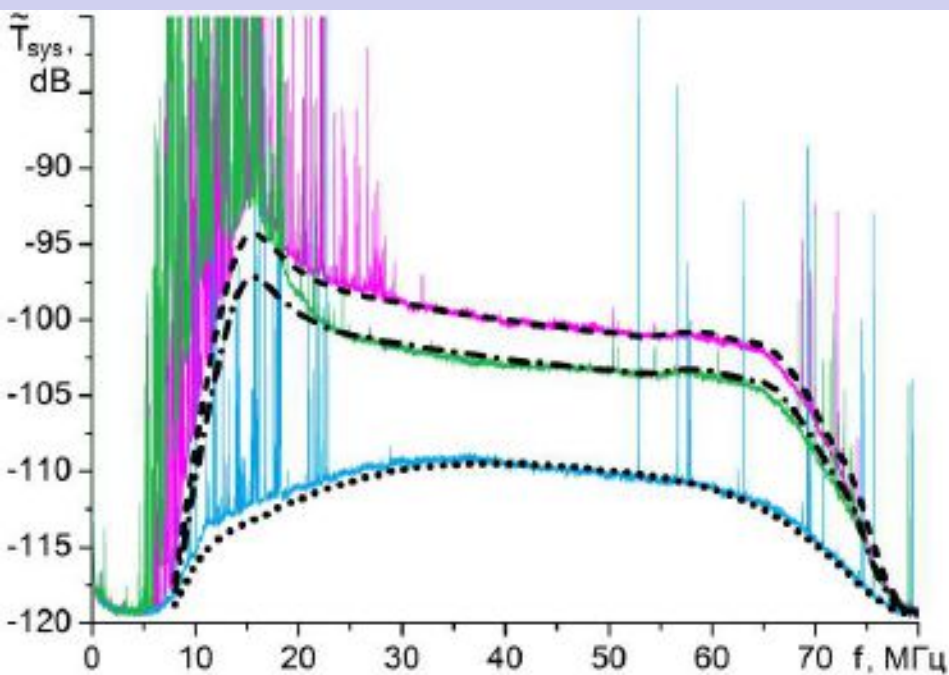


Section	Dipole output	Amplifier input	Amplifier output
A_e	ηA_e	$\chi \eta A_e$	$G \chi \eta A_e$
T_{ext}	ηT_{bg}	$\chi \eta T_{bg}$	$G \chi \eta T_{bg}$
T_{int}	$\frac{1}{G \chi} T_{\text{amp}}$	$\frac{1}{G} T_{\text{amp}}$	T_{amp}

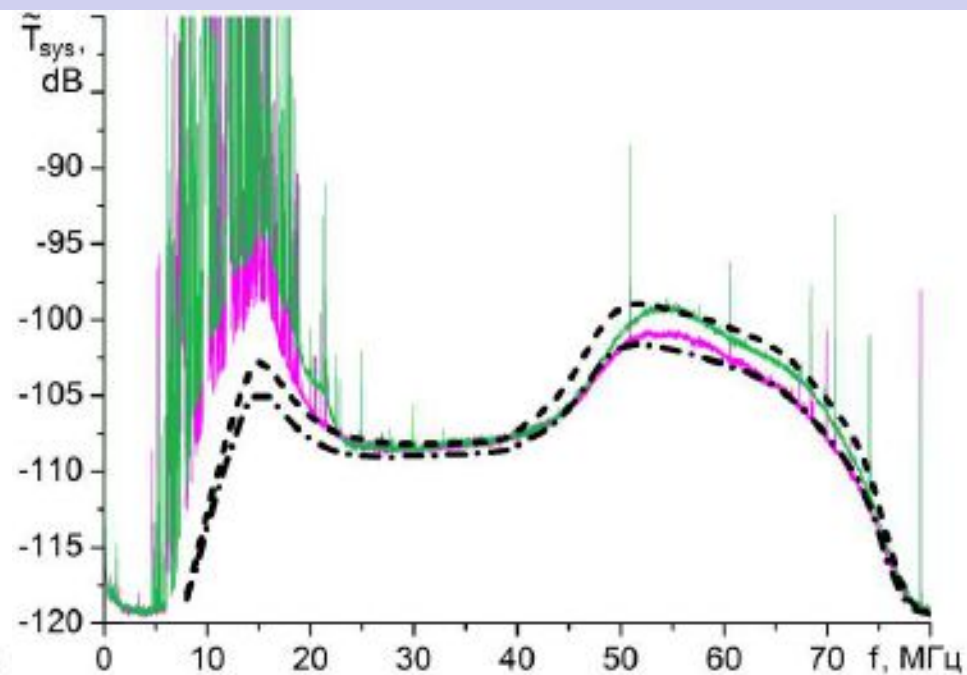
$$\Delta S_{\min} = \frac{2 k_B}{\eta A_e \sqrt{\Delta t \cdot \Delta f}} \cdot \left(\frac{1}{G \chi} T_{\text{amp}} + \eta T_{bg} \right) = \frac{2 k_B}{\eta A_e \sqrt{\Delta t \cdot \Delta f}} \cdot (T_{\text{int}} + T_{\text{ext}})$$

$$= \frac{2 k_B T_{\text{ext}}}{\eta A_e \sqrt{\Delta t \cdot \Delta f}} \cdot \left(1 + \frac{T_{\text{int}}}{T_{\text{ext}}} \right) = \frac{2 k_B \eta T_{bg}}{\eta A_e \sqrt{\Delta t \cdot \Delta f}} \cdot \left(1 + \frac{1}{SND} \right) = \frac{2 k_B T_{bg}}{A_e \sqrt{\Delta t \cdot \Delta f}} \cdot \left(1 + \frac{1}{SND} \right)$$

GURT subarray noise calculations and measurements

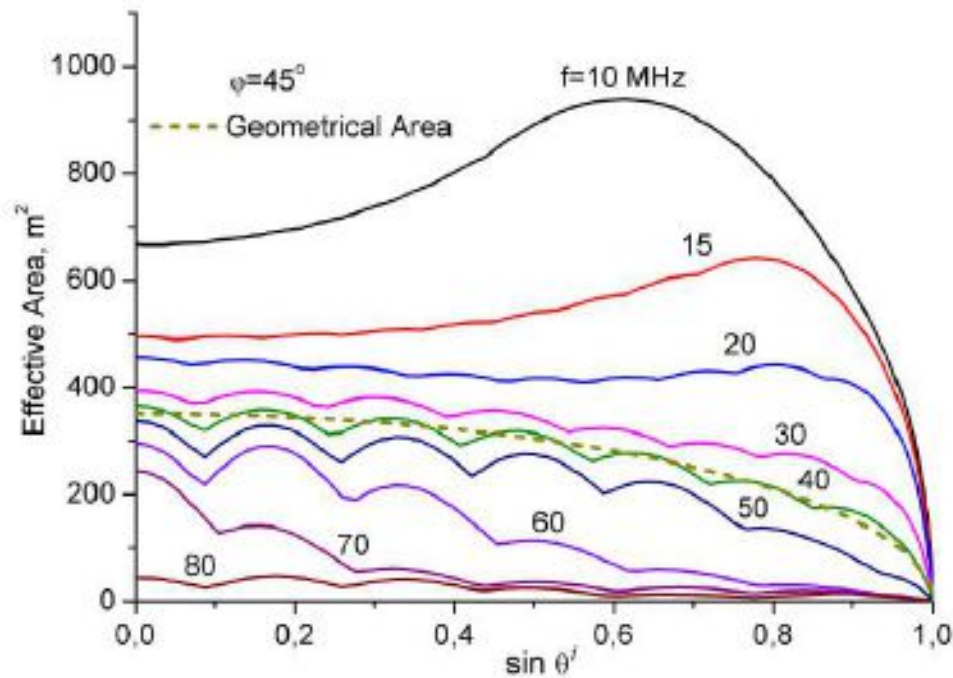


Close to zenith direction

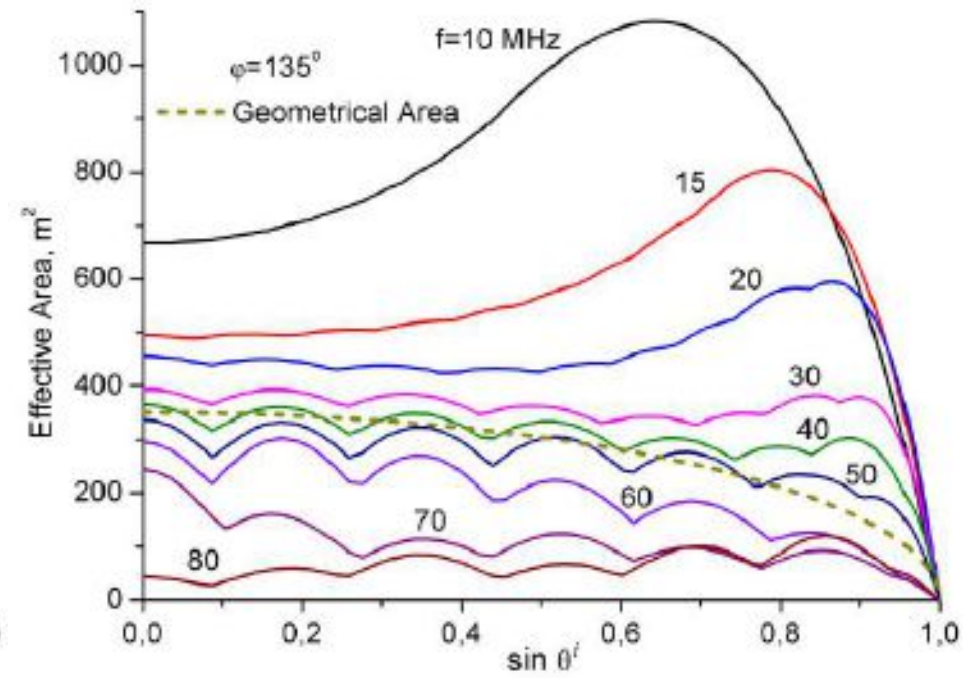


Close to horizon direction

GURT antenna subarray results



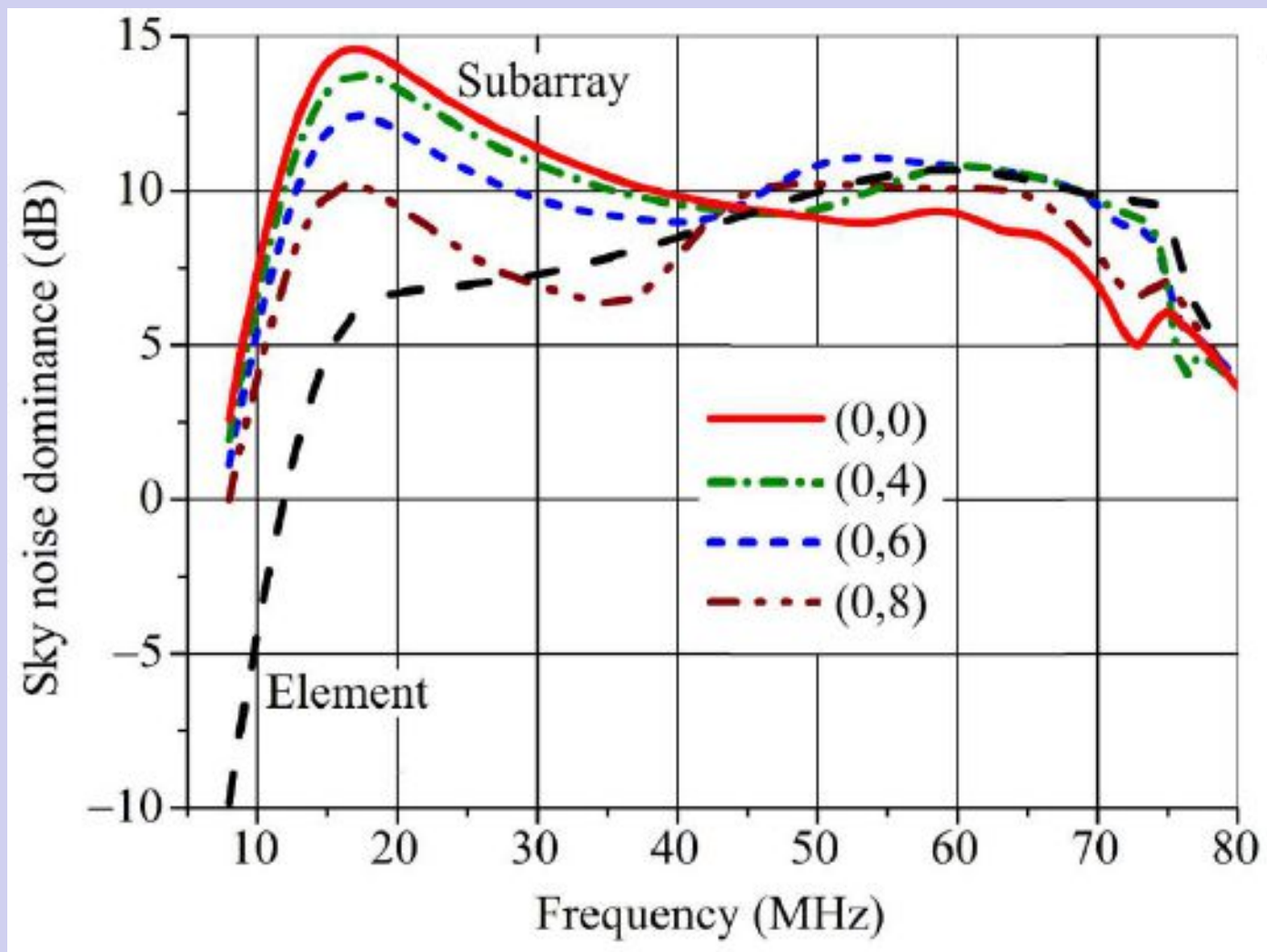
E-plane



H-plane

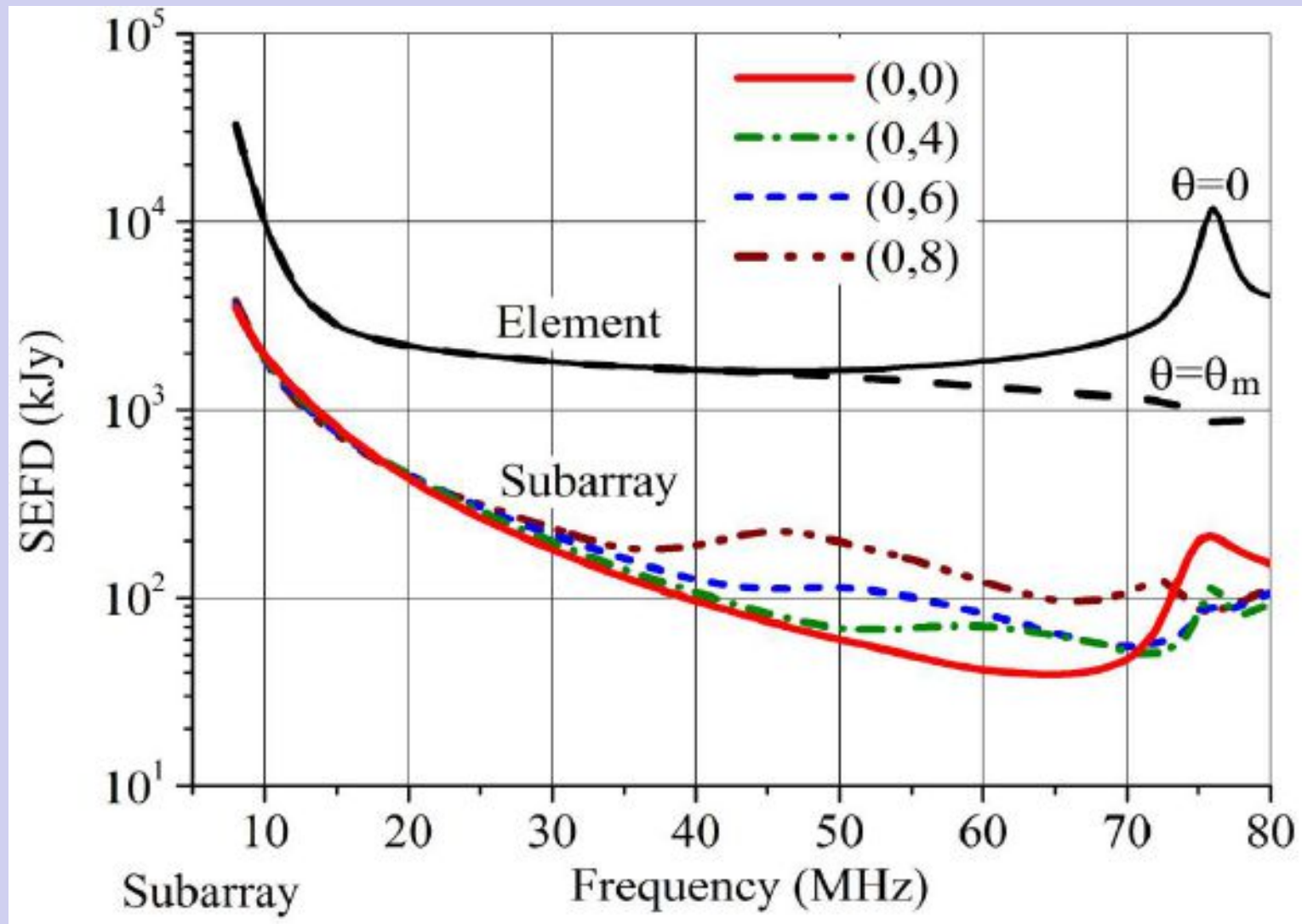
Variation of subarray effective area vs. angle of wave coming

GURT Sky Noise Dominance (SND)



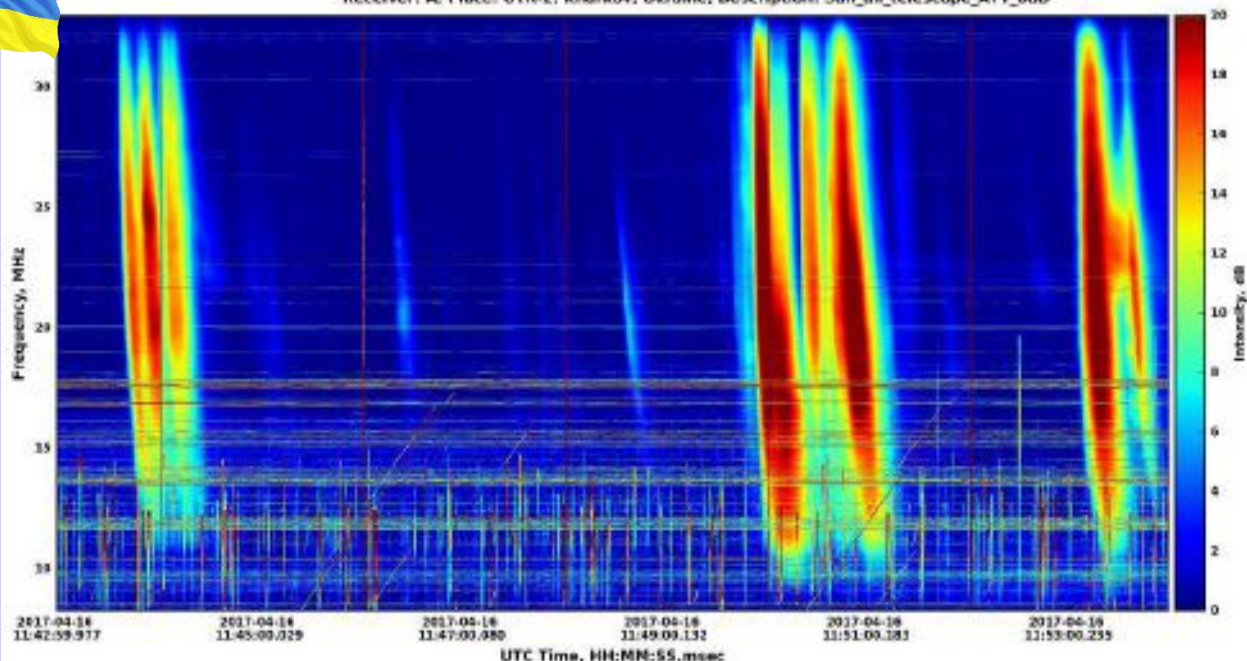
P. Tokarsky, A. Konovalenko, S. Yerin, "Sensitivity of an Active Antenna Array Element for the Low-Frequency Radio Telescope GURT," *IEEE Transactions on Antennas and Propagation*, vol. 65, is. 9, p. 4636–4644, 2017. DOI: 10.1109/TAP.2017.2730238

GURT system equivalent flux density (SEFD)



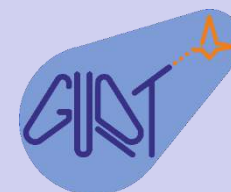
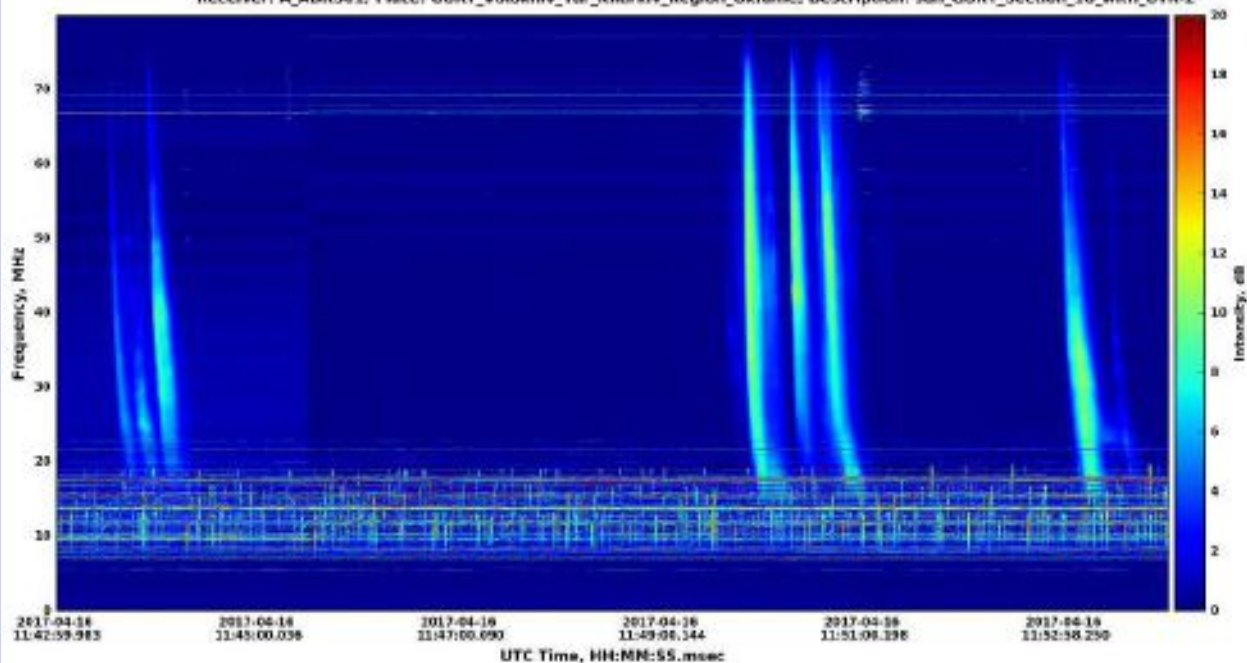


Dynamic spectrum cleaned and normalized starting from file A160417_104206.jds channel A
Initial parameters: dt = 0.2 Sec, df = 4.028 kHz, Processing: Averaging 6 spectra (1.201 sec.)
Receiver: A, Place: UTR-2, Kharkov, Ukraine, Description: Sun_all_telescope_ATT_8dB



**North-South arm
(1440 dipoles)**

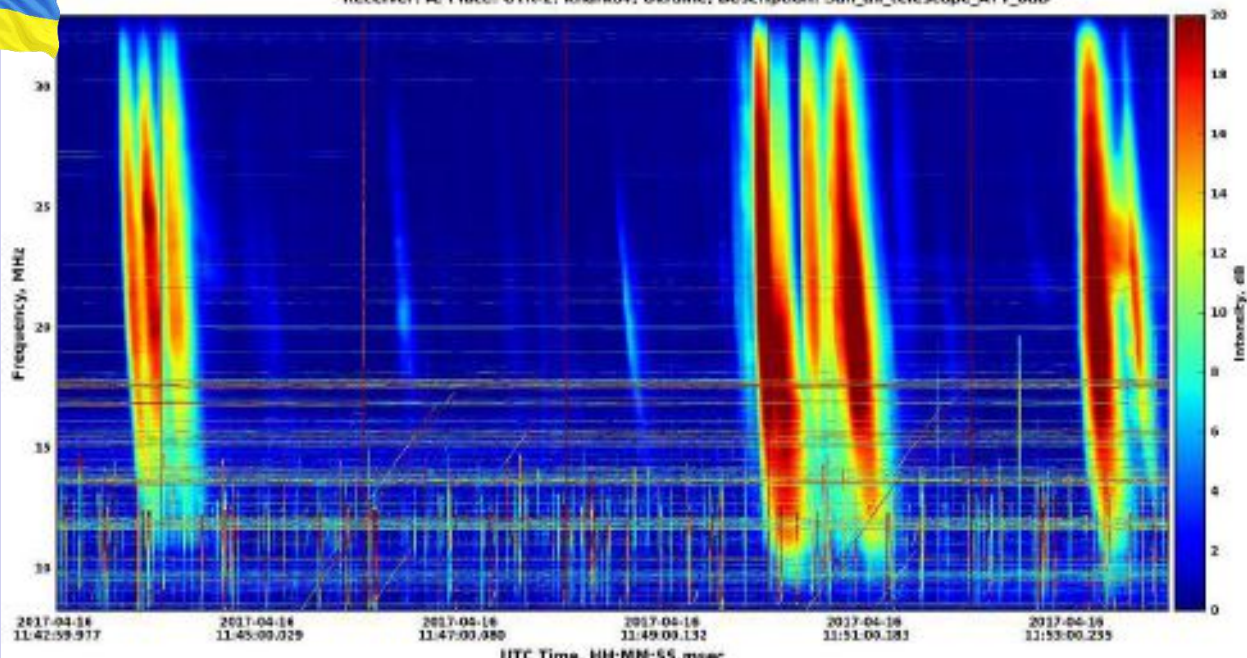
Dynamic spectrum cleaned and normalized starting from file A170416_094503.jds channel A
Initial parameters: dt = 0.05 Sec, df = 9.0 kHz, Processing: Averaging 6 spectra (0.3 sec.)
Receiver: A_ADR501, Place: GURT_Volokhiv_Yar_Kharkiv_Region_Ukraine, Description: sun_GURT_Section_10_with_UTR-2



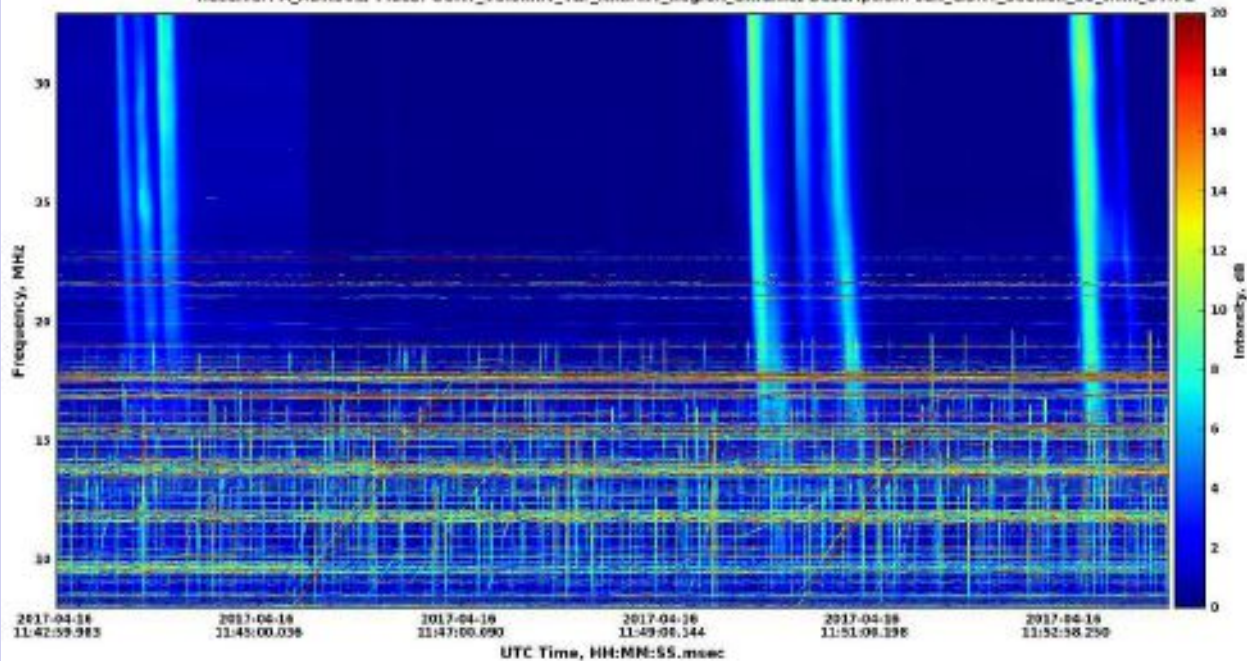
**Single subarray
single linear
polarization
(25 dipoles)**



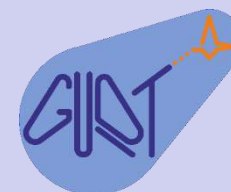
Dynamic spectrum cleaned and normalized starting from file A160417_104206.jds channel A
Initial parameters: dt = 0.2 Sec, df = 4.028 kHz, Processing: Averaging 6 spectra (1.201 sec.)
Receiver: A, Place: UTR-2, Kharkov, Ukraine, Description: Sun_all_telescope_ATT_8dB



Dynamic spectrum cleaned and normalized starting from file A170416_062633.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.0 kHz, Processing: Averaging 6 spectra (0.6 sec.)
Receiver: A_ADR501, Place: GURT_Volokhiv_Yar_Kharkiv_Region, Ukraine, Description: sun_GURT_Section_10_with_UTR-2



