Si vis pacem for bellum

INSTRUCTIONS

anti-UAV calculations
(small special tactical group)

Kyiv, 2024

content

1. Introduction

UAV detection and countermeasures play an important role in ensuring the safety of the Ukrainian Armed Forces' advanced units, as well as artillery assets, equipment, and warehouses. In fact, UAV detection is a function of SIGINT (electronic reconnaissance), and UAV countermeasures are a function of EW (electronic warfare). Due to the lack of special military SIGINT/EW systems, soldiers must master the use of small-scale individual-use equipment.

 Use counter-UAV means in accordance with the plan and procedures developed in advance to minimize risks to personnel and other objects.

 It is important to remember that the use of portable counter-UAV means in In combat conditions, it can be dangerous and should only be carried out by experienced and professional specialists in compliance with all safety requirements.

 Always follow the manufacturer's instructions when using technical means of detecting and countering UAVs and, if necessary, seek help from specialists.

2. Anti-UAV calculation

 Individual counter-UAV means have significantly less effectiveness without the simultaneous use of UAV detection capabilities. In addition, the use of counter-UAV capabilities without proper training and coordination can harm friendly units.

The anti-UAV calculation must include at least:

1. UAV detection equipment operator (crew commander) - work with technical UAV detection equipment, coordinate crew actions, coordinate with neighboring units and the base, communications.
2. Operator of counter-UAV equipment - work with technical counter-UAV equipment.

Recommended composition of the anti-UAV crew:

1. UAV detection equipment operator (crew commander) - work with technical UAV detection equipment, coordinate crew actions, coordinate with neighboring units and the base, communications.
2. Operator of counter-UAV equipment - work with technical counter-UAV equipment.
3. Support group (2 fighters) - assistance in setting up positions, conducting surveillance, providing security and fire cover.
4. Driver (may be part of the support group).

All anti-UAV crew members must know the technical means and be able to use them to enable interchangeability.

In case of staffing restrictions, the anti-UAV crew may consist of one fighter who performs all actions independently and must have the appropriate skills to operate all equipment.

3. Technical support

The anti-UAV calculation uses the following technical means:

1. UAV detection means.
2. Counter-UAV means.
3. Communication means.
4. Power supply.
5. Means of orientation on the terrain.

3.1. UAV detection tools

The anti-UAV crew must use all available means and methods to detect air targets in the area of responsibility, such as:

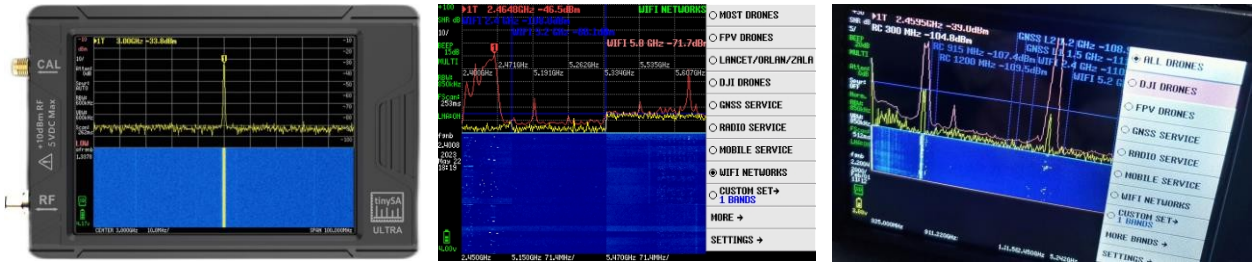
- Electronic RF drone detectors.
- Optical observation devices (binoculars, spotting scopes, PNB, etc.).
- Thermal imaging observation devices (monoculars, sights, etc.).
- Auditory control (sensory organs, active headphones, special microphones, etc.).
- Information from other sources, such as SIGINT, air defense and neighboring divisions.

For long-range and early detection of UAVs, electronic devices are used - drone detectors. Some modern industrial drone detectors independently (automatically) determine the manufacturer and type of UAVs and display its name on the display, in addition, they automatically report the detection of UAVs using sound and light signals. Such devices can be both stationary and portable, and have a fairly high cost.

Portable Industrial Drone Detectors for Industrial Use

Due to the lack of available portable industrial drone detectors, we produce homemade devices (drone detectors) that are based on the spectrum analyzer "tinySA Ultra" or "SA6". The spectrum analyzer "tinySA Ultra" has a special adapted firmware "REP UAV" for convenient and understandable use.

Portable DIY Drone Detectors Portable Drone Detectors

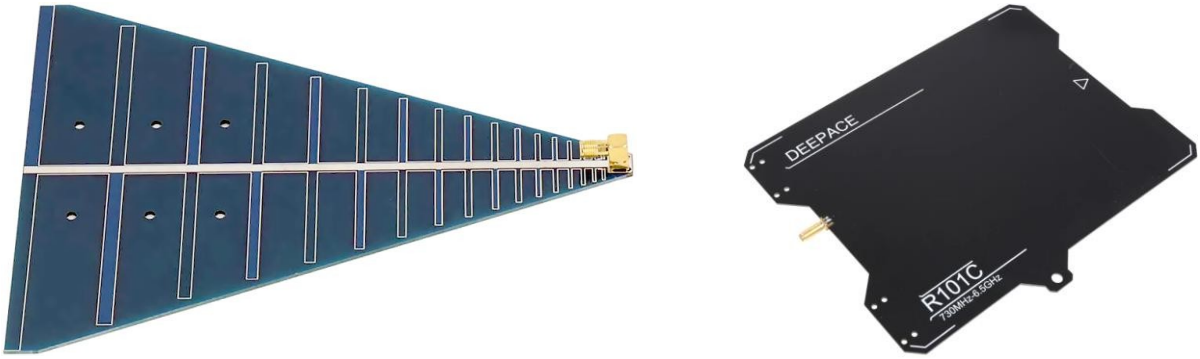


Spectrum analyzer "tinySA Ultra" with special firmware "REP UAV v2.5.2a"

All drone detectors, both industrial and homemade, can work with directional antennas to find the direction of the UAV or with non-directional ones for 360-degree circular monitoring.

Non-directional single-band whip antennas
(choose antennas with a swivel mount)

Non-directional all-band whip antennas omnidirectional



Directional all-band antennas (log-periodic "triangle" and horn)
"vivaldi")

Highly directional "wave channel" antennas ("yagi"), in the photo for the 2.4/5.8 ranges

8
GHz

3.2. Counter-UAV means

Counteraction to UAVs consists of jamming (suppressing) UAV radio frequencies (or rather, the frequency bands used by UAVs). Powerful transmitters with corresponding antennas are used for this purpose. UAV counteraction devices can be stationary, portable and mobile. In addition, due to different types of antennas, they can be of circular action (the so-called "dome EW") and directional (the so-called "anti-drone gun"). In turn, anti-drone guns also differ in design and appearance - long "space blasters" have a very narrow radiation angle (about 10 degrees) and require constant and careful "aiming", flat "shovel/iron/frying pan/patel-like" devices provide a wider radiation angle (30 ÷ 60 degrees) and can be used "in direction". In turn, emitters for different frequencies also have different radiation angles (the lower the frequency, the larger the radiation angle), below are approximate values for flat wide-angle anti-drone guns:

- 1.2/1.5 GHz - 60°÷120°
- 2.4 GHz - 30°÷40°
- 5.2/5.8 GHz - 20°÷30°

The total power of portable dome electronic warfare is approximately 100÷500 W, anti-drone guns - from 10 W to 150 W. Dome electronic warfare and anti-drone guns can have from one to nine jamming channels, some models have a built-in detector drones. In some models of anti-drone guns, for more effective jamming a certain range, two jamming units are installed, which operate in different polarizations - in order to The jamming was effective at any position of the UAV relative to the anti-drone gun antennas.

To be able to operate in different modes and for different tasks, counter-UAV devices usually have separate switches for each frequency range (jamming channel) - this saves battery power and reduces the risk of being detected.

The effective range of portable dome electronic warfare systems (which operate continuously and require a stable power supply) is 300÷2000 meters. Most anti-drone guns are effective at a distance of 1500÷2500 meters for control and video transmission signals and up to 1500 meters for navigation signals. In the case of operation in urban conditions, the effective range of counteraction to UAVs is sharply reduced due to obstacles in the form of urban infrastructure. Even tree branches dampen radiation - the higher the frequency, the more such interference affects.

Examples of portable dome electronic warfare systems with circular and sector (panel) antennas

Examples of targeted anti-drone guns

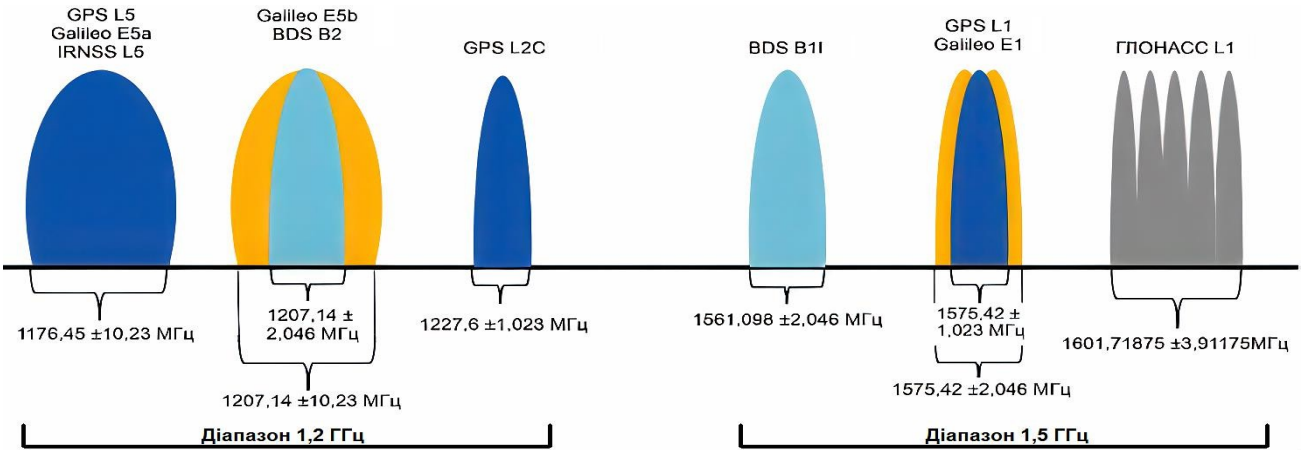
Examples of Wide-Antagonist Anti-Drone Guns

Typically, control frequencies, video transmission frequencies, and frequencies of satellite navigation systems (GNSS - Global Navigation Satellite System) are jammed. In turn, jamming of satellite navigation involves blocking the reception of GNSS signals from all known operators, since blocking one or more GNSS operators may be ineffective.

The list of frequency bands that some UAVs use and that need to be jammed is given in the table (if one frequency is given, it is the central frequency of the frequency band).

UAV model	Control, MHz(bandwidth, MHz)	Telemetry, MHz (bandwidth, MHz)	Video, MHz (strip, MHz)	Navigation, MHz
Hall 421 Lancet Merlin	433÷435	863÷873 (0.21) 902÷928 (0.21)	1100÷1250 (5) 2160÷2450 (5) 2520÷2550 (5)	1561 1575 1596÷1608
Orlan	200÷450	863÷928 (band 2, 4; signal 0.1, 0.2, 0.25, 0.4)	1080÷1300 (10, 14)	CRPA Comet
Orlan M		960÷1050 (2, 4)	2300÷2700 (2, 4, 8, 16, 32)	CRPA Comet
Supercam (10 bands of 150 kHz, total band 5 MHz)		837÷887 (5) 860÷917 (5) 970÷975 (5) 1004÷1020 (5)	976.5÷1222.5 (8) 1296÷1302 (8) 1365÷1375 (8) 1383÷1390 (8)	1572,42 1575,42 1602
Supercam (2 bands of 4 MHz)		1015÷1120 (4+4) 1124÷1132 (4+4) 1110÷1387 (4+4)	976.5÷1222.5 (8) 1296÷1302 (8) 1383÷1400 (8)	1572,42 1575,42 1602
Aileron (10 bands of 150 kHz, total bandwidth 5 MHz)	860÷1020 (5)	860÷1020 (5)	976.5÷1222.5	1572,42 1575,42 1602
Orion		890÷920 (1)		1572,42 1575,42 1602
pomegranate		915÷928 (12.5)		1572,42 1575,42 1602
Tachyon		915÷920 (5)		1572,42 1575,42 1602
FPV	400 ÷450 700÷1050 868 (26) - standard frequency 915 (26) - standard frequency 1100÷1300 2400÷2585		1080÷1320 (26) 2400÷2500 (26) 4900 (26) 5700÷5900 (26)	
DJI	2400÷2585 (20) 5150÷5300 (20) 5725÷5850 (20)			1500 (1550÷1620)
Autel	2400÷2585 (20, 40) 5150÷5300 (20, 40) 5725÷5850 (20, 40)			1500 (1550÷1620)
Autel EVO MAX 4T	850÷940 (20, 40) 2400÷2483 (20, 40) 5150÷5250 (20, 40) 5725÷5850 (20, 40)			1200 (1170÷1260) 1500 (1550÷1620)
Satellite military navigation range (GNSS L2)				1200 (1170÷1260) 1227.6 +/-12

Satellite navigation civil range (GNSS L1)				1500 (1550÷1620) 1575.42 +/-12



Frequency ranges of satellite navigation system (GNSS) operators

3.3. Power supply means

In field conditions, there is often no access to power supply, so to ensure long-term and uninterrupted operation of UAV countermeasures, it is necessary to have additional power sources. Such sources may be:

- Portable generators220 V.
- Car sockets12 V.
- Charging stations.
- Solar panels.
- Inverters.
- Additional battery packs.
- Power banks.

Please note that if you have an additional external battery anti-drone gun unit, it needs to be connected to the power/charge portbefore starting work If you connect an additional external battery when the built-in battery is discharged, the capacity of the additional external battery will be used not only to operate the device, but also to charge the built-in battery, and the output current of the additional external battery may become excessively large, which may damage the power connector and wires, as well as overheat both the built-in and additional external battery.

Some models of anti-drone guns have removable batteries, so the built-in battery is replaced with an additional fresh one - as is done with radio stations.

3.4. Communication means

Communication is provided by using personal radio stations. The anti-UAV crew uses communication for the following purposes:

1. Communication with adjacent units to receive and/or transmit messages about threats from the sky.
2. Communication with neighboring units to receive messages about the launch of their UAVs.
3. Interaction within the calculation and communication with the base regarding movements between positions, transportation of equipment, delivery of batteries, etc.

3.5. Orientation aids

The key to successfully completing any task is the availability of navigation tools and the ability to use them.

Each anti-UAV crew member must have a compass and a smartphone with installed mapping software (Delta, Nettle, MilChat, Bronya, KomBat, Alpine Quest, etc.).

Special software allows for preliminary reconnaissance of the area before entering the position, planning the routes of the crew, assembly points and shelters for vehicles, placing or loading the necessary objects and marks on the map.

3.6. Equipment check

Having a certain equipment, it is necessary to know its technical characteristics and, more importantly, its real capabilities.

For UAV detection tools, you need to know the following:

- Range (distance and/or altitude) of detection of certain types of UAVs drone detector.
- Distance (distance and/or height) of identification of certain types UAV drone detector.
- Range (distance and/or altitude) of detection of certain types of UAVs means of acoustic observation (sensory organs, active headphones, special directional microphones, microphone arrays, etc.).
- Distance (distance and/or height) of identification of certain types UAVs using acoustic surveillance equipment (sensory organs, active headphones, special directional microphones, microphone arrays, etc.).
- Range (distance and/or altitude) of detection of certain types of UAVs optical observation means (binoculars, spotting scopes, etc.).
- Distance (distance and/or height) of identification of certain types UAVs with optical observation equipment (binoculars, spotting scopes, etc.).
- Range (distance and/or altitude) of detection of certain types of UAVs thermal imaging surveillance equipment (monoculars, sights, etc.).
- Distance (distance and/or height) of identification of certain types UAVs with thermal imaging surveillance equipment (monoculars, sights, etc.).
- Accuracy of direction determination for certain types of UAVs

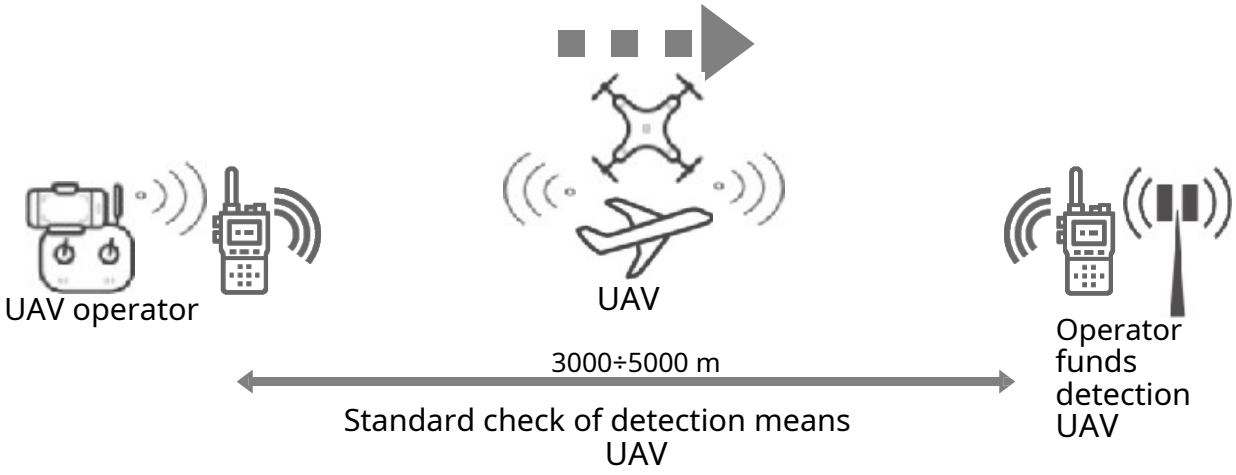
in various ways. For counter-UAV means, it is necessary to know the following:

- Maximum range (distance and/or height) of effective jamming certain types of UAVs.
- Operating time of UAV countermeasures on the built-in battery with different loads (with different numbers of switched-on jamming channels).
- Timeoperation of UAV countermeasures with an additional external battery connected with different loads (with a different number of jamming channels enabled).
- Operating time of UAV countermeasures before noticeable heating occurs equipment.
- The effect of radiation from an anti-drone gun or electronic warfare "dome" on electronic devices at different distances and directions relative to the UAV countermeasure equipment.

To test the equipment, it is necessary to position the test participants (UAV, UAV operator (control panel), UAV detection equipment operator, UAV countermeasure equipment operator, observer(s)) appropriately.

3.6.1. Testing UAV detection equipment

Option 1.



