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Electromagnetic compatibility in distributed power systems

***Abstract**. The article presents the issues regarding correct design of power circuits in multi-module electronic devices. At present, in more and more distributed power networks, DC-DC insulated galvanic converters are used. The high level of electromagnetic disturbances, both radiated and conductive, consist the key problem. The results of investigations of radiated and conductive disturbances emission of low impulse power supply developed on the basis of the guidelines contained in the article are presented.*

***Streszczenie.** Przedstawiono zasady poprawnego projektowania układów zasiania w wielomodułowych urządzeniach elektronicznych. Głównym problemem jest tu wysoki poziom zaburzeń promieniowanych i przewodzonych. Przedstawiono konstrukcję zasilacza impulsowego dla którego zmierzono poziomy zaburzeń elektromagnetycznych promieniowanych i przewodzonych (**Kompatybilność elektromagnetyczna w systemach zasilania rozproszonego**).*

Keywords: *switching power supply; multi-module power supply system; electromagnetic compatibility*
Słowa kluczowe: zasilacz impulsowy; wielomodułowy system zasilania; kompatybilność elektromagnetyczna

Introduction

Research on the issues of electromagnetic compatibility of electrical equipment and electronic products should be considered advanced both because of the issues of standards and guidelines (guides design devices). The test methods have been developed with the standardized ways for the radiated and conducted electromagnetic disturbances measurements determining maximum levels of disturbances for different groups of devices operating in specific environments. Guidelines for electromagnetic disturbances immunity tests are given in [1-8], while the standards [9-13] apply to issues related to the disturbances emission. Propagation paths of electromagnetic disturbances are known and effective methods of reducing them to levels not higher than the required standards were developed. During the tests the device is treated as a functional whole, the resultant electromagnetic disturbances level is assessed. Generally the electrical construction of the equipment under test is not considered in detail, as well as issues related to its internal electromagnetic compatibility. Such test procedures, in conjunction with frequent neglect of the EMC issues, may make the complex multi-module devices work erratically and exhibit greater susceptibility to external electromagnetic disturbances. The main propagation paths of internal conducted disturbances include power circuits. Equally harmful effect on the operation of the device is caused by large electromagnetic disturbances coming from radiated emission sources which are very often the individual circuit blocks. The designer should take care not only about the correct design of the electronics but also about electronic modules included in the devices which should meet the relevant standards supply requirements of EMC. Especially important issue is the right solution for the electrical part and the printed circuit board so as to ensure the compliance of the designed device with EMC.

The power supply system with the distributed architecture

Nowadays, in an increasing number of electronic devices modular, power systems with the distributed architecture (DPS – Distributed Power Systems) are used. A block diagram of such a solution is shown in Fig. 1. Main power supply, continuous or pulse, converts the alternating voltage on one of the predetermined value of the DC voltage that by central power rail is supplied to the local DC-to-DC converters, powering the distributed power supply receiving points (Point of Load) with a maximum power consumption below a few tens of Watts.

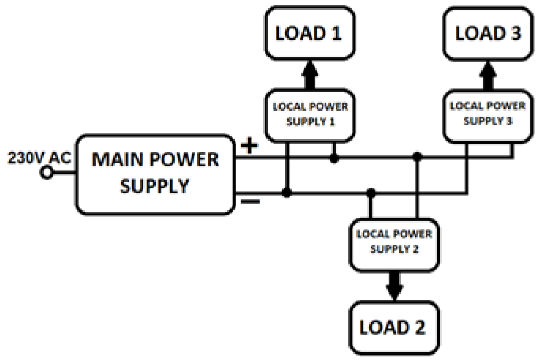

Fig.1. Distributed architecture power supply system (DPS)

Advantages of the presented system can be easily seen in the case of the simultaneous occurrence of several supply voltages within the device. In traditional designs, main power supply connected with the motherboard connector of the device provides all the required supply voltage. Supply power to the individual modules provides a system of paths, sometimes quite complex, occupying a considerable area on the base plate of the device. In addition, in the case of blocks with an average power consumption (approx. 100 Watts), powered by low voltage, the value of the currents flowing through the power paths are even a dozen or so amps, causing unnecessary release of heat during the operation.