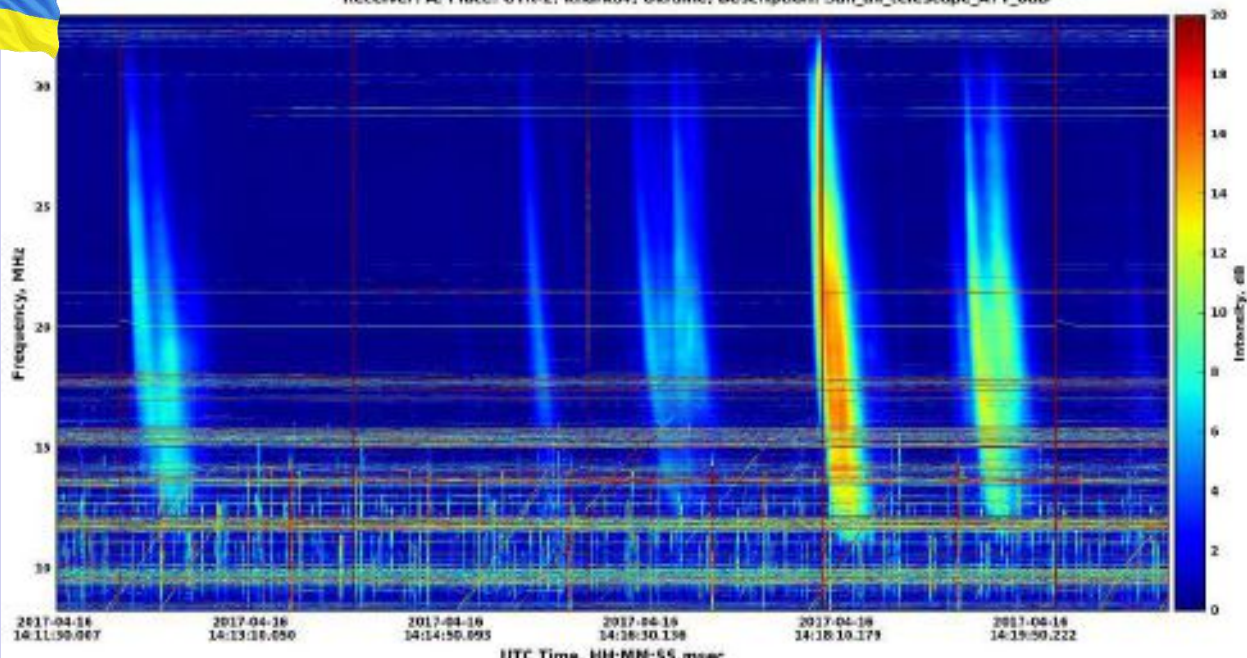
**North-South arm
(1440 dipoles)**



**Single subarray
single linear
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(25 dipoles)**

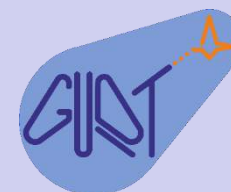
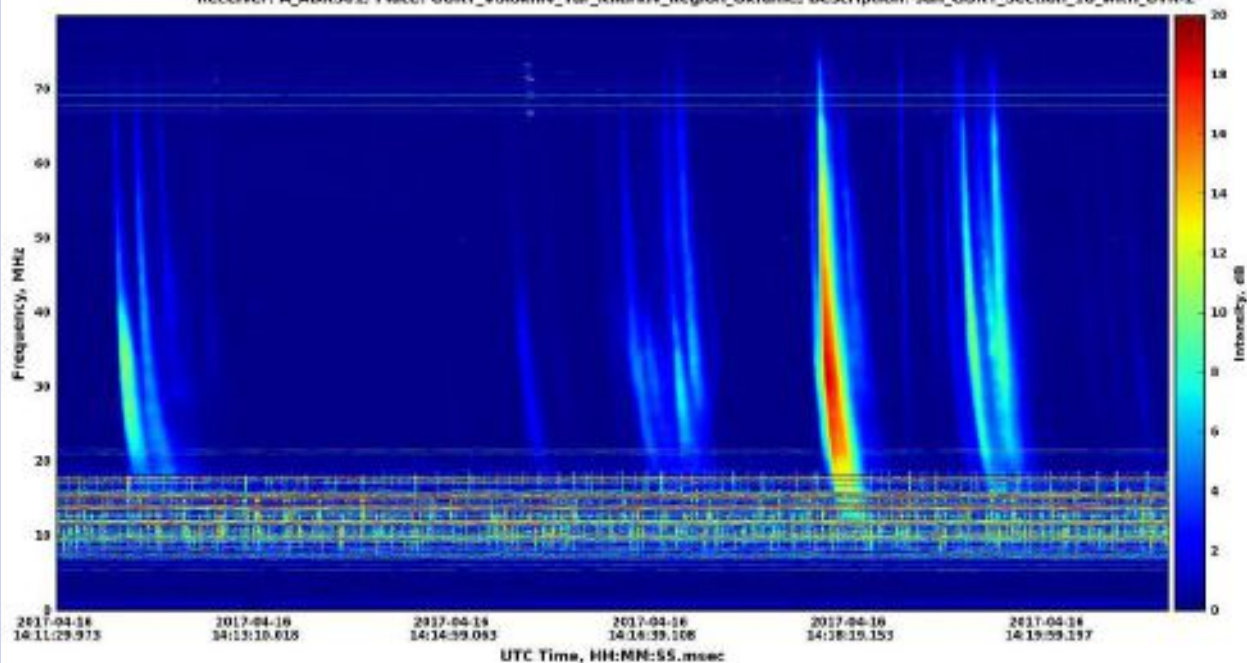


Dynamic spectrum cleaned and normalized starting from file A160417_104206.jds channel A
Initial parameters: dt = 0.2 Sec, df = 4.028 kHz, Processing: Averaging 5 spectra (1.0 sec.)
Receiver: A, Place: UTR-2, Kharkov, Ukraine, Description: Sun_all_telescope_ATT_8dB



**North-South arm
(1440 dipoles)**

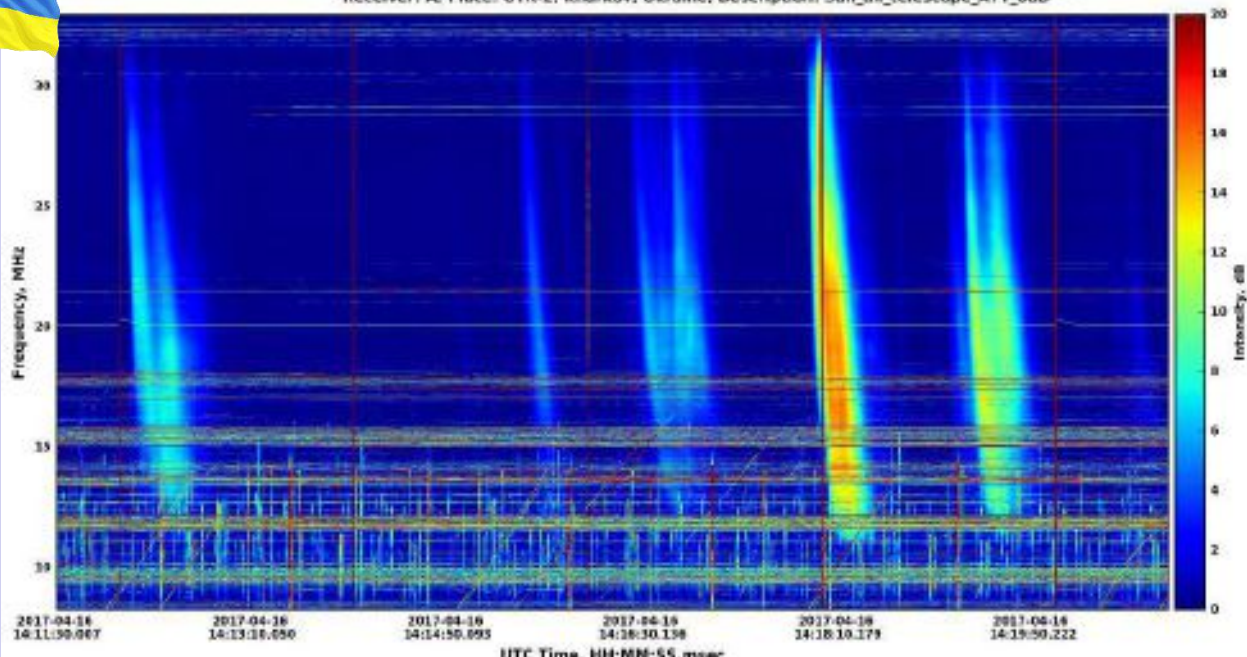
Dynamic spectrum cleaned and normalized starting from file A170416_062633.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.0 kHz, Processing: Averaging 5 spectra (0.5 sec.)
Receiver: A_ADR501, Place: GURT_Volokhiv_Yar_Kharkiv_Region_Ukraine, Description: sun_GURT_Section_10_with_UTR-2



**Single subarray
single linear
polarization
(25 dipoles)**

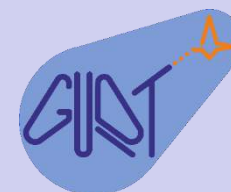
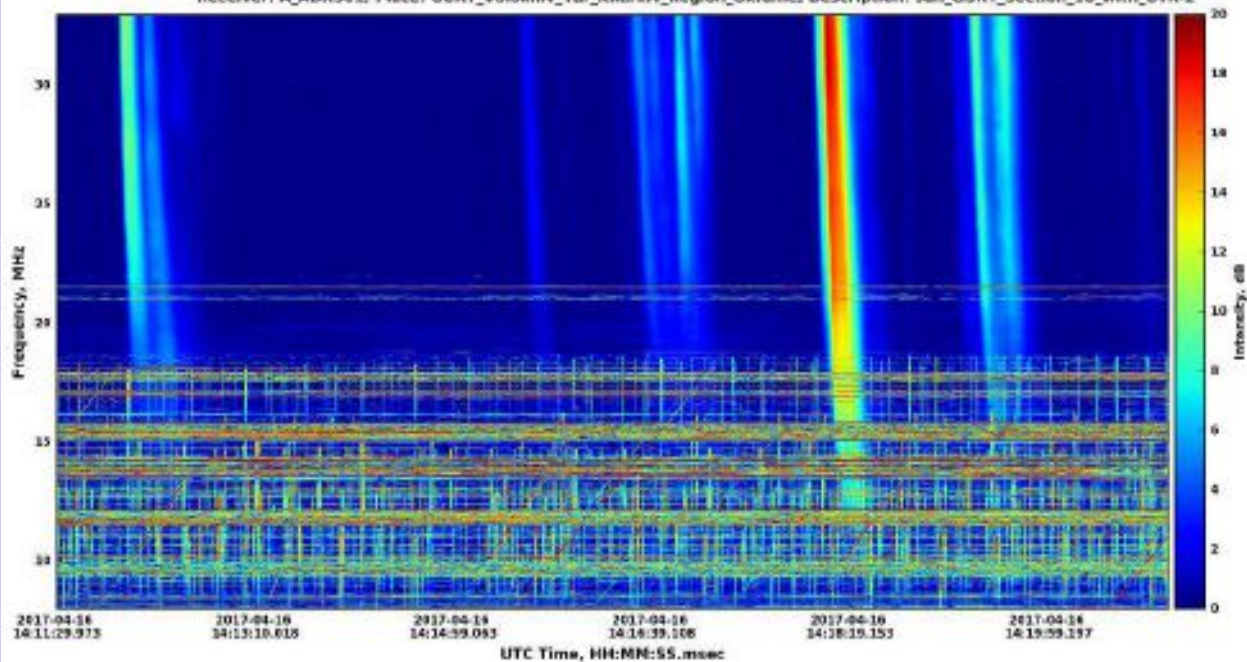


Dynamic spectrum cleaned and normalized starting from file A160417_104206.jds channel A
Initial parameters: dt = 0.2 Sec, df = 4.028 kHz, Processing: Averaging 5 spectra (1.0 sec.)
Receiver: A, Place: UTR-2, Kharkov, Ukraine, Description: Sun_all_telescope_ATT_8dB

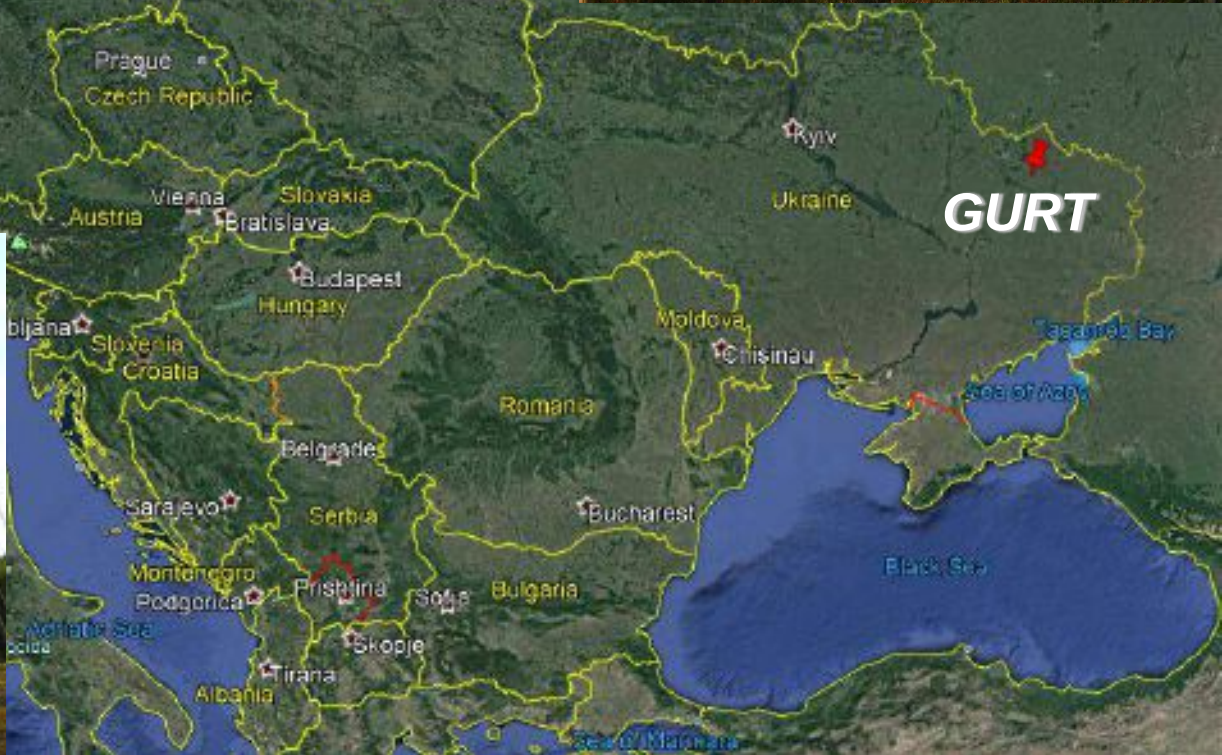


**North-South arm
(1440 dipoles)**

Dynamic spectrum cleaned and normalized starting from file A170416_062633.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.0 kHz, Processing: Averaging 5 spectra (0.5 sec.)
Receiver: A_ADR501, Place: GURT_Volokhiv_Yar_Kharkiv_Region_Ukraine, Description: sun_GURT_Section_10_with_UTR-2



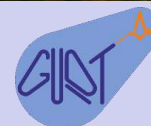
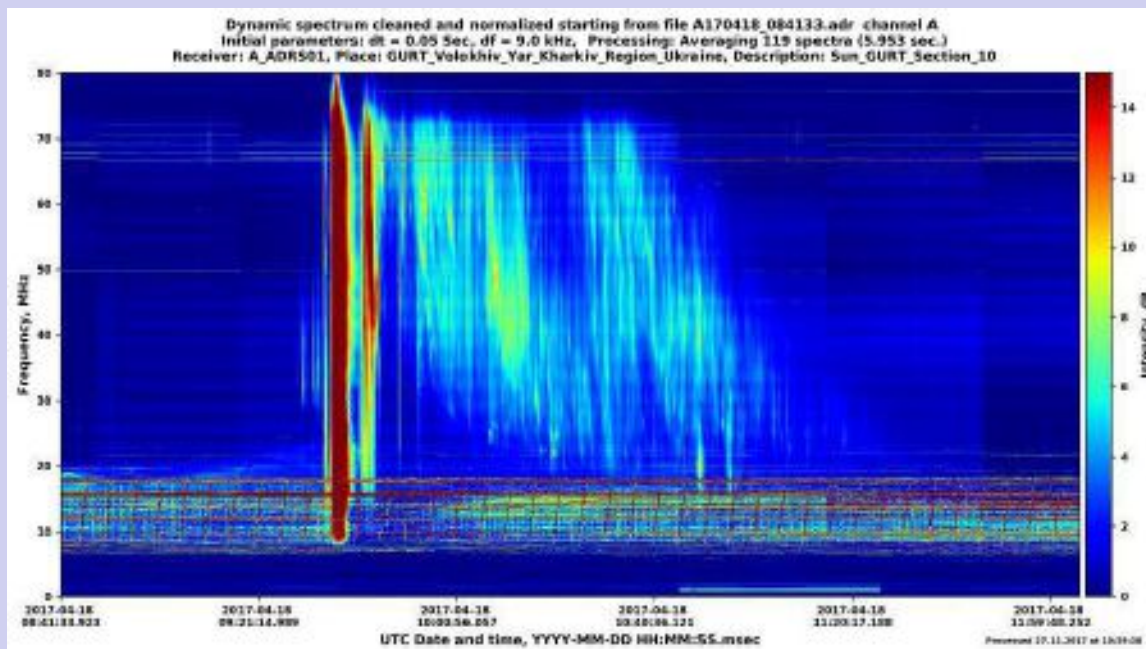
**Single subarray
single linear
polarization
(25 dipoles)**



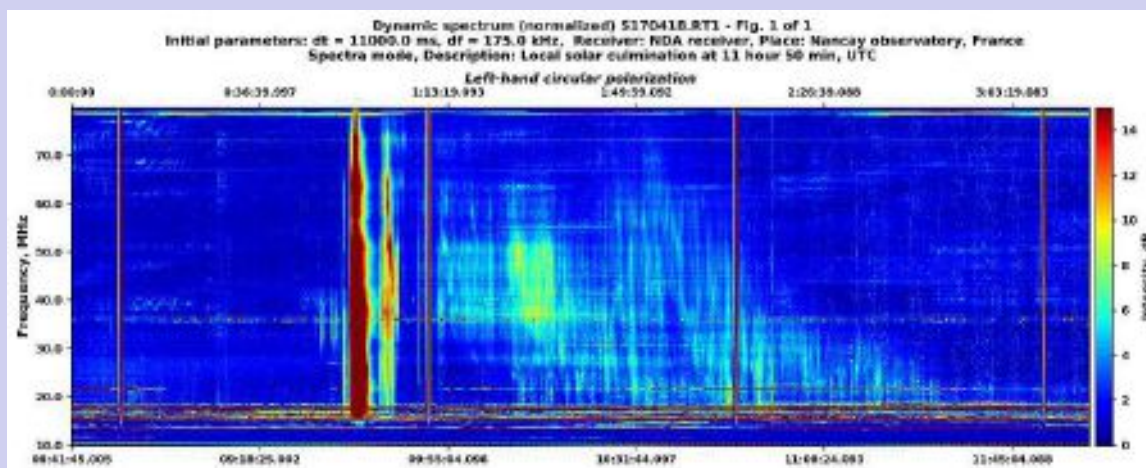


Advantages of cosmic radio sources observations with high sensitivity

GURT
subarray of
25 active
elements



Nançay
Decametric
array
72 antennas

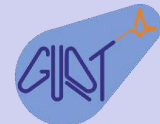
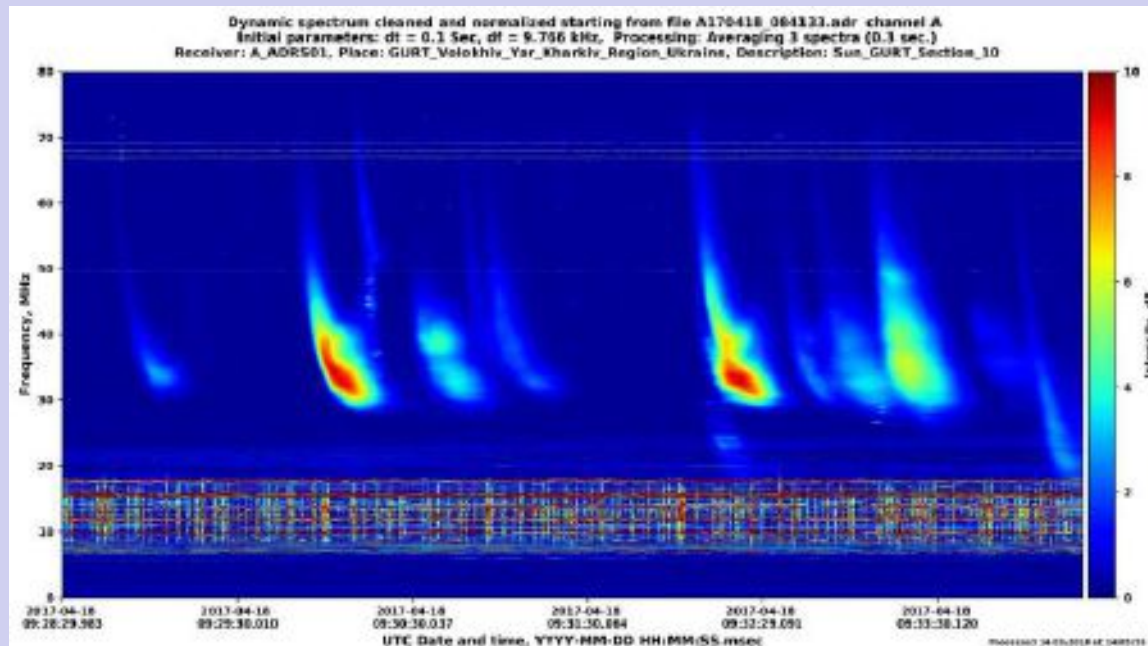