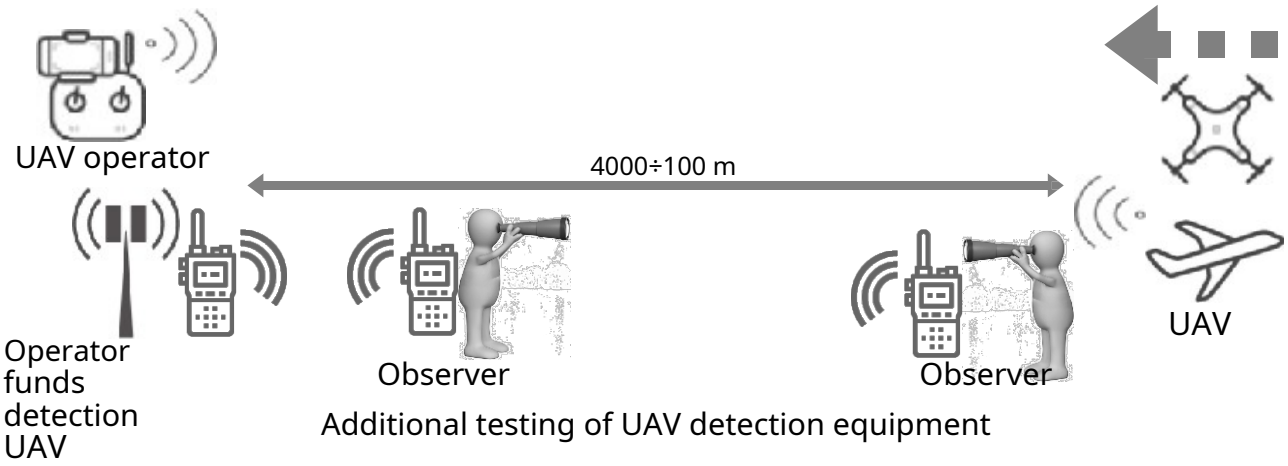
1) The UAV detection equipment operator is located at a distance of 3000÷5000 meters from the UAV operator and communicates with him via radio.
2) The UAV operator launches the UAV at an altitude of 100 meters and sends it towards the location of the detection equipment operator. There should be no obstacles in the form of hills and/or vegetation between the UAV and the UAV operator. The UAV should be in the direct line of sight of the UAV operator.
3) The UAV detection equipment operator switches on his device and scans the frequency range(s) on which the UAV operates and records the presence or absence of signals. The optimal direction and polarization of the antenna are selected.
4) The UAV operator periodically reports the distance from the UAV to himself via radio.
5) As the UAV approaches, the UAV detection device should display a signal from the UAV and gradually increase.
6) After the UAV detection equipment operator confirms that a stable signal has been received and that the UAV can be identified, the UAV operator returns the UAV to the take-off point.

Repeat the procedure for different UAV altitude values.

This test is performed with all available UAVs - both quadcopter and fixed-wing types. The maximum range (distance and/or altitude) of detection and identification of certain UAV types is recorded for the UAV detection device under test.

In the same way, the detection range of various types and models of UAVs is checked using acoustic, optical and thermal imaging surveillance equipment.

Option 2.



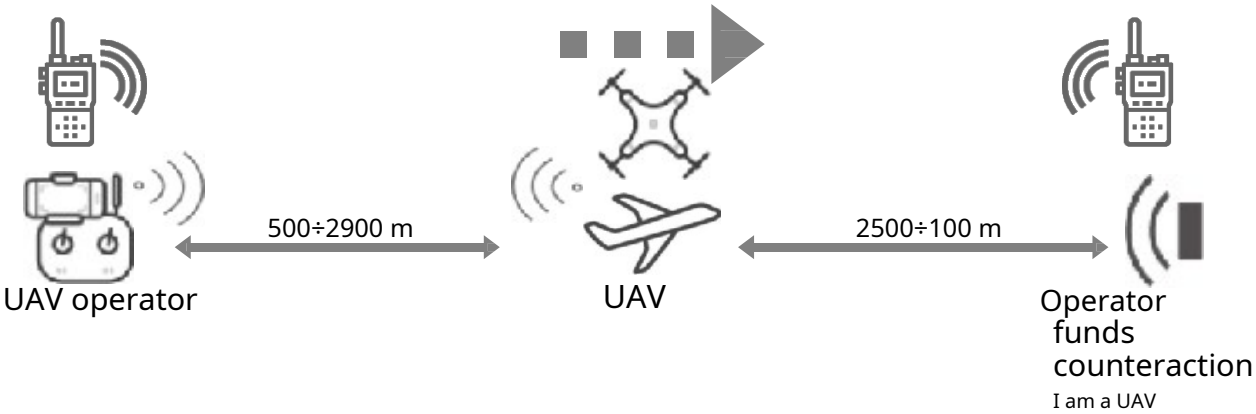
Additional testing of UAV detection equipment

1) The UAV detection equipment operator is located together with the UAV operator.
2) The UAV operator sets the UAV's return altitude to 100 meters and sets the return-to-home mode upon loss of control signal, launches the UAV at an altitude of 100 meters and sends it to a distance of 4,000 meters from himself. There should be no obstacles in the form of hills and/or vegetation between the UAV and the UAV operator. The UAV must be in the direct line of sight of the UAV operator.
3) The UAV operator turns off his control panel, and the UAV begins to move to the take-off point.
4) The UAV detection equipment operator switches on his device and scans the frequency range(s) on which the UAV operates and records the presence or absence of signals. The optimal direction and polarization of the antenna are selected.
5) The observer(s) periodically transmit via radio the position of the UAV (distance to the operator of the UAV detection equipment) according to previously studied landmarks.
6) As the UAV approaches, the UAV detection device should display a signal from the UAV and gradually increase.
7) After the UAV returns to the take-off site, the UAV operator turns on his control panel and safely lands the UAV.

Repeat the procedure for different UAV return altitudes. This test is performed with all available UAVs, both quadcopter and fixed-wing types. The maximum range (distance and/or altitude) of detection and identification of specific UAV types is recorded for the UAV detection device under test.

In the same way, the detection and identification range of various types and models of UAVs is checked using acoustic, optical and thermal imaging surveillance equipment.

3.6.2. Testing UAV countermeasures Option 1.

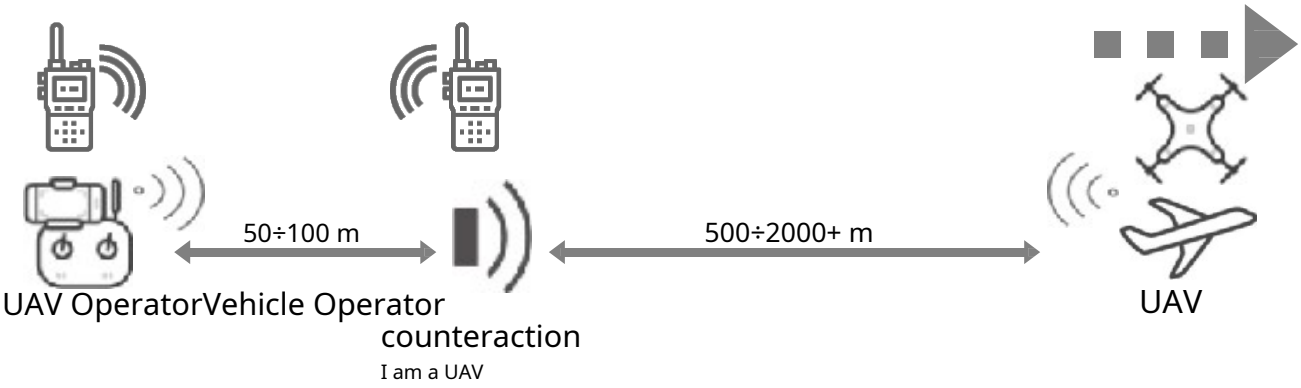


Standard check of counter-UAV means

1) The counter-UAV operator is located at a distance of 3000 meters from the UAV operator and communicates with him via radio.
2) The UAV operator launches the UAV at an altitude of 100÷200 meters and sends it to a distance of 500 meters from himself. There should be no obstacles in the form of hills and/or vegetation between the UAV and the UAV operator. The UAV should be in the direct line of sight of the UAV operator.
3) The operator of the counter-UAV means turns on the jamming of satellite navigation signals and informs the UAV operator about this.
4) The UAV operator reports whether the UAV's satellites have disappeared.
5) The operator of the UAV countermeasures system switches off the jamming of satellite navigation signals and informs the UAV operator about this.
6) The operator of the UAV countermeasures system switches on the jamming of the UAV control signals and informs the UAV operator about this.
7) The UAV operator reports whether the UAV control has been lost.
8) The operator of the UAV countermeasures system turns off the jamming of the UAV control signals and informs the UAV operator about this.
9) Points 2÷8 are repeated with an increase in the distance between the UAV and the UAV operator, for example, 1000, 1500, 2000, 2500, 2900 meters.

Such a test is performed with all available UAVs - both quadcopter and fixed-wing types. The maximum range (distance and/or altitude) of effective jamming of certain types of UAVs (separately for navigation signals and for control signals) is recorded for the UAV countermeasure being tested.

Option 2.



Additional testing of counter-UAV equipment

1) The operator of the counter-UAV means is located in front of the UAV operator at a distance of 50-100 meters and communicates with him via radio.
2) The UAV operator launches the UAV at an altitude of 100÷200 meters and sends it to a distance of 500 meters from the UAV countermeasures operator. There should be no obstacles in the form of hills and/or vegetation between the UAV and the UAV operator. The UAV should be in the direct line of sight of the UAV operator.
3) The operator of the counter-UAV means turns on the jamming of satellite navigation signals and informs the UAV operator about this.
4) The UAV operator reports whether the UAV's satellites have disappeared.
5) The operator of the UAV countermeasures system switches off the jamming of satellite navigation signals and informs the UAV operator about this.
6) The operator of the UAV countermeasures system switches on the jamming of the UAV control signals and informs the UAV operator about this.
7) The UAV operator reports whether the UAV control has been lost.
8) The operator of the UAV countermeasures system turns off the jamming of the UAV control signals and informs the UAV operator about this.
9) Points 2÷8 are repeated with an increase in the distance between the UAV and the operator of the counter-UAV means, for example, 1000, 1500, 2000 meters.

Such a test is performed with all available UAVs - both quadcopter and fixed-wing types. The maximum range (distance and/or altitude) of effective jamming of certain types of UAVs (separately for navigation signals and for control signals) is recorded for the UAV countermeasure being tested.

4. Security measures

The anti-UAV crew is forced to work in close proximity to the contact line, so it is always necessary to adhere to priorities, namely:

Priority #1: Ensuring the safety of fighters - use of all available personal protective equipment, covert movement, arrangement of several work places (positions), camouflage, reliable cover for each other, development of approach/retreat routes, etc.

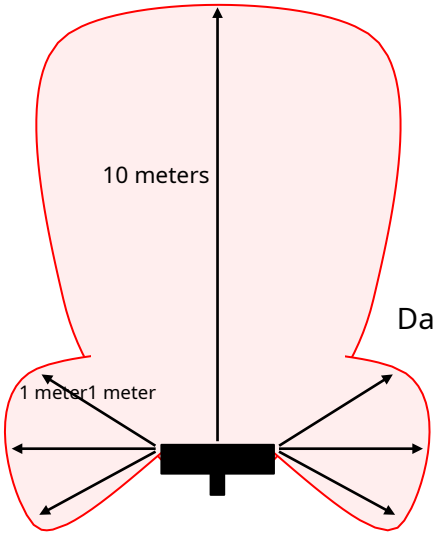
Priority #2: Task Completion - competent planning and strict adherence to commands and operational procedures.

Priority #3: Preserving Equipment - careful and safe handling of technical equipment.

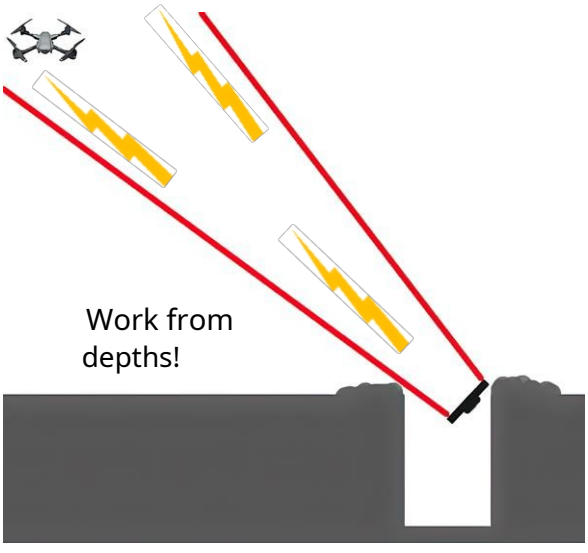
Given the specific nature of the work, one should always be aware of the dangers that lie in wait for such a special unit. Counter-UAV means emit a very powerful signal that can be seen many kilometers away, so when using counter-UAV means, it is necessary to adhere to the following rules:

- Do not point the switched-on UAV countermeasure device with its antenna at people, animals and electronic equipment from a distance of less than 5 meters - possible harm to health and damage to equipment For a powerful dome electronic warfare system, the dangerous distance can be 10 meters or more.
- Do not place the switched-on "frying pan" type counter-UAV device front part on the surface and do not lean it against the surface - damage to the electronic circuits is possible.
- Do not operate the counter-UAV device from open areas terrain, from hills and buildings - there is a high risk of being detected. Work from depressions (trenches, trenches) or hiding behind the terrain and buildings.

- Do not allow the device battery level to become critically low counteracting UAVs (less than 10%).
- Do not allow the device body and components to become significantly hot. counteracting UAVs.
- Do not place or carryeven switched off electronic devices detection and counteraction of UAVs near electronic warfare systems, radars and other emitting devices - irreversible damage to the electronic circuits of UAV detection and counteraction devices is possible.
- Do not activate counter-UAV devices unless necessary - additional risk of being detected. Use counter-UAV devices only when necessary and only in accordance with the task - this way you will extend the life of the devices and the personnel of the anti-UAV crew.



Danger zone!



Hazardous radiation zone of the UAV countermeasure device (panel antenna)

Minimizing visibility works countermeasure devices UAV

5. Operational procedures 5.1. Preparatory part 5.1.1. Receiving the task

The task is assigned by the unit commander, to whom the anti-UAV crew is assigned (subordinated).

5.1.2. Planning the execution of the task

The crew commander, having received the BR, plans the execution of the task and communicates it to all the crew members and to the unit commander.

A map of the area of the crew's work area is loaded onto smartphones or tablets, showing the location of the crew's positions, directions of work, potential targets, and the location of enemy and friendly units.

5.1.3. Preparation and testing of technical equipment

Having information about the task, the calculation prepares and checks the technical means that will be used to complete the task.

Considering that most technical means of calculating anti-UAVs are energy-dependent, first of all, the state of the power elements of all components is checked, including personal smartphones and tablets.

If it is impossible to use certain technical equipment due to damage, they are sent for repair, which is reported to the crew commander.

The integrity of technical equipment, as well as the condition of transport containers, suitcases, backpacks, etc., is checked.

5.1.4. Selection and arrangement of positions

Before moving to a position, it is necessary to conduct a thorough reconnaissance of the terrain in order to select a location that will provide maximum coverage of the area of responsibility. The calculation must take into account the terrain, the presence of shelters, the height and visibility of the position, the accessibility of the position for the approach and exit of equipment. It is necessary to ensure safety when moving to the position in order to avoid detection by the enemy.

When choosing positions, it is necessary to take into account many factors, including the capabilities of the available technical means of detecting and countering UAVs. This is mainly the real, not hypothetical, detection distance of UAVs and the effective suppression distance of UAVs.

The conditions and circumstances of choosing positions may differ due to the specifics of the direction or other input factors. Accordingly, when choosing a position, you need to consider:

1. Inspection and work sectors.
2. What tools will you use to work?
3. What and at what heights/distances/directions can you detect and organize counteraction taking into account the terrain, relief, buildings, vegetation, etc.
4. Where could the shelling come from?
5. Where are the reliable shelters located, where you can take cover if necessary.
6. Where to hide/leave equipment and vehicles.
7. Routes and sequence of emergency retreat in case of unexpected deterioration of the combat situation.

The arrangement of positions should take place before any active work of the crew in this area. The arrangement of positions involves the use or creation of temporary shelters and their camouflage. It should be especially borne in mind that the equipment for countering UAVs can noticeably heat up and can be visible in a thermal imager from a large distance both from the ground and from the air, so it is necessary to take measures for heat shielding of such equipment. Similarly, it is necessary to take care of similar camouflage of vehicles, the engine and wheels of which will be warm for a long time after stopping, even in winter.

When working in populated areas with multi-story buildings, it is better to use dominant heights if sufficient working range is required. But it should be remembered that dominant heights are an easy and well-aimed target for the enemy, so it is necessary to prepare shelters and escape routes more carefully.

If you need to work from buildings, you need to constantly change your location - this will reduce the risk of being detected by radio emissions, but you need to be careful when moving so that you are not visible visually, and there is also a risk of being hit by numerous debris from shells hitting buildings.

Working in pairs, the UAV detection operator and the UAV countermeasure operator are located at a distance of at least ten meters along the front from each other. This is due to two factors: ensuring the survival of the unit during shelling and the impossibility of operating a sensitive drone detector near the powerful radiation of UAV countermeasures.

5.1.5. Camouflage

When setting up a position, the crew must take into account the requirements of camouflage in order to minimize the possibility of detection by the enemy. It is important to ensure protection from aerial observation, for example, by using natural shelters, forest belts, houses or canopies, which in turn should not block the sectors of operation of UAV countermeasures. It is also necessary to ensure careful camouflage of equipment and machinery, using camouflage means, for example, camouflage nets, leaves, snow, branches, etc.

Camouflage must be prepared and applied in accordance with local conditions. The crew must check the camouflage of the position from different directions and from heights to ensure the effectiveness of the camouflage. In addition, camouflage must be constantly maintained and updated in accordance with changes in the environment.

 **Important! Never openly display an anti-gun, no matter what color or shape it is! Always carry a camouflage net cape and cover yourself and the anti-drone gun! When using FPV drones and "bombers", the enemy can use the tactic of remotely observing the decoy drone. Accordingly, if you jam the decoy drone, another drone observer can "draw" you and transmit your coordinates for destruction with available means. Therefore, always assume that the enemy sees you and always camouflage yourself - both from visual observation and from observation using thermal imaging cameras**

5.1.6. Organization of communication

To establish communication with neighboring units, the crew commander or free fighters of the support group establish communication with other units located in the area of operation of UAV detection and countermeasures, and connect to their radio networks - receive radio stations or register their communication channels in their radio stations, and also exchange radio call signs. The main thing here is timely mutual information.

Interaction within the crew occurs using all means that can be used in the current conditions - voice communications, gesture or light signs, radio communications, mobile communications, and the like.

 Nothing like "Bird in the Sky" should ever be played on the radio. "Wingon 12", "Our copter", "Working", etc. Whatever connection is used, the use of the coding table should become a habit. The table should be constantly updated.
This is the responsibility of the crew commander.

 Any message must be conveyed with the understanding that it may be heard an enemy whose goal is to find and kill. Don't make it easy for him. Always remember - the enemy is listening.

5.2. Completing the task

After moving to a given point, the crew immediately begins to detect the UAV, simultaneously setting up positions and installing equipment. At any time, the crew

must be ready to perform the task of countering UAVs. At this stage, it is necessary to ensure constant monitoring of the airspace in the area of responsibility by all fighters of the calculation, using all available means: drone detectors, acoustic, optical, night and thermal imaging surveillance equipment.

5.2.1. UAV detection

Depending on the equipment configuration and the task at hand, the UAV detection operator can either conduct periodic monitoring of UAV frequencies, leaving cover for this purpose, or continuously work to detect and/or track UAVs.