However, the main problem, negatively affecting the validity of the device, is caused by radiation and conducted electromagnetic disturbances propagated in (or by) power supply system. The elimination of these disturbances requires a significant effort from the designer, sometimes without the intended positive effect. Distributed power systems are largely devoid of these drawbacks.

As a local DC-to-DC converters switched power supplies are used, insulated or non-insulated. In addition to the basic advantages of switch mode power supplies, which is their high efficiency, the use of isolated converter provides galvanic isolation between the receiver and the main power bus.

This solution is willingly used in the construction of industrial and laboratory equipped containing a set of sensitive analog blocks (eg. Measuring amplifiers with high gain, signal conditioning units, etc.) cooperating with a digital block, which is usually the source of disturbances of a significant level. Similarly, the safe separation of parts of low and high voltage requires a distributed power system.

Most often, as the galvanic isolated power supplies, barrier converters operating in FLAYBACK configuration are used [15, 16, 18]. When the separation is not necessary, the standard configuration is applied, which lowers BUCK voltage or increases BOOST voltage [15, 16, 18].

Depending on the required stability of the voltage provided to the local receiver, pulse converters are used with or without output voltage stabilization, as shown in Fig. 2a) and 2b). Output voltage stabilization of the power supply at a particular level requires galvanic separated, fast negative feedback loop. As the separating elements integrated optocouplers with a photodiode or phototransistor are mainly used.

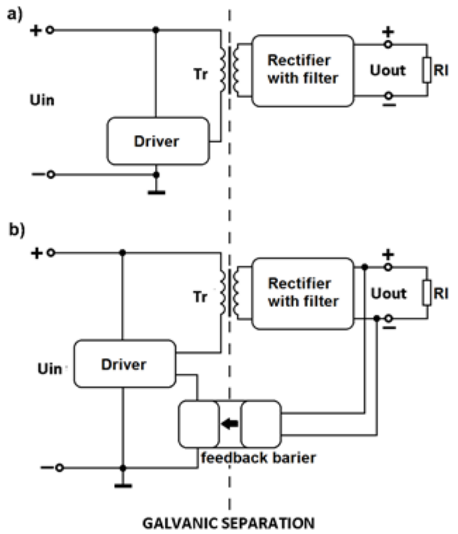

Fig.2. Basic switch mode power supplies settings; a) without stabilized output voltage; b) with stabilized output voltage

Switching power supply design

In order to fully illustrate the structural problems related to the small and medium-power pulse power supply of meeting the requirements of EMC an example application of such a system was prepared. Then, a series of measurements of the radiated and conducted emission of electromagnetic disturbances of a model device was performed.

The following design assumptions were adopted:

- input voltage 12 V,
- output voltage 12 V,
- the maximum output power P_{max} = 3 ($I_{out\ max}$ = 0,25 A),
- efficiency η ≥ 70% at P_{max},
- full input – output galvanic isolation,
- stabilization of the output voltage in the feedback loop,
- operating frequency of 65 kHz,
- work in industrial environment equipment.

The power supply uses the popular driver type MC34063 company ST Microelectronics [14]. The schematic diagram is shown in Fig. 3. The main source of emissions of disorders of the processes are related to impulse work MOSFET, which periodically activates the primary winding of an isolation transformer. Capacity C6 determine the frequency of the system. The system time constant R2, C3 (Snubber) limits the speed and capacity build-up drain, protecting the transistor from damage, in addition to reducing the level of emissions disorders. A similar function is performed by a combination of series connected diodes pulse (D2, D3) of Zener diodes (D4, D5), giving moreover, part of the energy losses to the power supply, thus increasing the efficiency of the inverter. Attach the input filter capacitors C4 and C5 increases damping generated in the disorders conducted. The secondary winding of the transformer rectifier supplies D6 with the band filter capacitors C1, C2. The output voltage is stabilized in a negative feedback loop consisting of components R1, R3, D7 opto1. The system is protected against overload, monitoring power consumption by the voltage drop across the sampling resistor R5.