<http://bass2000.obspm.fr>

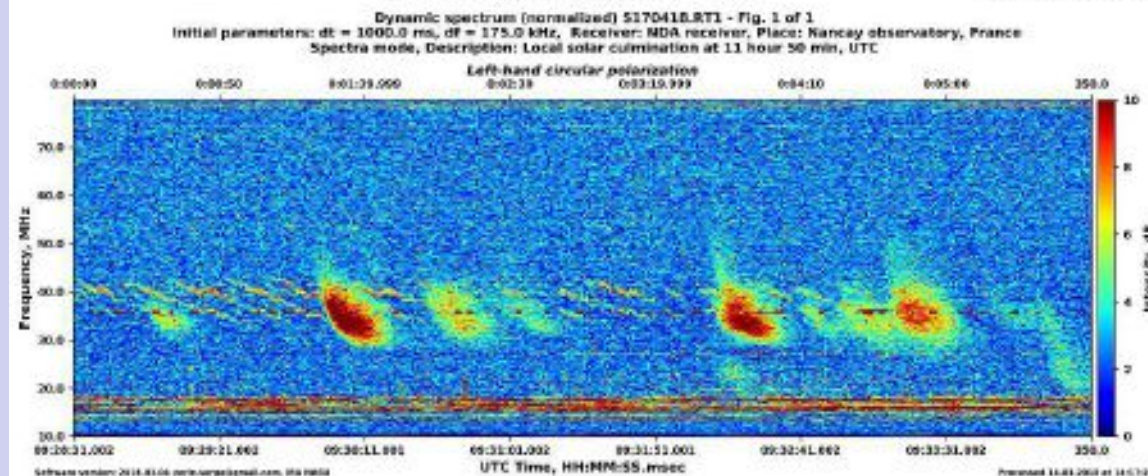


Advantages of cosmic radio sources observations with high sensitivity

GURT
subarray of
25 active
elements



Nançay
Decametric
array
72 antennas

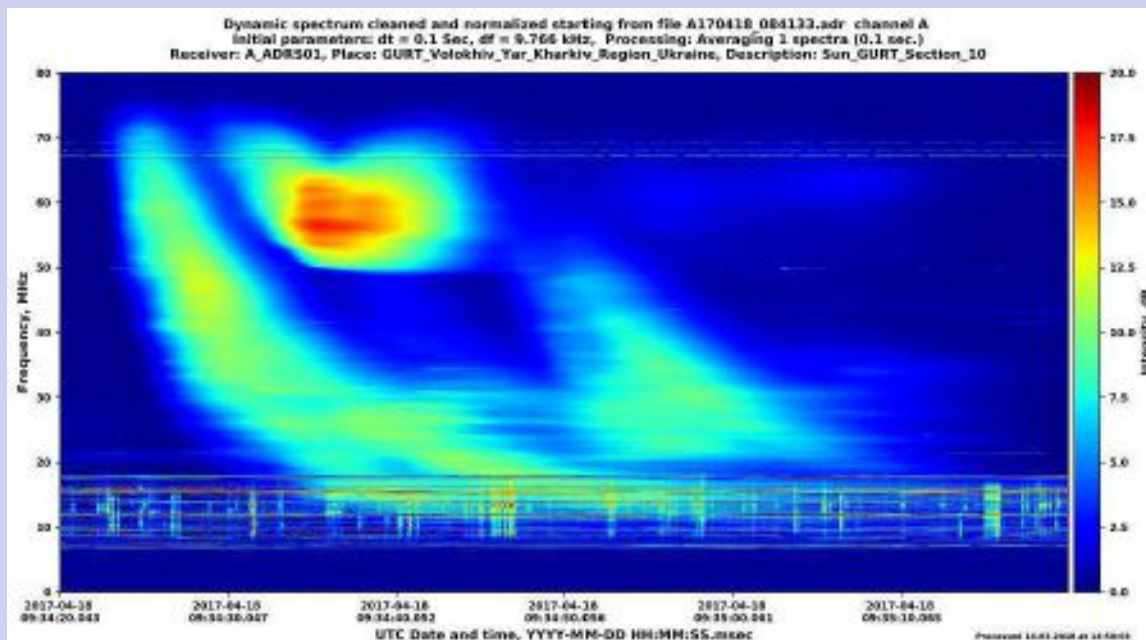


<http://bass2000.obspm.fr>

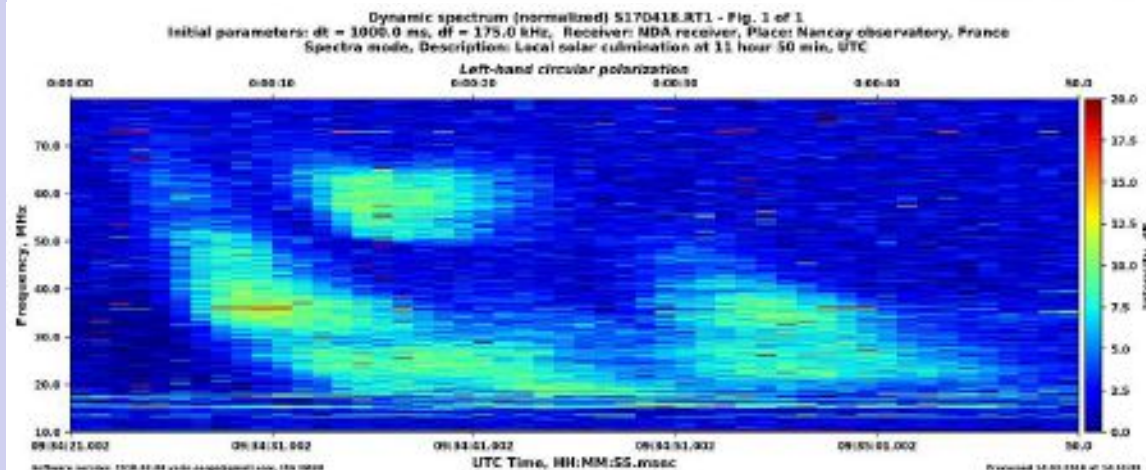


Advantages of cosmic radio sources observations with high sensitivity

GURT
subarray of
25 active
elements



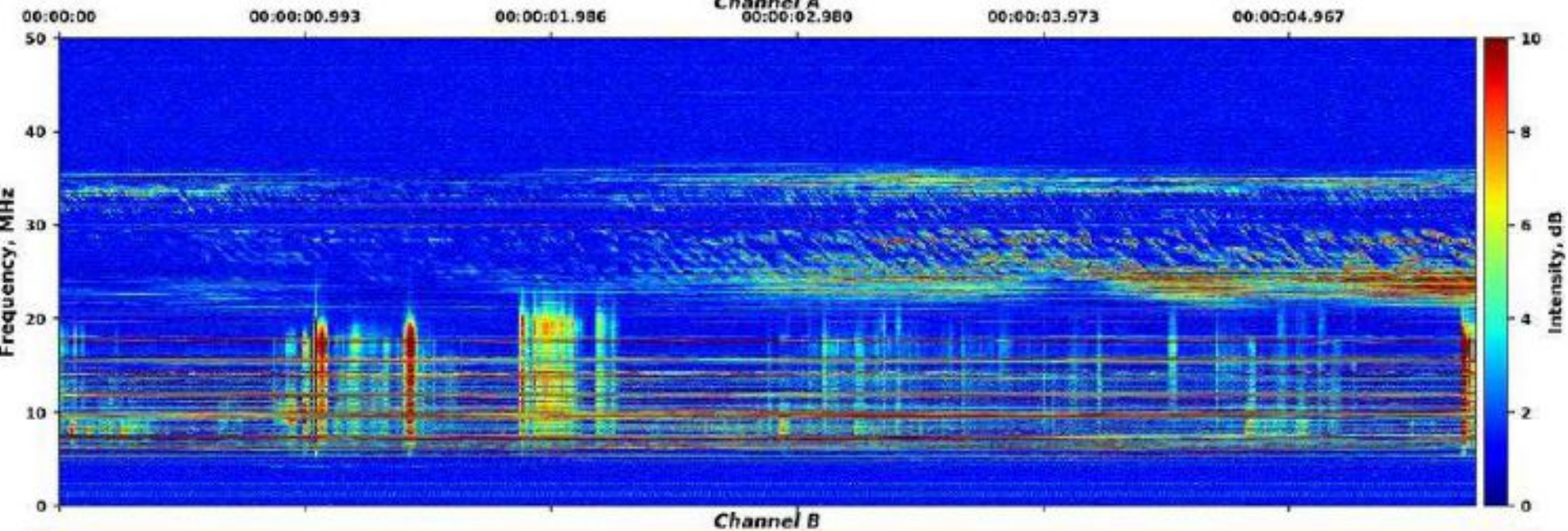
Nançay
Decametric
array
72 antennas



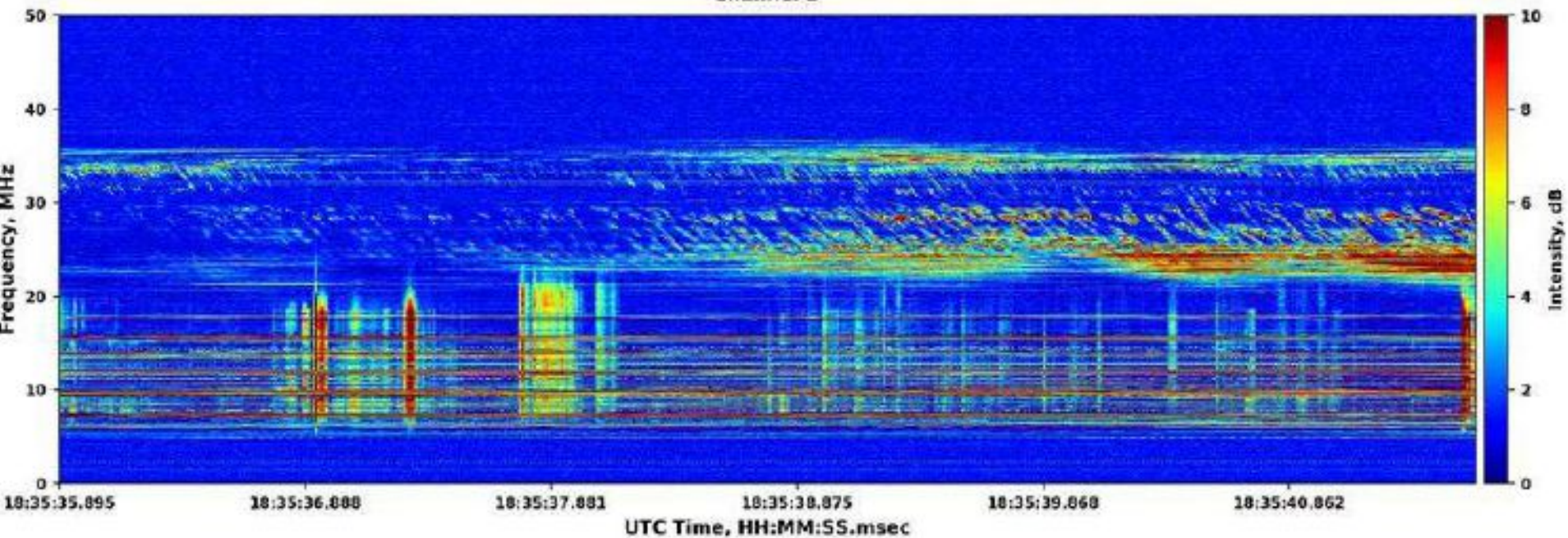
<http://bass2000.obspm.fr>



Channel A



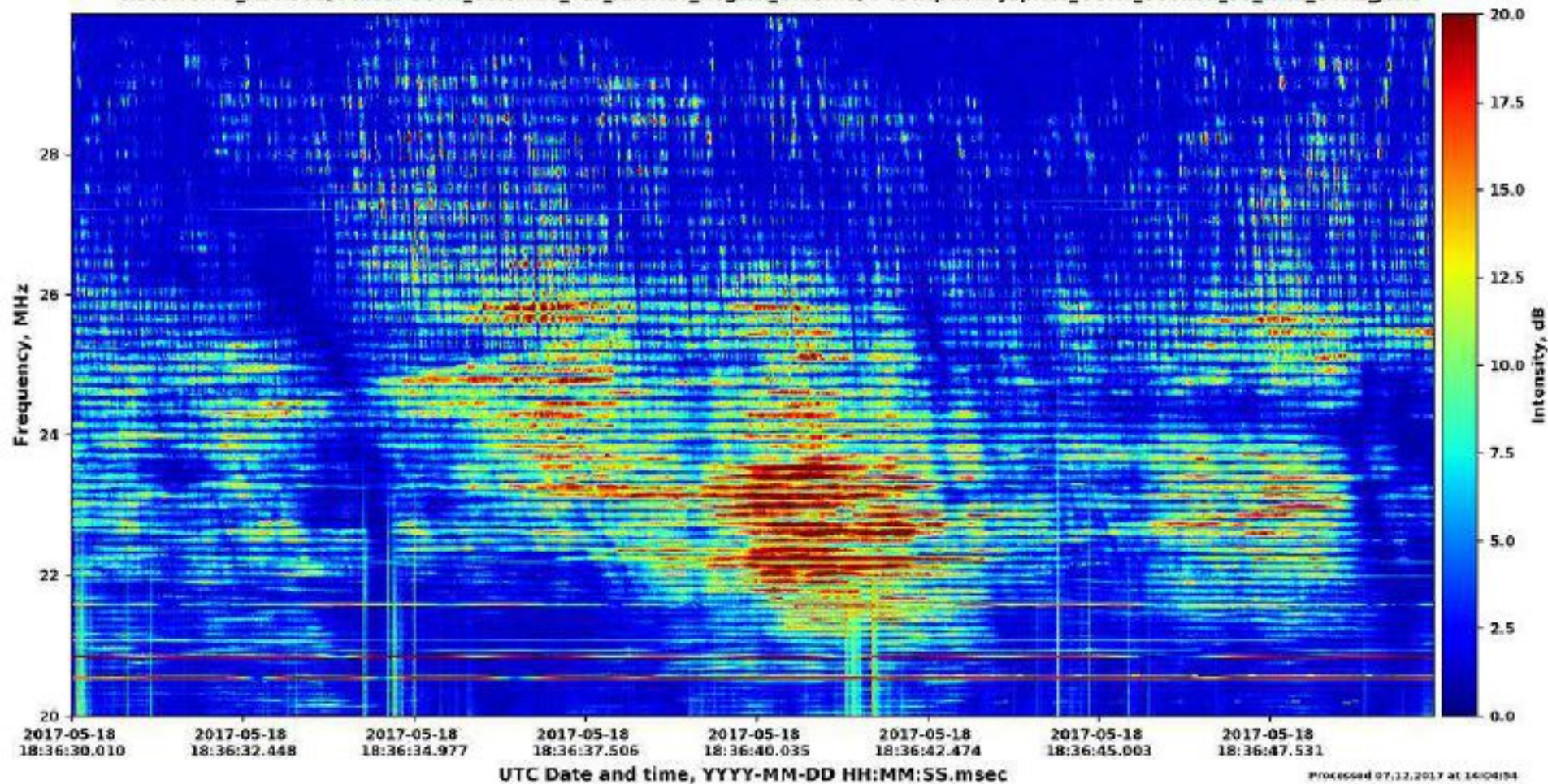
Channel B



Dynamic spectrum cleaned and normalized starting from file B170518_183608.adr channel A

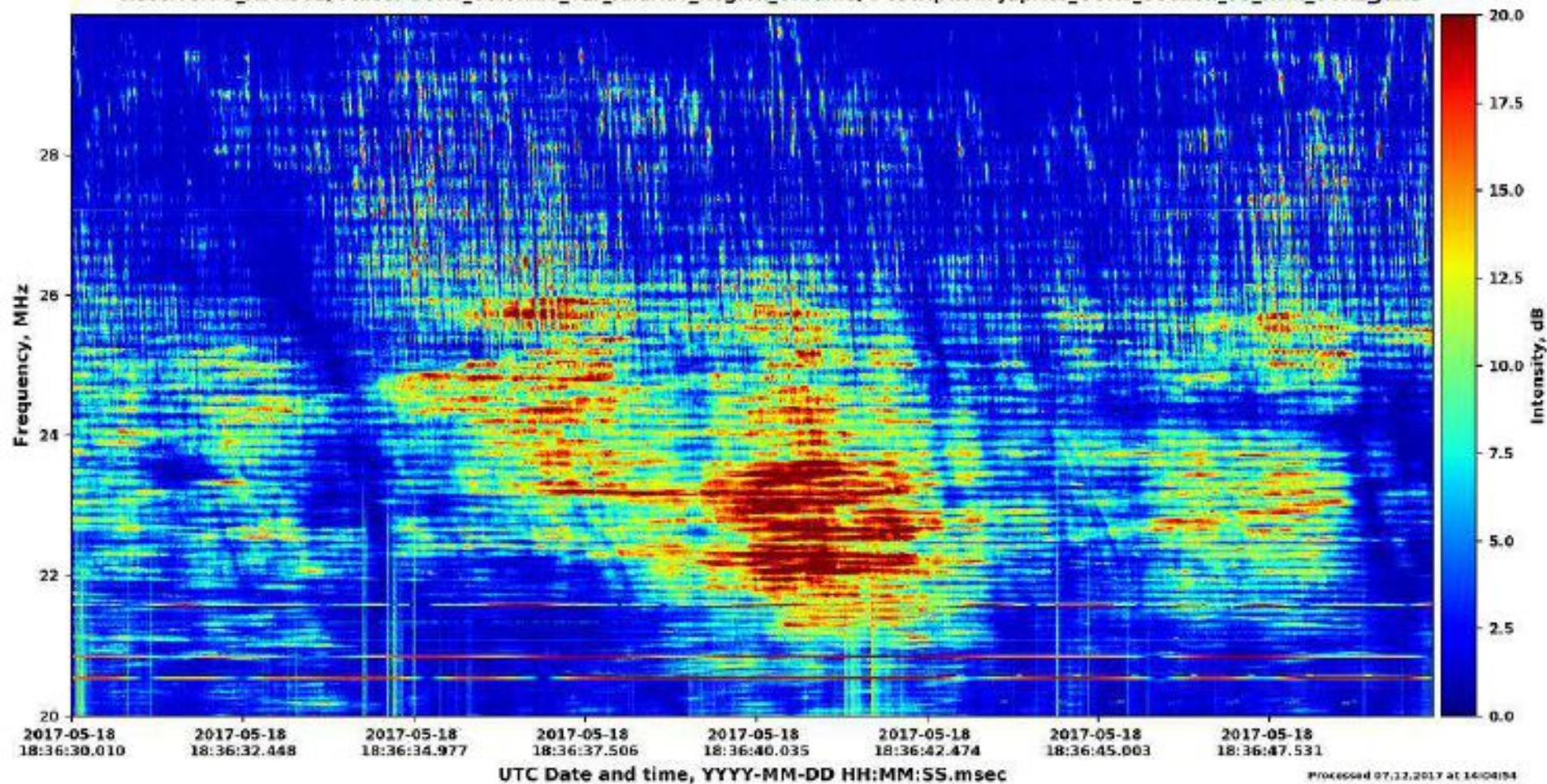
Initial parameters: $dt = 0.005$ Sec, $df = 9.0$ kHz, Processing: Averaging 1 spectra (0.005 sec.)

Receiver: B_ADRS02, Place: GURT_Volokhiv_Yar_Kharkiv_Region_Ukraine, Description: Jupiter_GURT_Section_09_with_UTR2_Juno



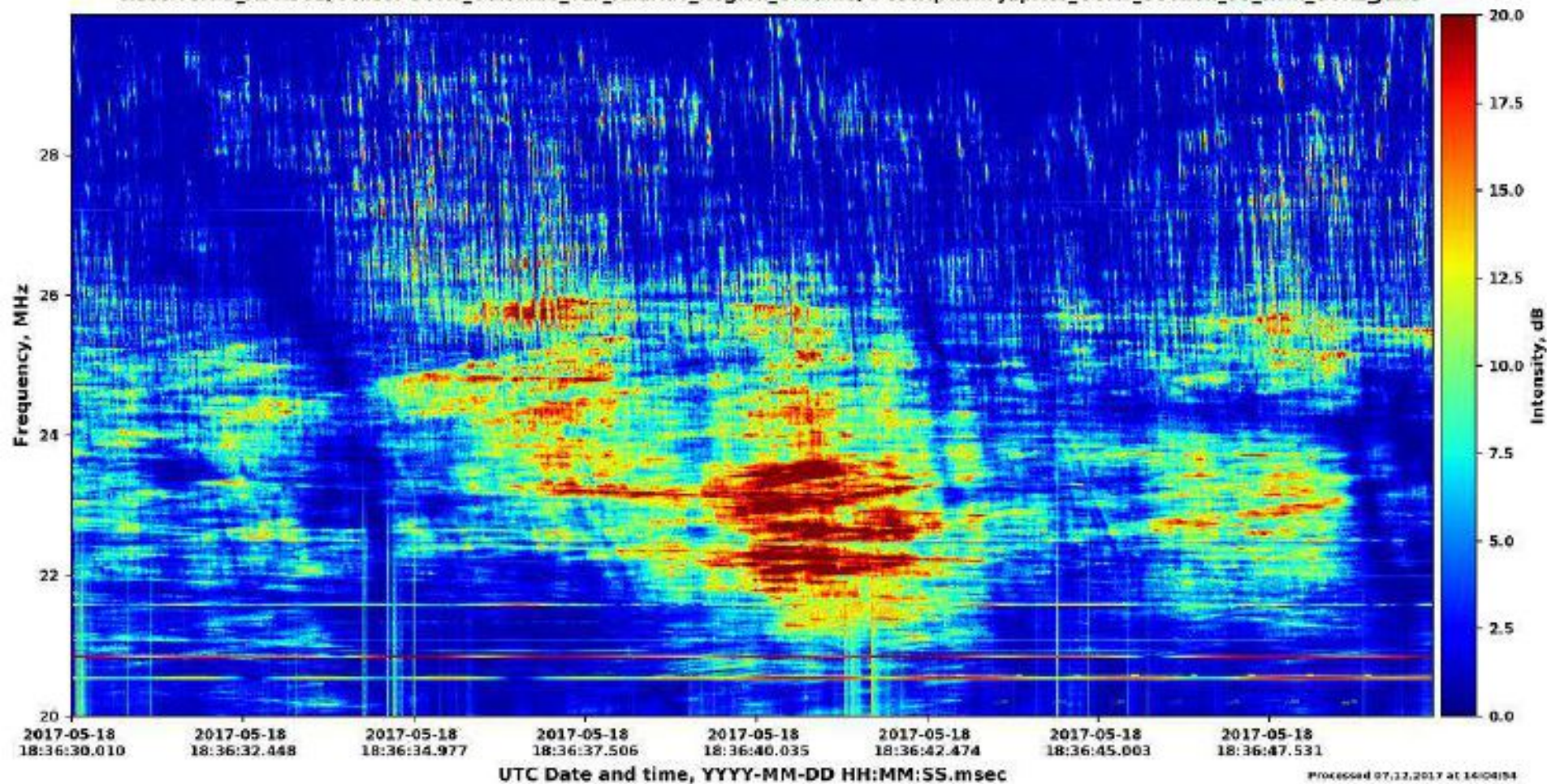


Dynamic spectrum cleaned and normalized starting from file B170518_183608.adr channel B
Initial parameters: $dt = 0.005$ Sec, $df = 9.0$ kHz, Processing: Averaging 1 spectra (0.005 sec.)
Receiver: B_ADRS02, Place: GURT_Volokhiv_Yar_Kharkiv_Region_Ukraine, Description: Jupiter_GURT_Section_09_with_UTR2_Juno

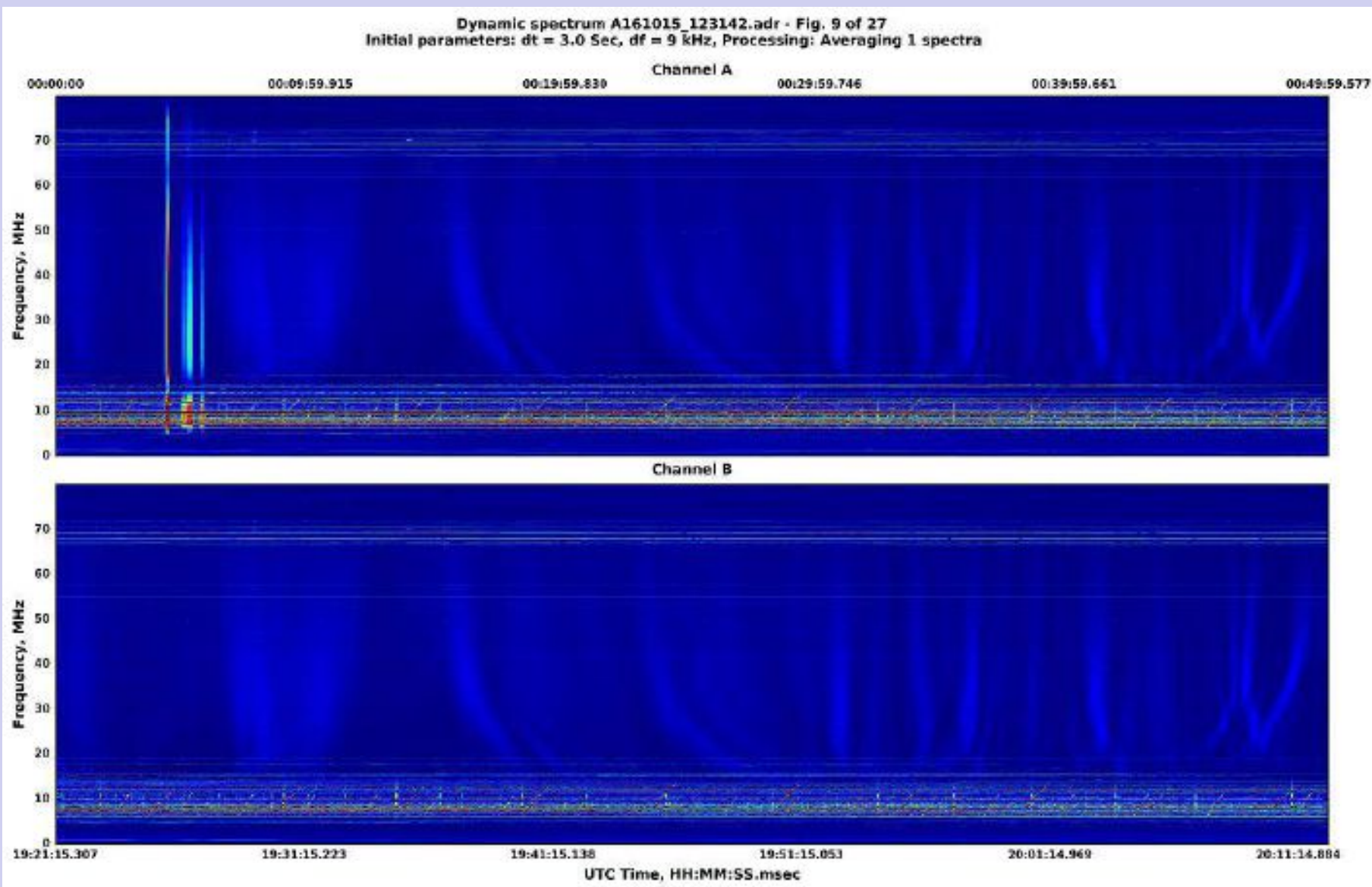


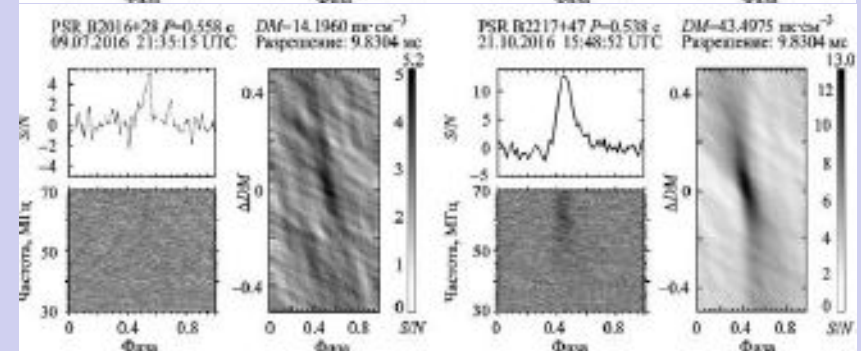
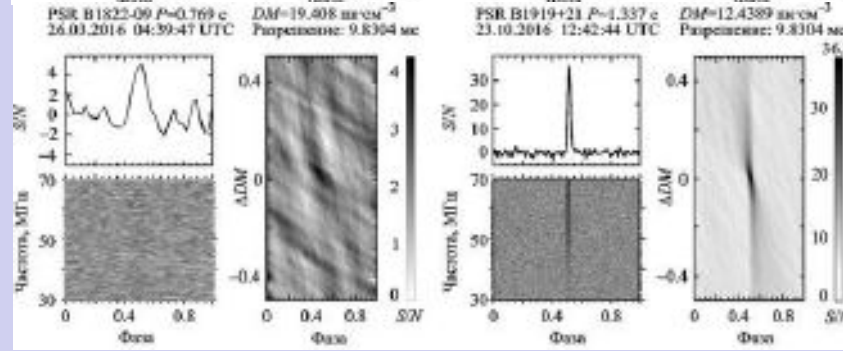
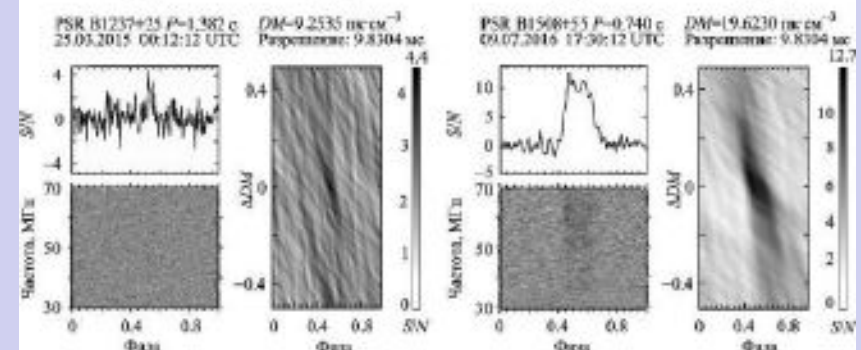
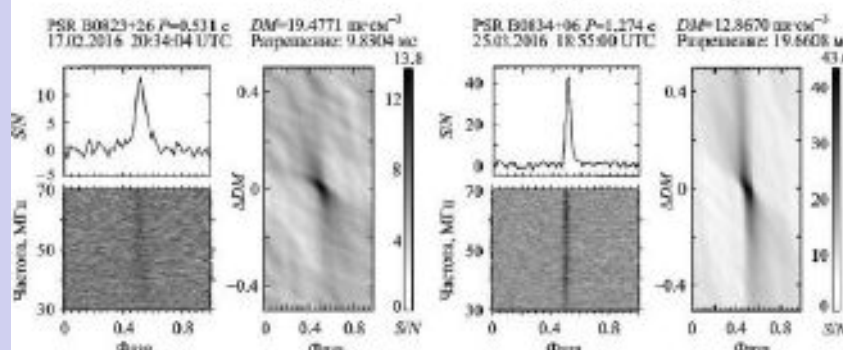
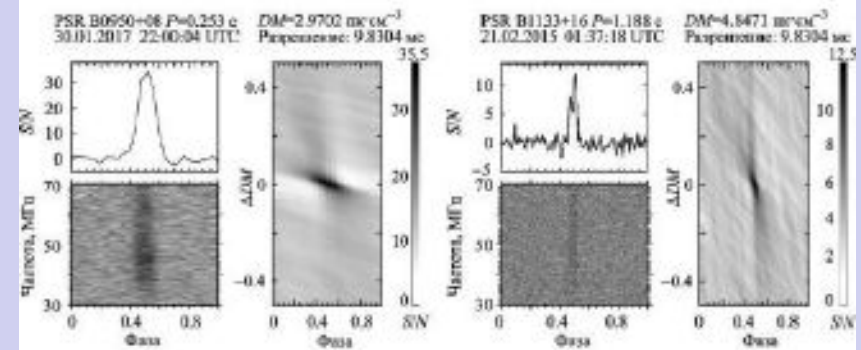
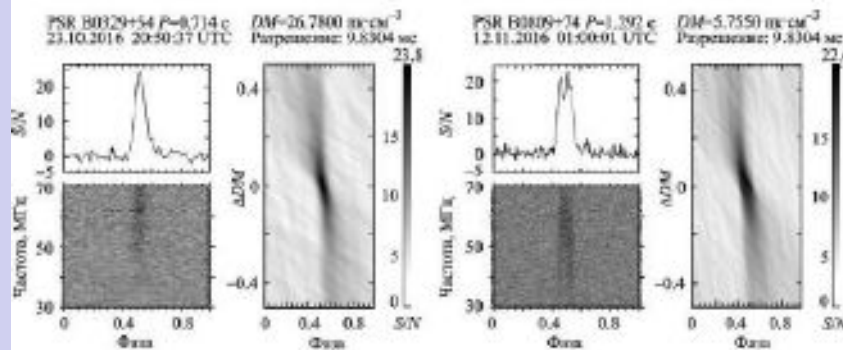
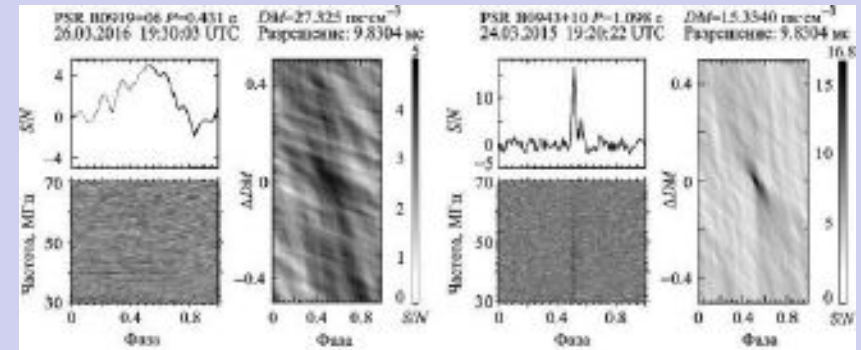
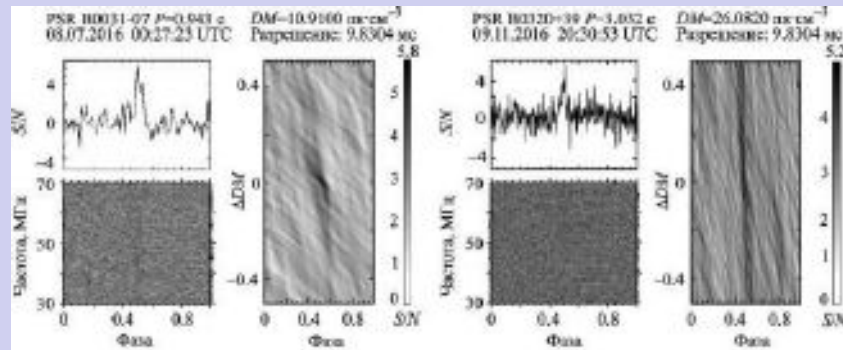


Dynamic spectrum cleaned and normalized starting from file B170518_183608.adr sum A + B
Initial parameters: dt = 0.005 Sec, df = 9.0 kHz, Processing: Averaging 1 spectra (0.005 sec.)
Receiver: B_ADRS02, Place: GURT_Volokhiv_Yar_Kharkiv_Region_Ukraine, Description: Jupiter_GURT_Section_09_with_UTR2_Juno



Scintillations of 3C405 (Cyg A) source







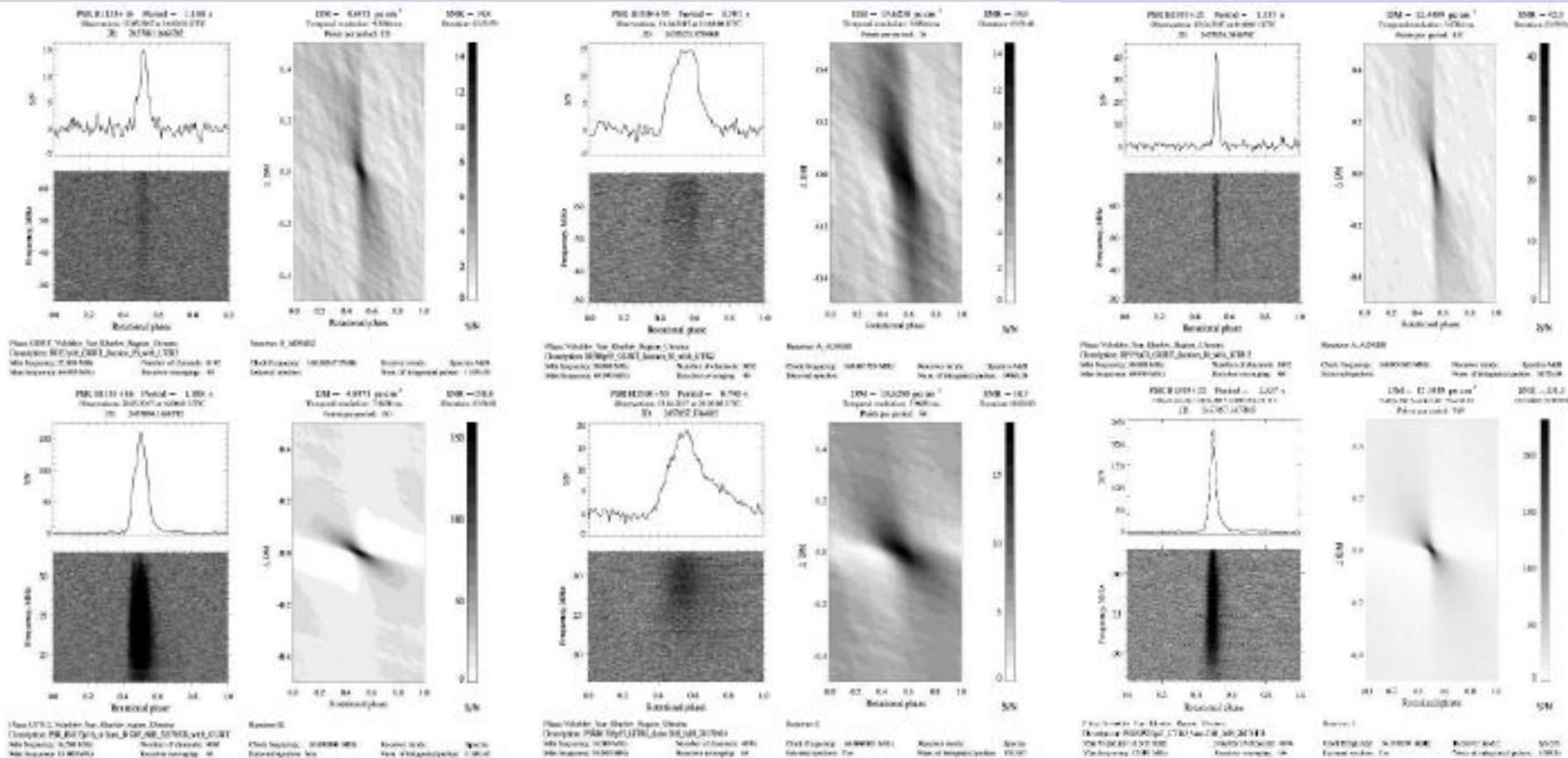
Pulsar observations with single GURT subarray

Pulsar name	DM, pc /cm ³	SNR	Period, s	Flux density, Jy	
				GURT	Stovall / Izvekova
B0031-07	10.896	6	0.943	320 (160)	6370 (3190)
B0320+39	26.082	5	3.032	300 (150)	220 (110) 230 (120)* [61 MHz]
B0329+54	26.780	24	0.714	1190 (600)	4160 (2080)
B0809+74	5.752	22	1.292	1280 (640)	1870 (350)* [61 MHz]
B0823+26	19.475	14	0.531	350 (180)	450 (230)
B0834+06	12.858	44	1.274	1550 (780)	4680 (2340)
B0919+06	27.325	5	0.431	810 (410)	770 (160)* [85 MHz]
B0943+10	15.330	17	1.098	470 (240)	1290 (350)* [61 MHz]
B0950+08	2.970	36	0.253	1470 (740)	2330 (620)*[102.5 MHz]
B1133+16	4.487	15	1.188	6000 (3000)	4710 (2360)
B1237+25	9.260	6	1.382	170 (90)	510 (250)
B1508+55	19.623	15	0.740	2000 (1000)	2130 (1060)
B1822-09	19.408	5	0.769	3100 (1550)	2220 (1110)
B1919+21	12.431	42		3000 (1500)	2100 (430)* [61 MHz]
B2016+28	14.176	5	0.558	270 (140)	590 (290)
B2217+47	43.548	13	0.538	750 (380)	10100 (5050)

Averaged (4 hours) pulsar pulses

GURT subarray

UTR-2



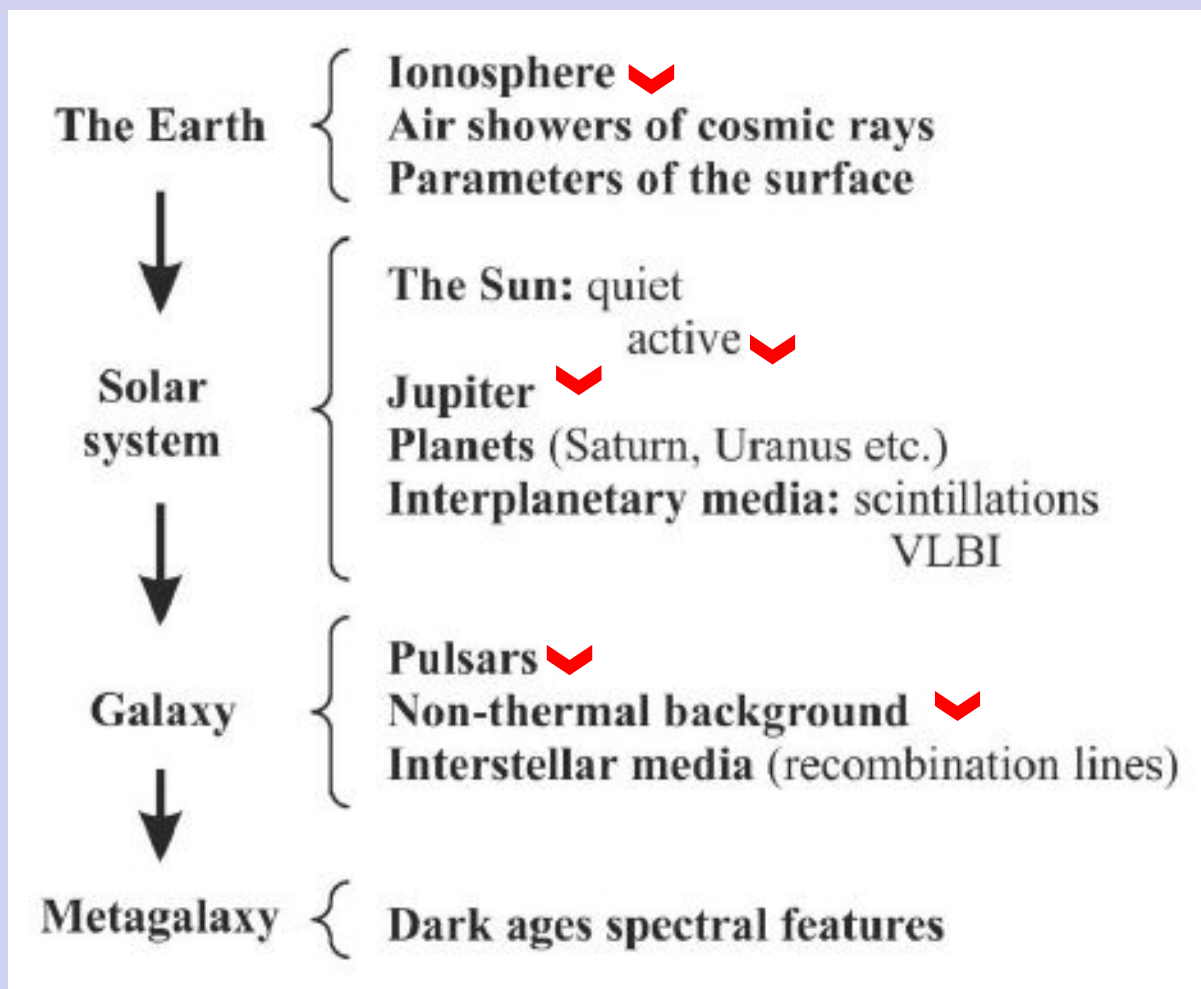
B1133+16

B1508+55

B1919+21

Results of observations of pulsars with GURT subarray and UTR-2 radio telescope in the mode of arms signal combining

Objects that can be studied with GURT subarray





Thank you for attention!