Important! Monitoring the area for the purpose of detecting UAVs is necessary not only in the direction of the enemy, but also in all directions, including its rear and upper hemisphere. This is due to the enemy's tactics of attacking from different directions. Modern tactics of using loitering munitions also provide for an attack vertically from above to reduce the visibility of the UAV's approach.

All crew members work to detect UAVs, using their senses and available technical means (radio frequency, acoustic, optical, thermal imaging devices, etc.).

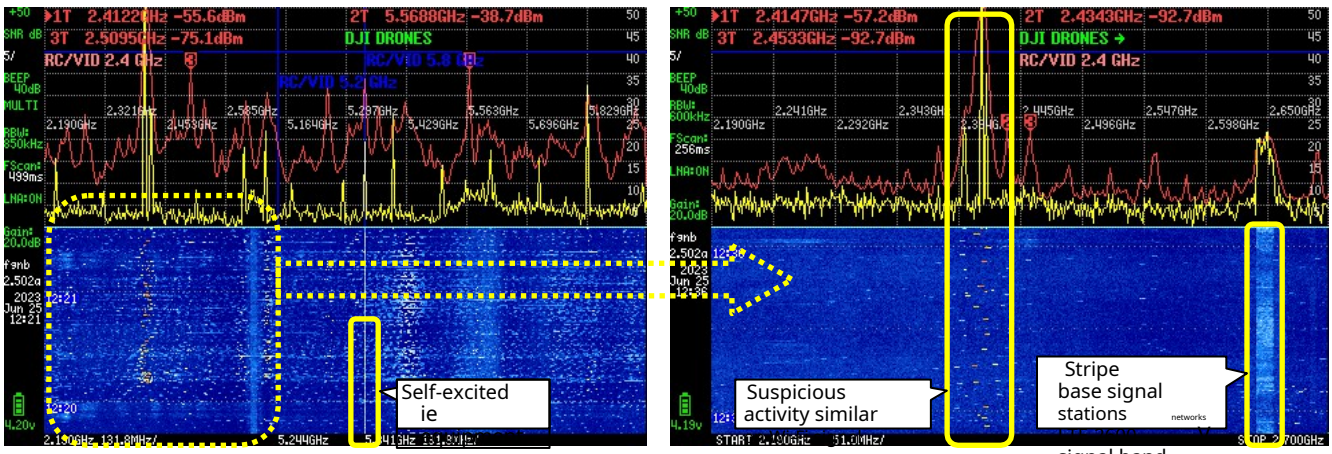
The UAV detection operator coordinates the detection of aerial targets, identifies and tracks them, communicates with adjacent units and, if necessary, provides guidance to the UAV countermeasure operator.

Considering that most UAVs use radio communication with their operator, it is easier to detect a UAV by its radio emission than visually or by sound, so do not wait for the characteristic buzzing, but immediately start monitoring with a drone detector. Due to the limited number of Mavics and the gradual saturation of our units with electronic warfare equipment, the enemy monitors our positions from a distance of about one to two kilometers, using powerful optics of quadcopters. Accordingly, you will not see or hear enemy UAVs, but thanks to the drone detector, you will clearly know about the presence of a UAV in a certain direction.

To detect a UAV using a drone detector, you should first enable the "EW" preset, since it contains, in addition to all UAV ranges, also navigation ranges. Study the situation in all frequency ranges, in all directions and altitudes, as well as with vertical and horizontal polarization.

After a few seconds of drone detector operation, constant (stationary) interference can be seen on the spectrogram - these can be electronic warfare equipment, mobile operator base stations, Wi-Fi access points, constantly operating repeaters, equipment self-excitation frequencies, etc. These interferences and frequencies are recorded by the UAV detection equipment operator in order to ignore them in future work.

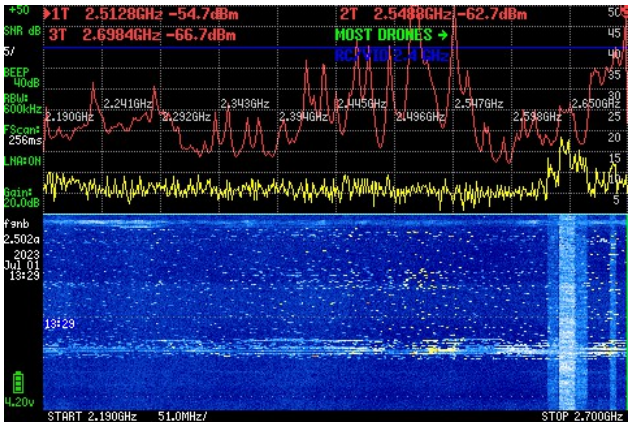
To reduce the impact of interference that can distract the operator of UAV detection equipment, it is necessary to minimize the use of mobile devices with Wi-Fi and Bluetooth in the anti-UAV crew's work area, such as smartphones with mobile Internet distribution via Wi-Fi, thermal imagers with Wi-Fi, fitness bracelets with Bluetooth, weather stations, etc. At the same time, stationary Wi-Fi access points will not distract the operator's attention, because their signal is constant in power and direction. A drone detector can "see" such access points several hundred meters away, even if they are located inside buildings.



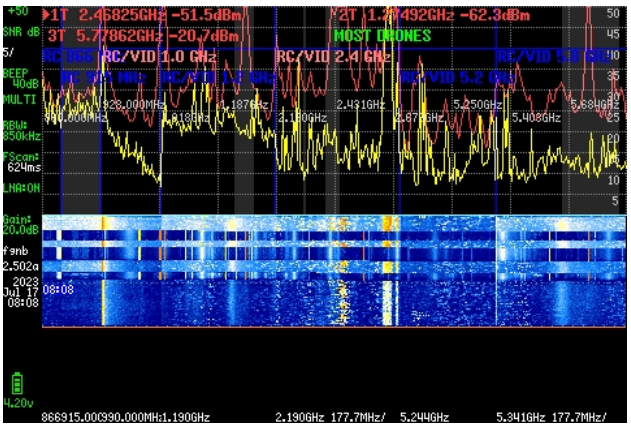
Example of stationary interference - LTE-2600 network and equipment self-excitation

It is necessary to keep electronic devices such as laptops, mobile phones and smartphones - they create a lot of interference in a wide range of frequencies, even with the GSM, 3G, 4G, Wi-Fi, Bluetooth radio modules turned off.

It is necessary to limit the use of radio stations near the drone detector. The powerful radiation of the radio station transmitter "blinds" the drone detector receiver. When the transmission is turned on on the radio station, the drone detector will not be able to receive weak signals and will show no signal. If the operator of the UAV detection equipment personally uses the radio station, during the transmission period, it is necessary to carry the drone detector at arm's length, pointing the antenna in the opposite direction from the radio station.



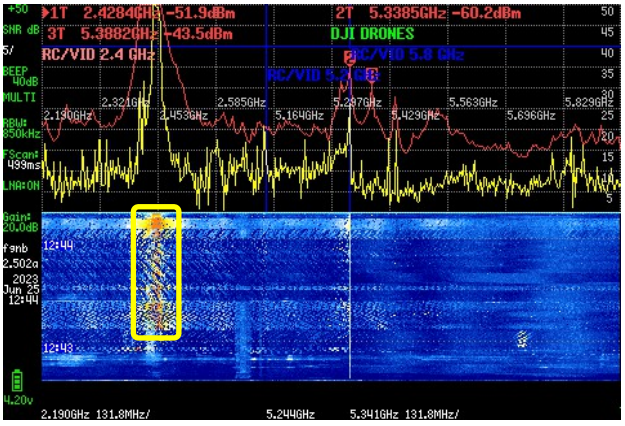
Interference from smartphone



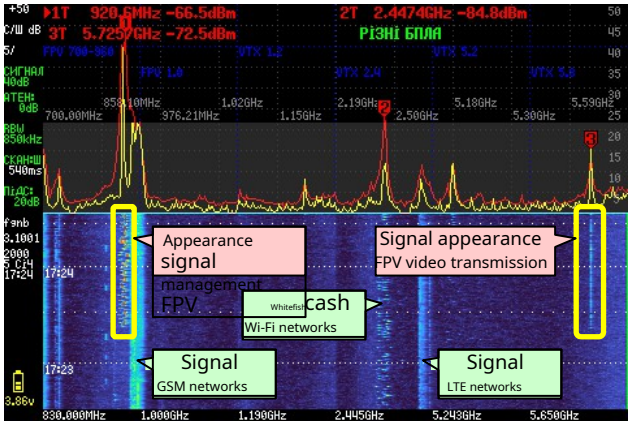
Radio interference

The appearance of a sharp and characteristic increase in the signal level (spike) on the monitoring frequencies and characteristic white/yellow/red stripes on the spectrogram, which fit a known pattern, means the appearance of a UAV or the activation of electronic warfare in the crew's operating area.

In this case, the operator of the UAV detection equipment makes a report in accordance with the established procedure.



Appearance of a signal from a UAV (FPV drone) in the 2.4 GHz control range)



The appearance of signals from UAVs at a frequency of 915 MHz (signal

and at a frequency of 5.725 GHz (video transmission)

Important! When a suspicious signal is detected, the UAV detection operator can expand the entire screen to a separate frequency range where the signal appeared for a more detailed study. But you can’t get carried away with observing the signal in one frequency range; you need to periodically turn on the “VARIOUS UAVS” preset to monitor all ranges, in all directions and heights, as well as with vertical and horizontal polarization. For example, if a signal from a DJI quadcopter was detected in the 2.4 GHz range, this quadcopter can monitor the operation of an FPV kamikaze drone from a long distance, which operates at a frequency of 400-1100 MHz and can suddenly

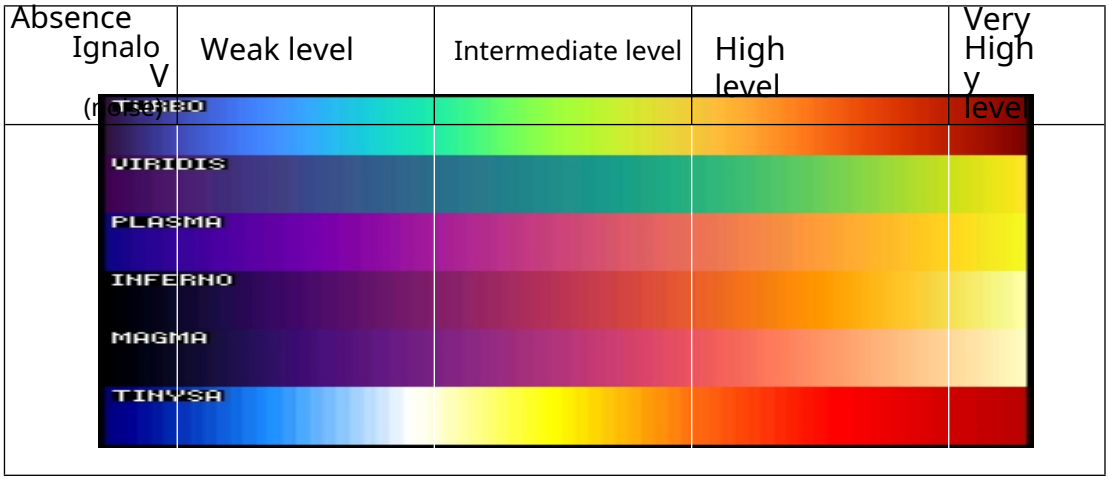
fly in from the other side.

Due to the fact that most modern UAVs operate with a radio channel in the frequency hopping (pseudo-random frequency hopping) mode, the bursts from the UAV will quickly jump in frequency on the drone detector display, and characteristic dashes will be displayed on the spectrogram.

Display of frequency hopping signal from UAV

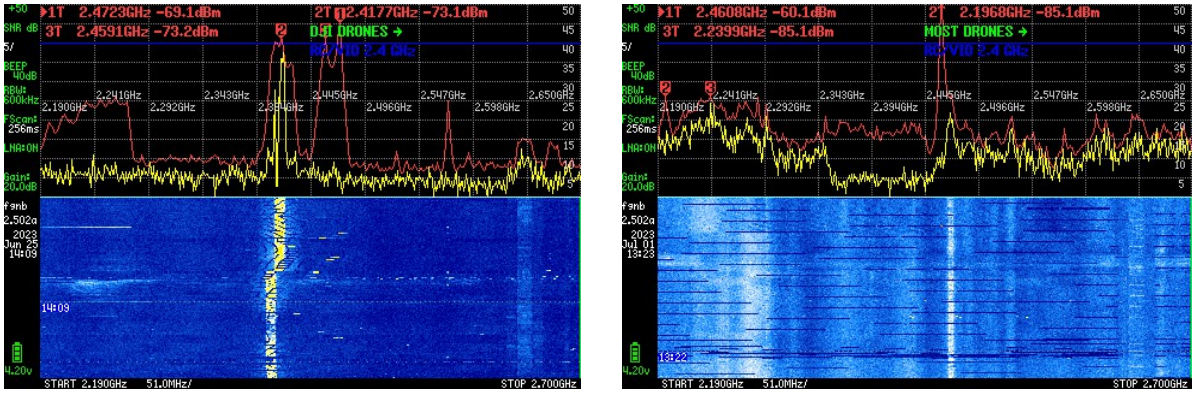
5.2.1.1. Signal level and distance to the UAV.

Correspondence of colors to signal level for all color schemes of the spectrogram:



For all color schemes, red or yellow colors indicate high signal strength.

To understand what the current signal level is, and, accordingly, to roughly determine the distance to the UAV, you can use the spectrogram display. If the signal level from the UAV is very weak, and there are no other powerful signal sources around, the spectrum analyzer automatically increases the gain, and the noise begins to "pull out", which looks like a light background on the spectrogram, while the signal from the UAV will be low-contrast (pale).



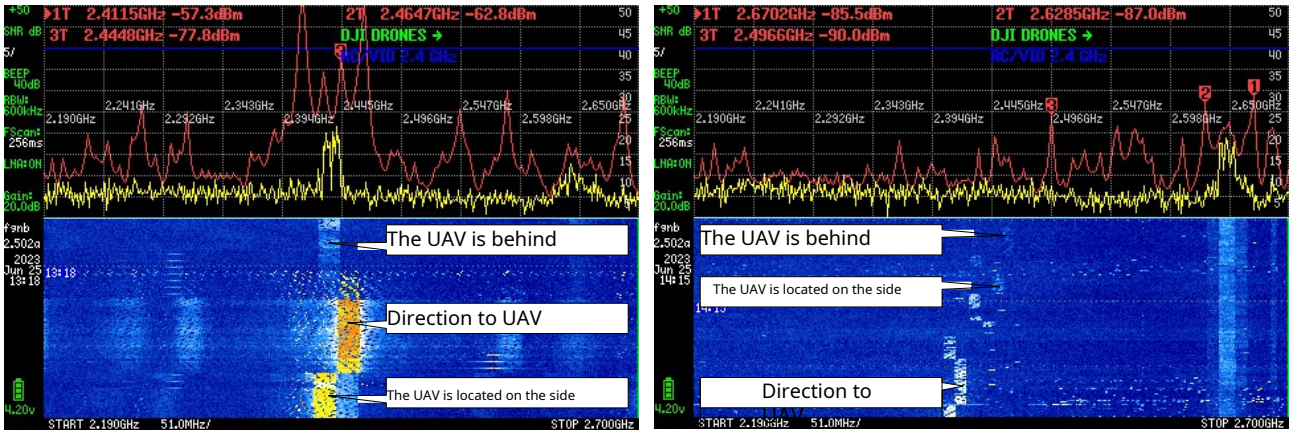
Example of displaying a strong and weak signal from a UAV (DJI quadcopter) (left) distance 500 meters, on the right distance 4000 meters)

Important note! An increase in the signal level from the UAV indicates its approaching - make a report and take precautions!

 At extreme UAV detection distances, altitude plays a very important role. antennas and/or drone detectors above the ground - raising the antenna from the ground to the height of a human can already dramatically improve the reception of weak signals.

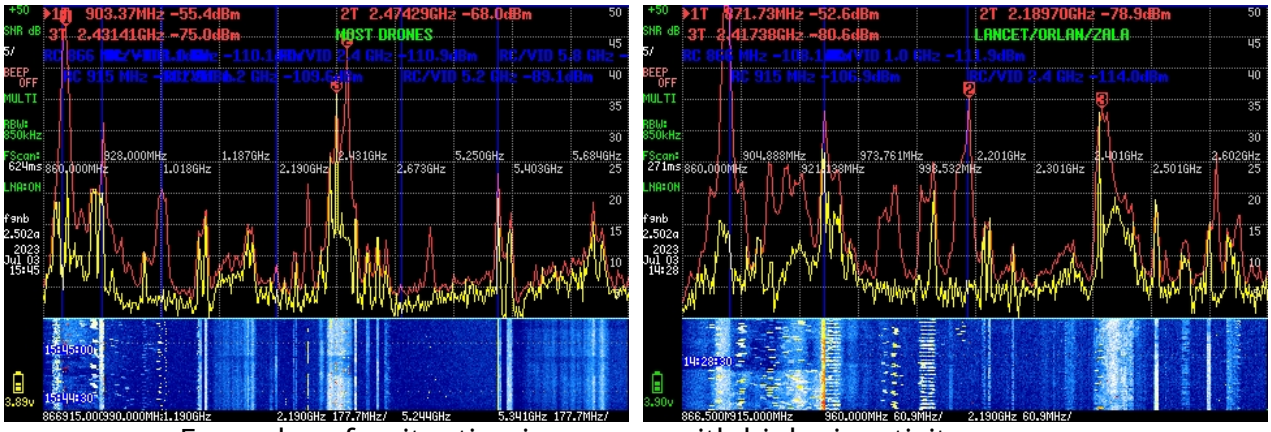
5.2.1.2. Determining the direction of the UAV.

To quickly determine the direction of the UAV, it is necessary to sharply turn the drone detector with a directional antenna left or right by 90 degrees and up and down and compare the intensity (brightness) of the signal on the spectrogram. The greatest brightness indicates the approximate direction (bearing) of the UAV. The accuracy of determining the direction with a triangle antenna is approximately 60 degrees. To track the UAV, it is necessary to periodically turn the drone detector left and right within a certain sector and adjust the direction based on the maximum intensity (brightness) of the signal on the spectrogram.



Searching for direction on UAV - observing the change in signal intensity on the spectrogram

If there are several UAVs in the air, the display will show several bursts with different amplitudes and bandwidths, depending on the types of UAVs, distances and directions to them.



Examples of a situation in an area with high air activity

5.2.1.3. Additional capabilities for the UAV detection operator.

Please note that it is possible and necessary to use a drone detector also detect the work of electronic warfare - both enemy and friendly. The work of electronic warfare means is manifested as an increase in the power of the radio signal in a wide band (bands), as opposed to individual bursts as when detecting a UAV.

In addition, the drone detector, based on a spectrum analyzer, can detect operation of many types of radio stations in the corresponding frequency ranges. Analog radio stations can be listened to by connecting active headphones or an active speaker system to the drone detector and turning on the corresponding option in the menu.

By properly analyzing the drone detector readings, you can determine a lot of useful information. For example, if the enemy has created constant interference at a frequency of 1.5 GHz (satellite navigation), but suddenly this interference disappears for a while - this may mean that in this area the enemy will use their UAVs, which need

GPS/GLONASS.