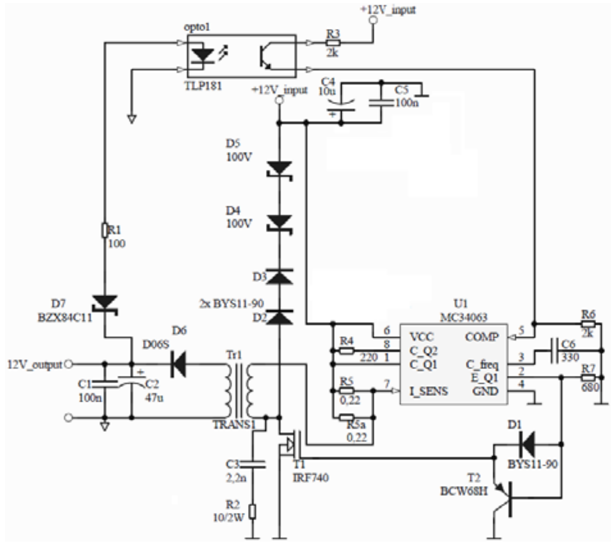

Fig. 3. Schematic diagram of the switching power supply with galvanic isolation

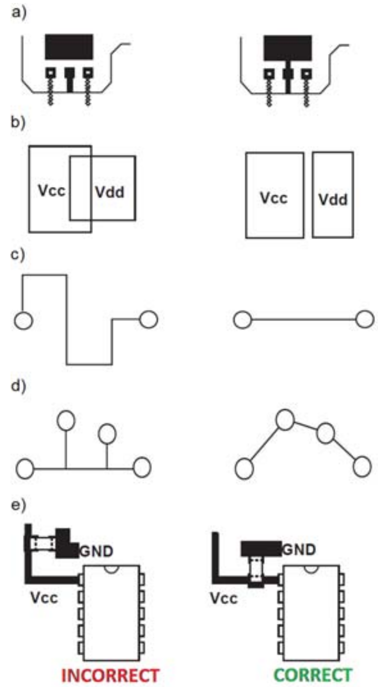

Fig. 4. Solutions used in the printed circuit boards of power supplies

By joining the project printed circuit (see Fig. 6) account should be taken of the relevant EMC requirements vision punt design rules [17] that:

- use thick paths for connections (so that they were the main drainage path of disorders – have the lowest resistance) and outfeed high-current,
- plug all unused entry items to the points about specific potential, as in Fig. 4 a (so that they don't neutralize secondary source HF.),

- sided circuits lead power path so as not to overlap. 4 b (so that the signals from the different instead to each other not touches),
- use as short as possible and simple connections between the elements of the Fig. 4 c, d (so as to avoid "antennas" – generate disturbances and loops which can be followed by a strengthening of the unwanted signal),
- in the case of wired connections inputs and outputs power supply system use shielded cables with screen connected with both parties in a way that is as short as possible,
- locking elements power supply circuits set close to the ends of the element. 4 e,
- in multi-module circuits do not form a loop in the mass or power circuit, Fig. 5.

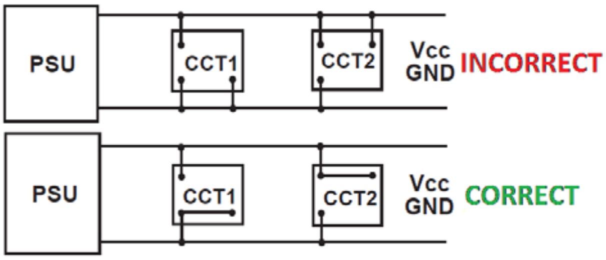

Fig. 5. Ways of carrying bus rails in multi-module electronic devices

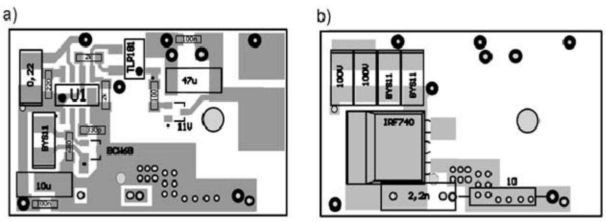

Fig. 6. View of two-sided printed circuit board power supply size 42×26 mm a) BOTTOM side; b) From TOP page