Q & A

Our main publications on the topic

Tokarsky P., Konovalenko, A., Yerin. S. **2017. Sensitivity of an active antenna array element for the low-frequency radio telescope GURT.** *IEEE Transactions on Antenna and Propagation*, 65(9), pp.4636-4644. DOI: 10.1109/TAP.2017.2730238

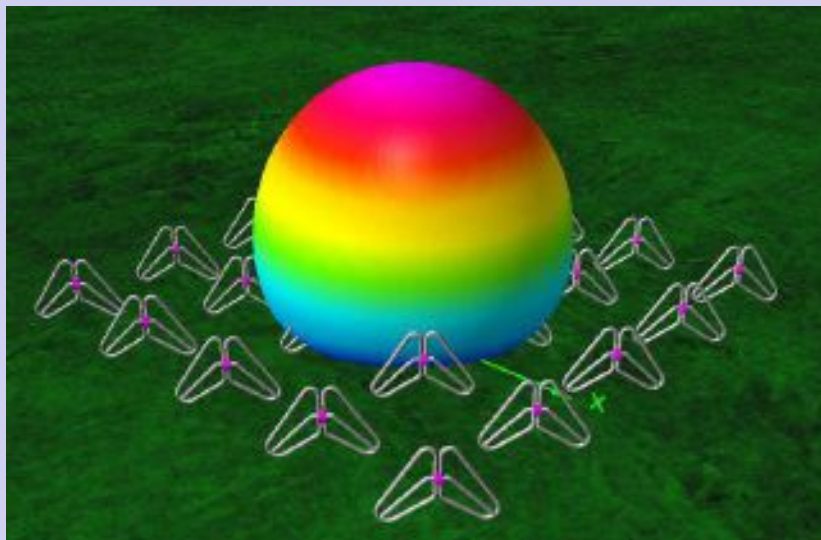
Konovalenko, A., Sodin, L., Zakharenko, V., Zarka, P., Ulyanov, O., Sidorchuk, M., Stepkin, S., Tokarsky, P., Melnik, V., Kalinichenko, N., Stanislavsky, A., et al. **2016. The modern radio astronomy network in Ukraine: UTR-2, URAN and GURT.** *Experimental Astronomy*, 42(1), pp.11-48. DOI: 10.1007/s10686-016-9498-x

Zakharenko, V., Konovalenko, A., Zarka, P., Ulyanov, O., Sidorchuk, M., Stepkin, S., Koliadin, V., Kalinichenko, N., Stanislavsky, A., Dorovsky, V., Shepelev, V., et al. **2016. Digital receivers for low-frequency radio telescopes UTR-2, URAN, GURT.** *Journal of Astronomical Instrumentation*, 5(04), p.1641010. DOI: 10.1142/S2251171716410105

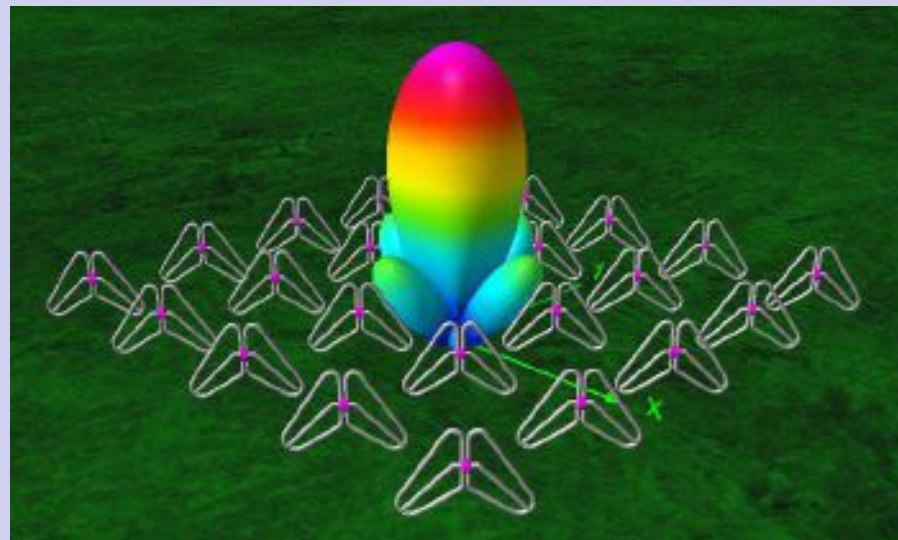




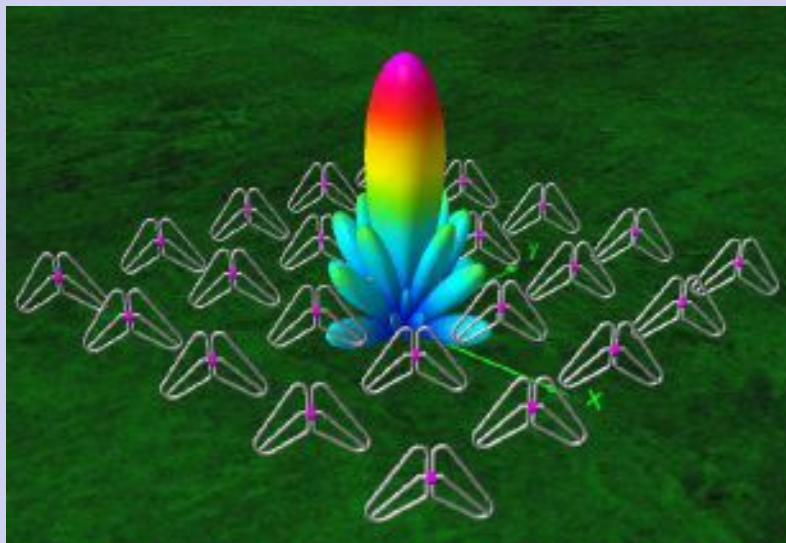
GURT Subarray



10 MHz



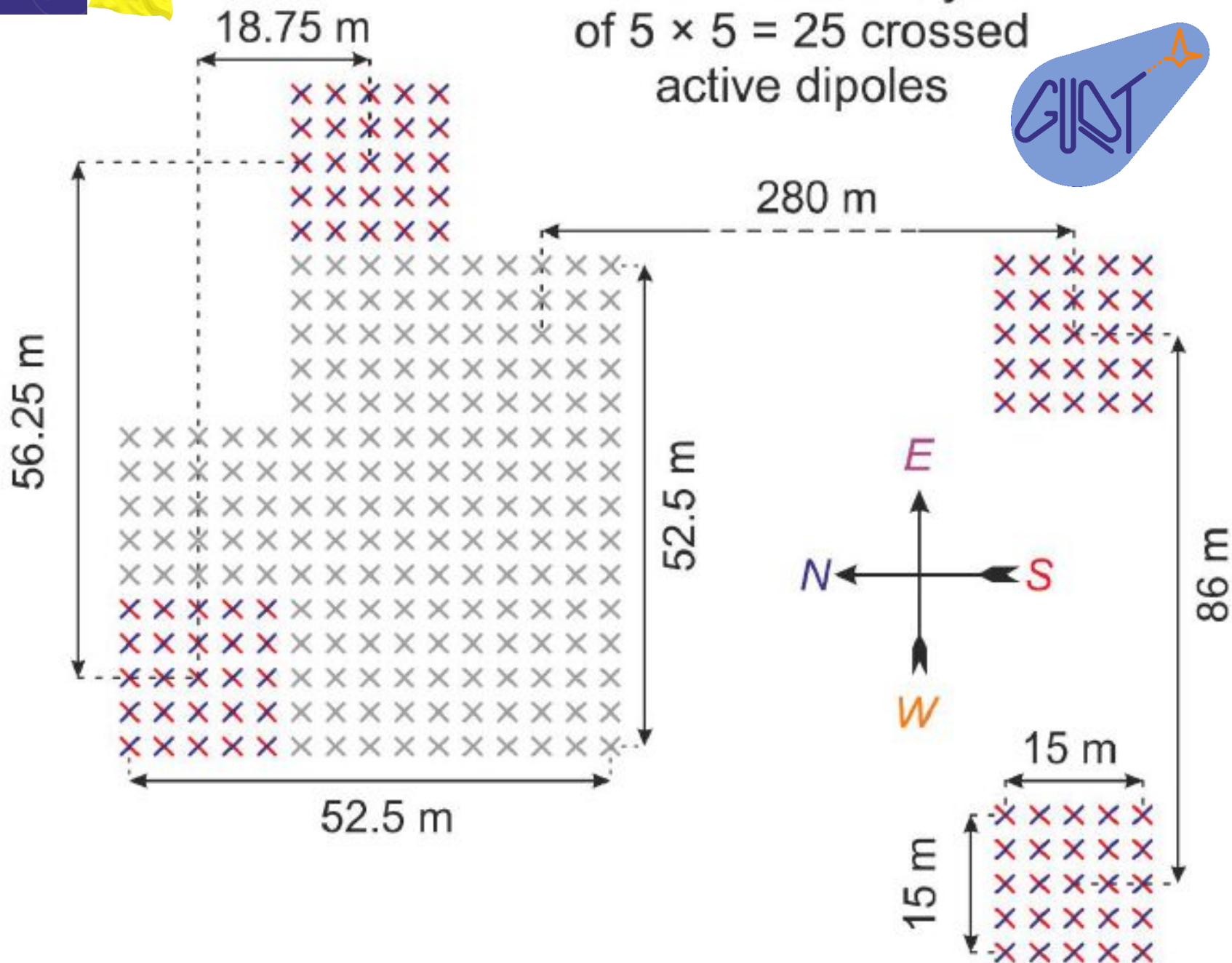
40 MHz



70 MHz



GURT Subarrays of $5 \times 5 = 25$ crossed active dipoles



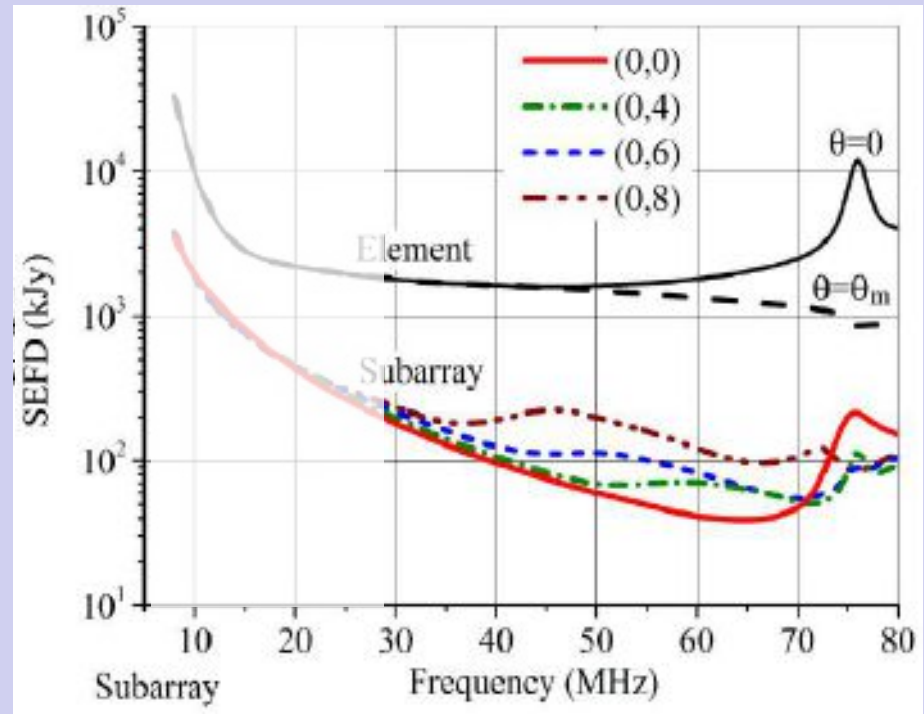
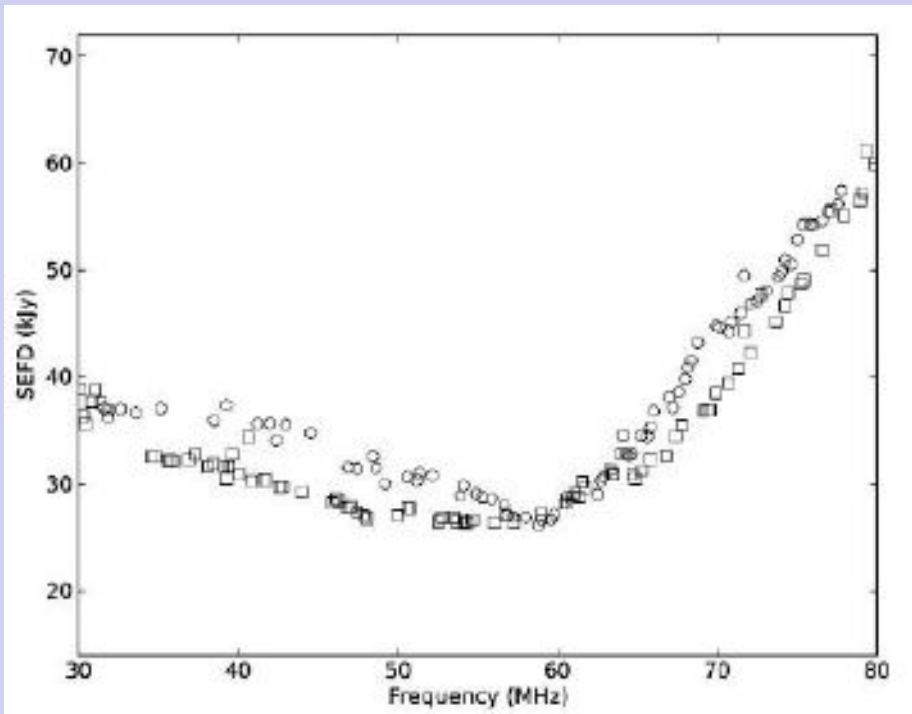
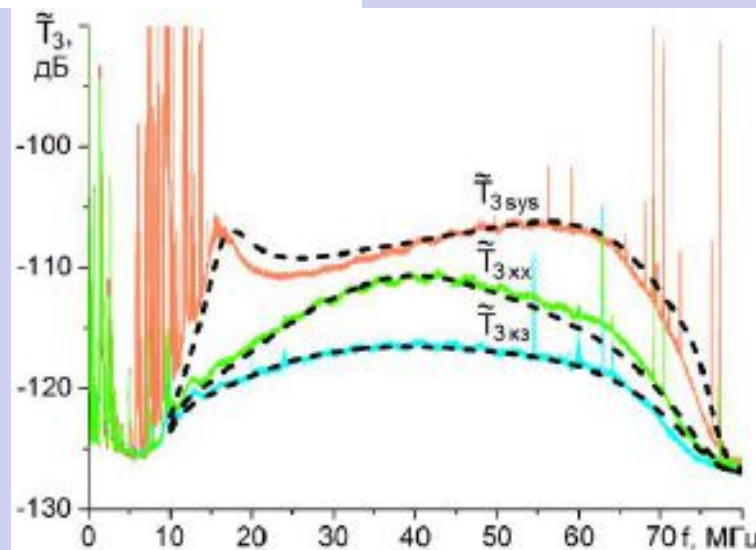
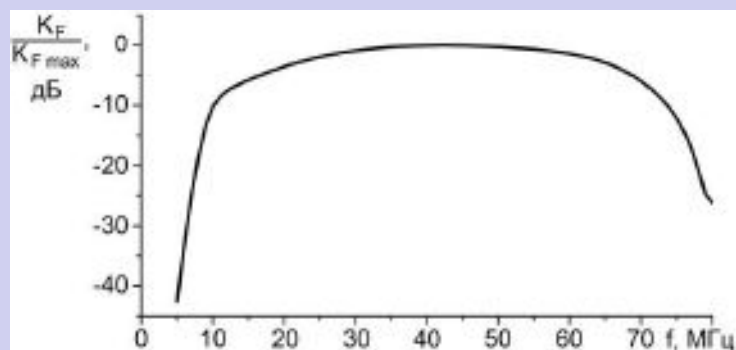
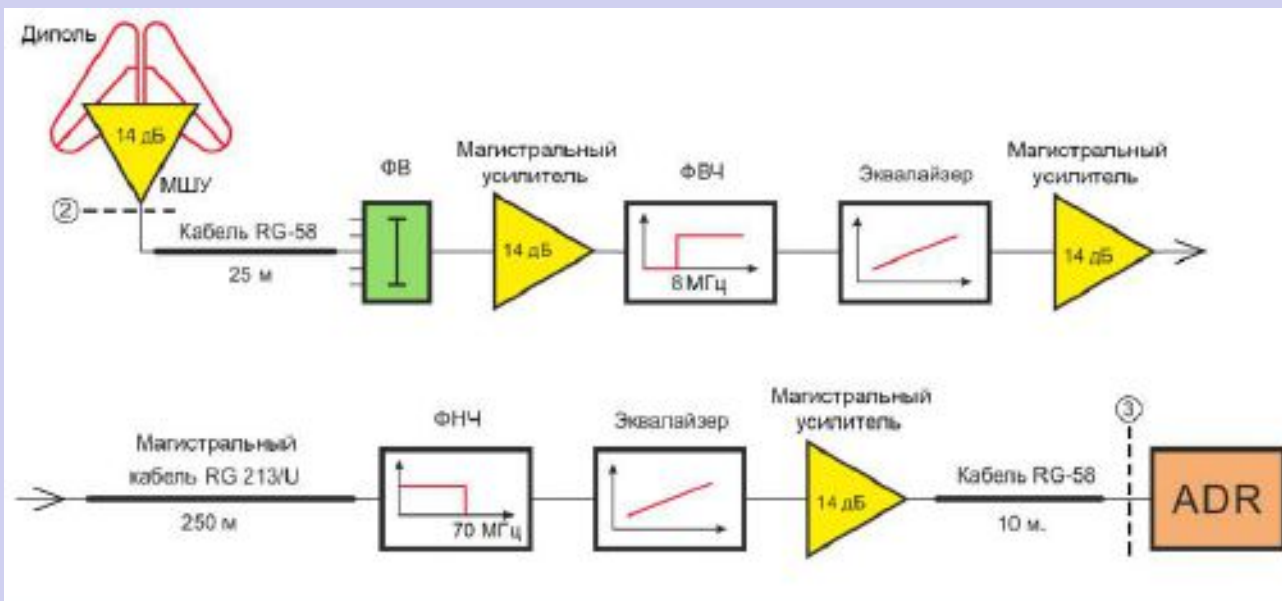


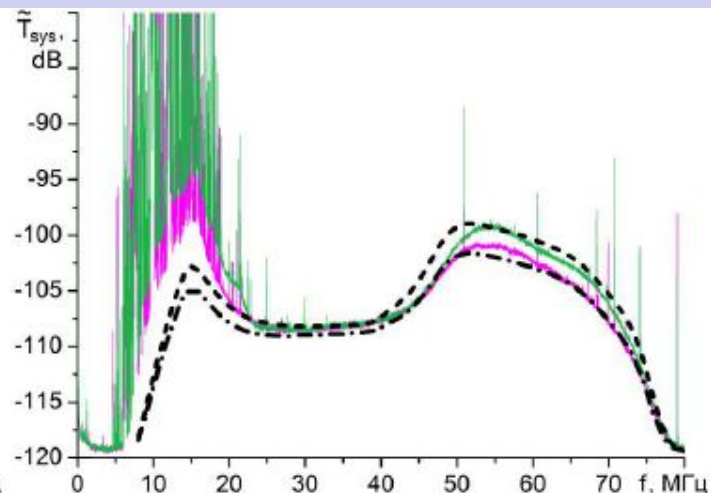
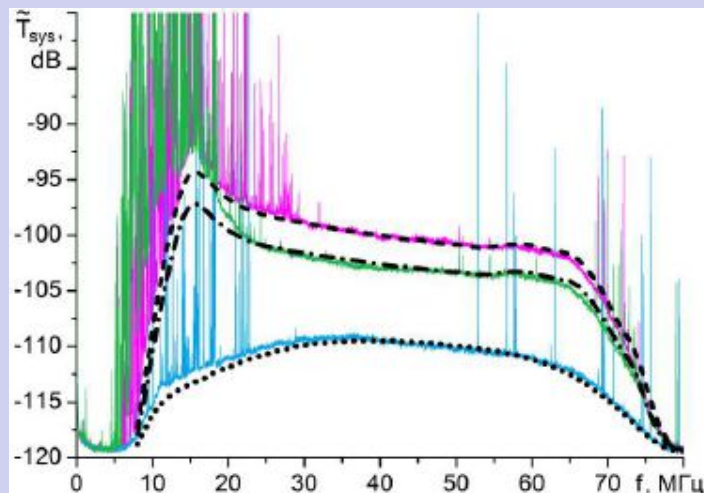
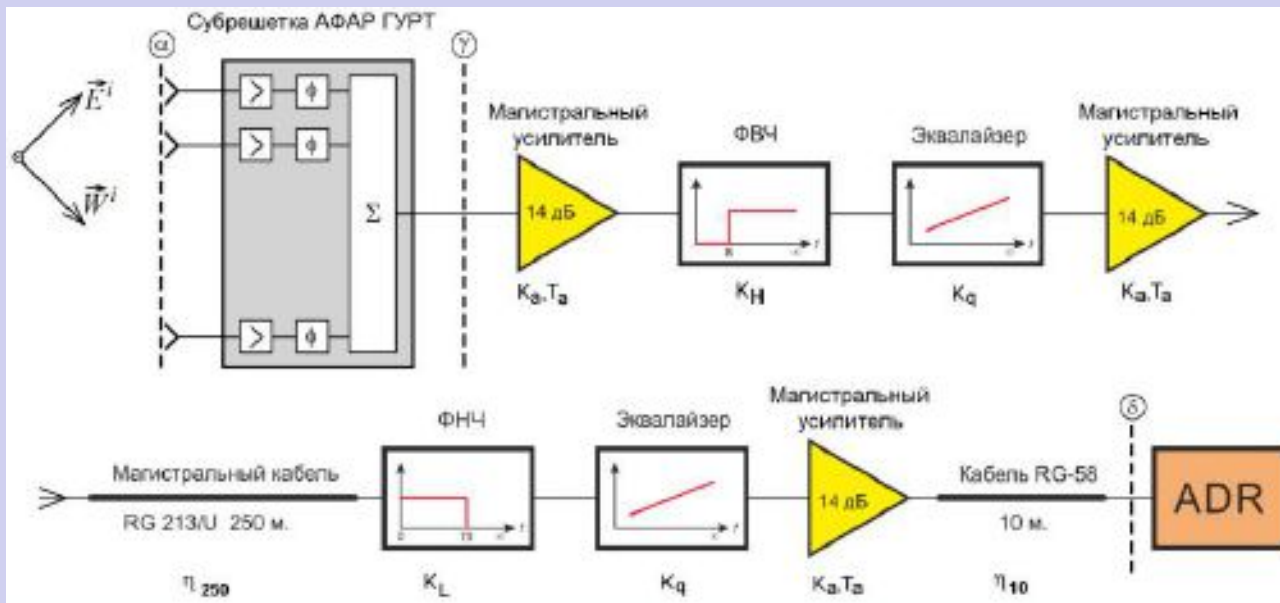
Fig. 22 -left panels: plots of the SEFD as a function of frequency for the various LOFAR operating bands and station configurations. These curves are derived using the procedure described in Sect. 12.6.

In the LBA, the circles are LBA_INNER core stations and the squares are LBA_OUTER core stations. Values are plotted separately for the LBA_INNER (circles) and LBA_OUTER (squares) station configurations. Empirical system temperature values and sky temperatures were determined as described in the text. The LBA system is clearly sky dominated at frequencies below ≈ 65 MHz. Above that frequency, the instrumental noise term dominates.