5.2.2. Counteracting UAVs

If the crew is tasked with countering enemy UAVs, the counter-UAV operator works according to the instructions of the UAV detection operator (crew commander).

All actions with technical means of countering UAVs must be announced so that the crew is prepared for possible retaliatory actions by the enemy in the event of radiation direction finding and an attempt to find and destroy the crew's personnel and equipment.

To counter UAVs, the operator uses pre-prepared technical means, taking into account all safety measures.

 **It is recommended to use counter-UAV means only when Visual contact is established and the operator can monitor the UAV's response to jamming.**

Of course, if it is necessary to jam a spotter drone that was detected using a drone detector and is at a great distance, it is necessary to try to neutralize it in order to stop targeted artillery shelling from the enemy.

When a target is detected by the UAV detection equipment operator, he records the direction to the object, clarifies the UAV affiliation with friendly units and, in case of uncertain affiliation, transmits the data to the UAV countermeasures operator. The crew commander determines the possibility of hitting the target, taking into account the distance to it and other circumstances, and gives a command to the UAV countermeasures operator, who begins working with technical means in the received direction, taking the elevation angle of the anti-drone gun at 20 degrees from the horizon at a distance to the target of more than 500 meters and 30 ÷ 45 degrees at a distance of less than 500 meters. Taking into account the prompts of the UAV detection equipment operator, the UAV countermeasures operator turns on certain jamming channels - which correspond to the frequency ranges of the detected UAV. In the absence of precise information on the frequency ranges of the detected UAV (detected), the UAV countermeasures operator turns on all jamming channels.

 It should be noted that in the case of direct visibility of the UAV (in this case we are talking about we are talking about "wedding drones" DJI, Autel and the like), it is possible to determine its affiliation "friend or foe" by performing the following jamming algorithm:

1) Turn on the jamming of control frequencies and<u>do not include</u> jamming navigation frequencies (1.5 GHz).
2) If there is no permanent interference for navigation frequencies in your area and the quadcopter does not have its own GPS jammer, then the quadcopter, upon loss of control signal, should automatically return "home".
3) It is necessary to observe in which direction the quadcopter starts moving: if towards the enemy, it is definitely an enemy UAV, if towards us, it (maybe) is our UAV.
4) If the UAV moves towards the enemy, immediately turn on jamming of navigation frequencies to force the UAV to stop and land.

During the operation of the UAV countermeasures, the UAV detection operator, in the event that it is impossible to use the drone detector due to powerful radiation ("blinding" of the drone detector receiver), switches to audio-visual observation, and together with other fighters of the calculation, monitors the UAV, which is (are) under the influence of the UAV countermeasures, and also detects possible other UAVs.

In the absence of visual observation of the UAV, which (which) is under the action of UAV countermeasures, after a minute of continuous operation of the anti-drone gun in the received direction, the gun is turned off, after which the operator of the UAV detection means conducts a new search for the target using a drone detector, thus adjusting the work of the UAV countermeasure operator. This is necessary because, having lost control, the UAV can be noticeably blown away by the wind, and thus can leave the zone of destruction by UAV countermeasures. Such a "minute" algorithm

anti-drone gun operation - correction" is applied before the UAV lands, or until the signal from the UAV disappears.

Depending on the selected operating mode of the UAV countermeasures and the capabilities of the UAV itself, the operator can force the drone to:

1) Hover, or go in for a landing, or fly along an uncontrolled trajectory with wind drift (jamming of control and navigation signals).
2) Leave the counteraction zone (in case of using signal amplifiers on the drone and remote control and professional work of the drone operator).

After working through the counter-UAV means, the crew must change position or move to cover to prevent damage due to UAV countermeasures.

During the operation of counter-UAV means (anti-drone gun, dome (REM, etc.), the operator of the UAV countermeasures must regularly (every minute) monitor the power supply parameters (remaining battery capacity) and the temperature of the devices, preventing critical battery discharge and overheating of the housing and electronic circuits. In case of emergency (completion of the mission, UAV attack, etc.), the operation of UAV countermeasures with a critical battery discharge and/or critical heating of the equipment is allowed, but it should be noted that such work may lead to a reduction in the service life of the equipment or to its further failure. The crew commander must prioritize between completing the mission and preserving the equipment for future missions.

5.2.2.1. Work of the operator of counter-UAV means as part of an infantry unit

Working as part of the main unit, the counter-UAV operator sets up positions 100÷200 meters behind the controlled area and switches on his equipment using the instructions of observers who are at the forward SP and report the location of the UAV, its type, the direction of the UAV movement and the result of the counter-UAV operation. The information is transmitted in coded form, for example:

"First", this is "Second", please accept the message, over.
I am "First", on the line, over (pulls out a table of codes). "First", I am "Second", five blue foxes, as I understand, over. I am "First", I read you, five blue foxes, over.

(In this example, "blue" is the name of the landmark, "fox" is the type of UAV, "five" is the direction of movement or no movement).

Please note that observers should not report on UAVs detected when they are above them - for enemy radio reconnaissance, this would mean receiving the coordinates of the SP. A report should be made in the event of a UAV being above a territory where there are no friendly units.

The procedure for the operation of the counter-UAV means operator with an anti-drone gun. 1) Having received a message about the appearance of a UAV (location, direction, altitude, possibly the type of UAV), the counter-UAV means operator takes a position in the direction of the UAV, taking into account his protection from detection and destruction.

2) The map determines the approximate distance to the UAV and the possibility of using counter-UAV means at that distance.
3) While in cover, the counter-UAV operator and other fighters carry out visual and auditory observation.
4) If a decision is made to use counter-UAV means, the operator of the counter-UAV means turns on all jamming channels of the anti-drone gun and, together with other fighters, tries to see the UAV that the anti-drone gun is working on.

5) In case of visual detection of a UAV, the operator of the UAV countermeasures begins to turn off the control jamming channels one by one, monitoring the UAV reaction. At the same time, the navigation channel jamming (1.5 GHz range) is not turned off.

6) If, when a certain jamming channel is turned off, the UAV after a few seconds begins to move not with the wind, but according to the commands of its operator, it is necessary to immediately turn on this jamming channel.
7) The counter-drone operator turns off other control jamming channels if they do not affect the UAV - to save battery power and to prevent overheating of the anti-drone gun.
8) If the battery charge is sufficient to keep the UAV under the obstacle for a long time, it is necessary to continue to jam the UAV until it lands.

performing a safe landing algorithm in the absence of navigation and control signals, or due to a discharged battery.

If the counter-drone operator has a drone detector, it will detect the drone itself. During the operation of the anti-drone gun, the drone detector moves to a place that is not affected by the radiation of the anti-drone gun.

5.3. Withdrawal from position

After completing the task, the crew must quickly and safely leave the position. It is important to maintain camouflage and not leave traces of your presence - to enable the crew to use the prepared positions in the future.

When leaving a position, you must check (recount) your equipment and things so as not to leave anything valuable behind.

After leaving the position, it is necessary to ensure the safety of the crew and equipment during transportation to the base or to the next place of work. The crew must use camouflage measures and plan the route to avoid detection by the enemy.

 After using technical means to detect and counter UAVs,
Perform the necessary technical checks, charging and maintenance of the devices immediately to ensure they are ready for next use.

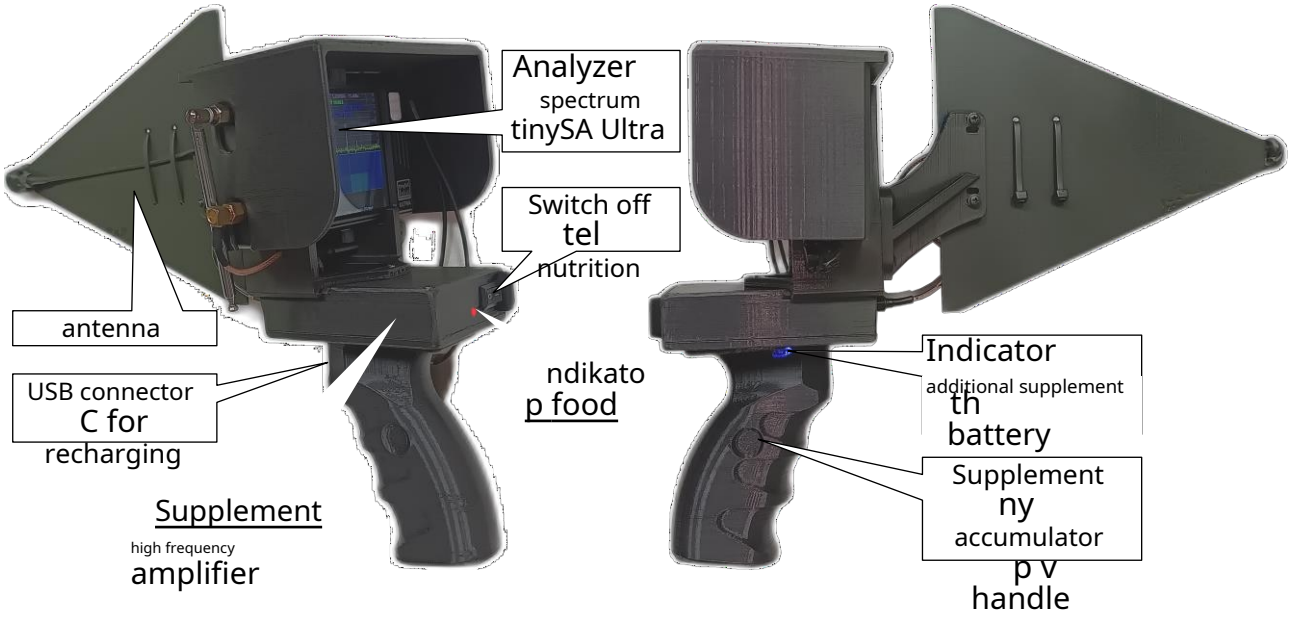
6. Appendix 1. Operating procedure for the drone detector based on the spectrum analyzer "tinySA Ultra" with firmware version v3.2.0

6.1 Description

The drone detector is designed for long-range and early detection of UAVs and other radio emission objects.

The drone detector consists of the following components:

- Standard equipment:
  - Spectrum analyzer "tinySA Ultra with built-in battery". Antenna is directed "triangle".
  - Additional HF amplifier with 20 dB gain (optional 30 dB or 40 dB).
  - Additional battery built into the handle of the holder. Coaxial cable from the antenna to the RF amplifier (mounted). Coaxial cable from the RF amplifier to the spectrum analyzer (mounted). USB-C cable for powering the spectrum analyzer (mounted).
  - Stylus on a rubber cord. Plastic or metal holder. Case for storage and transportation.
  - Plug for spectrum analyzer calibration connector.
  - Coaxial cable for spectrum analyzer calibration.
  - CableUSB-C for charging drone detector and for Programming a spectrum analyzer (for experienced professionals).
  - Telescopic antenna. Can be used for all-round monitoring.
- Additionally, the following can be supplied:
  - External light and sound signaling unit.
  - Audio cable with 3.5 mm TRS connectors for connecting active headphones. Non-directional all-range pin antenna with magnetic base and cable.
  - Highly directional "wave channel" antenna ("yagi") with cable.



Assembled drone detector

(actual appearance may differ from that shown in the pictures)

The drone detector is a passive receiver that does not emit any radiation and, accordingly, cannot be detected or located by electronic warfare equipment.

Spectrum analyzer "tinySA Ultra" is a device for displaying radio signals within the frequency range of 100 kHz ÷ 6000 MHz. Accordingly, such a device can display radio signals from all known UAVs, electronic warfare systems, radio stations, Wi-Fi devices, etc.

The maximum detection range of a UAV by this drone detector depends on many conditions (UAV flight altitude, UAV transmitter power, antenna or drone detector height above the ground, antenna type, presence of an additional RF amplifier, presence of obstacles in the form of terrain, buildings, forest plantations, etc.) and is:

- Quadcopter-type UAVs that are at altitude50÷500 meters - from 1 km to 5 km (using a directional antenna).
- Aircraft-type UAVs that fly at altitude1000÷5000 meters - from 10 km to 30 km (using a directional antenna).

 This model of drone detector does not yet have automatic detection capabilities identification of UAVs, all analysis of the information is carried out by the operator, who determines the characteristic radio frequency emissions according to previously studied patterns of signal emission spectra for various UAV models. The operator of the UAV detection equipment must undergo appropriate training in the use of such a device and the identification of UAV models according to their signal emission spectrum patterns.

6.2. Terms of Use

When working with a drone detector, the following rules must be observed:

1. Do not place the antenna near transmitting antennas and never touch the antenna (any) metal objects to avoid damage to electronic components by static electricity!
2. Do not leave the device under direct sunlight or other heat radiation due to the possibility of damage to plastic parts.
3. Do not expose the device to rain or moisture. Protect (cover) the device when using it in rain or snow.
4. Avoid dust and soot getting on the surface of the device. If the surfaces are dirty, clean the device with a dry and soft cloth or napkin.
5. Before use and during operation, periodically check the charge of the batteries - the built-in spectrum analyzer and the additional one in the holder. On a fully charged built-in battery, at a positive temperature, the spectrum analyzer can operate from 2 to 6 hours - depending on the selected display brightness. In the drone detector, where there is an additional battery, the total operating time increases and is from 6 to 20 hours, respectively.

6. Check the tightness of the coaxial cable connectors periodically. Do not apply excessive force when tightening the connectors.
7. Periodically pay attention to the inscription "+50 S/N dB" or "+100 S/N dB" in the upper left corner of the display - if it is red or pink, it is necessary to calibrate the spectrum analyzer to improve the quality of the device. To calibrate, connect the short coaxial cable included in the kit to the spectrum analyzer connectors "CAL" and "RF", then go to the menu Settings > More > Calibrate > Calibrate radio. Wait until the procedure is successfully completed. After calibration, the aforementioned inscription will be white if the automatic display scale is enabled, or green if the manual scale is enabled.

8. The directional antenna should be oriented vertically in most cases (vertical polarization), but periodically monitoring should be carried out with the antenna oriented horizontally (horizontal polarization).

FPV quadcopters with a horizontal antenna have horizontally polarized signals if they have telemetry transmission enabled.

Vertical polarization of the antenna

AntennasHorizontal polarization

9. When searching for the direction to the signal source, it should be kept in mind that the accuracy of determining the direction with a triangular log-periodic or rectangular horn antenna is approximately 60 degrees, with a "wave channel" type antenna - approximately 10-20 degrees.
10. To work from closed positions, you can connect a remote pin antenna (for example, a car antenna) to the drone detector.

11. The non-directional whip antenna should be directed vertically upward.
12. The detection range of UAVs increases when the antenna and/or drone detector is raised higher above the ground (if this can be implemented).

6.3. Setting

Before using the drone detector, you must first properly configure the spectrum analyzer in accordance withrecommended basic settings , which are listed in the table. Given your experience and preferences, you can make other settings at your discretion and under your own responsibility.

Setting	Meaning	Location in the menu	Note
Brightness	100%	Main menu>Screen	Set maximum display brightness to 100% (see also section 6.14.)
Automatic blackout	Off	Main menu>Screen	Disable automatic display brightness reduction (also see section 6.14.)
Frequency markers	3	Setting	Set the number of signal maximum markers
Spectrogram	Size: Big Palette: Inferno	Setting	Turn on the spectrogram, select the "large" size and select a palette: "Turbo" - to display all signals <or> "Inferno" - to emphasize powerful signals
Sound signal		Setting	Turn on the sound signal (also see section 6.14.) Select the desired volume level. Select a comfortable beeper frequency (default 1760 Hz)
Frequency Grid		Setting	Enable display of grid and frequency value
Names ranges		Setting	Include range names
Anxiety level	40.0 dB	Setting	Set the alarm threshold level - horizontal blue line (see also section 6.14.)
Scale graphs	Auto	Setting	Set automatic display scale
Built-in MBP	/☐	Setting>More	Enable built-in RF amplifier - for combination with additional 20 dB RF amplifier (also see section 6.5.) <or> Turn off the built-in HF amplifier - for the complete set with the additional HF amplifier 40 dB
External coefficient MBP	20.0 dB	Setting>More	Specify the gain of the external RF amplifier (depending on the model)
Calibrate radio	√	Settings>More>Calibrate	Start radio channel calibration
Calibrate the screen	√	Settings>More>Calibrate	Perform touch screen calibration
Hour	gg-hh-ss	Settings>More>Set date and time	Set the correct time (hours-minutes-seconds)
Date	rr-mm-dd	Settings>More>Set date and time	Set the correct date (year-month-day)
Time of fading maximum	10 sec.	Settings>More>Internal settings	Peak decay rate (red line)
Reaction time noise level	5 sec.	Settings>More>Internal settings	Speed of adaptation to the environment
Time reactions scale	10 sec.	Settings>More>Internal settings	Display scaling speed
Display noise threshold	☐	Settings>More>Internal settings	Disable display of minimum level values
Display ranges	Evenly	Settings>More>Internal Settings>Display ranges	Displaying equal size ranges

Deployment		Settings>More>Internal settings>Image ranges	Enable zoom function

6.4. Technical specifications

model	DD-TU1 - basic model DD-TU1S - with built-in beeper with DD-TU1M- metal holder parts DD-TU1SM - with built-in beeper and metal holder parts
Maximum range UAV detection quadcopter type, which are at a height 50÷500 meters	From 1 to 5 kilometers (using a directional antenna)
maximum range UAV detection aircraft type, which are on height 1000÷5000 meters	From 10 to 30 kilometers (using a directional antenna)
Accuracy definitions directions to UAV	• Non-directional whip antenna: cannot be determined direction • Directional log-periodic antenna: approx.60 degrees • Highly directional antenna "wave channel": approximately10÷20 degrees
Frequency range analyzer spectrum	100 kHz ÷ 6000 MHz
Frequency range generator	100 kHz ÷ 800 MHz (sine), 100 kHz ÷ 4400 MHz (square wave)
RF amplifier in analyzer spectrum	Frequency range: 100 kHz ÷ 4000 MHz Gain: reduced from 20 dB at 100 kHz to 6 dB at 4000 MHz
Additional RF amplifier	Frequency range: 10 MHz ÷ 6000 MHz Gain: Can be 20 or 30 or 40 dB (also see section 6.3.) Maximum Input Level: 33 dBm @ 1 GHz (2 W)
Display diagonal	10 cm / 3.95", 480×320 pixels
Opening hours from batteries	• 8 hours (on the battery built into the spectrum analyzer) • 16 ÷ 20 hours (with additional battery)
Nutrition	• Built-in battery in the spectrum analyzerLi-Polymer 3000 mAh • Additional batteryLi-Ion ≥6000 mAh
Current consumption (analyzer + amplifier)	• 495mA from USB-C (display brightness 100%) • 395mA from USB-C (display brightness 6%)
Charger	5V (USB-C)
Light indication	• Powered by additional battery • Charging an additional battery • Charging the spectrum analyzer
Sound indication	Built-in beeper: buzzer sounds when a strong signal exceeds a specified threshold level (models DD-TU1S, DD-TU1SM)
Connectors	• Antenna -SMA Female • Calibration -SMA Female
Audio output	Analog, linear, TRS 3.5 mm (for connecting active headphones or an active acoustic system)

Complete map memory	MicroSD 32GB
Holder material	Plastic PLA or PET/PETG (models DD-TU1, DD-TU1S) Plastic + metal (models DD-TU1M, DD-TU1SM)
Operating temperature	- 10℃÷ +40℃
Working humidity	≤85%
Body color	Black/camouflage
Overall dimensions	320×140×260 mm
weight	640 ÷ 800 g - plastic holder (depending on material) 975 g - plastic holder with metal parts

6.5 Notes on the 5.8 GHz band

The spectrum analyzer "tinySA Ultra" has low sensitivity in the 5.8 GHz range. Searching for signals in this range is possible only with a high-quality external RF amplifier, which, in turn, still does not guarantee long-range detection of UAVs.