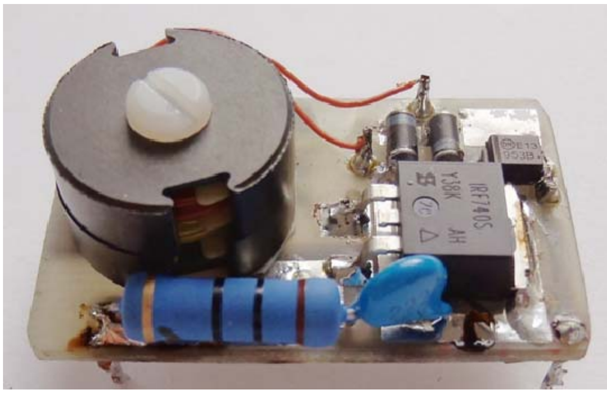

Fig. 7. General view of the model impulse power supply

Study of radiated and conductive emission of the converter

Measurements of radiated emission of electromagnetic disturbances conducted in the frequency range 30 MHz ÷ 1 GHz, while the emission of electromagnetic disturbances conducted was measured in the range of 150 kHz ÷ 30 MHz. The study was performed in accordance with the guidelines contained in the standards [10 to 13] for two levels of output power supply P_{out}, respectively of:

(1) P_{out1} = 0,9 W (30% of P_{max}, I_{out1} = 75 mA)
(2) P_{out2} = 2,7 W (90% of P_{max}, I_{out2} = 225 mA)

System during testing collaborated with resistive load. The results of measurements of emissions radiated and conducted disturbances are shown in Fig. 8 ÷ 17.

A. Emission of radiated disturbance

Fig. 8 ÷ 15 shows the emission of disturbances radiated power supply at the connection between the system and the load and power supply cord made shielded and unshielded. Also specified emission limits disturbances for devices operating in industrial conditions and the level of background electromagnetic (the unit is switched off).

In the first step measurement was performed using an initial peak detector (PK) and for areas in which there were levels exceeding limit values set out for the detector quasi-peak (QP), then made the measurement detector verify the quasi-peak (QP).

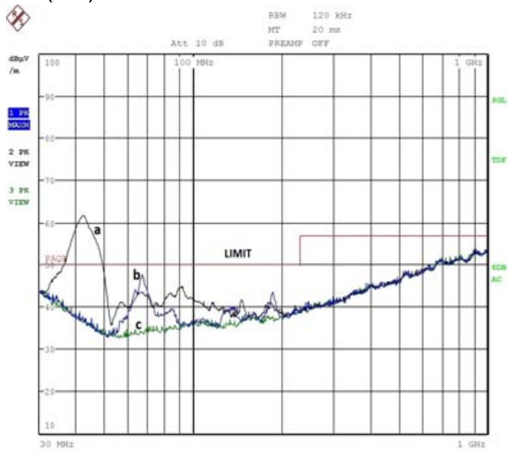

Fig. 8. The emission of radiated disturbance power supply for power P_{out1} by a horizontal antenna setting, the curve a - wires unshielded, curve b - shielded cables, curve c - background level