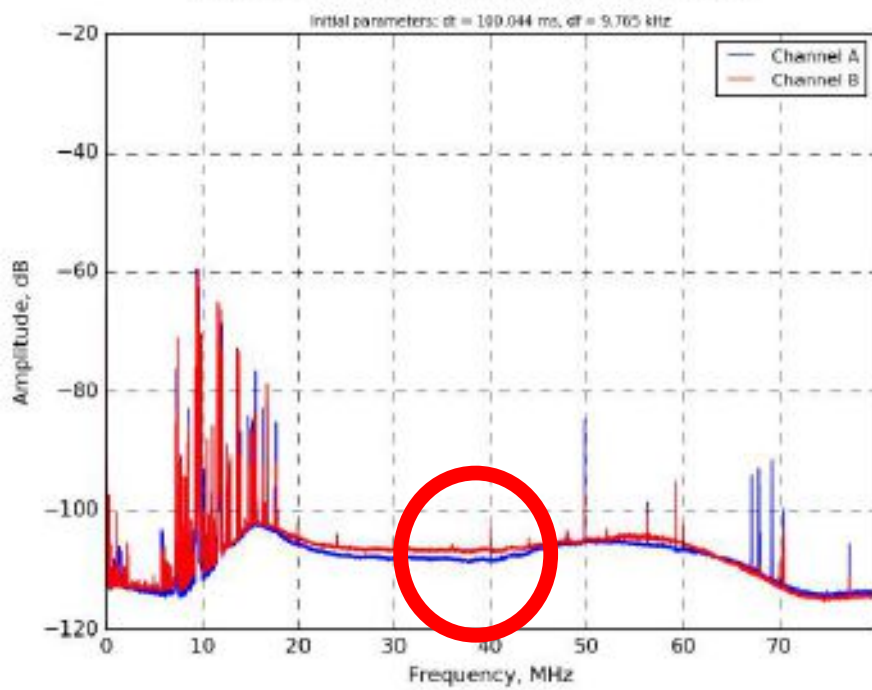
Сравнение результатов моделирования и измерений шумовых характеристик антенного элемента ГУРТ

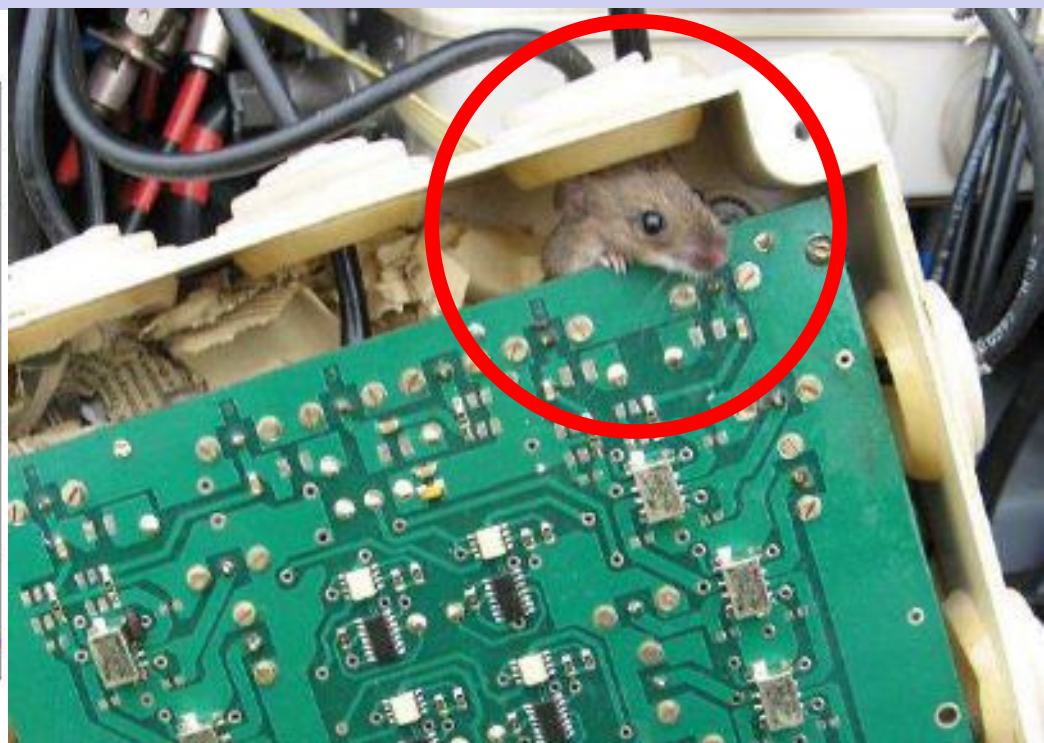
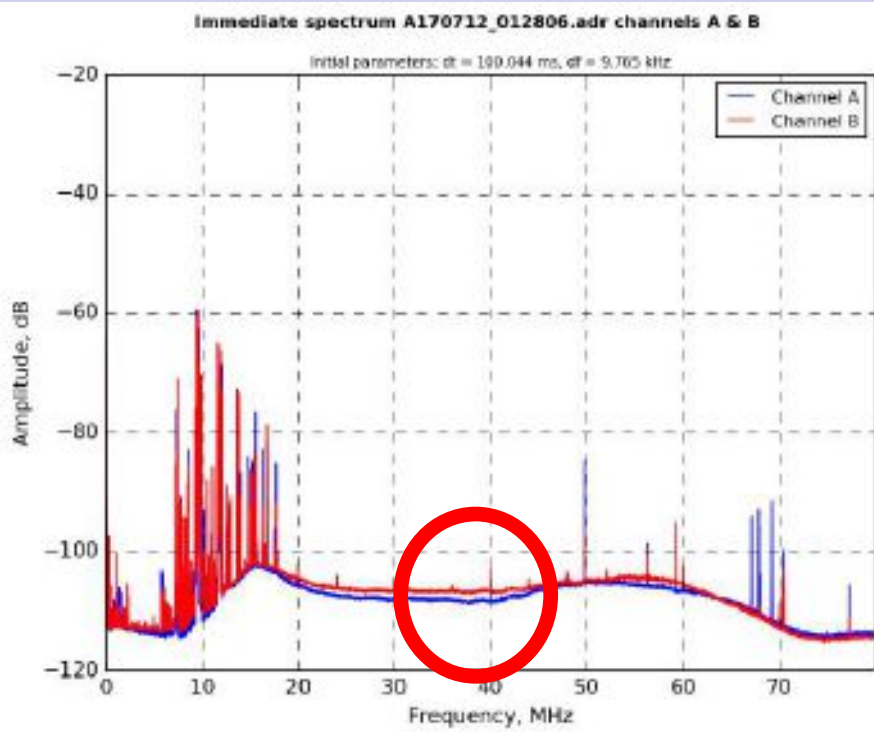


Сравнение результатов моделирования и измерений шумовых характеристик субрешетки ГУРТ

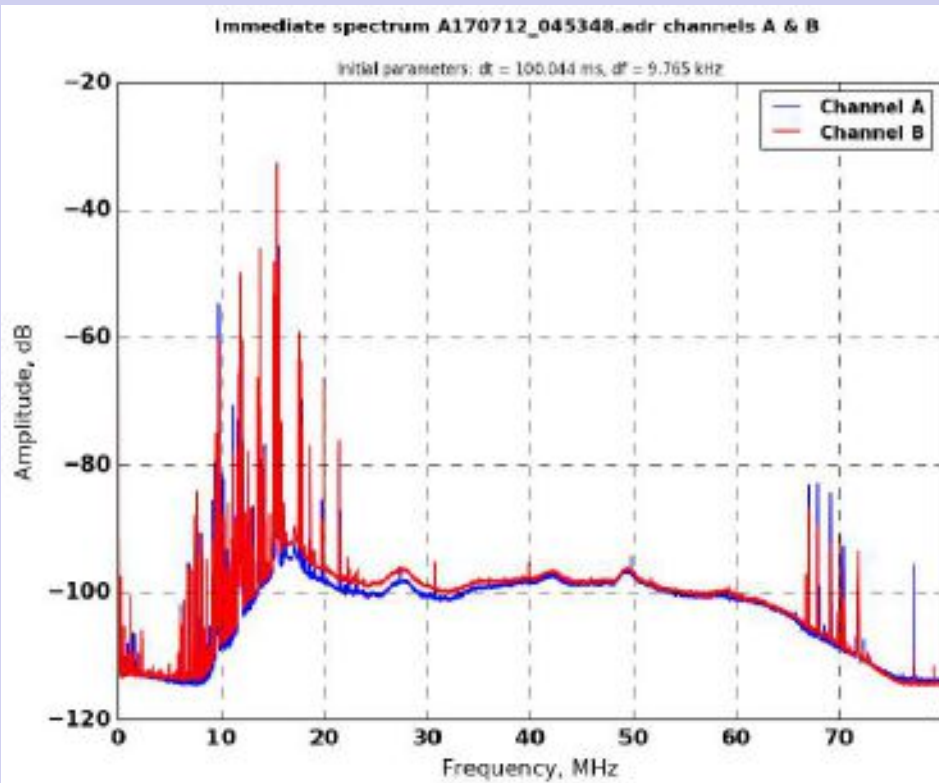


Immediate spectrum A170712_012806.adr channels A & B

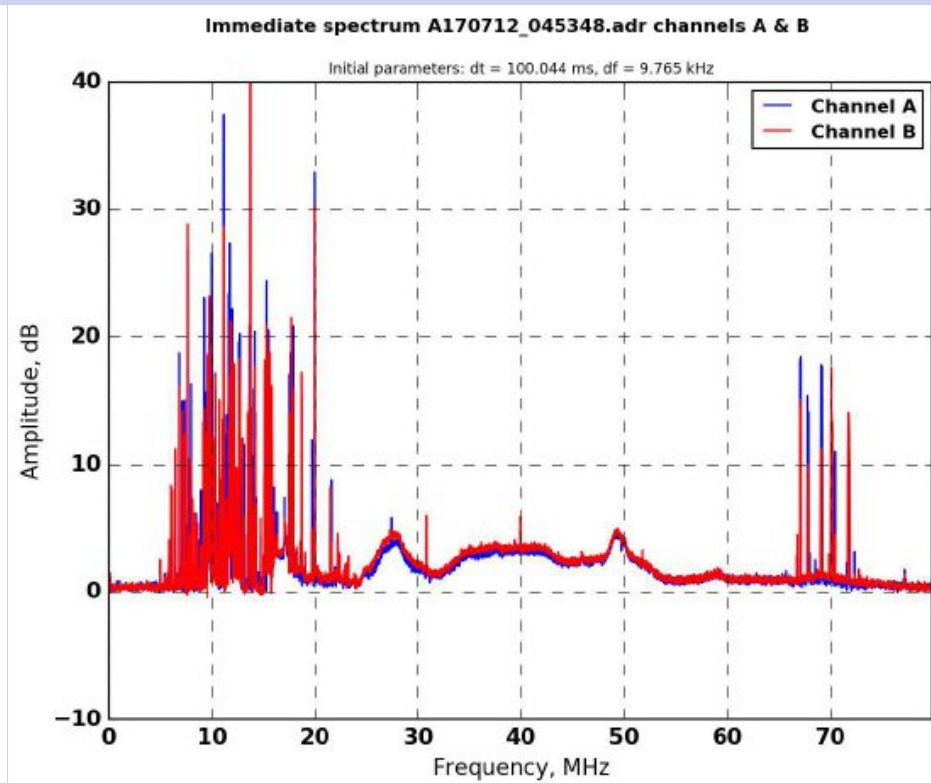




Нормирование спектра (повышение контраста)



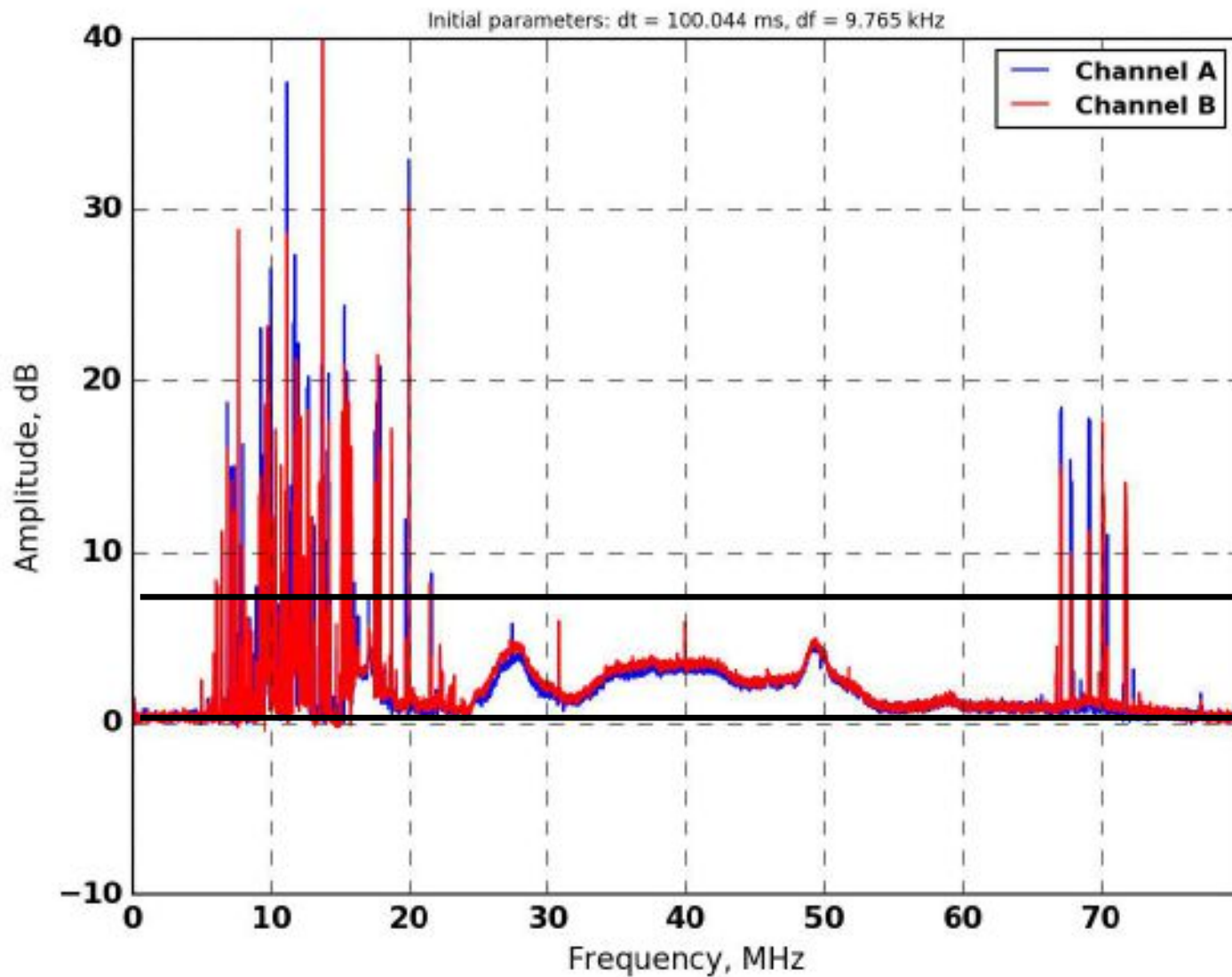
до



после

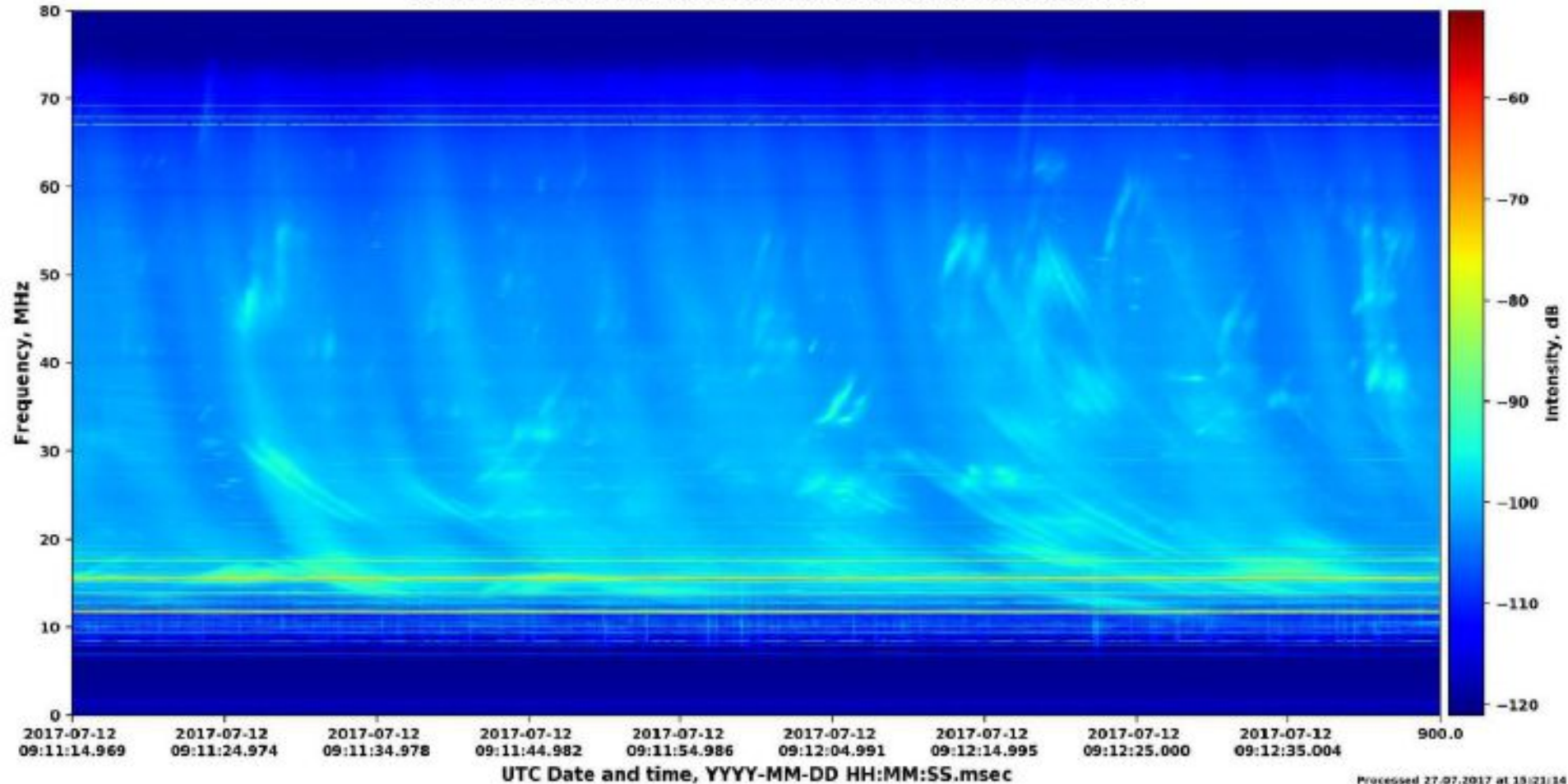


Immediate spectrum A170712_045348.adr channels A & B



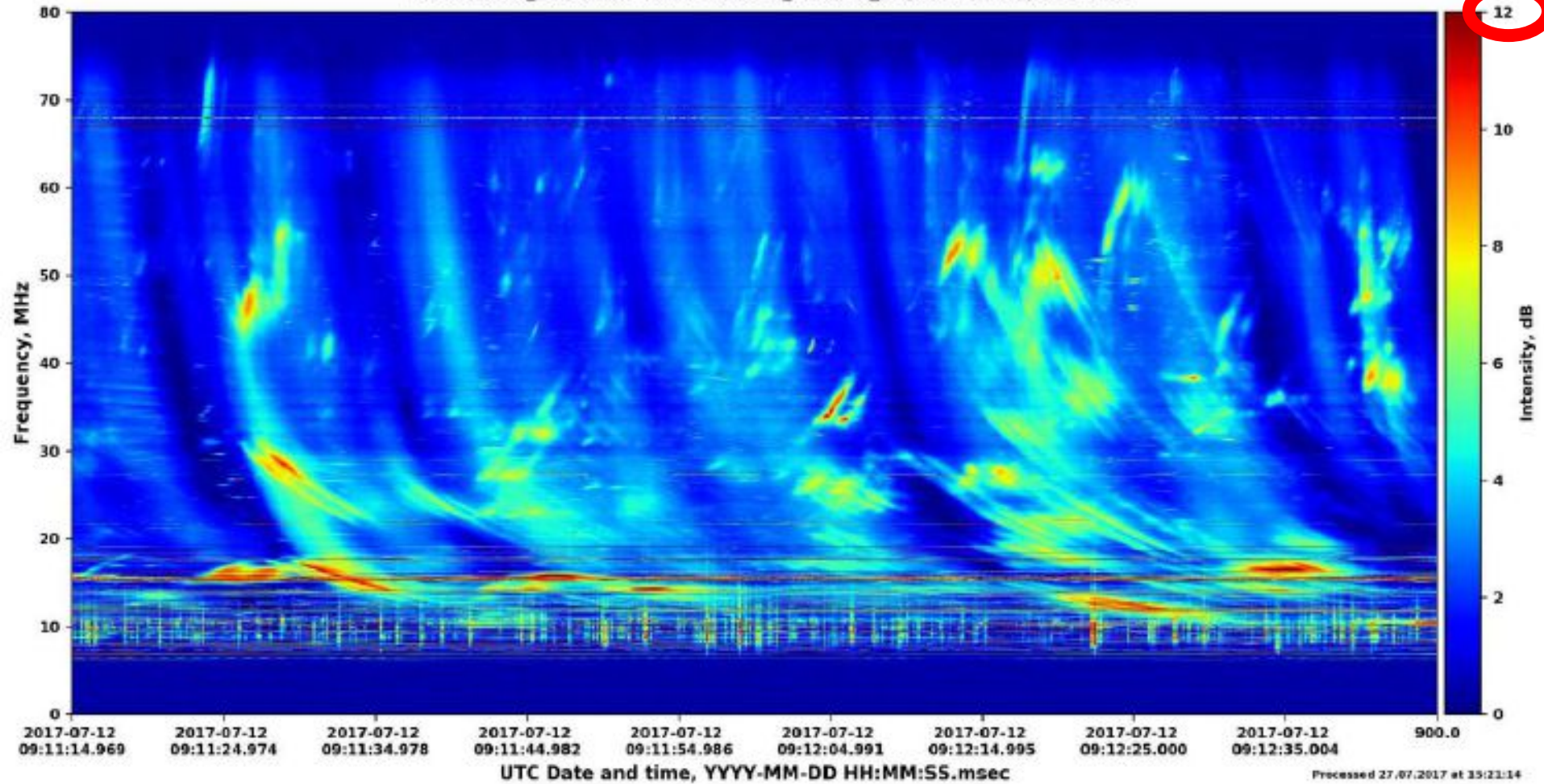
Нормирование спектра (до)

Dynamic spectrum starting from file A170712_091055.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.0 kHz, Processing: Averaging 1 spectra (0.1 sec.)
Receiver: A_ADR501, Place: Grakove_Kharkiv_Region, Description: SUN

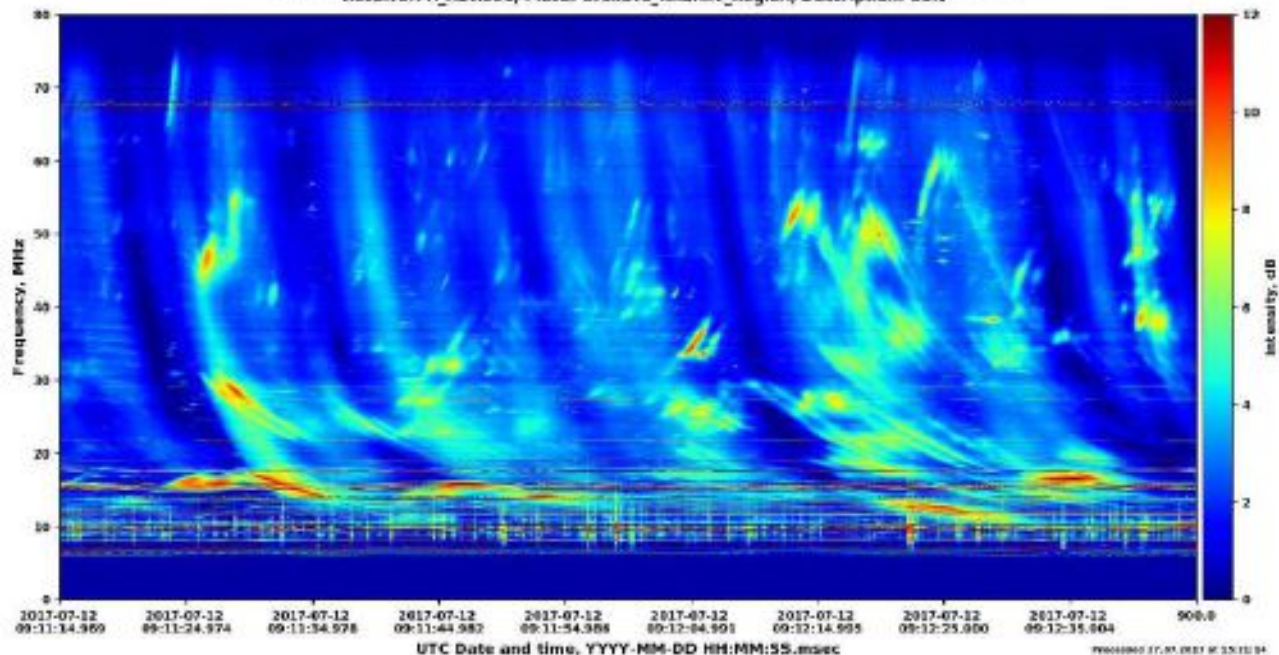


Нормирование спектра (после)

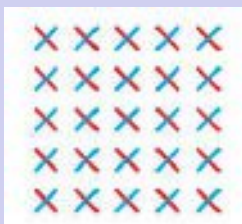
Dynamic spectrum cleaned and normalized starting from file A170712_091055.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.0 kHz, Processing: Averaging 1 spectra (0.1 sec.)
Receiver: A_ADRS01, Place: Grakove_Kharkiv_Region, Description: SUN



Dynamic spectrum cleaned and normalized starting from file A170712_091055.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.0 kHz, Processing: Averaging 1 spectra (0.1 sec.)
Receiver: A_ADR501, Place: Grakove_Kharkiv_Region, Description: SUN

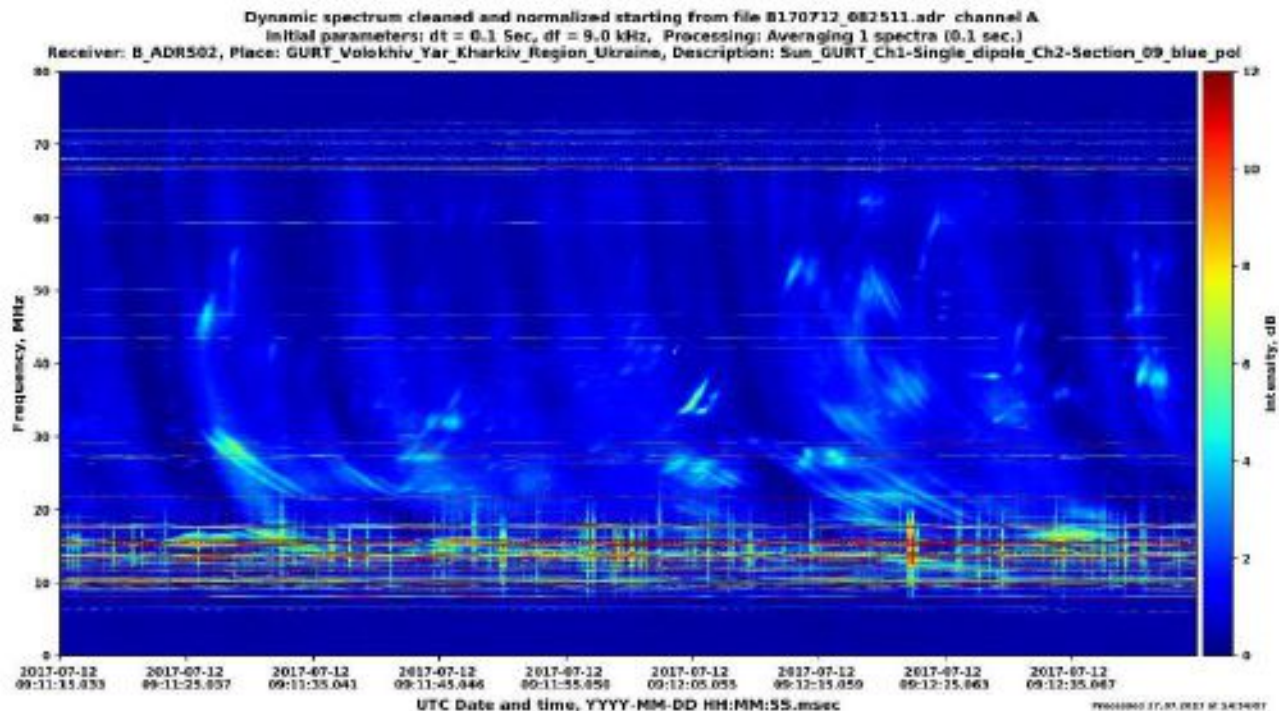


25 dipoles



GURT subarray
vs.

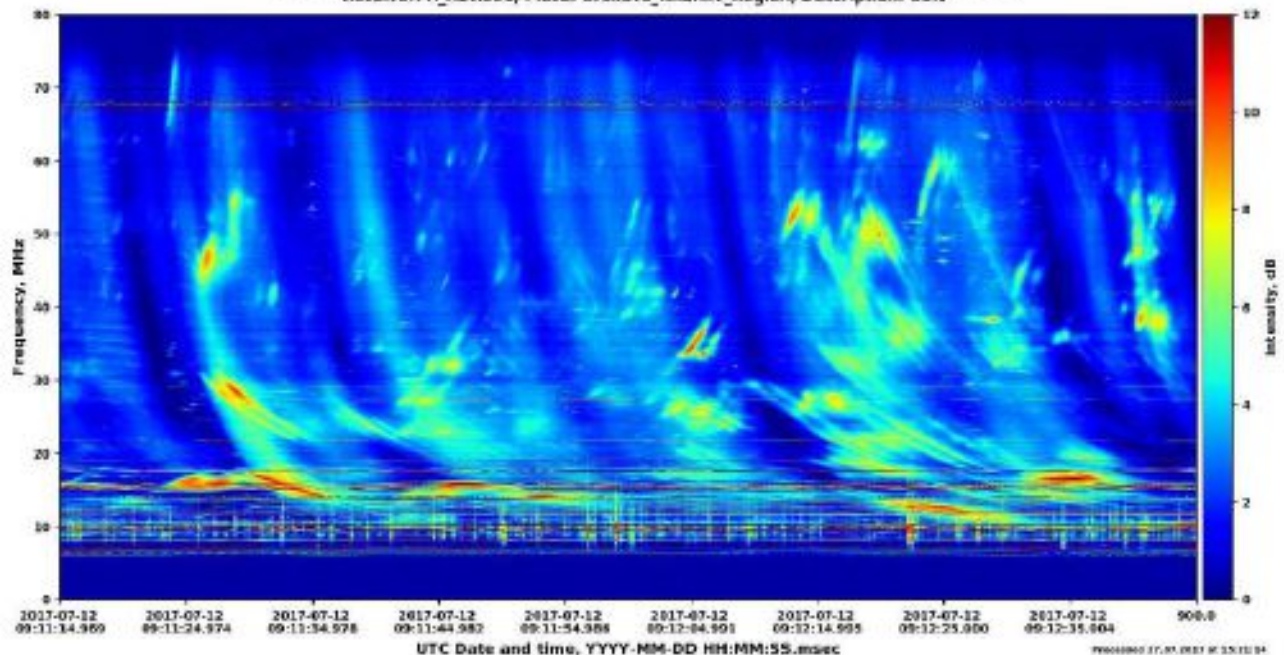
GURT dipole
in 0 - 80 MHz range



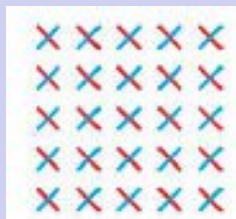
1 dipole



Dynamic spectrum cleaned and normalized starting from file A170712_091055.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.0 kHz, Processing: Averaging 1 spectra (0.1 sec.)
Receiver: A_ADR501, Place: Grakove_Kharkiv_Region, Description: SUN

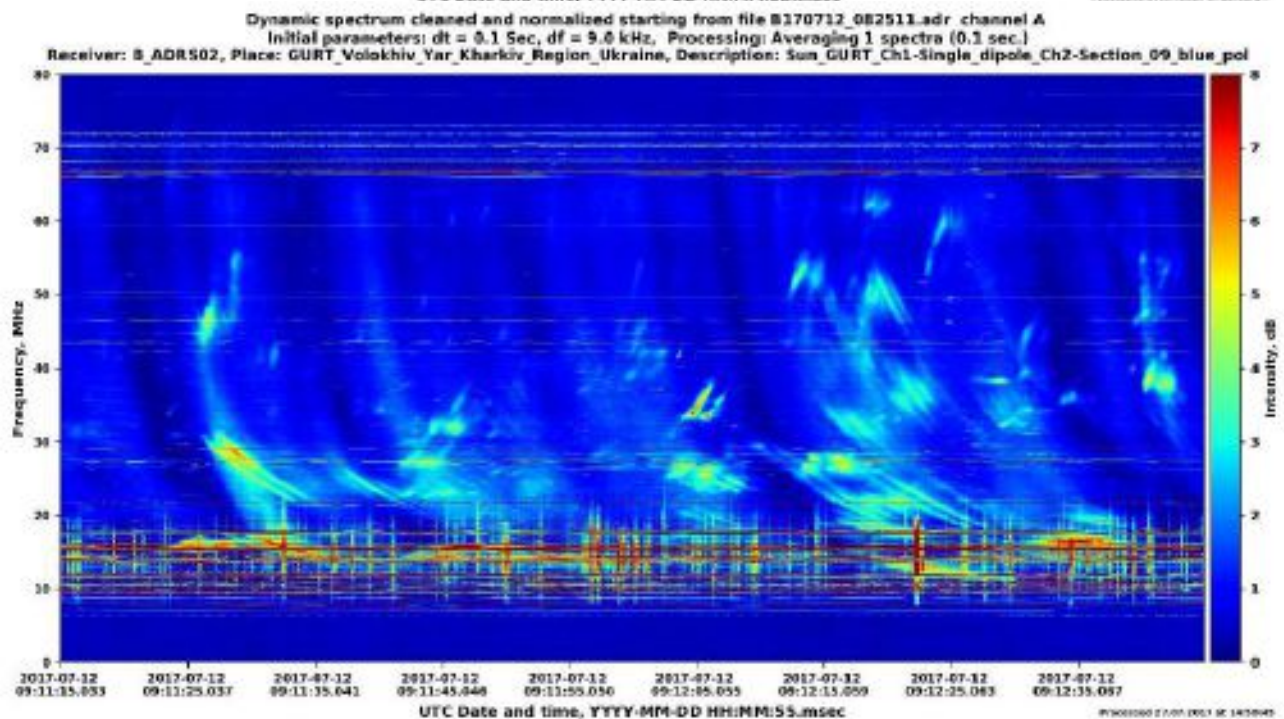


25 dipoles



GURT subarray
vs.