When scanning the 5.8 GHz range, we recommendtemporarily disable the built-in RF amplifier - menu item "Settings>More>Built-in UWB", this will eliminate additional interference introduced by the built-in HF amplifier in this range.

6.6. Spectrum analyzer controls "tinySA Ultra"

tinySA Ultra Spectrum Analyzer Controls

Please note that the touch screen responds to pressure, not touch. Accordingly, you need to press the screen with a stylus, nail, finger or other blunt object.

6.7. Switching on, power control and charging

The drone detector has dual power supply - a built-in spectrum analyzer battery and an additional battery in the handle of the holder. The additional battery is used to power an additional RF amplifier and to extend the operating time of the spectrum analyzer.

6.7.1. Turning on

First, turn on the power supply from the additional battery using the key switch - the red indicator to the left of the switch will light up. If the indicator does not light up, turn the switch off and on again to restart the additional battery controller. After turning on the power supply from the additional battery, turn on the spectrum analyzer using the switch on its top panel.

Occasionally, the extra battery controller may become locked, meaning that you cannot turn it on with the key switch, even if you are sure that the extra battery is charged. In this case, connect the charger to the USB-C port on the front of the handle to reset the extra battery controller.

6.7.2. Power control

 Note that the additional battery powers the spectrum analyzer, i.e., when When powered by an additional battery, the spectrum analyzer is constantly recharging and operates not on its built-in battery, but on the additional battery. Accordingly, the additional battery will be discharged first, while the battery built into the spectrum analyzer will most likely still have a high charge level.

On the right side of the handle there is a hole for monitoring the charge of the additional battery, which consists of four blue indicators. During operation, the indicators will decrease from left to right. Each indicator is 25% of the charge. When the additional battery is turned on by the key switch, the blue indicators glow constantly , and after switching off they glow for about 10÷30 seconds. Periodically check the charge indicator.

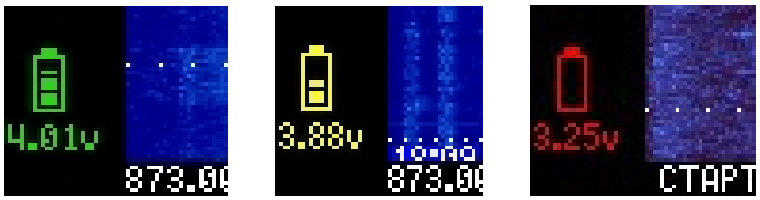
If only one blue indicator is lit, the drone detector's extra battery needs to be charged.

If the last blue indicator is flashing, it means that the additional battery charge is almost empty.

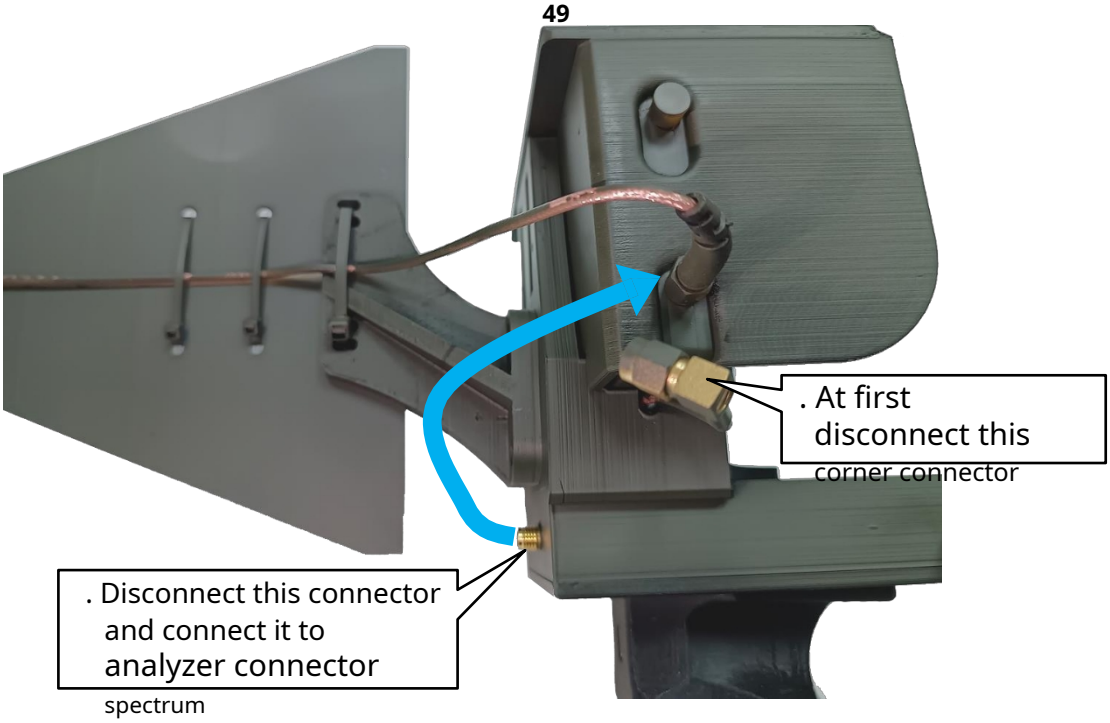
If none of the blue indicators and the red indicator are lit, the drone detector's additional battery is discharged. In this case, the additional RF amplifier stops working, and the spectrum analyzer operates on its built-in battery.This is a normal condition when the drone detector is operating for a long time without the possibility of charging it. In this case, you can use the spectrum analyzer for some time only on its built-in battery. To do this, switch the antenna cable from the input of the additional amplifier to the lower connector of the spectrum analyzer. All functions of the drone detector will work, but without an additional RF amplifier, the sensitivity and, accordingly, the detection range of the UAV will bea little less in the ranges of 600-900 MHz and 2.4 GHz and significantly less in the 5.2 GHz and 5.8 GHz ranges.

If your kit includes an additional 40 dB RF amplifier, the built-in amplifier (USHP) must be turned off in the settings. Accordingly, when directly connecting the antenna to the spectrum analyzer, it will be necessary to turn on the built-in USHP in the spectrum analyzer settings menu (see section 6.3.). After restoring the charge of the additional battery and restoring the normal cable connection, do not forget to turn off the built-in USHP again in the spectrum analyzer settings menu.

Monitor the charge of the spectrum analyzer's built-in battery using the icon in the lower left corner of the display.



Spectrum analyzer battery charge icon



Connecting the antenna directly to the spectrum analyzer

Be extremely careful when connecting and disconnecting the connectors to the drone detector! Antenna connectors are not designed to withstand high force and require smooth, even tightening.

6.7.3. Charging

To charge the drone detector, connect the 5V charger to the USB-C port on the front of the handle, the blue indicators of the extra battery will flash from right to left. Once fully charged, all four indicators will be solid.

While charging the additional battery,Be sure to turn on the power of the drone detector with the key switch so that the built-in battery of the spectrum analyzer is also charged. Charging of this battery is accompanied by the glow of the red indicator on the top panel of the spectrum analyzer. After full charging, this indicator will go out.

After the additional battery has finished chargingand a built-in spectrum analyzer battery , turn off the power of the drone detector with the key switch. Also, always turn off this key switch when the drone detector is not in use, because even if the spectrum analyzer is turned off, the power of the auxiliary battery is consumed to power the auxiliary RF amplifier.

6.8. Selecting the operating mode

After turning on the spectrum analyzer, you can select the required frequency range to search for specific types of UAVs, according to the task.

The special firmware of the spectrum analyzer has so-called "presets" - pre-configured frequency ranges with clear names for the convenience of detecting radio signals from various devices (UAVs, radio stations, mobile phones, Wi-Fi devices, electronic warfare equipment, GSM/3G/4G mobile operator networks, etc.). Presets can include a set of several frequency ranges, or one frequency range. The user can create several of his own presets with one frequency range, and can also create several of his own presets with a set of frequency ranges.

If a preset with a set of ranges was selected, pressing one of the ranges at the top of the display will expand it to the full width of the screen, pressing again will return it to the multi-range display.

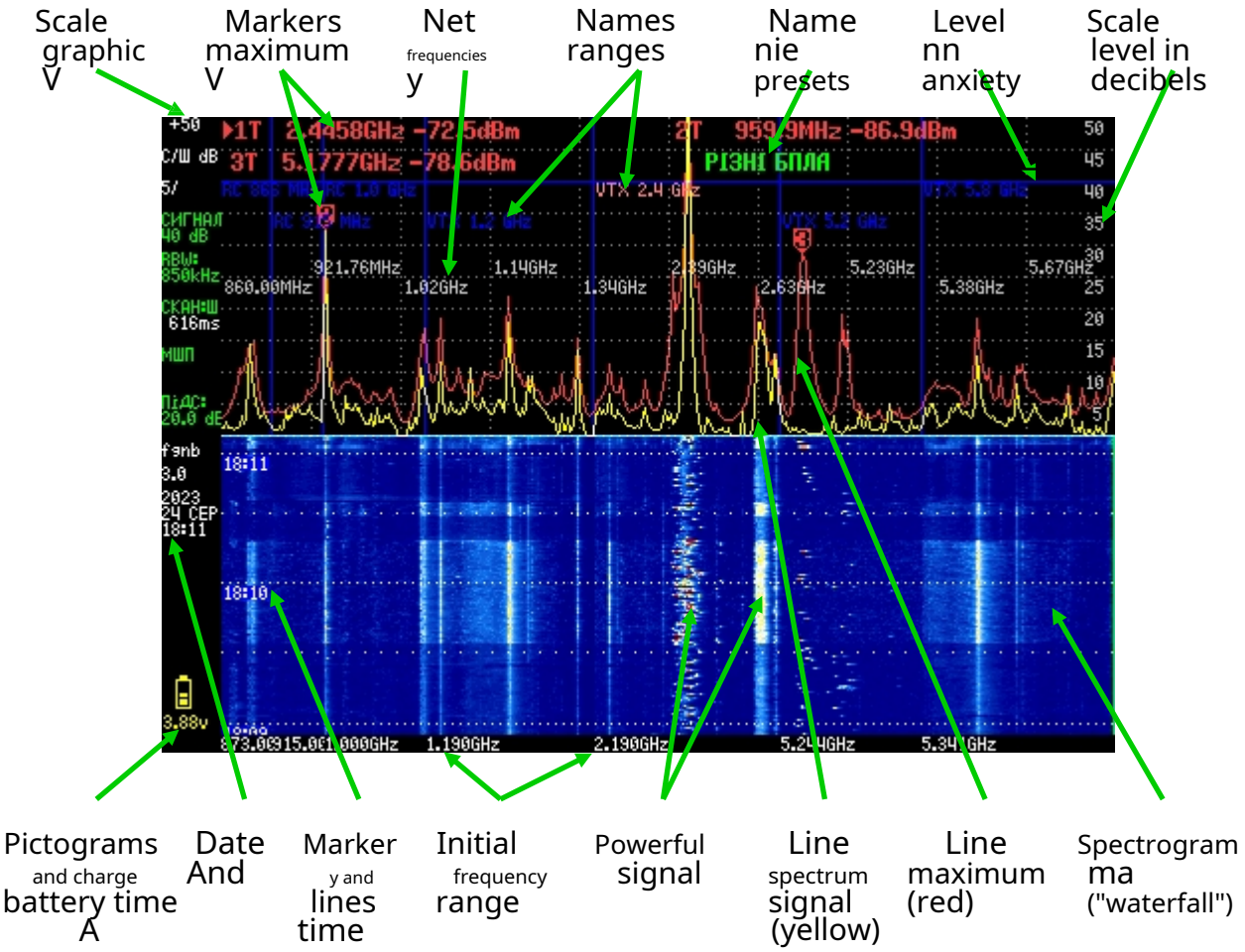
To detect a UAV using a drone detector, you should first enable the "VARIOUS UAVS" preset and study the situation in all frequency ranges of possible UAV operation, in all directions and heights, as well as with vertical and horizontal polarization.

After a few seconds of drone detector operation, constant (stationary) interference can be seen on the spectrogram - these can be signals from base stations of mobile operators, Wi-Fi access points, constantly operating repeaters, self-excitation of equipment, etc. These interferences and frequencies are recorded by the operator of UAV detection equipment in order to ignore them in future work.

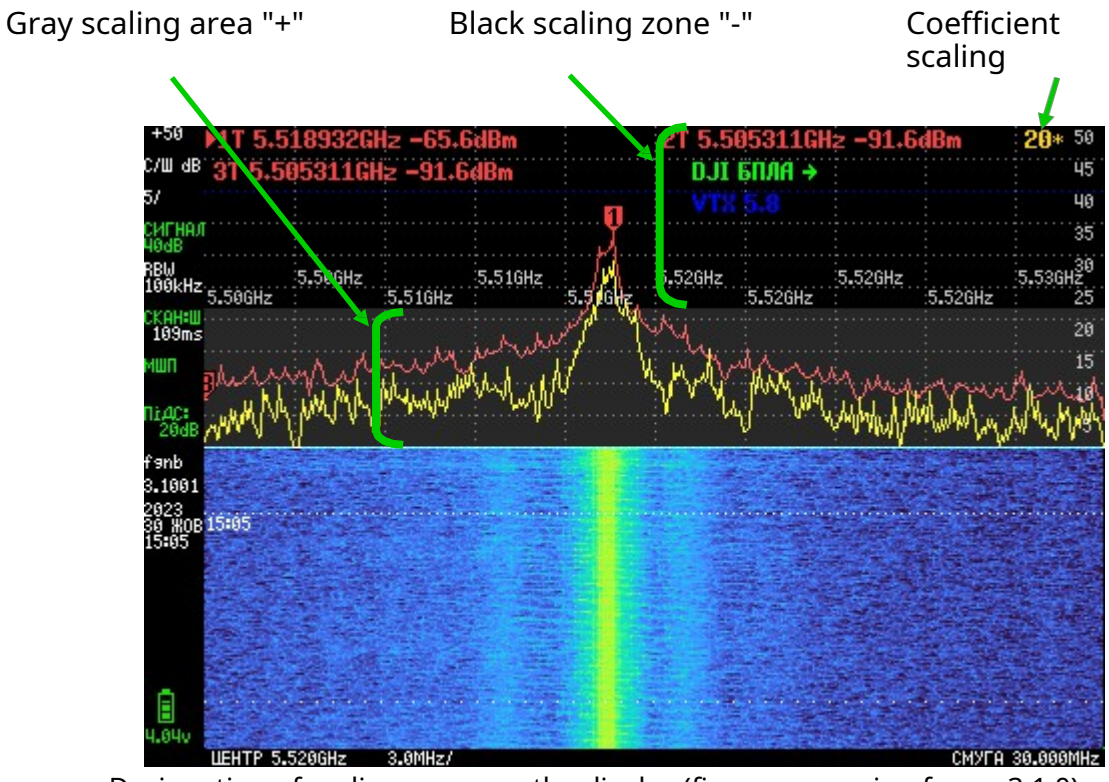
For quickdetermining the direction of the UAV , it is necessary to sharply turn the drone detector with a directional antenna to the left or right by 90 degrees and up and down - the operator finds the sector with the highest signal level, this is the approximate direction (bearing) to the UAV. The accuracy of determining the direction with such a drone detector is approximately 60 degrees. If there is time and opportunity, you can clarify the direction to the UAV by slowly rotating the drone detector within a certain sector and observing minor changes in signal intensity on the spectrogram.

6.9. Display elements on the display

Below are the main display elements.



Designation of the main display elements on the display (firmware version v3.0.0.0)



Designation of scaling zones on the display (firmware version from v3.1.0)

In addition to the display elements shown in the figures, the display on the left also shows:

- "Signal40 dB" in green - the sound alarm is on (40 dB is the threshold).
- “Signal off” in pink – the sound alarm is disabled.
- "Scan:ShXXXms" scanning speed of the current preset.
- “USHP” in green – the built-in high-frequency amplifier is on.
- "Pods:20 dB" in green - gain level of external HF amplifier.
- "SD" in green - microSD card is inserted (not shown in screenshots).

6.10. Scaling function

Starting with firmware version v3.1.0, the spectrum analyzer has a scaling function that "stretches" a certain section of the spectrum and spectrogram, and allows you to examine in detail the necessary signal for its study and identification.

Depending on the bandwidth of the selected range (preset), the maximum scaling factor may be different. The scaling factor can have the values x5, x20, x100, x500, x2000, x10000. The scaling factor is displayed in the upper right corner of the display in yellow for firmware version v3.1.0, or in the upper left corner of the display in green for firmware version v3.2.0.

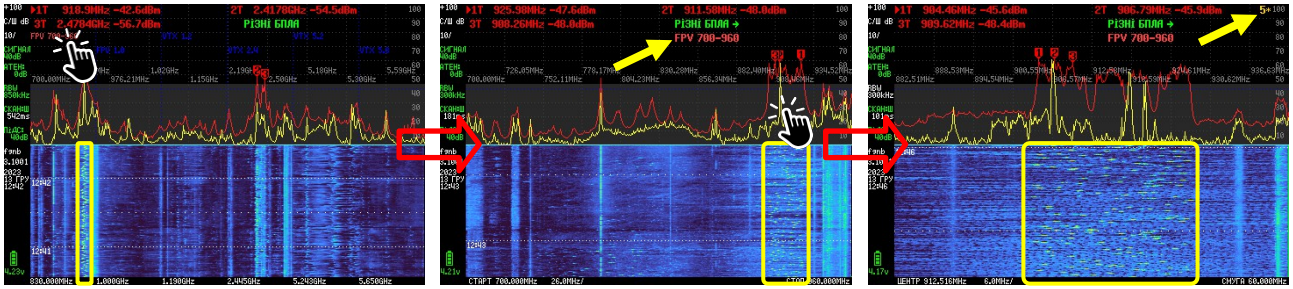
 You can freely combine manual and automatic scaling.

6.10.1. Method 1 - manual scaling

To zoom in on the area of interest, tap the stylus on the signal spike within the gray area of the display. To zoom out, tap the stylus above the signal spike within the black area of the display.

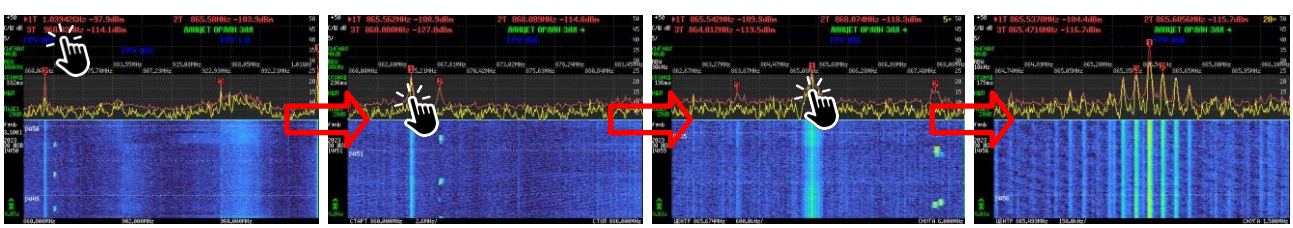
We recommend that you first expand the desired range to the full width of the screen by clicking on the range at the top of the display - this will allow you to more accurately hit the signal spike with the stylus.