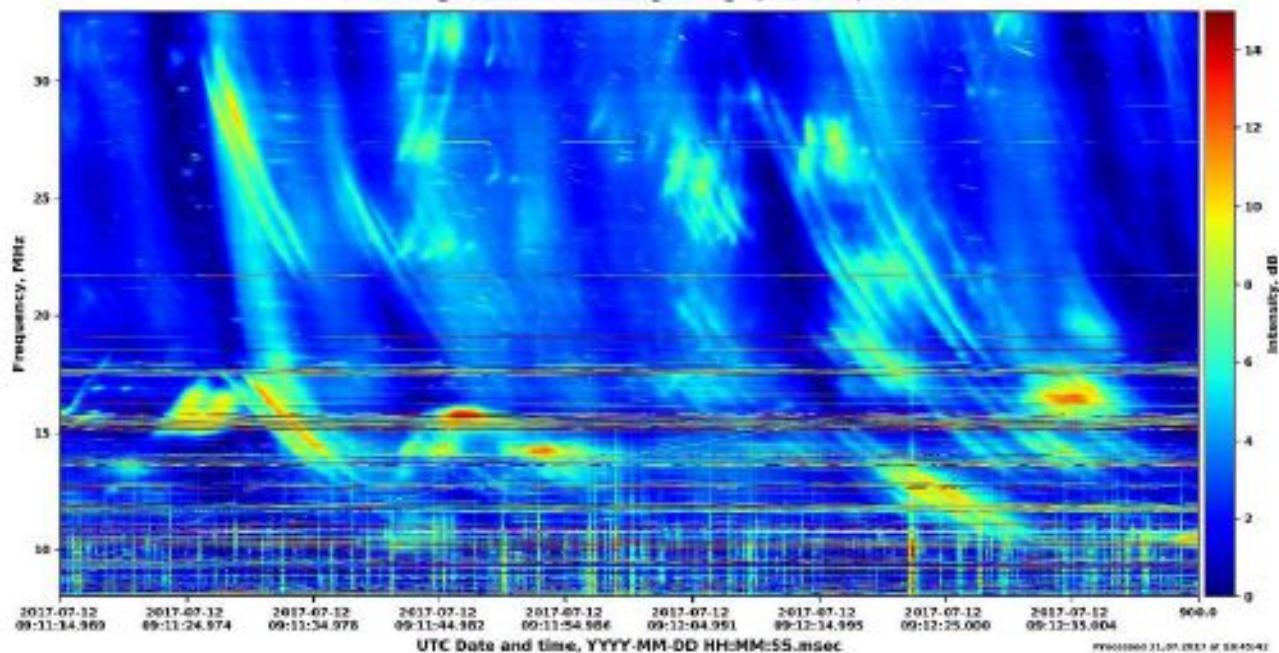
GURT dipole
in 0 - 80 MHz range



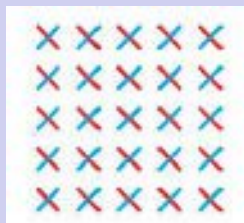
1 dipole



Dynamic spectrum cleaned and normalized starting from file A170712_091055.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.6 kHz, Processing: Averaging 1 spectra (0.1 sec.)
Receiver: A_ADR501, Place: Grakove, Kharkiv_Region, Description: SUM

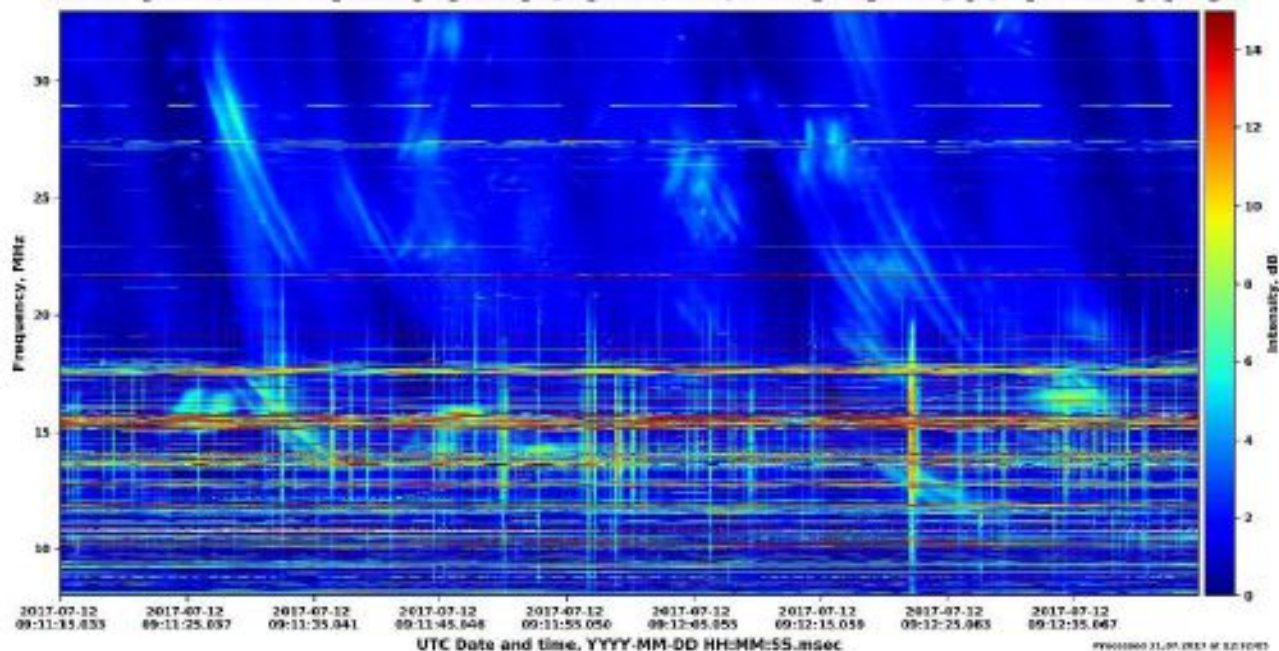


25 dipoles



GURT subarray
vs.
GURT dipole
in 8 - 33 MHz range

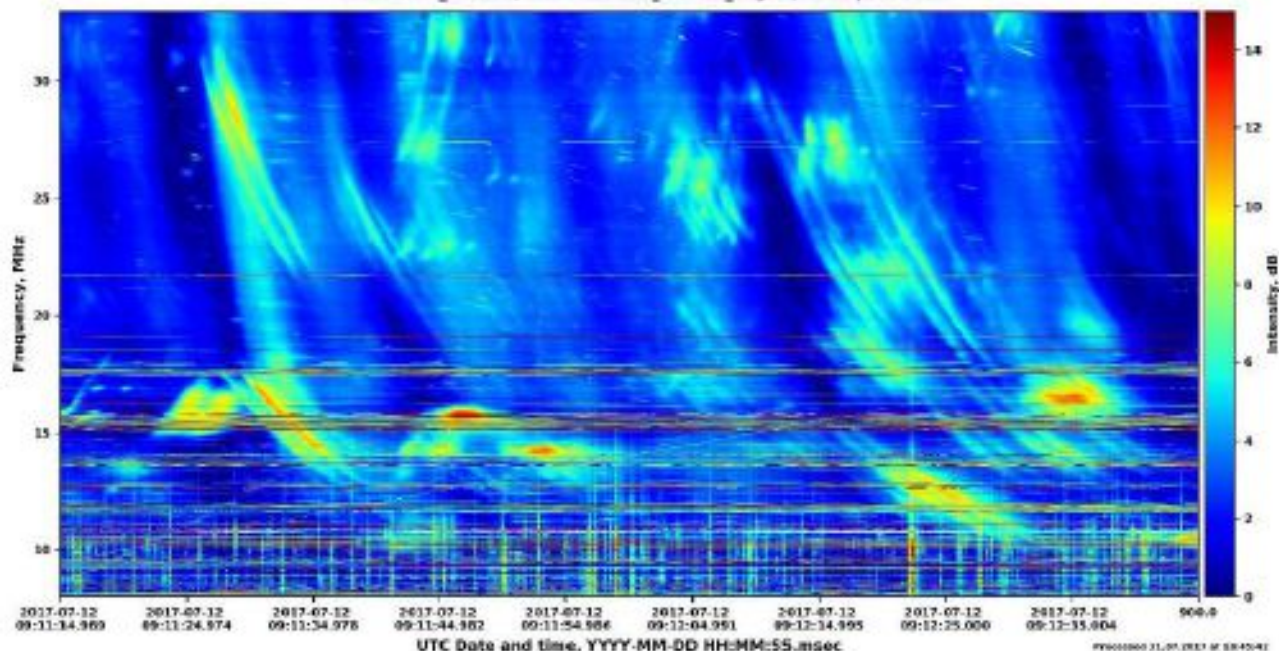
Dynamic spectrum cleaned and normalized starting from file B170712_082511.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.6 kHz, Processing: Averaging 1 spectra (0.1 sec.)
Receiver: B_ADR502, Place: GURT_Volokhiv_Yar, Kharkiv_Region, Ukraine, Description: Sun_GURT_Ch1-Single_dipole_Ch2-Section_09_blae_pol



1 dipole



Dynamic spectrum cleaned and normalized starting from file A170712_091055.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.0 kHz, Processing: Averaging 1 spectra (0.1 sec.)
Receiver: A, ADR501, Place: Grakove, Kharkiv_Region, Description: SUM



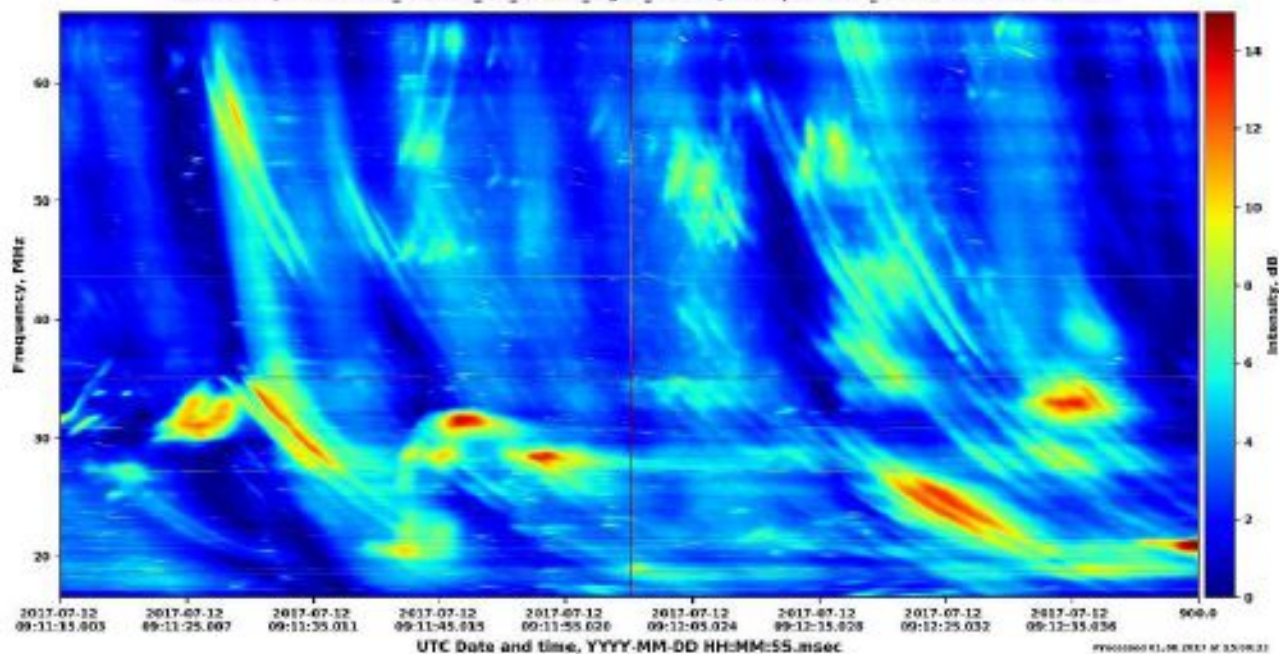
25 dipoles



GURT subarray
vs.

UTR-2 North Arm
in 8 - 33 MHz range

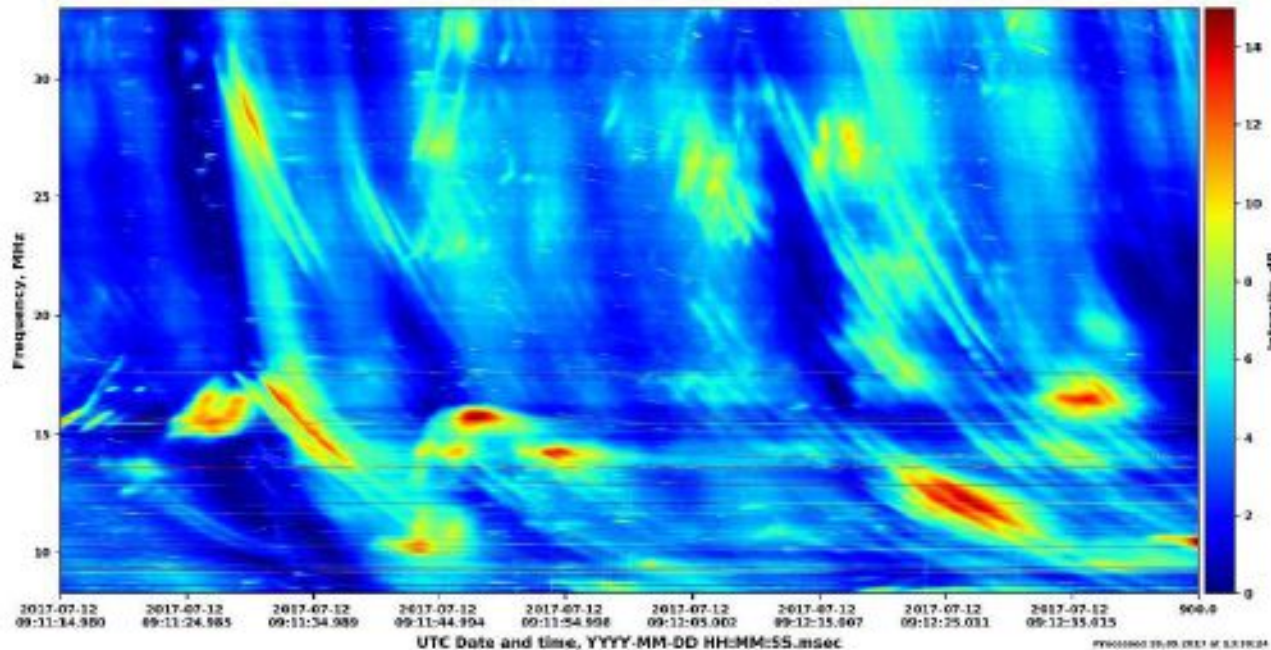
Dynamic spectrum cleaned and normalized starting from file D120717_090932.jds channel A
Initial parameters: dt = 0.1 Sec, df = 8.057 kHz, Processing: Averaging 1 spectra (0.1 sec.)
Receiver: D, Place: UTR-2_Volokhir_Yar_Kharkiv_region_Ukraine, Description: Sun_2017-Ch1=North-Ch2=West



720 dipoles



Dynamic spectrum cleaned and normalized starting from file P120717_090123.jds channel A
Initial parameters: dt = 0.1 Sec, df = 4.028 kHz, Processing: Averaging 1 spectra (0.1 sec.)
Receiver: P, Place: UTR-2, Kharkov, Ukraine, Description: URAN-2 DSPZ

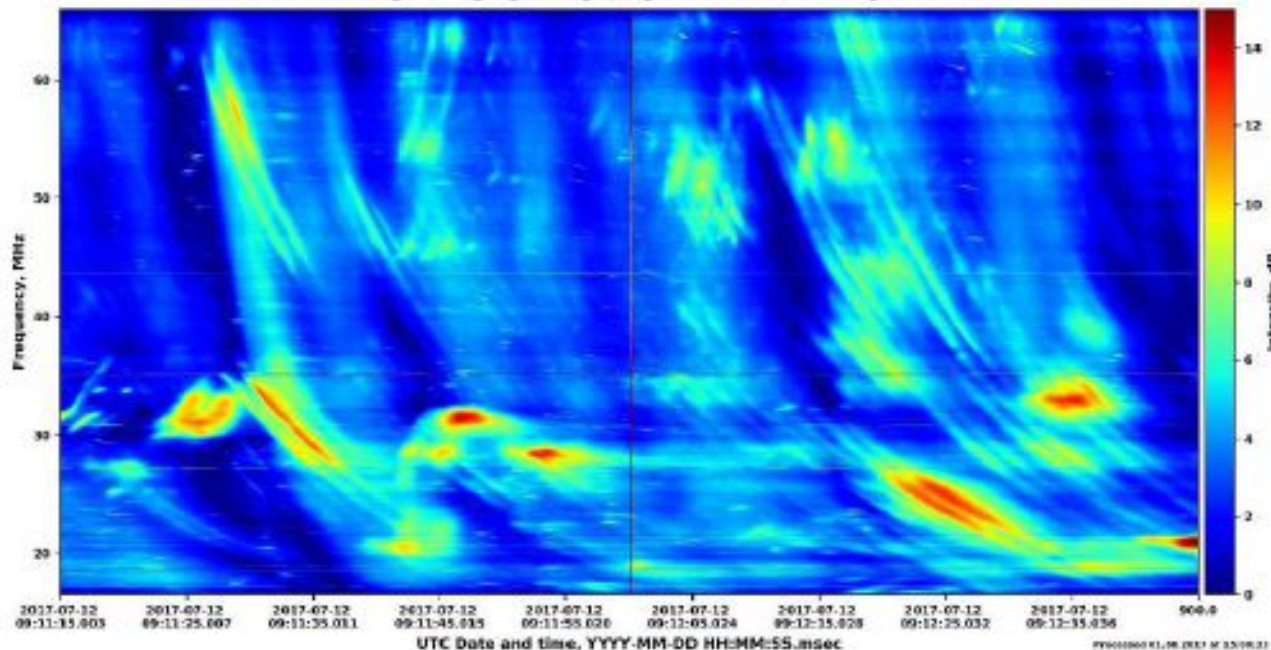


512 dipoles
(16 x 32)
Rectangular
configuration

URAN-2 Full telescope
vs.

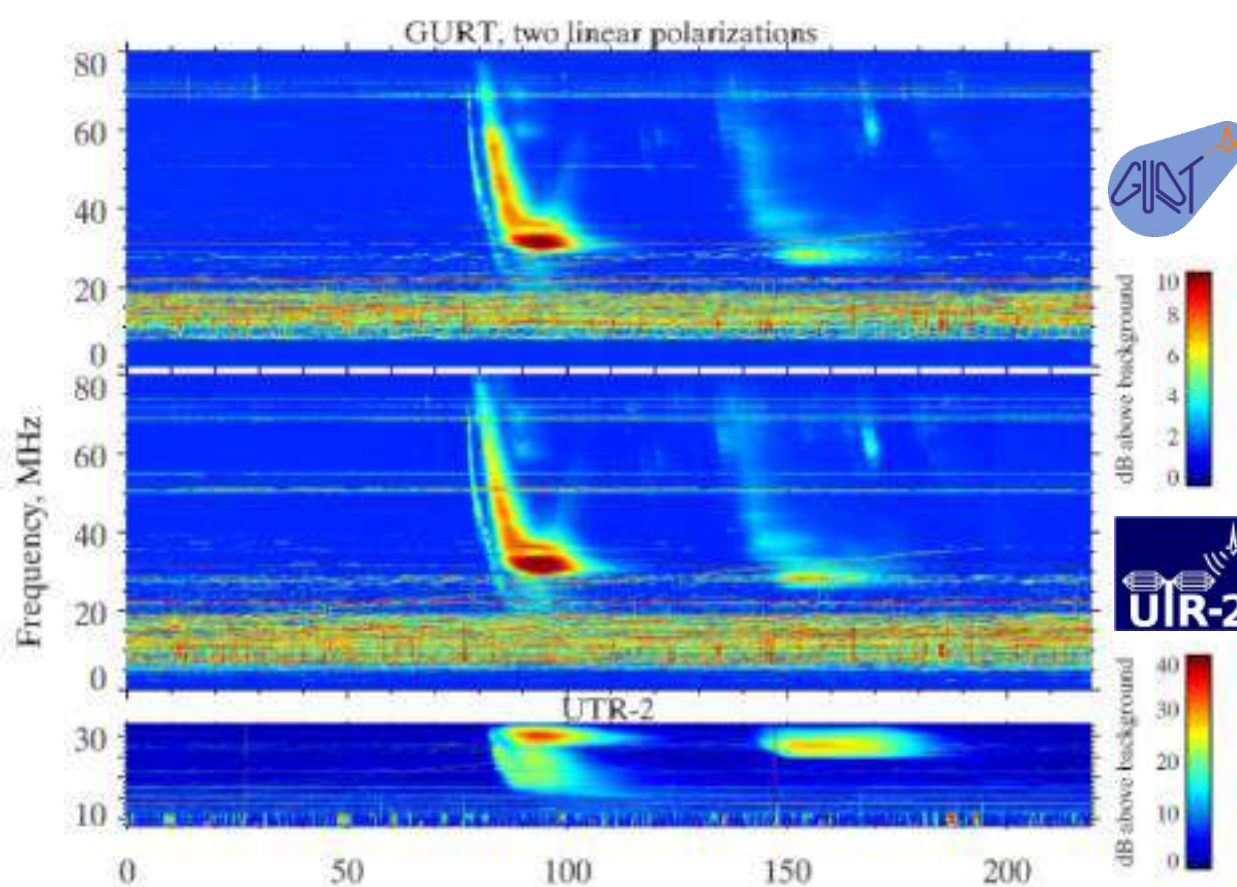
UTR-2 North Arm
in 8 - 33 MHz range

Dynamic spectrum cleaned and normalized starting from file D120717_090932.jds channel A
Initial parameters: dt = 0.1 Sec, df = 8.057 kHz, Processing: Averaging 1 spectra (0.1 sec.)
Receiver: D, Place: UTR-2_Volokhiv_Yar_Kharkiv_region_Ukraine, Description: Sun_2017-Ch1=North-Ch2=West

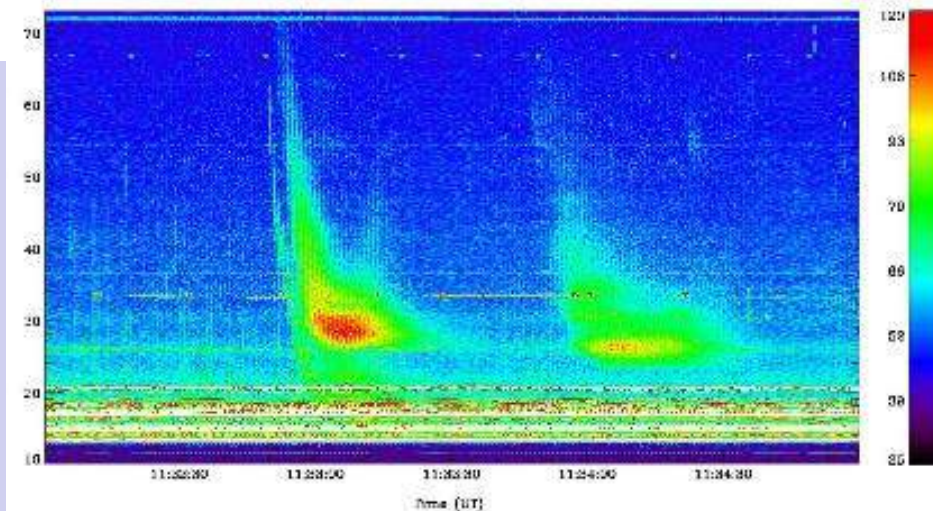


720 dipoles
(6 x 120)
Almost linear
array



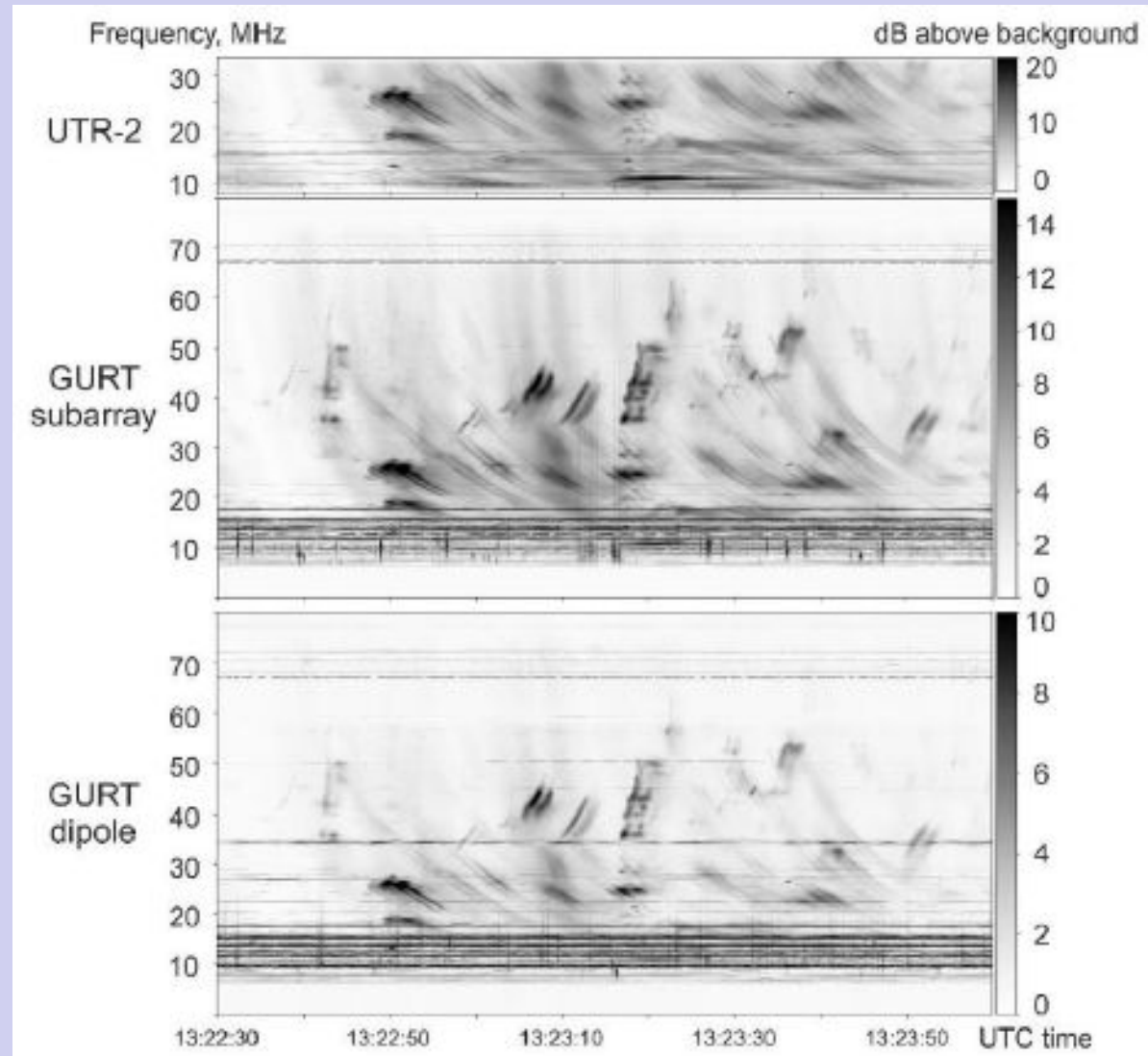
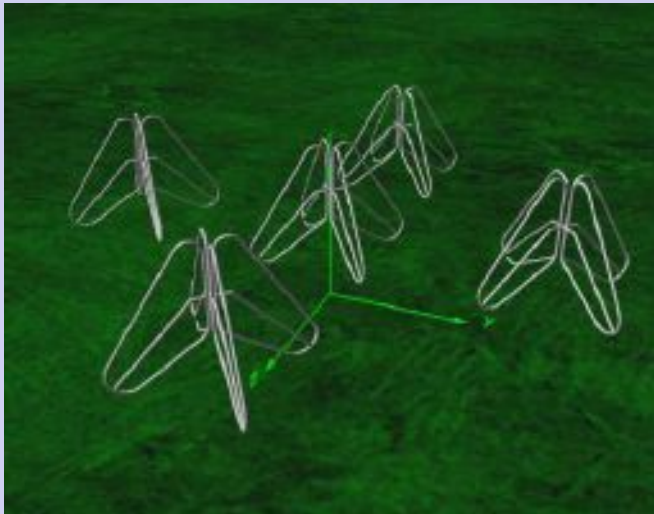
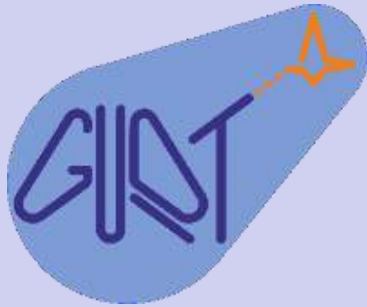


Comparison of solar bursts received with GURT subarray, UTR-2 radio telescope and Nançay Decametric Array (France)



<http://bass2000.obspm.fr/home.php>

Studies of double pairs under the ionosphere cutoff



Юпитер - Джуно, УТР-2, ГУРТ



NASA'S HARDEST EVER MISSION

After five years and 1.6 billion miles, Juno went into orbit around Jupiter at 4.53am yesterday.

Any 5, 200 Launches from Cape Canaveral, Florida

THE JUPITER RECONVOLE
Faster than a speeding bullet, Juno is the fastest spacecraft ever launched from Earth.

THE SHIPSHIP
Juno is the fastest spacecraft ever launched from Earth. It will make 37 orbits around Jupiter before returning to Earth in 2025. The spacecraft is the first to orbit Jupiter since the Galileo mission in 1995.

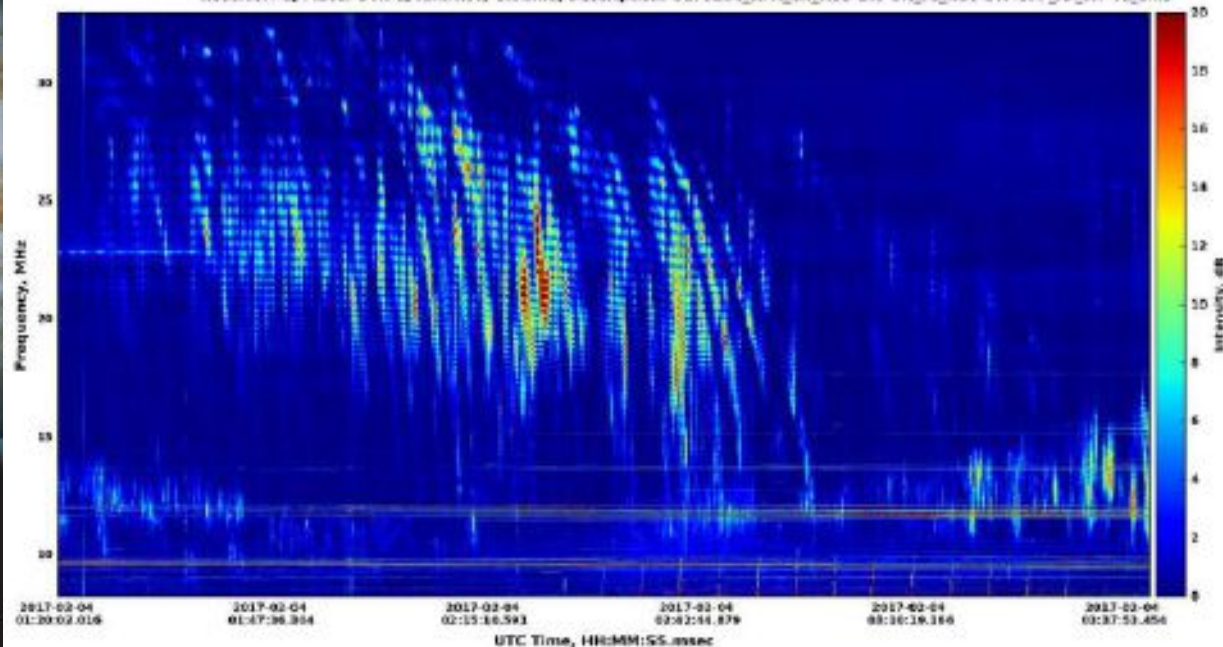
THE JUPITER RECONVOLE
Faster than a speeding bullet, Juno is the fastest spacecraft ever launched from Earth.

THE SHIPSHIP
Juno is the fastest spacecraft ever launched from Earth. It will make 37 orbits around Jupiter before returning to Earth in 2025. The spacecraft is the first to orbit Jupiter since the Galileo mission in 1995.

THE JUPITER RECONVOLE
Faster than a speeding bullet, Juno is the fastest spacecraft ever launched from Earth.

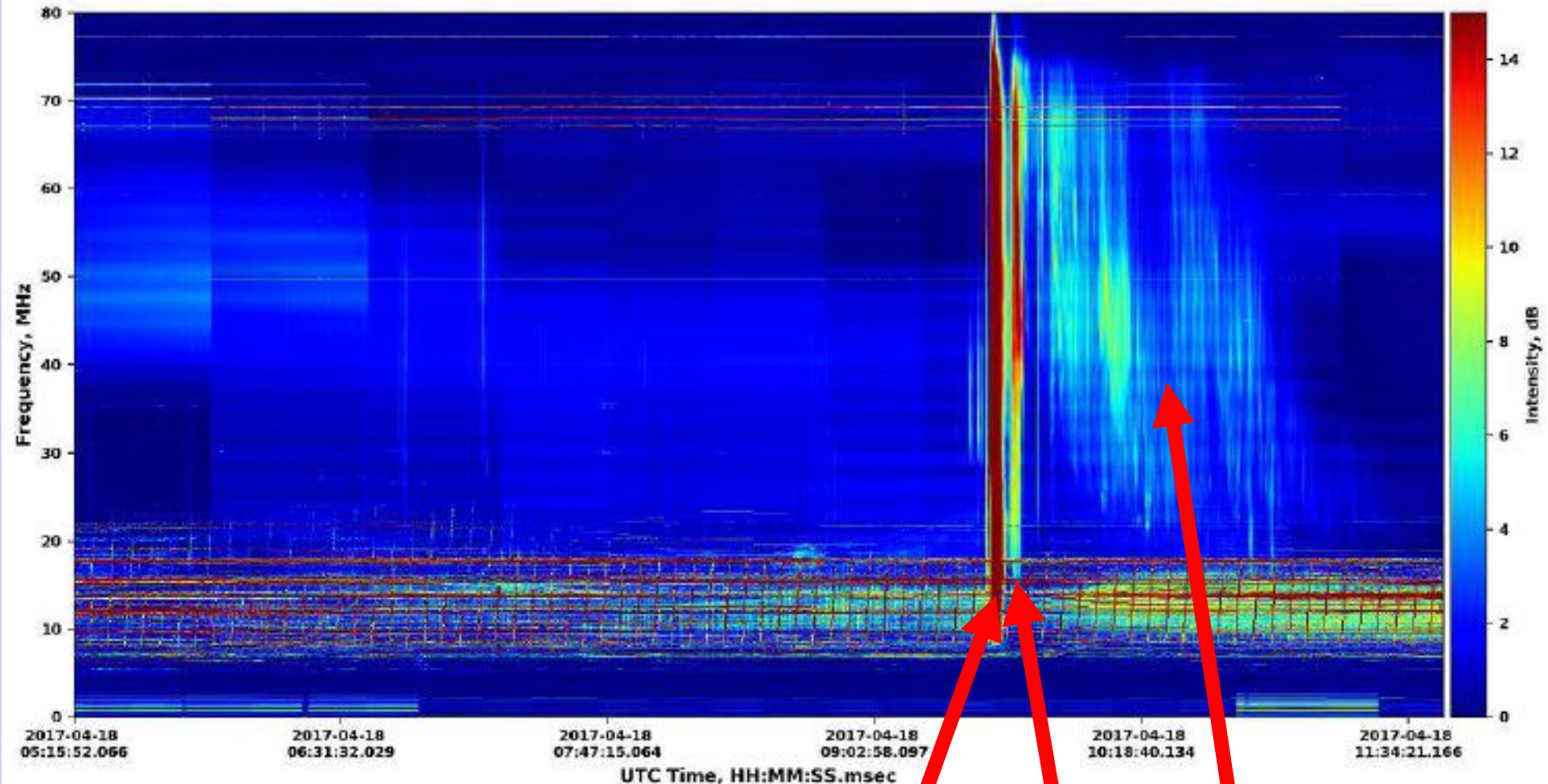
THE SHIPSHIP
Juno is the fastest spacecraft ever launched from Earth. It will make 37 orbits around Jupiter before returning to Earth in 2025. The spacecraft is the first to orbit Jupiter since the Galileo mission in 1995.

Dynamic spectrum cleaned and normalized starting from file C040217_012600.jds channel A
Initial parameters: dt = 0.005 Sec, df = 4.028 kHz, Processing: Averaging 1666 spectra (8.271 sec.)
Receiver: C, Place: UTR-2, Kharkov, Ukraine, Description: C170204_to-A_CR_NS3-EW-ON_rC_NS5-EW-OFF_rD_WF-rE_3ms



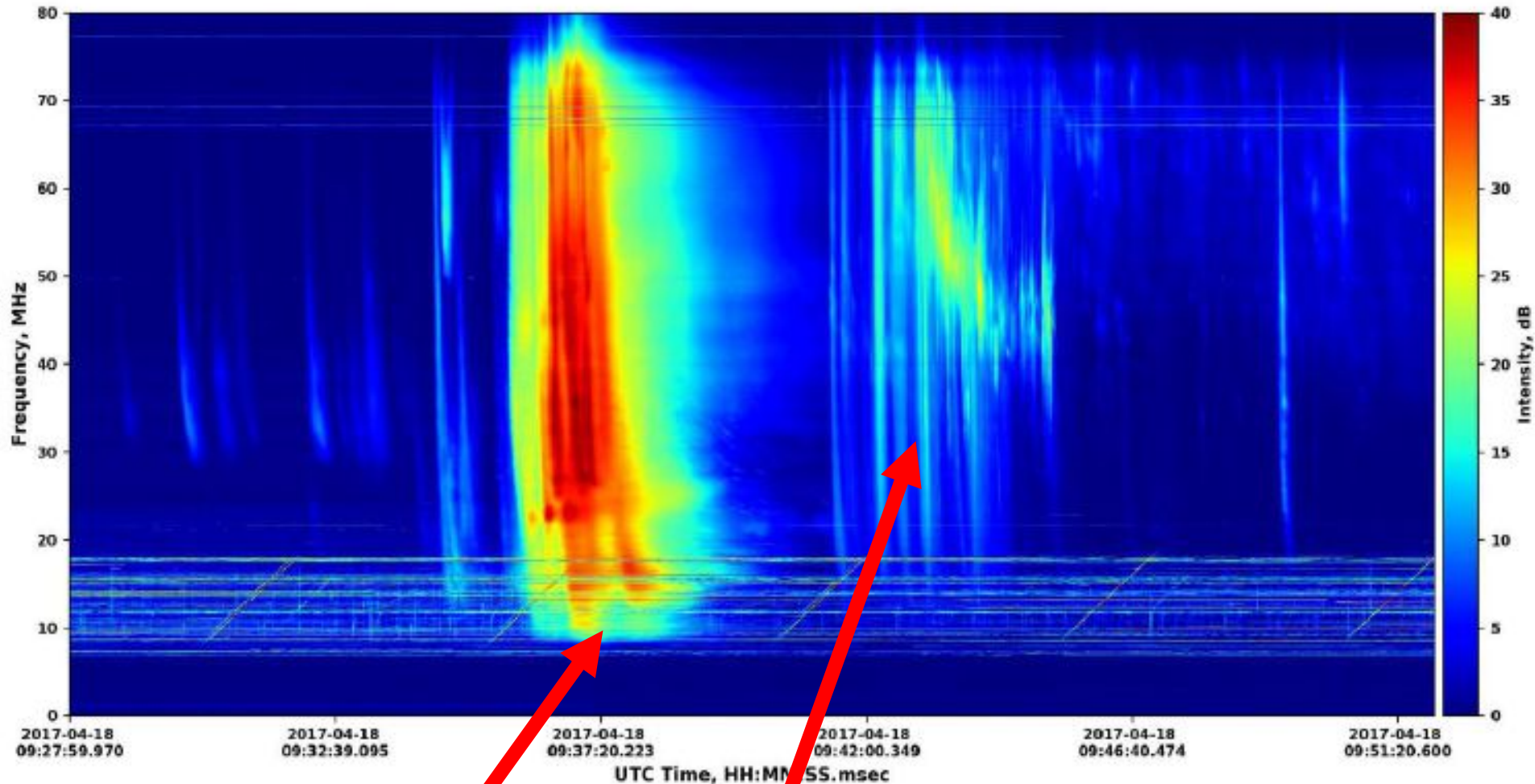
You should analyze events in various time scales
6,5 hours / picture scale

Dynamic spectrum cleaned and normalized starting from file A170418_051552.adr channel B
Initial parameters: dt = 0.1 Sec, df = 9.0 kHz, Processing: Averaging 227 spectra (22.71 sec.)
Receiver: A_ADRS01, Place: GURT_Volokhiv_Yar_Kharkiv_Region_Ukraine, Description: Sun_GURT_Section_10



You should analyze events in various time scales
22 minutes / picture scale

Dynamic spectrum cleaned and normalized starting from file A170418_051552.adr channel B
Initial parameters: dt = 0.05 Sec, df = 9.0 kHz, Processing: Averaging 14 spectra (0.7 sec.)
Receiver: A_ADRS01, Place: GURT_Volokhiv_Yar_Kharkiv_Region_Ukraine, Description: Sun_GURT_Section_10

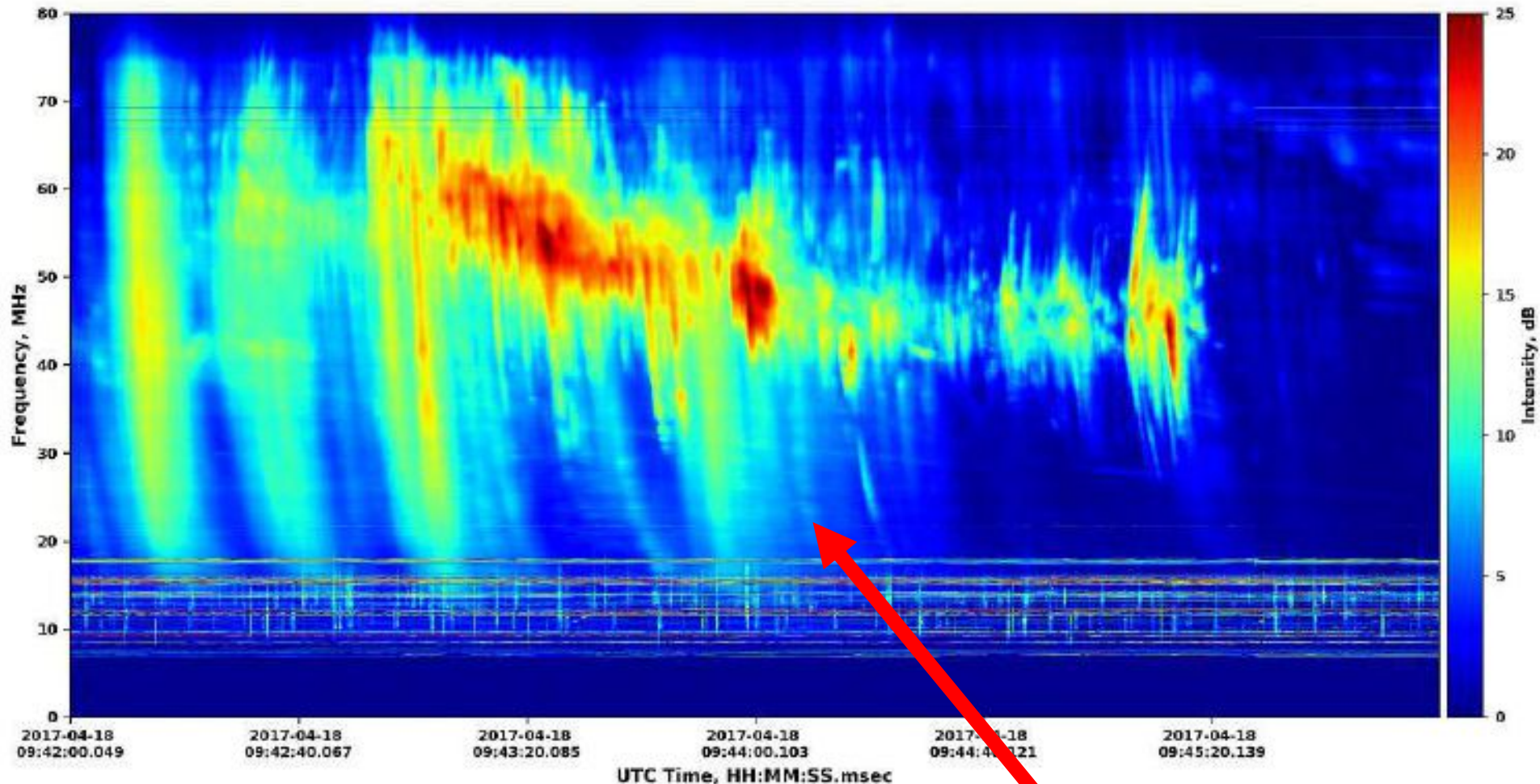


III

II

You should analyze events in various time scales
4 minutes / picture scale

Dynamic spectrum cleaned and normalized starting from file A170418_051552.adr channel A
Initial parameters: dt = 0.1 Sec, df = 9.0 kHz, Processing: Averaging 2 spectra (0.2 sec.)
Receiver: A_ADRS01, Place: GURT_Volokhiv_Yar_Kharkiv_Region_Ukraine, Description: Sun_GURT_Section_10



Совместные наблюдения пульсаров на ГУРТ и УТР-2

B1133+16

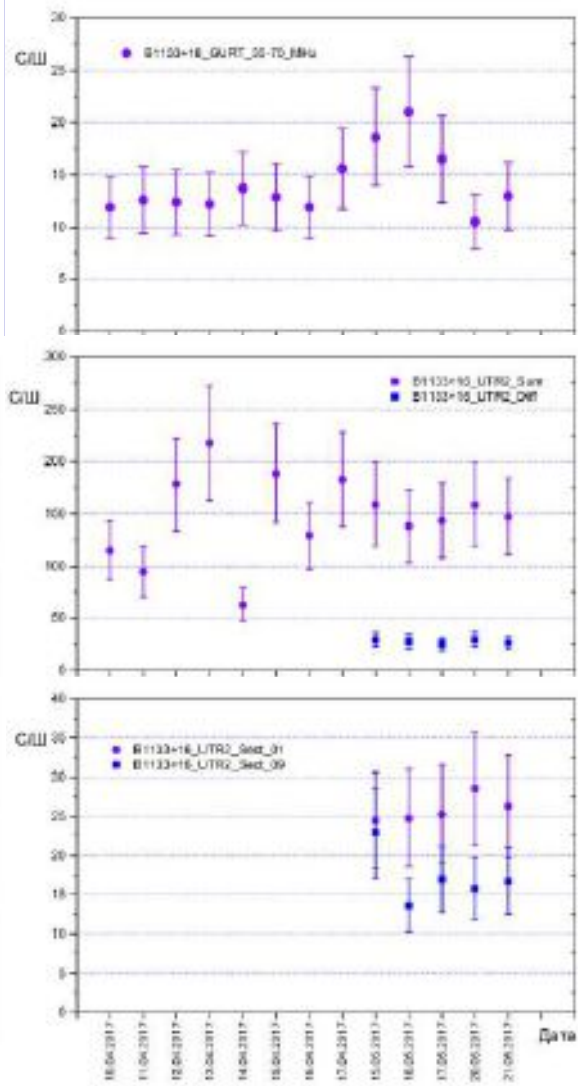
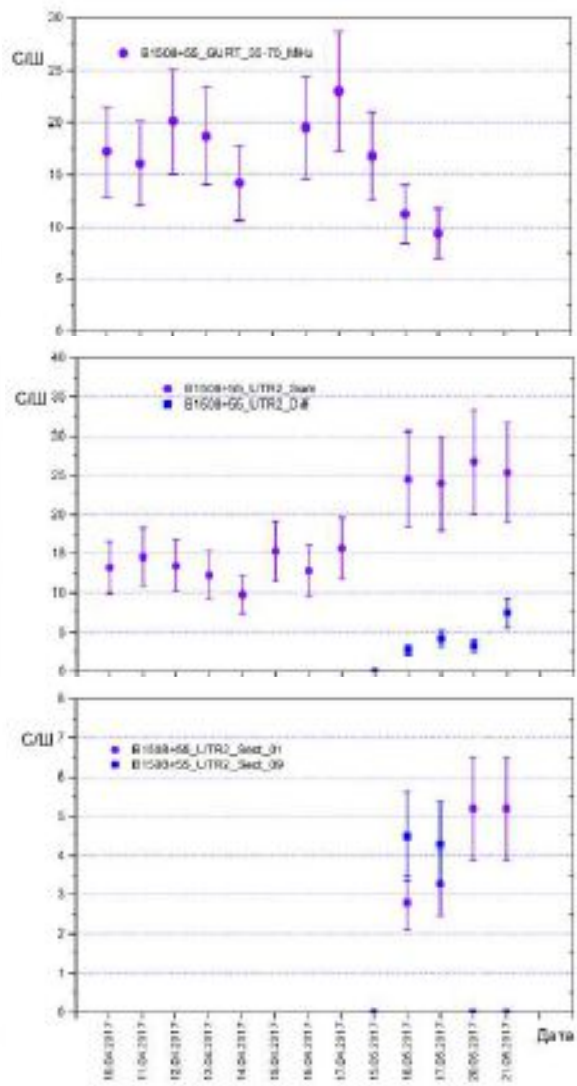
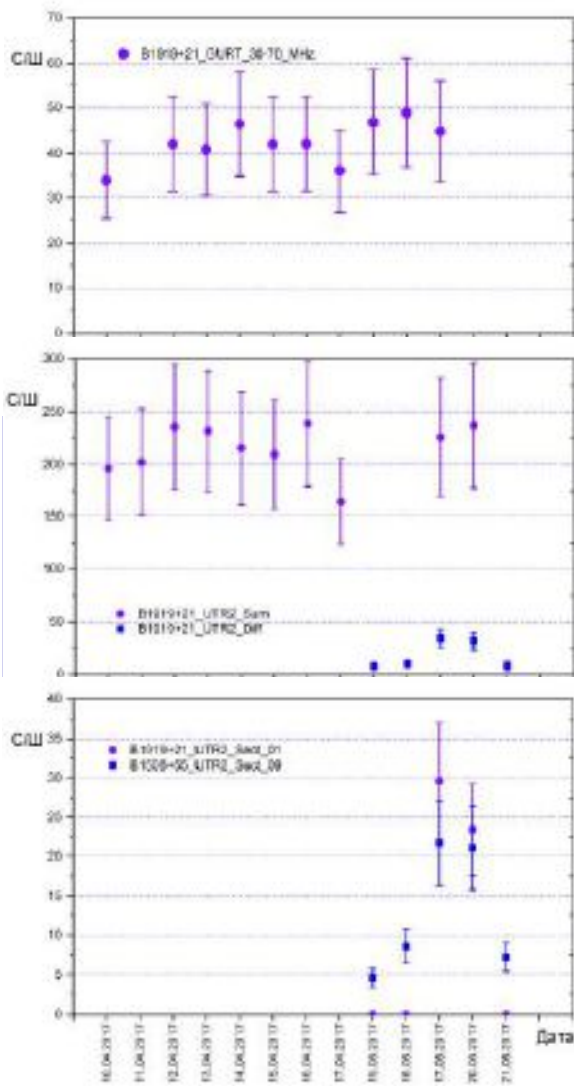
B1508+55

B1919+21

Субрешетка
ГУРТ

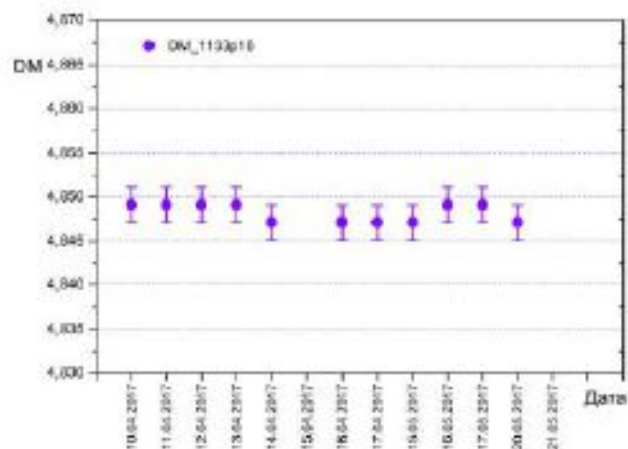
Радиотелескоп
УТР-2 (+ / -)

Секции УТР-2
(№1 и №9)

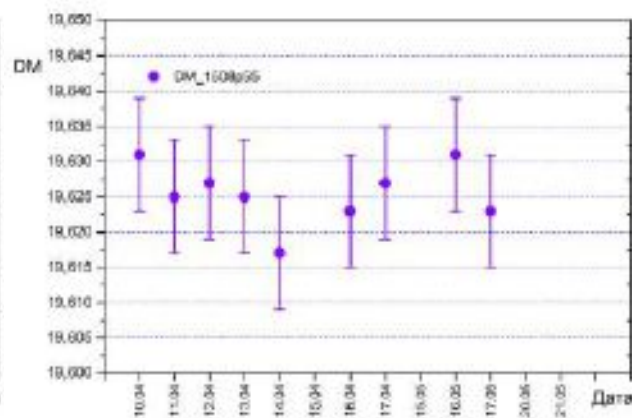


Определение меры дисперсии усредненных импульсов пульсаров с помощью УТР-2

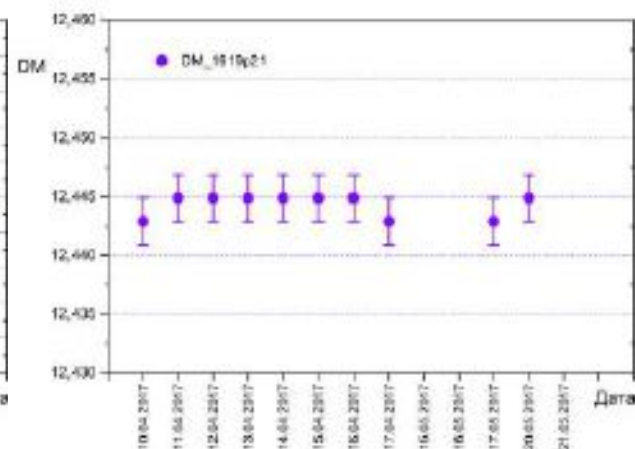
B1133+16

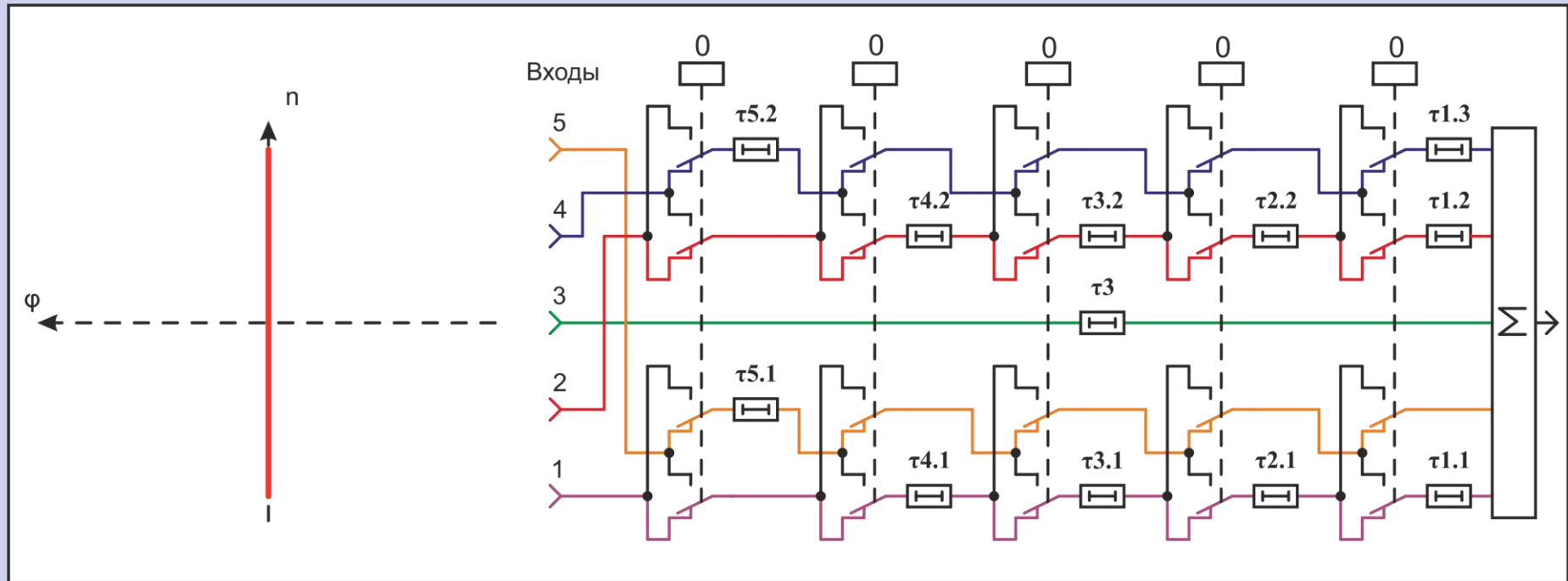


B1508+55



B1919+21



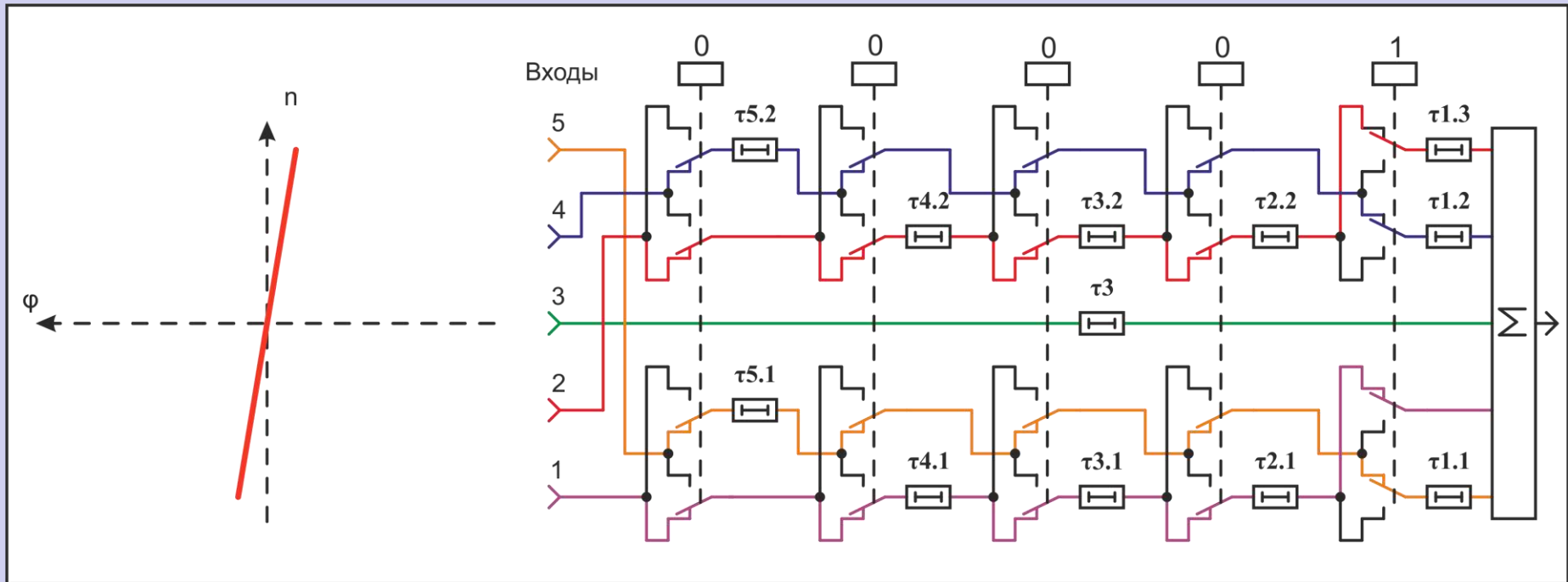


$$\Delta L_i = 0 \text{ m}$$

Control code:

00000

$$\theta_{0i} = 0^\circ$$

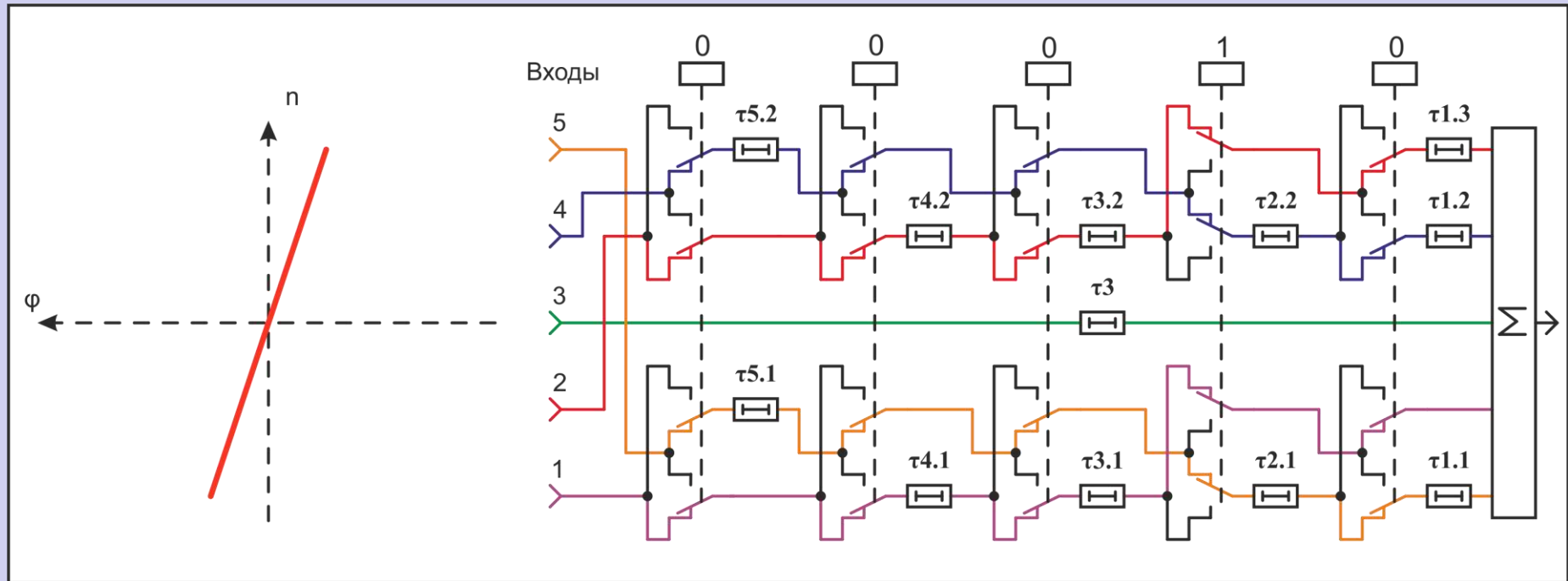


$$\Delta L_i = 0,3 \text{ m}$$

Control code :