To quickly exit the zoom mode, select any preset in the menu. After turning off and on the spectrum analyzer, the selected zoom is not saved.

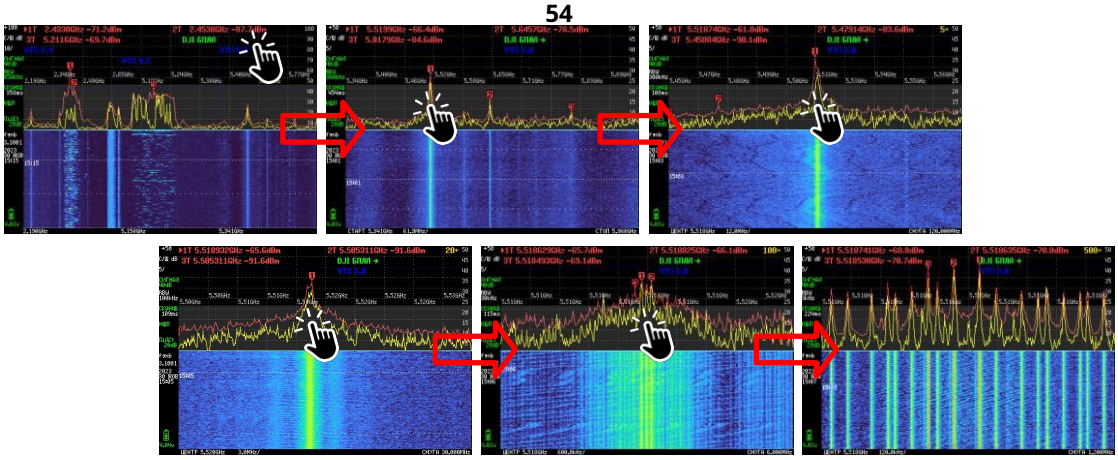


Example of manual scaling of a signal with a center frequency of 915 MHz

In this example, we first expand the desired range to the full width of the screen, then scale the signal burst. The signal we are observing is the frequency hopping signal for controlling the FPV drone, ELRS standard, center frequency 915 MHz, band approximately 26 MHz (from 902 MHz to 928 MHz). To the right of this signal is the GSM base station band.



Example of manual scaling of a signal with a center frequency of 866 MHz

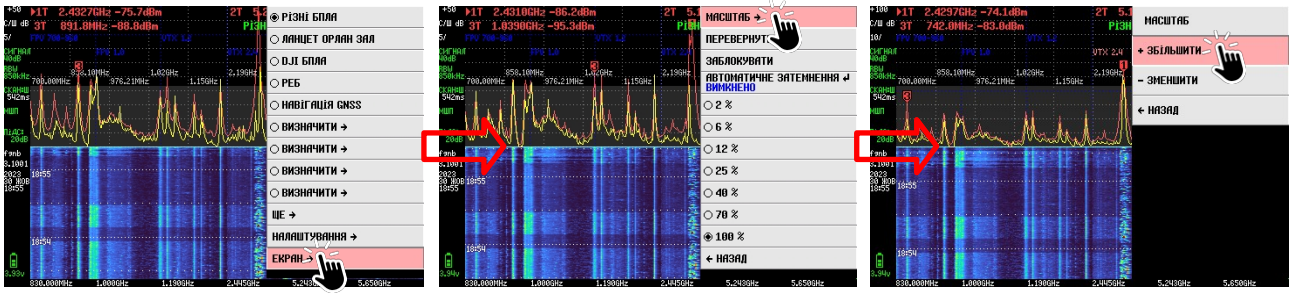


Example of manual signal scaling in the 5.8 GHz range

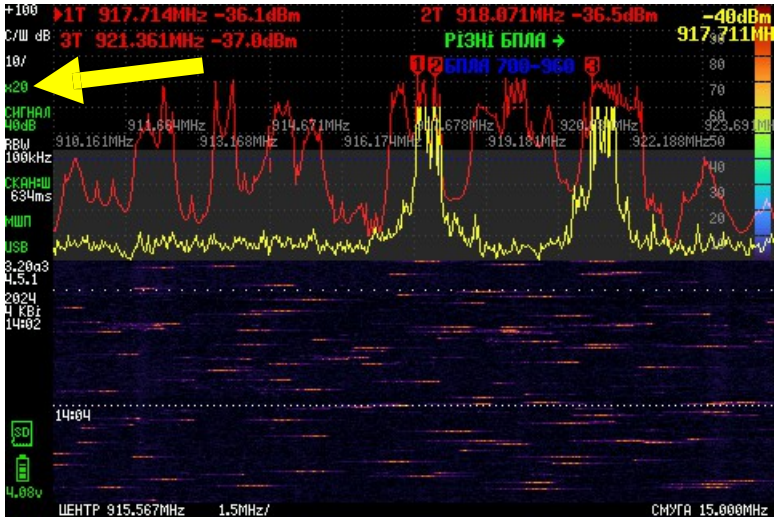
6.10.2. Method 2 - Automatic scaling of the strongest signal

At any time, open the main menu, and in the screen settings, click on the "+ zoom in" line to zoom in on the strongest signal. The strongest signal is selectedfrom all ranges displayed on the display . The strongest signal will be in the middle of the display.

You can zoom in or out multiple times through the mentioned menu.



Using the "Scale" submenu in the display settings



Displaying the scaling factor for firmware version v3.2.0.

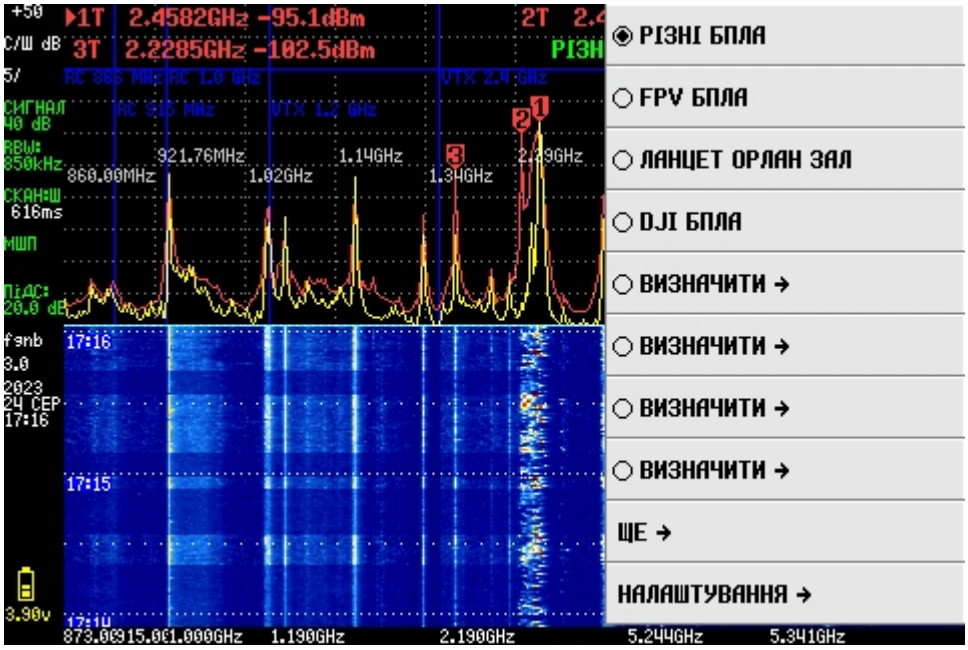
6.11. Frequency search

During normal operation (when the menu is not displayed), by pressing the wheel left or right, it is possible to move marker #1 along the spectrum and find out the exact frequency of a certain burst. You can press the wheel briefly to move the marker a short distance, or you can hold the wheel down to make the marker move quickly along the spectrum. While moving the marker, the spectrum display freezes, and is restored automatically one second after releasing the wheel.

Please note - if you have markers disabled in the settings, then a short press of the wheel to the right will select the display of individual frequency ranges in a preset with a set of several frequency ranges (left to right), and a short press of the wheel to the left will return the display of all frequency ranges of the current preset.

6.12. On-screen menu

To open the menu, click on the spectrogram or on the wheel.



Main menu

To navigate the menu, use the stylus by touching the desired menu items, or the wheel - move it left and right to move the menu item selection down and up, respectively, and press the wheel to select the selected item.

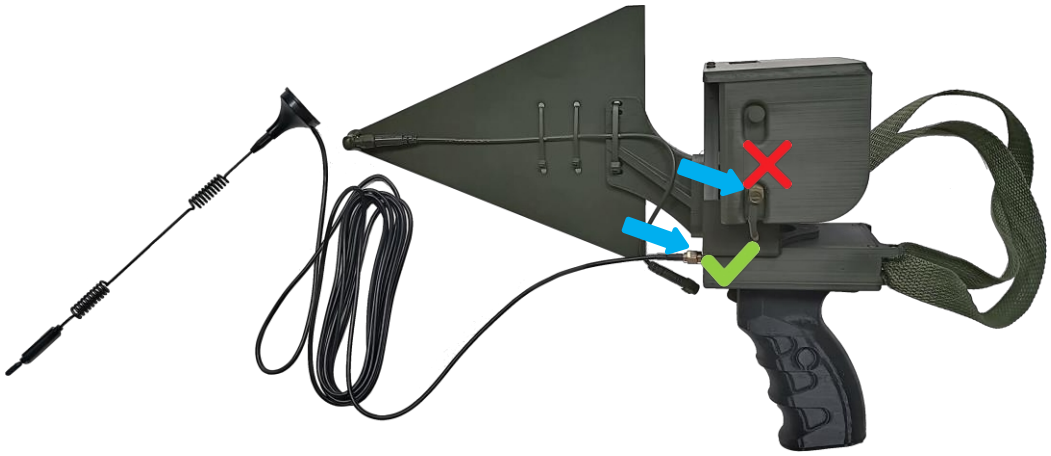
The selected preset is indicated by an icon with a black circle.

To navigate through the menu pages, use the links "**MORE** " and**BACK**". Menu items with arrow" " lead to a submenu.

To close the menu, press the display outside the menu or move the wheel to the left until the menu disappears. Starting with firmware 3.1.0, the menu closes automatically after 15 seconds if no actions are performed in the menu. After closing the menu, part of the spectrogram will be missing in the place where the menu was displayed - this is normal.

6.13. Operation of a drone detector with an external antenna

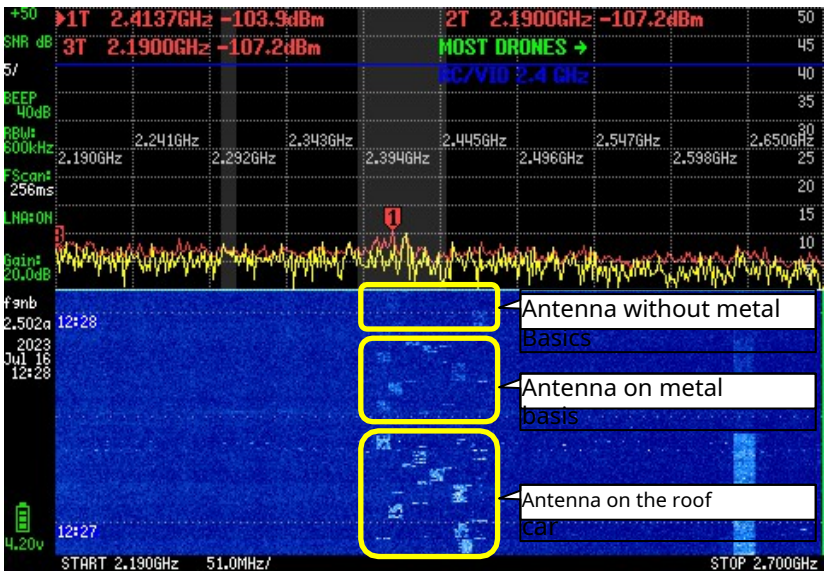
In case of a threat to life and impossibility of continuous monitoring with a directional antenna, the operator of UAV detection equipment can, while in a shelter or in a vehicle, connect an external pin antenna to the drone detector and install it outside. For this, an automobile all-range pin antenna with a cable and a magnetic base is used. The antenna must be connected to the input of an external RF amplifier. It is advisable to install such an antenna on a flat metal base - a car roof, metal zinc from cartridges, a metal box (box) from ammunition, or any flat metal (iron) object will do. The antenna should be installed vertically and in the center of the metal base, but most importantly - as high as possible (as far as the cable will last). You can simply tape the antenna to a stick stuck in the ground. In this way, you can organize a safe stationary round-the-clock monitoring point. When connecting the drone detector to a power supply or power bank, its operating time can be unlimited. For the convenience of detecting signals from UAVs, you can enable sound and light alarms in the drone detector.



Connecting a remote antenna to a drone detector

Be extremely careful when connecting and disconnecting the connectors to the drone detector! Antenna connectors are not designed to withstand high force and require smooth, even tightening.

Please note that non-directional all-band whip antennas haveless sensitivity than directional antennas, so it should be taken into account that the detection distance of UAVs with such antennasis noticeably reduced - for example, DJI quadcopters can only be detected from a distance of 1000÷1500 meters, while with a directional antenna this distance is up to 5000 meters. We recommend replacing the supplied cable with an RG223 cable of the required length.



6.14. Sound and light signaling

The spectrum analyzer has a function of sound and light signaling of the appearance of a strong signal that exceeds the specified threshold level. In addition, on the display the name of the range in which the signal exceeding the threshold level appeared turns pink. If the signal does not exceed the threshold level, the name of the range is displayed in blue.

The threshold level value (blue horizontal line on the display) is set depending on the operating conditions - menu item "Settings>Alarm level".

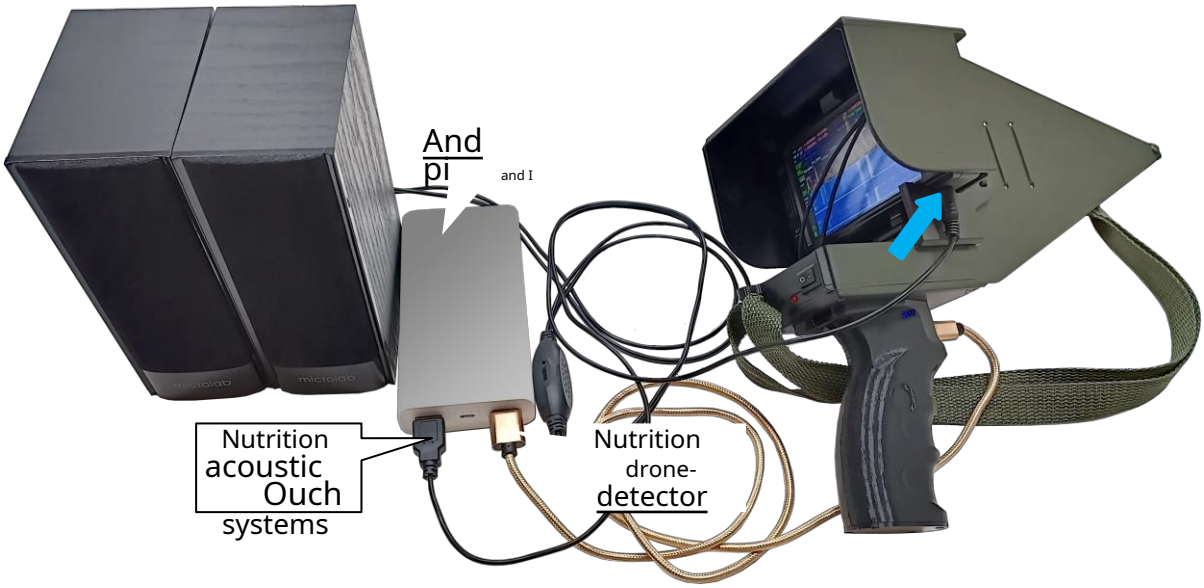
You can turn on and off the sound and light alarms independently.

6.14.1. Sound signaling

The sound alarm is activated when signals exceeding the set threshold level appear. Use the built-in beeper (models DD-TU1S, DD-TU1SM) or connect an external alarm unit, or an active speaker system, or active headphones to the 3.5 mm audio output jack - if the signal exceeds the set threshold level, a buzzer will sound. To enable the sound alert function, enable the "Sound signal" option in the settings and select the desired volume level and a comfortable tone (frequency) of the buzzer.

The buzzer tone will automatically increase in steps if the signal level has reached a threshold level and continues to grow.

Connecting active headphones



Connecting an active speaker system powered by USB

6.14.2. Light signaling

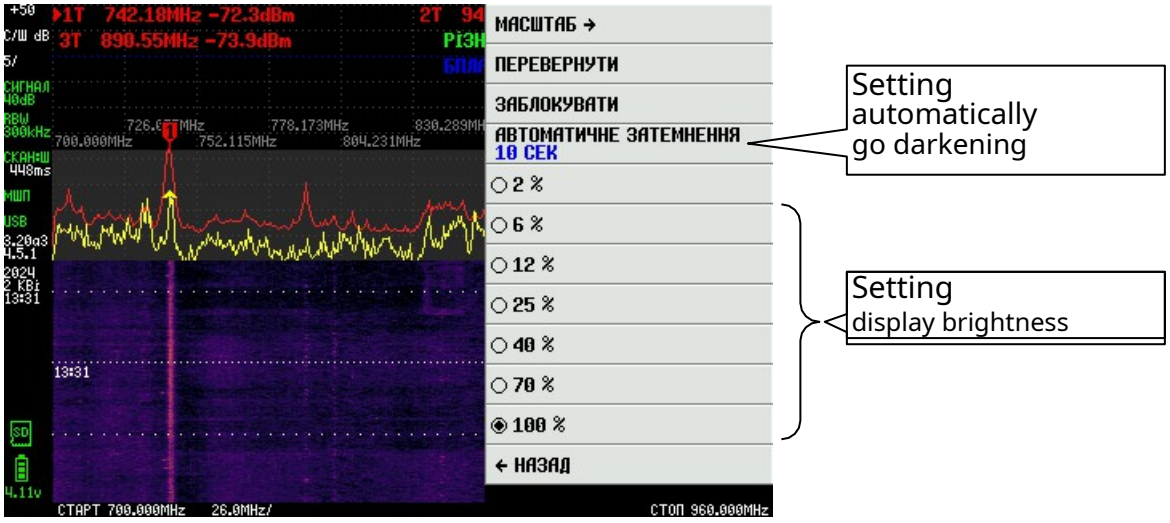
The light signaling works by automatically increasing the brightness of the display when signals exceed the threshold level appear.

To enable this feature, please follow these settings:

1. Select the desired display brightness in the "Screen" settings, greater than "2%". The following display brightness values are usually set:
   - During the day100%.
   - At dusk25%.
   - At night6%.
2. Enable the "Automatic dimming" function (automatic reduction of display brightness) in the "Screen" settings and specify the time interval in seconds after which the display brightness will become minimal (the value "2%").