00001

$$\theta_{0i} = 7^\circ$$

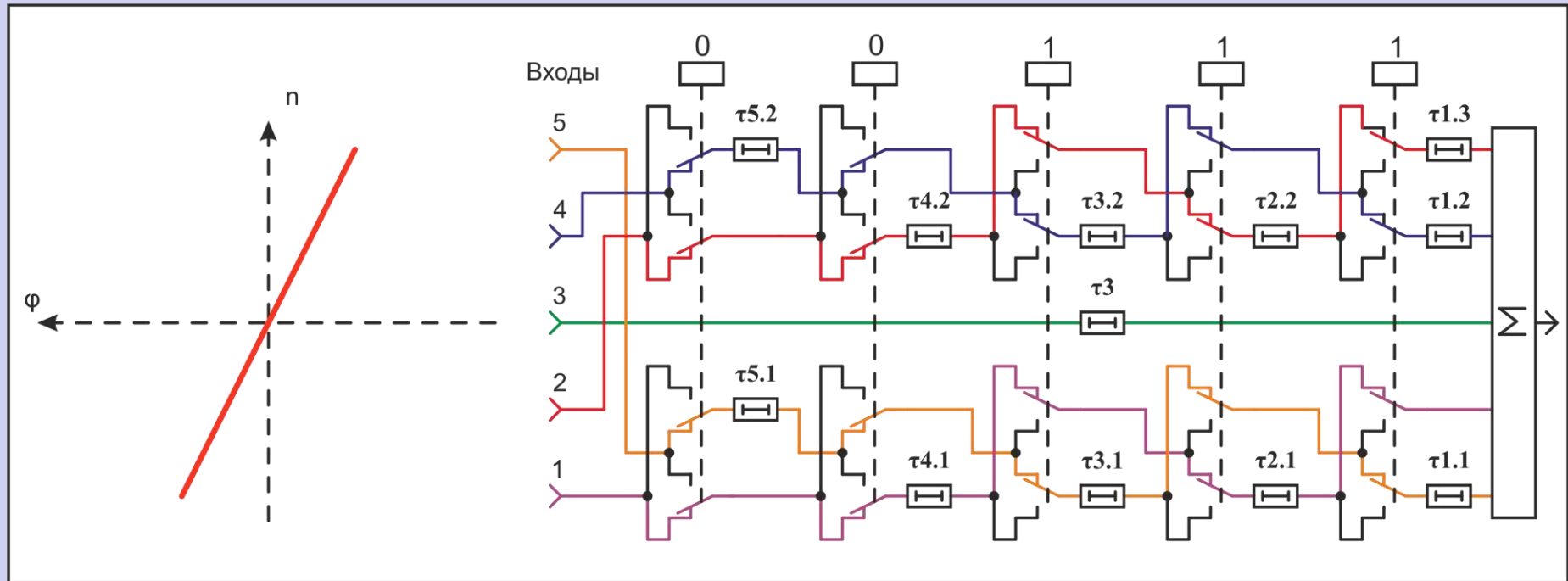


$$\Delta L_i = 0,6 \text{ m}$$

Control code :

00010

$$\theta_{0i} = 14^\circ$$

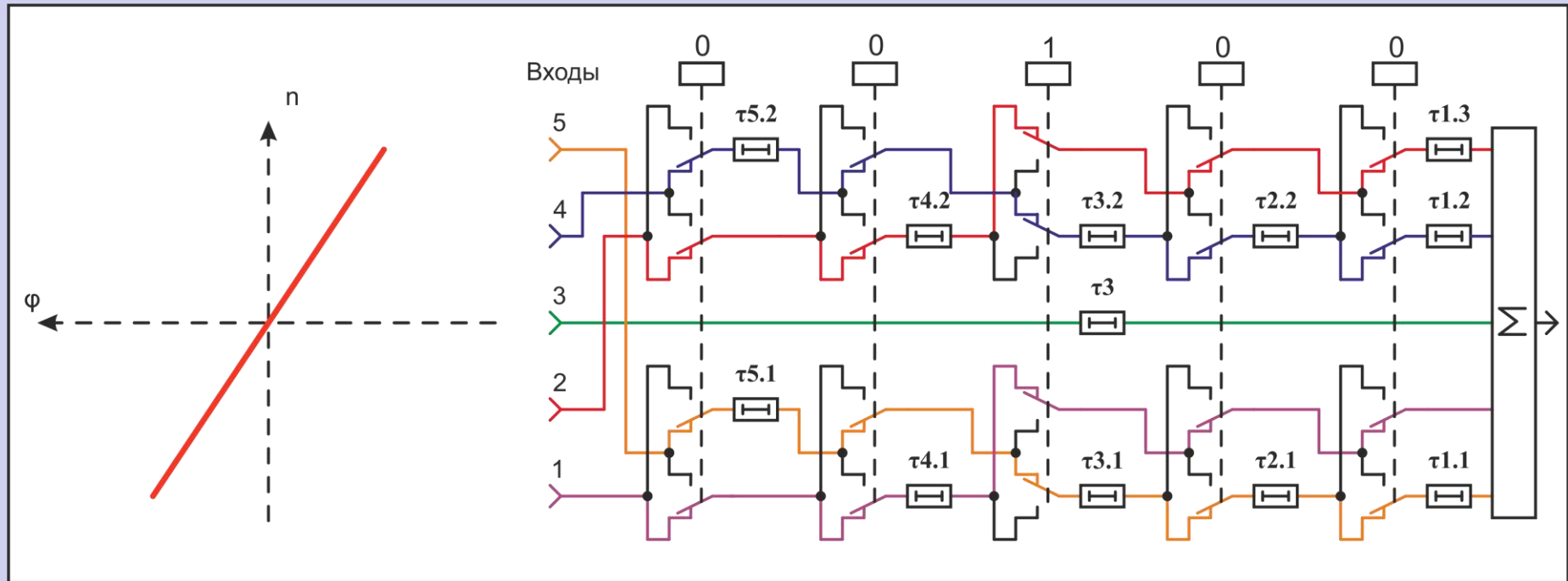


$$\Delta L_i = 0,9 \text{ m}$$

Control code :

00111

$$\theta_{0i} = 21,3^\circ$$

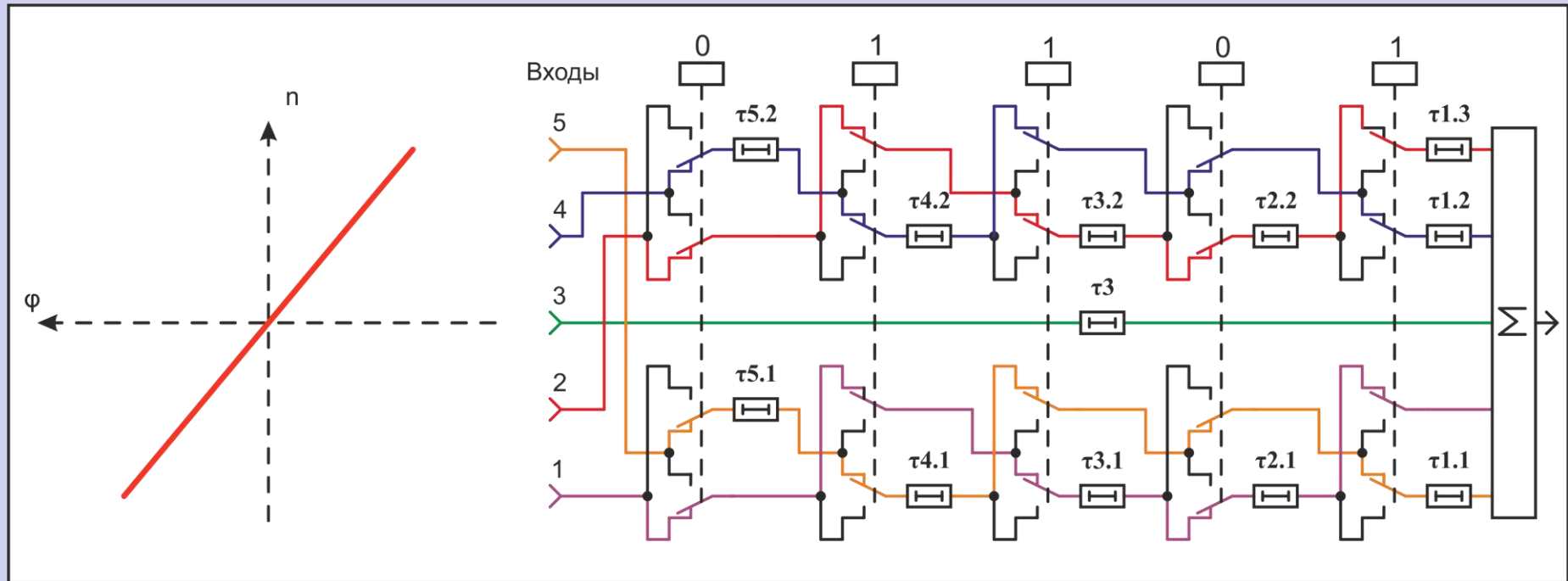


$$\Delta L_i = 1,2 \text{ m}$$

Control code :

00100

$$\theta_{0i} = 29^\circ$$

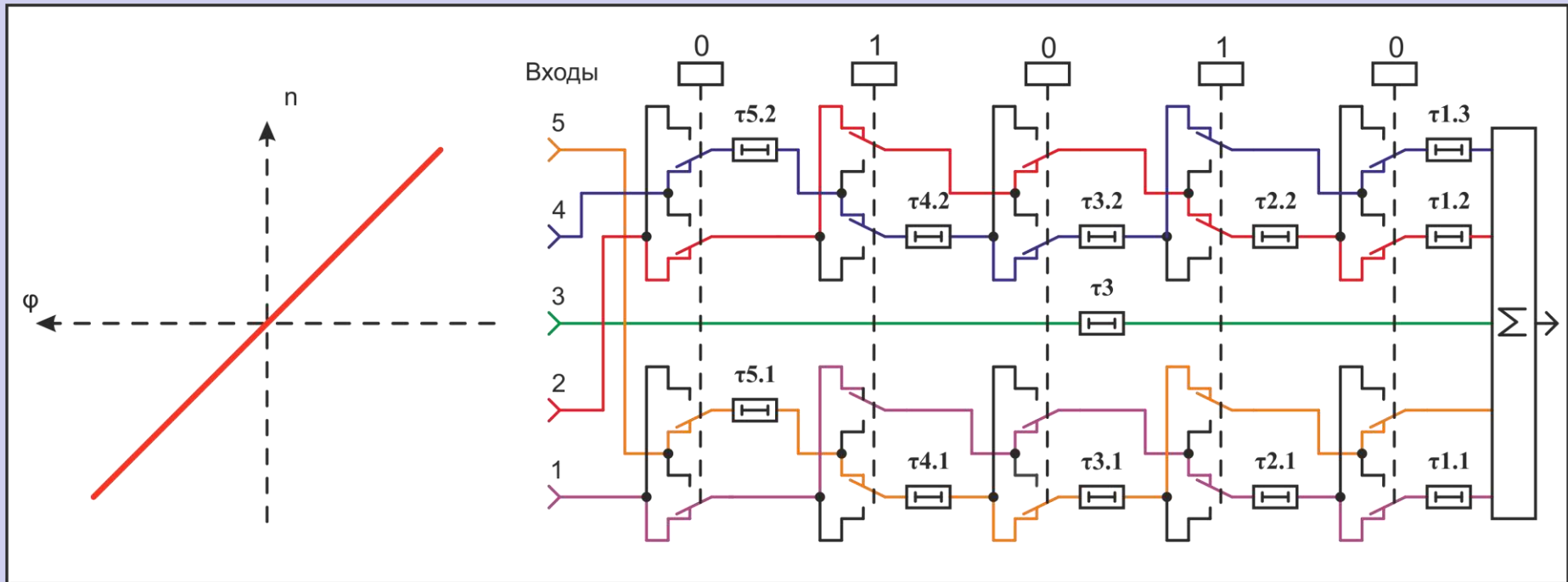


$$\Delta L_i = 1,5 \text{ m}$$

Control code :

01101

$$\theta_{0i} = 37,4^\circ$$

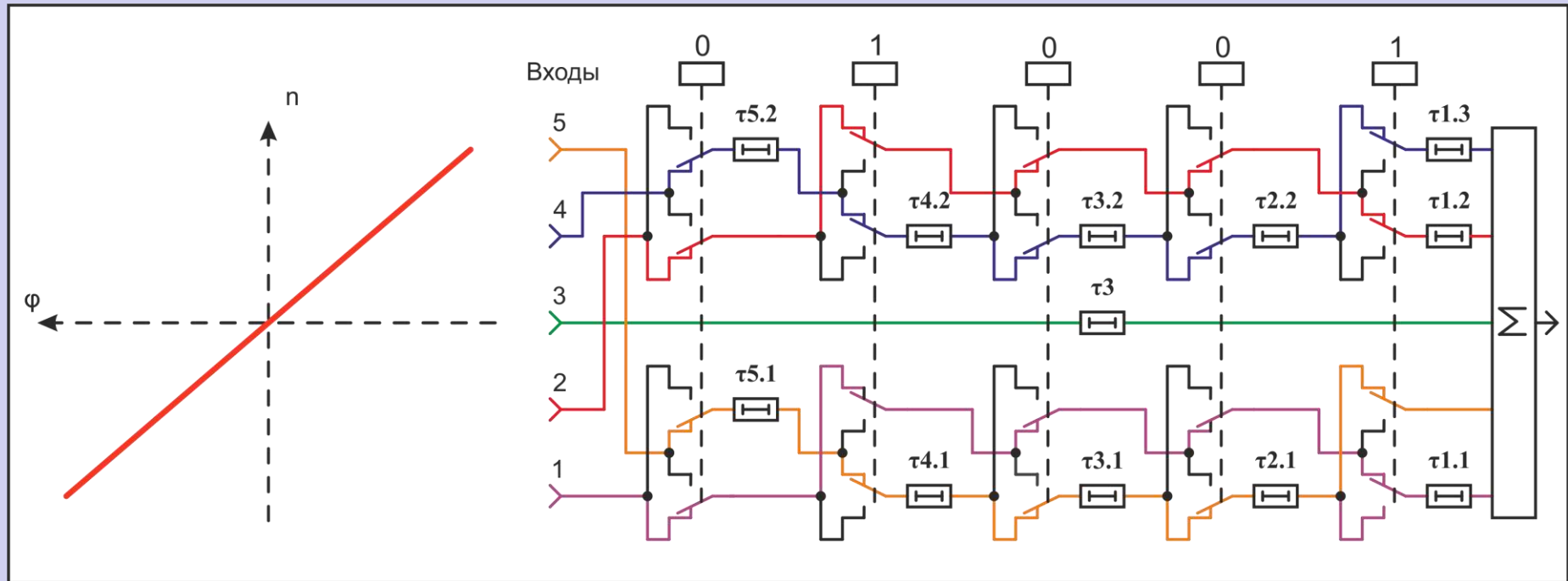


$$\Delta L_i = 1,8 \text{ m}$$

Control code :

01010

$$\theta_{0i} = 46,7^\circ$$

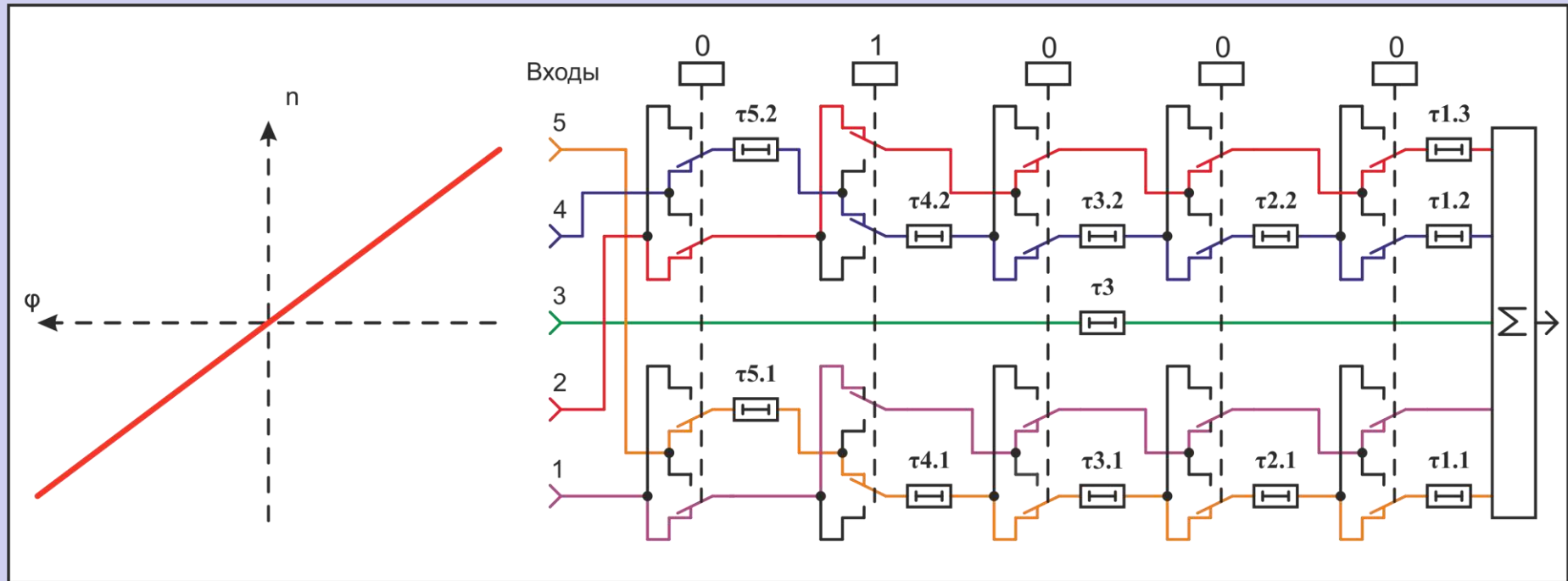


$$\Delta L_i = 2,1 \text{ m}$$

Control code :

01001

$$\theta_{0i} = 58,2^\circ$$



$$\Delta L_i = 2,4 \text{ m}$$

Control code :

01000

$$\theta_{0i} = 76,1^\circ$$

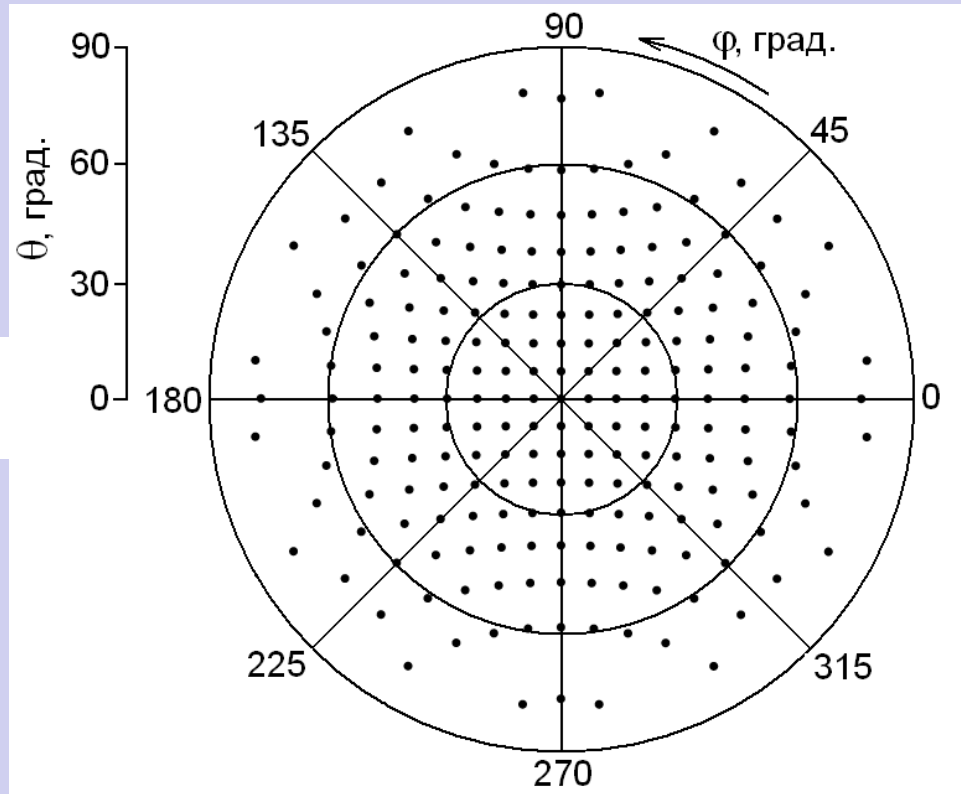
Углы фазирования секции ГУРТ

i	0	± 1	± 2	± 3	± 4	± 5	± 6	± 7	± 8
θ_{0i}	0°	$\pm 7^\circ$	$\pm 14^\circ$	$\pm 21,3^\circ$	$\pm 29^\circ$	$\pm 37,4^\circ$	$\pm 46,7^\circ$	$\pm 58,2^\circ$	$\pm 76,1^\circ$
Коды управления	00000	00001 10011	00010 10110	00111 10101	00100 11100	01101 11111	01010 11110	01001 11001	01000 11000
ΔL_i , м	0	0,3	0,6	0,9	1,2	1,5	1,8	2,1	2,4

$$L_{22} = 0,3 \text{ м}$$

$$\tau_{\min} = 1,518 \text{ нс}$$

Всего направлений фазирования в области реальных углов: **213**





GURT control system

Управление радиотелескопом GURT v15.6.22

Планирование Расписание Настройки Блок управления Каталоги Language/Язык Выход

Управление антенной выполняется
ОСТАНОВИТЬ

Начало **Окончание**

Версень 2015 г. **Версень 2015 г.**

Пн	Вт	Ср	Чт	Пт	Сб	Нд
31	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	1	2	3	4
5	6	7	8	9	10	11

18:00:00 18:30:00

Система координат
☒ Экваториальная ☐ Галактическая
Эпоха: ☒ 1950 ☐ 2000

Время
☒ UTC ☒ ДМВ ☐ Местное: UTC+3
17:08:47 Синхронизация: Таймер

Поляризация А
RA: 16:18:30
DEC: +28°0'
Z=22.61
U ☐ ☐ ☐ ☐ ☒ 1
V ☐ ☐ ☒ ☒ ☒ 7

Поляризация В
RA: 16:18:30
DEC: +28°0'
Z=22.61
U ☐ ☐ ☐ ☐ ☒ 1
V ☐ ☐ ☒ ☒ ☒ 7

Расписание **V-RA сканирование** **Сопровождение источника**
Слежение за Юпитером **Слежение за Солнцем**
Ручное управление **Контроль усилителей** **Слежение за Луной** **Топология**

Топология секций
Обновить состояние
Переключка

Поляризация А
00 20 04 00 00 00

Поляризация В

0 1 2 3

GURT New control system

Управление радиотелескопом GURT v15.6.22

Планирование
Расписание
Настройки
Блок управления
Каталоги
Language/Язык
Выход

Север

Восток

Юг

Закреть

Расписание

V-RA сканирование

Сопровождение источника

Слежение за Юпитером

Слежение за Солнцем

Ручное управление

Контроль усилителей

Слежение за Луной

Топология

☒ А
☒ В

Установить в зенит

Пошаговое изменение кодов

V к Северу

U к Востоку

U к Западу

V к Югу

Ручное управление

Открыть картинку

Ручное управление применять

☒ ко всем подключенным секциям телескопа
☐ к секциям открытой группы (ТОПОЛОГИЯ)
☐ к секции

5

☐ UTC
☒ ДМВ
☐ Местное: UTC+3

17:06:41

Синхронизация: Таймер

Поляризация А

RA: 16:16:24
DEC: +28°0'
Z=22.61

Поляризация В

RA: 16:16:24
DEC: +28°0'
Z=22.61

U

V

9

0

1

7

1

7



GURT control system

Управление радиотелескопом GURT v15.6.22

Планирование Расписание Настройки Блок управления Калогги Language/Язык Выход

Управление антенной выполняется
ОСТАНОВИТЬ

Начало **Окончание**

Вересень 2015 г. Вересень 2015 г.

Пн Вт Ср Чт Пт Сб Нд Пн Вт Ср Чт Пт Сб Нд

31 1 2 3 4 5 6 1 2 3 4 5 6

7 8 9 10 11 12 13 7 8 9 10 11 12 13

14 15 16 17 18 19 20 14 15 16 17 18 19 20

21 22 23 24 25 26 27 21 22 23 24 25 26 27

28 29 30 1 2 3 4 28 29 30 1 2 3 4

5 6 7 8 9 10 11 5 6 7 8 9 10 11

13:00:00 18:30:00

Система координат
☒ Экваториальная ☐ Галактическая
Эпоха ☒ 1950 ☐ 2000

Время
☐ UTC ☒ ДМВ ☐ Местное: UTC+3
17:10:13 Синхронизация: Таймер

Поляризация А
RA: 11:41:54
DEC: +4°27'
Z=78.63
U ☐ ☒ ☐ ☐ ☐ 8
V ☐ ☐ ☐ ☐ ☒ 1

Поляризация В
RA: 11:41:54
DEC: +4°27'
Z=78.63
U ☐ ☒ ☐ ☐ ☐ 8
V ☐ ☐ ☐ ☐ ☒ 1

Расписание **V-RA сканирование** **Сопровождение источника**

Слежение за Юпитером **Слежение за Солнцем**

Ручное управление **Контроль усилителей** **Слежение за Луной** **Топология**

09.25	17:06:00	H=	282	Z=78.3	x=+8	y=+1	U=08	V=01
09.25	17:08:00	H=	284	Z=78.7	x=+8	y=+1	U=08	V=01
09.25	17:10:00	H=	286	Z=79.0	x=+8	y=+1	U=08	V=01
09.25	17:12:00	H=	288	Z=79.3	x=+8	y=+1	U=08	V=01
09.25	17:14:00	H=	290	Z=79.6	x=+8	y=+1	U=08	V=01
09.25	17:16:00	H=	292	Z=79.9	x=+8	y=+1	U=08	V=01
09.25	17:18:00	H=	294	Z=80.2	x=+8	y=+1	U=08	V=01
09.25	17:20:00	H=	296	Z=80.6	x=+8	y=+1	U=08	V=01
09.25	17:22:00	H=	298	Z=80.9	x=+8	y=+1	U=08	V=01
09.25	17:24:00	H=	300	Z=81.2	x=+8	y=+1	U=08	V=01
09.25	17:26:00	H=	302	Z=81.5	x=+8	y=+1	U=08	V=01
09.25	17:28:00	H=	304	Z=81.8	x=+8	y=+1	U=08	V=01
09.25	17:30:00	H=	306	Z=82.1	x=+8	y=+1	U=08	V=01
09.25	17:32:00	H=	308	Z=82.4	x=+8	y=+1	U=08	V=01
09.25	17:34:00	H=	310	Z=82.8	x=+8	y=+1	U=08	V=01
09.25	17:36:00	H=	312	Z=83.1	x=+8	y=+1	U=08	V=01
09.25	17:38:00	H=	314	Z=83.4	x=+8	y=+1	U=08	V=01
09.25	17:40:00	H=	316	Z=83.7	x=+8	y=+1	U=08	V=01
09.25	17:42:00	H=	318	Z=84.0	x=+8	y=+1	U=08	V=01

Картинка

Комментировать

Отправить в блок управления

Сохранить .txt

Читать .txt

Количество свободных команд: 972

GURT receiving equipment



GURT Advanced Digital Receiver (ADR)

- Low noise level and low spurious signals level providing the high linear **dynamic range** ($\sim 120\text{dB}$)
- Maximal **ADC sampling frequency** – 160MHz
- Maximal input signal frequency – 180 MHz
- Permanent Absolute Time Synchronization of the output data with the ADC synchro pulse accuracy.
- Two modes of operation: **waveform** and **spectrometer**
- Storing of the **waveform** data from both channels (**650Mb/s at sampling rate 160MHz**) on the local data storing system during 4 hours.
- Controlled **signal digitizing relative delay in the range of 0 to $0.8\mu\text{s}$** (with 8 picoseconds step) between two input channels.
- Calculation of spectrograms in both channels and cross-spectrograms between channels
- **Averaging of the spectra and cross-spectra up to 32768 realizations** ($\sim 7\text{ s}$ at sampling rate 160MHz)
- **Network Client-Server architecture** of the high level software which allows the remote full control of the **ADR** and “on-the-fly” monitoring of the received signal.

GURT Advanced Digital Receiver (ADR)

Number of channels	2
Analog input bandwidth	180 MHz
Input impedance	50 Ohm
Input voltage	$\pm 1V$
ADC sampling frequency	20-160 MHz
ADC resolution	16 bits
ADC intrinsic dynamic range	75 dB
SFDR (spurious free dynamic range) (16384 samples per FFT)	112 dB
Intrinsic noise level (16384 samples per FFT)	-117 dB

FFT size	2048, 4096, 8192, 16384, and 32768
Output FFT samples resolution	32 bit
Speed of processing	4800 complex 32768 FFT per second
Count of averaged spectrums	16 - 32768
Selectable frequency band output	with step of 1024 samples
Maximal data rate (“ Waveform ” mode)	650 MB/sec
Maximal data rate (“ Spectrometer ” mode)	85 MB/sec

GURT Advanced Digital Receiver (ADR)

Parameters	DSPZ – UTR-2	ADR – GURT
Frequency band (MHz)	33	80
Number of freq. channels	8 192	16 384 (tunable)
Frequency resolution (kHz)	4	4,8
Time resolution (ms)	0,5	2
ADC resolution (bits)	16	16
Dynamic range (dB)	90	90
Input channels	2	2
On-line real-time possibilities		
Fast Fourier transform	yes	Yes
Wave-form (non limited resolutions)	yes	Yes
Auto- and complex cross-spectra	yes	Yes
Sum-Subtraction mode	no	Yes
Signals normalization	no	yes
Signals delay	no	yes