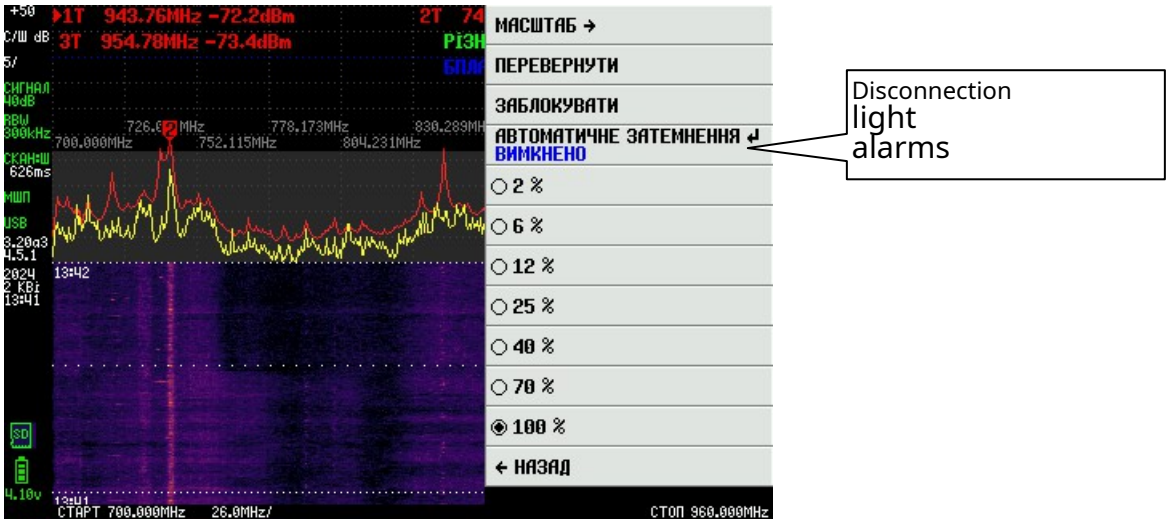
If there are no signals exceeding the set threshold level, the display brightness will be minimal (2%). When signals exceeding the set threshold level appear, the display brightness will automatically increase to the set value, thereby indicating the appearance of a strong signal. After the disappearance of the strong signal, after a set time interval, the display brightness will again become minimal (2%).

The higher the display brightness was set in the settings, the more noticeable the light signaling effect will be.



Menu "Screen" - setting up light signaling

To turn off the light signal, select "Off" for the "Auto Dimming" option.



Menu "Screen" - disabling light signaling

6.14.3. Setting up alarm exceptions ("special" ranges) Starting with firmware version v3.2.0, the spectrum analyzer has a new function for defining "special" ranges in which the alarm is turned off or a different alarm threshold level is set.

Disabling the alarm or making it harder (increasing) its threshold in certain ranges will allow you to exclude standard powerful sources of radio signals from the alarm, such as signals from base stations of cellular operators, which previously led to periodic unnecessary alarm activations.

In addition, it is possible to make certain ranges with greater sensitivity (lower alarm threshold level), for example, particularly dangerous bands, where any signal will mean the appearance of a UAV.

To disable the alarm in the "special" range, set the value "0" (zero) for the "Alarm Level" parameter. To set your own alarm threshold value, set the value for the "Alarm Level" parameter in decibels from "1" to "127".

 Ranges designated as "special" are displayed on the display as bars filled with gray dots. If the alarm is disabled for such a range, the display will not show the blue alarm threshold line within this range. If a threshold level other than the general one has been set, the blue threshold line will be displayed within this range at the set decibel mark.

The table shows a list of frequency bands of base stations (BS) of Ukrainian mobile operators, for which you can disable the alarm. On the spectrogram you will see the frequency bands of exactlyBS transmitters - since the transmitters have high power and operate continuously, and in the BS receiver bands there will be weak irregular signals from mobile terminals.

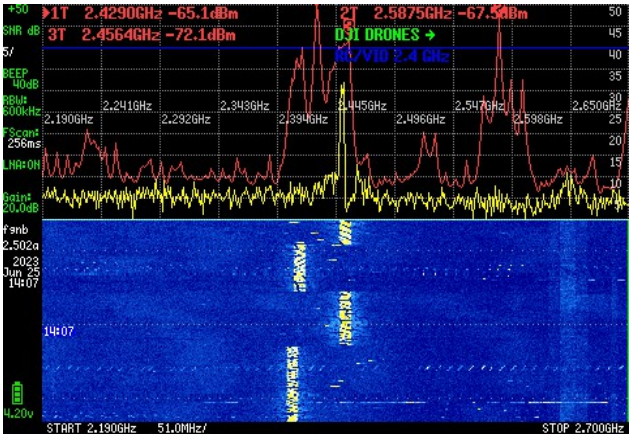
Check the table, find the frequency bands that are used in your region, and add them to the list of "special" bands.

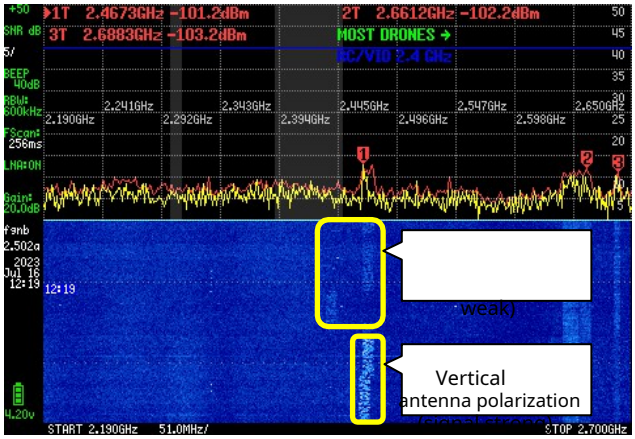
Operator / standard	BS receiver, MHz	Transmitter BS MHz	Receiver BS MHz	Transmitter BS MHz	BS receiver MHz	Transmitter BS MHz	Type networks
	PJSC "Kyivstar"		LLC "Lifecell"		PJSC "VF Ukraine"		
GSM-900	884.4 - 886.2 888.6 - 889.8 890.0 - 894.8 908.0 - 910.2	929.4 - 931.2 933.6 - 934.8 935.0 - 939.8 953.0 - 955.2	895.2 - 899.8 907.2 - 907.6	940.2 - 944.8 952.2 - 952.6	900.2 - 906.8	945.2 - 951.8	2G
DCS-1800	1725.2 - 1749.8 1770.2 - 1779.8	1820.2 - 1844.8 1865.2 - 1874.8	1710.2 - 1724.8	1805.2 - 1819.8	1750.2 - 1769.8 1780.2 - 1784.8	1845.2 - 1864.8 1875.2 - 1879.8	2G
LTE-900	890.0 - 895.0	935.0 - 940.0	895.0 - 900.0	940.0 - 945.0	900.0 - 905.0	945.0 - 950.0	4G
LTE-1800	1730.0 - 1750.0	1825.0 - 1845.0	1710.0 - 1725.0	1805.0 - 1820.0	1750.0 - 1770.0	1845.0 - 1865.0	4G
LTE-1800TH	1725.2 - 1749.8 1770.2 - 1779.8 1730.0 - 1750.0	1820.2 - 1844.8 1865.2 - 1874.8 1825.0 - 1845.0	1710.2 - 1717.6 1710.0 - 1725.0	1805.2 - 1812.6 1805.0 - 1820.0	1750.2 - 1769.8 1780.2 - 1784.8 1750.0 - 1770.0	1845.2 - 1864.8 1875.2 - 1879.8 1845.0 - 1865.0	4G
LTE-2600	2520.0 - 2535.0	2640.0 - 2655.0	2535.0 - 2545.0	2655.0 - 2665.0	2510.0 - 2520.0	2630.0 - 2640.0	4G
UMTS-WCDMA	1967,4	2157.4	1922.8	2112.8	1952.4	2142.4	3G
	1972,4	2162.4	1927,6	2117.6	1957,4	2147.4	3G
	1977,2	2167.2	1932.4	2122.4	1962,4	2152.4	3G

 In firmware v3.2.0already added several "special" ranges with frequency bands of base stations that are most common in Ukraine:

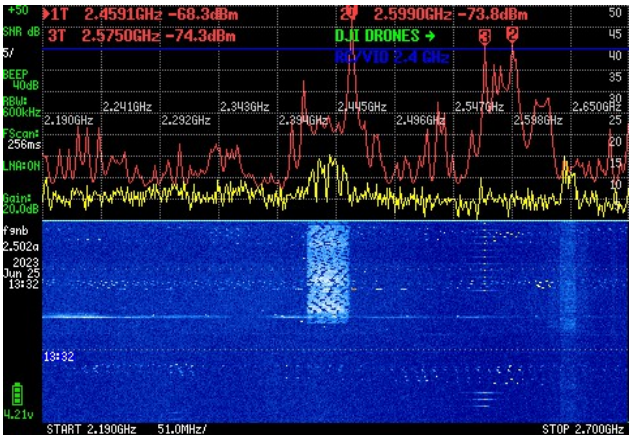
1. 925.0 - 960.0 MHz
2. 1805.0 - 1880.0 MHz
3. 2110.0 - 2170.0 MHz
4. 2620.0 - 2690.0 MHz

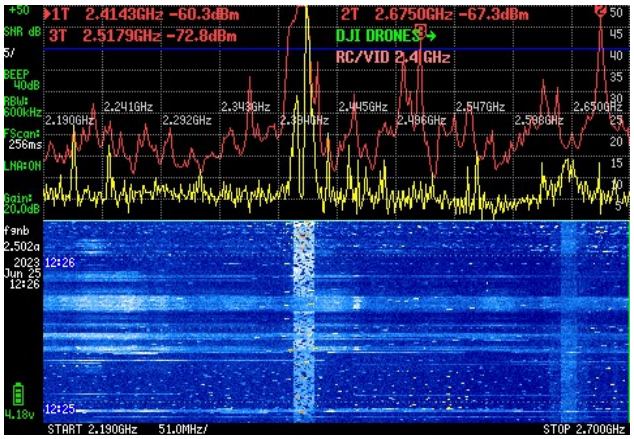
7. Appendix 2. Examples of emission spectrum templates of signals from some UAVs

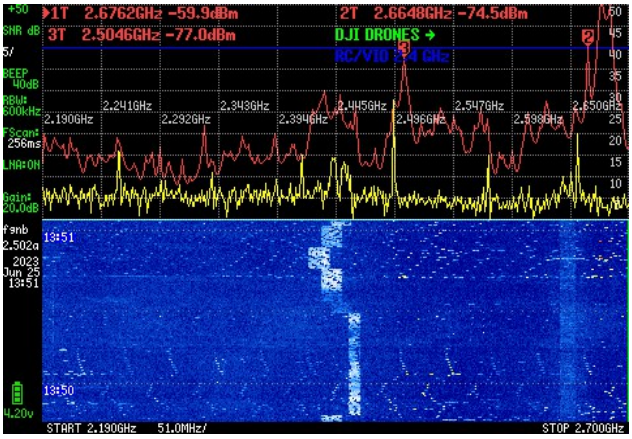


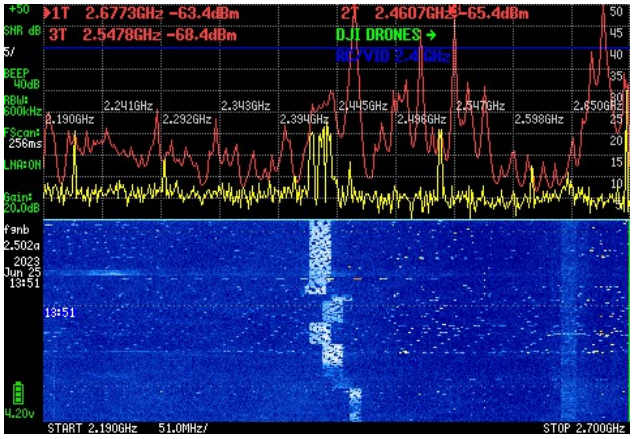


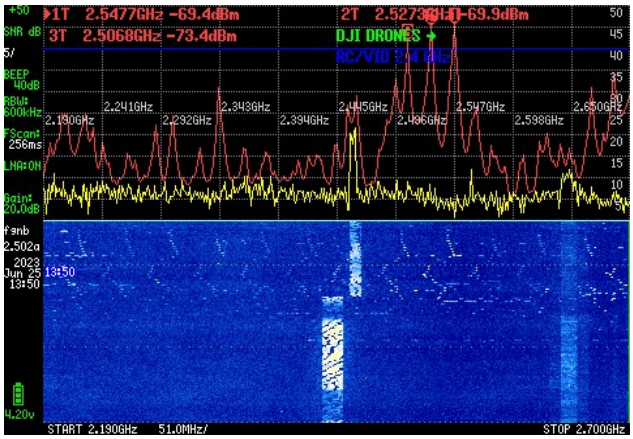
DJI quadcopters (if the connection with the remote control is poor, the quadcopter constantly changes channels)

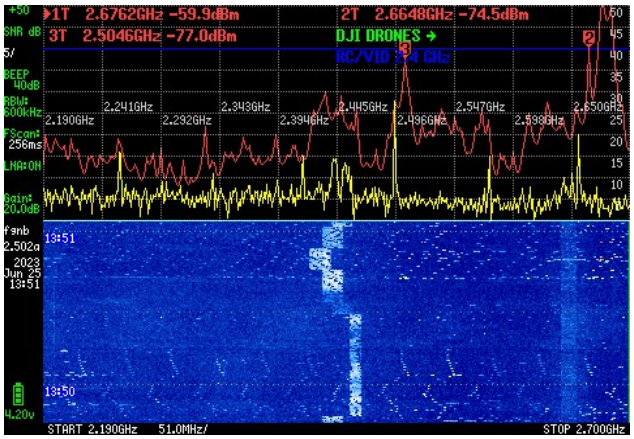




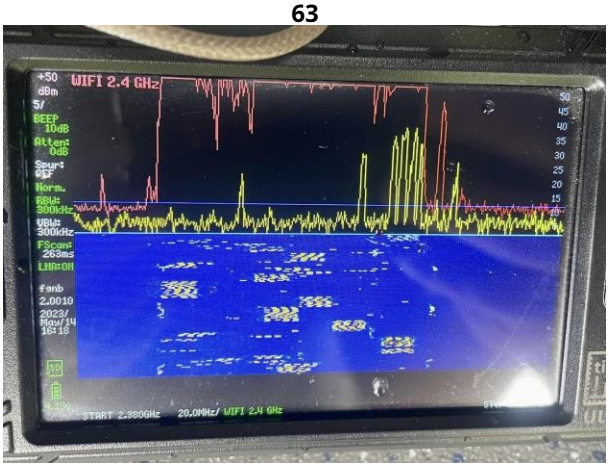




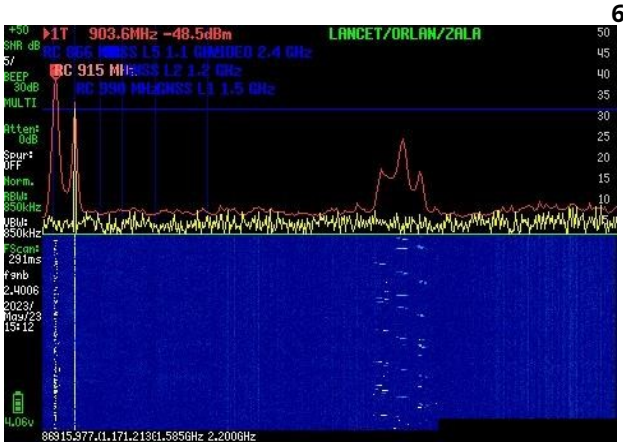




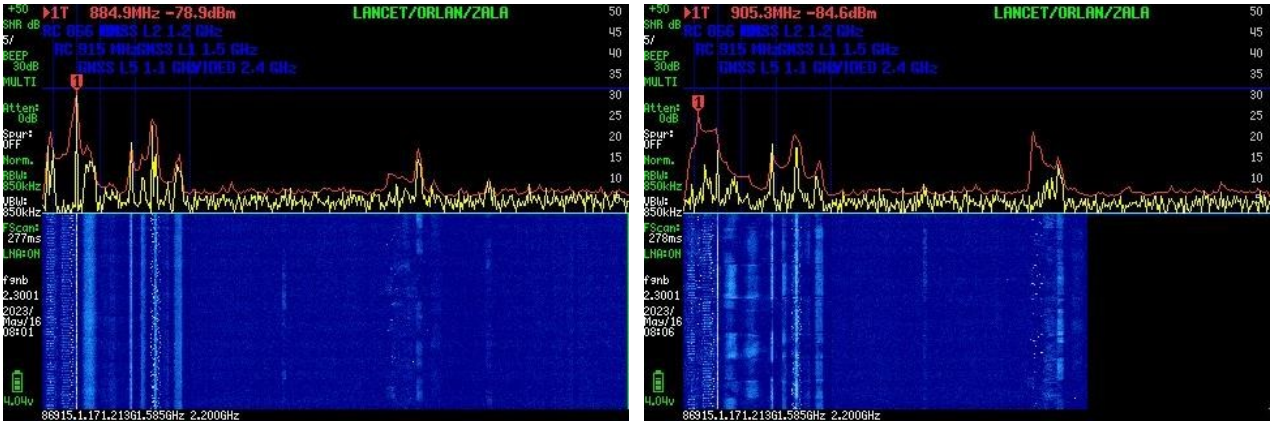
Quadcopters Autel Evo 2 / Lite+ (signal band is wider than DJI, but with poor connection with remote control, the quadcopter reduces the bandwidth for more stable communication)



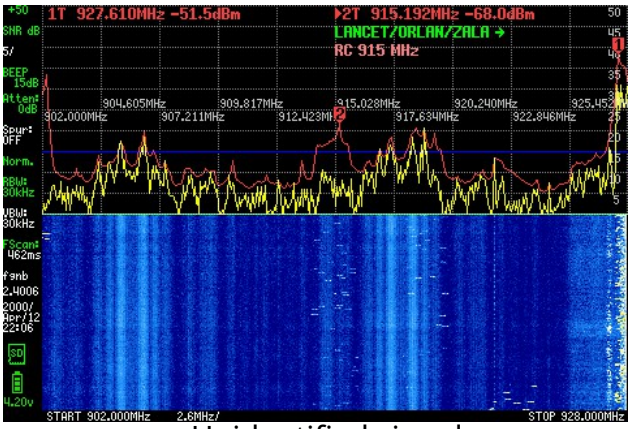
Quadcopter Autel Evo 2 Pro V3 Enterprise



Unknown aircraft-type UAV, distance 1÷3 km

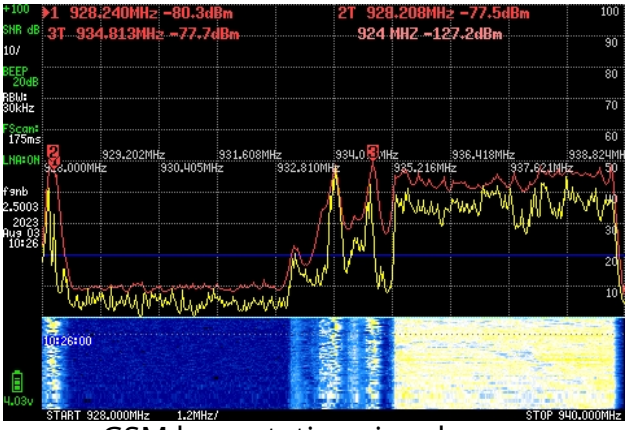


Two unknown aircraft-type UAVs

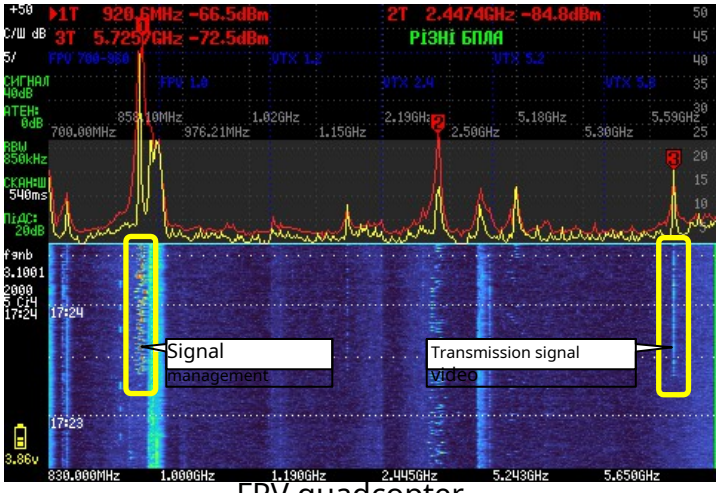


Unidentified signals,

900 on the right is the GSM-900 base station



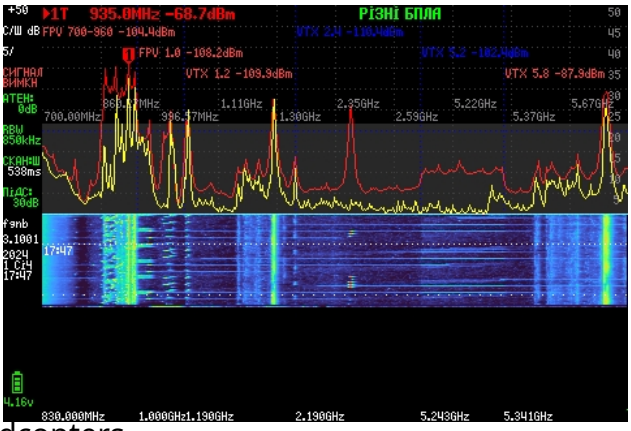
GSM base station signal-



FPV quadcopter

Control and telemetry: ELRS frequency hopping with a center frequency of 915 MHz and a bandwidth of approximately 26 MHz

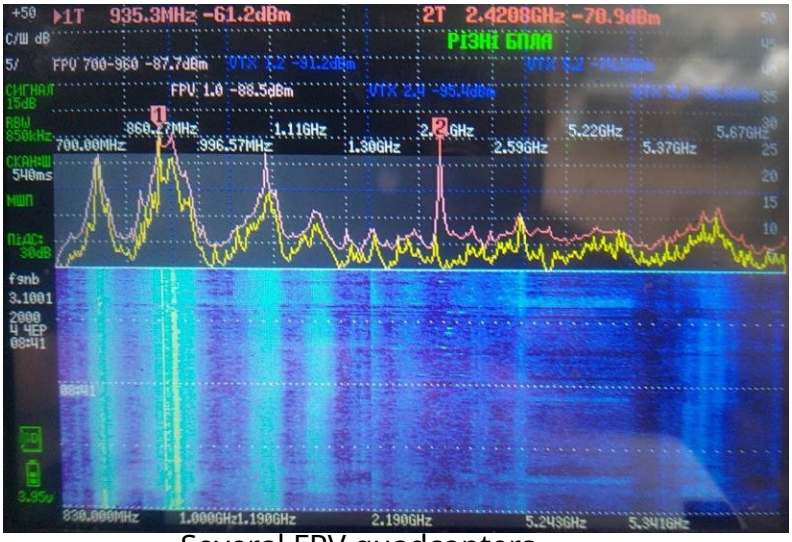
Video transmission: analog video in the 5.8 GHz range (in this example 5.725 GHz)



Several FPV quadcopters

Control and telemetry: frequency hopping at 868 MHz and 915 MHz

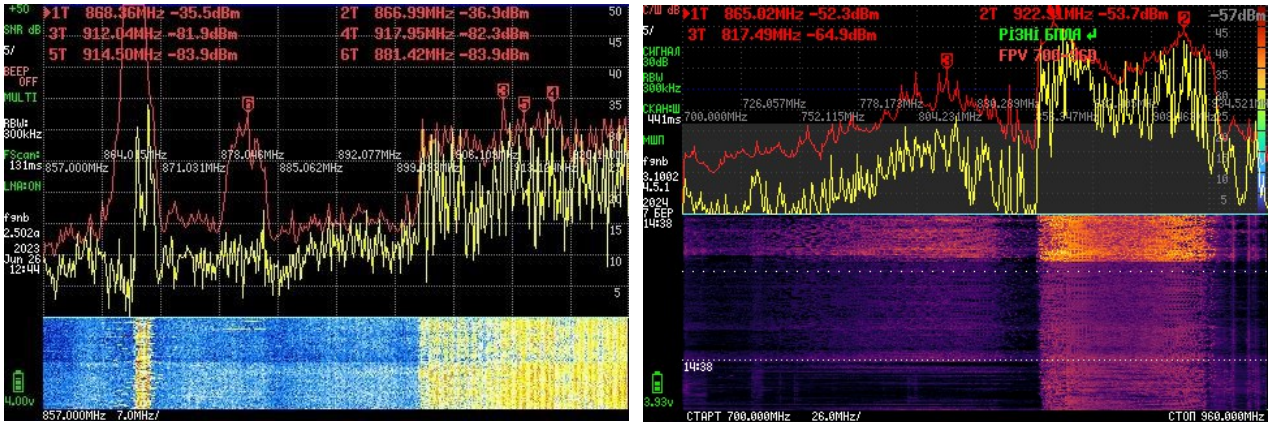
Video transmission: analog video in the 5.8 GHz range



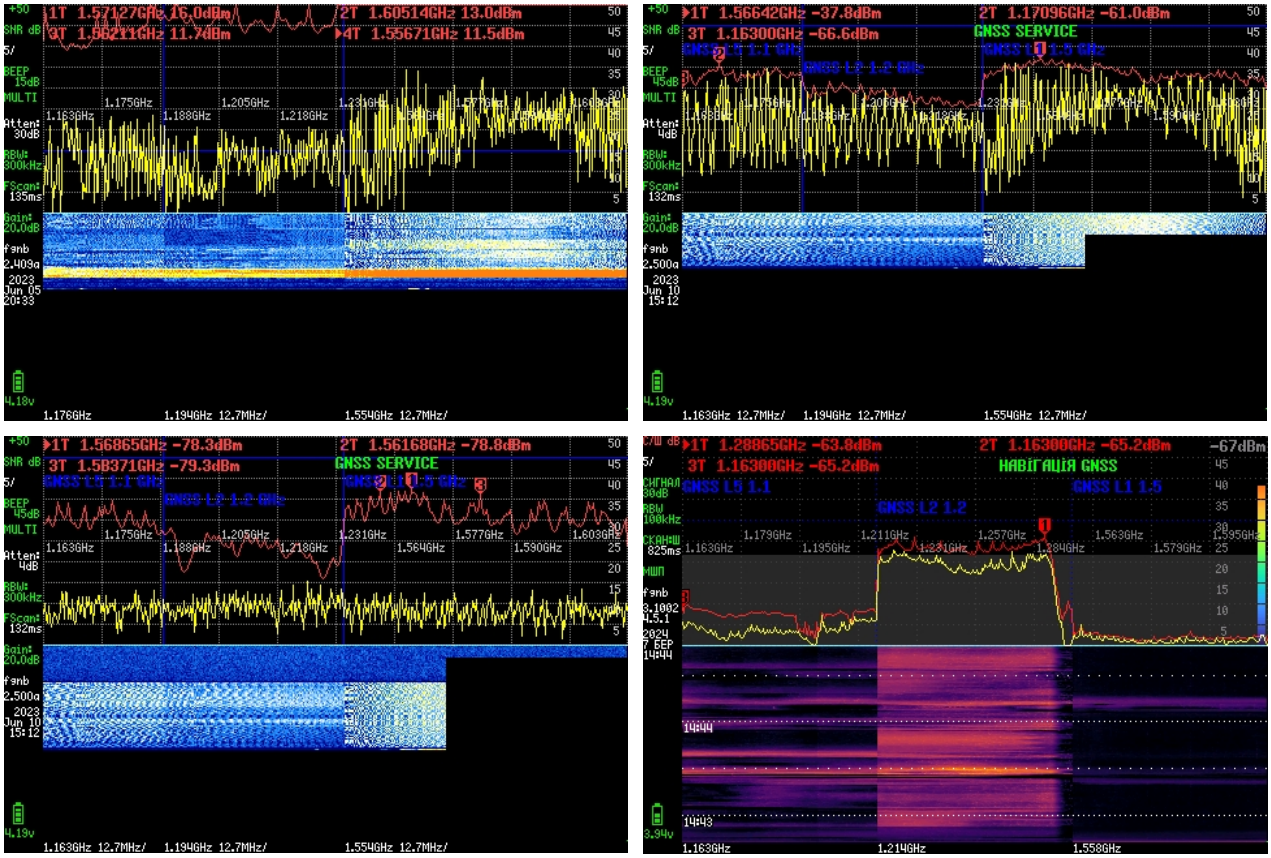
Several FPV quadcopters

At least six video transmission bands can be seen in the 5.8 GHz band

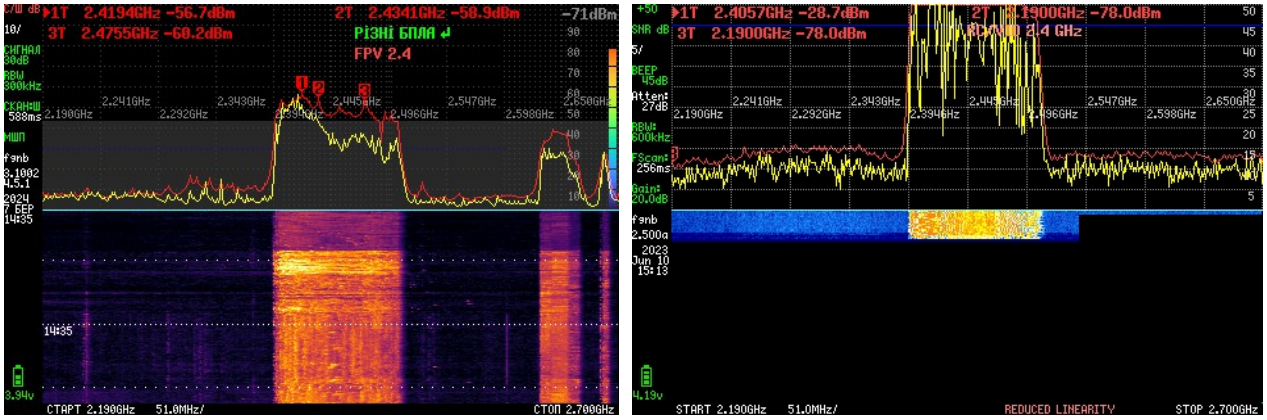
8. Appendix 3. Examples of templates of radiation spectra of electronic warfare signals



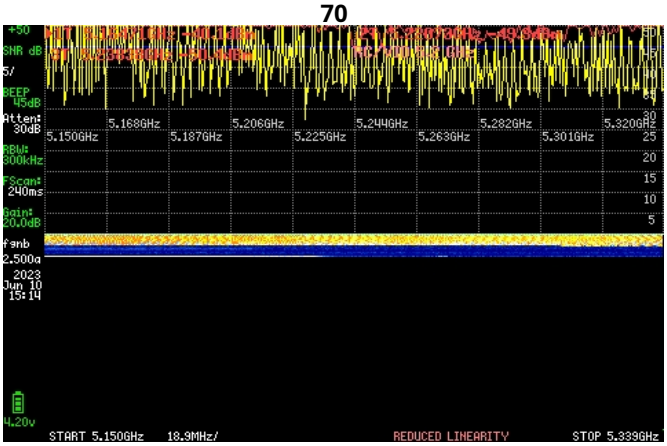
Electronic warfare signal in the range of 850÷950 MHz



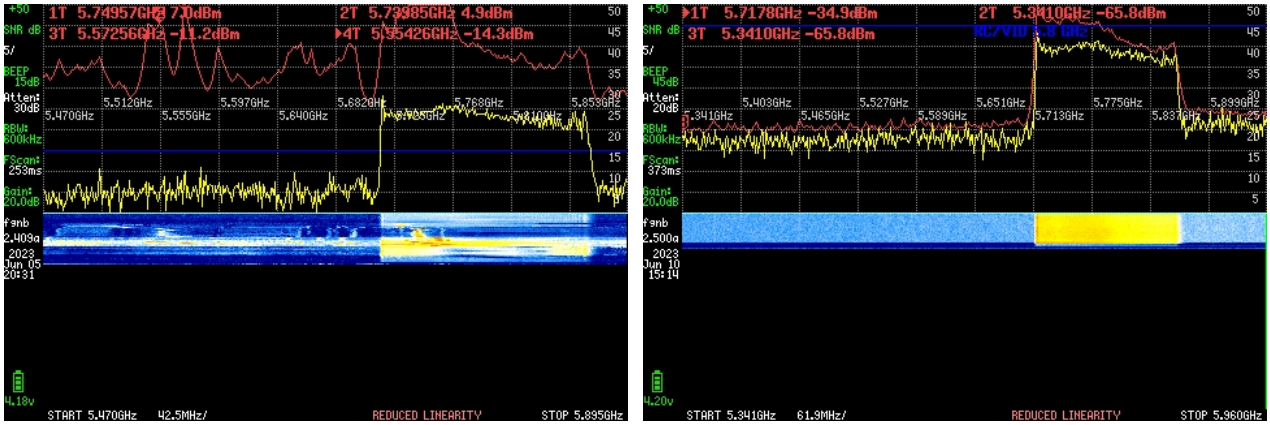
Electronic warfare signal in the satellite navigation range of 1.2 GHz and 1.5 GHz

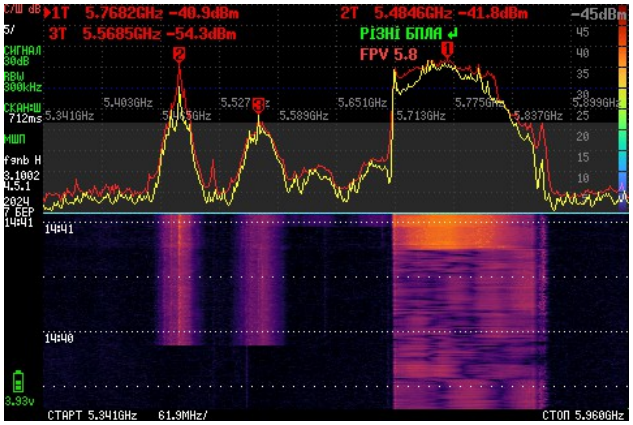


Electronic warfare signal in the 2.4 GHz range

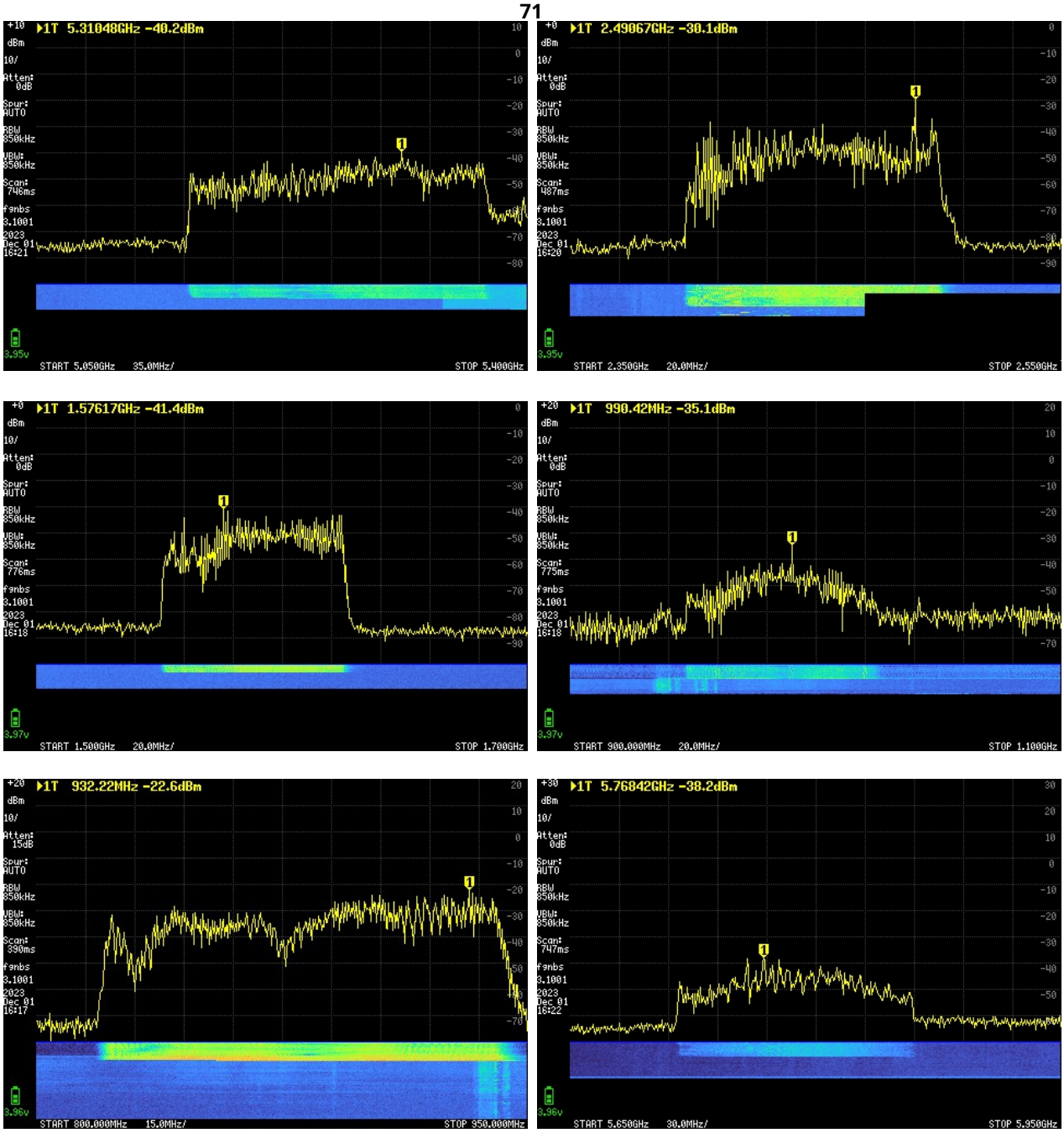


Electronic warfare signal in the 5.2 GHz range





Electronic warfare signal in the 5.8 GHz range



An example of testing a six-channel anti-drone gun