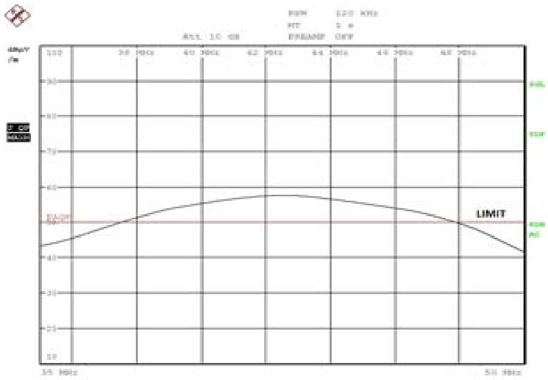

Fig. 9. Emission of radiated disturbance power supply for power P_{out1} with horizontal set antenna and cables unshielded - measurement verification detector QP

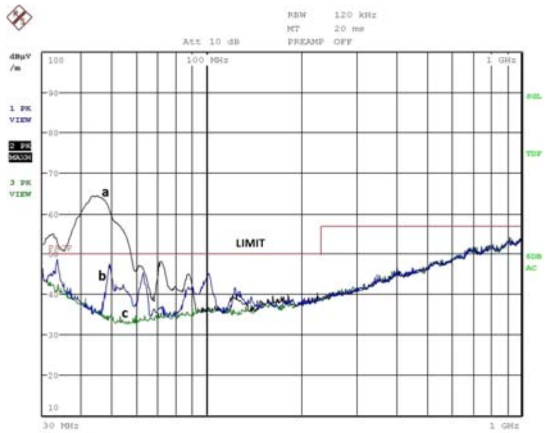

Fig. 10. Emission of radiated disturbance power supply for power P_{out1} with vertical antenna setting, the curve a - wires unshielded, curve b - shielded cables, curve c - background level

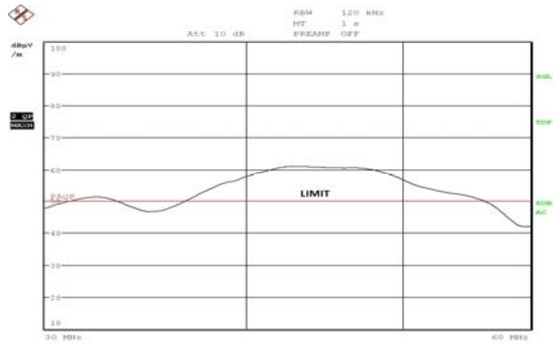

Fig. 11. Emission of radiated disturbance power supply for power P_{out1} on the vertical setting of the antennas and cables unshielded - the measurement verification detector QP

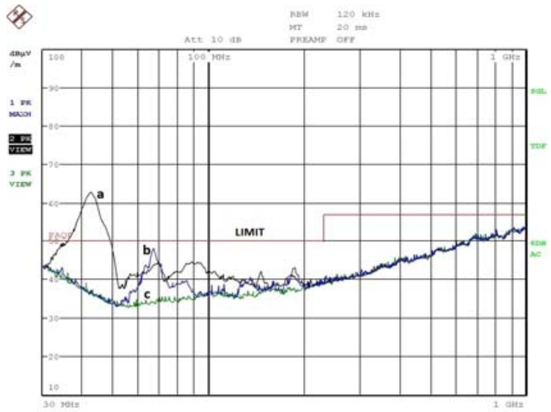

Fig. 12. Emission of radiated disturbance power supply for power P_{out2} by a horizontal antenna setting, the curve a - wires unshielded, curve b - shielded cables, curve c - background level

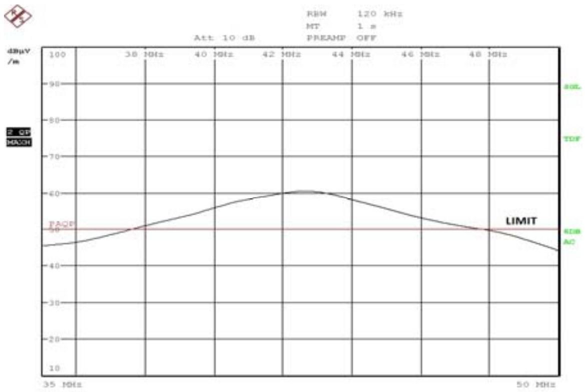

Fig. 13. Emission of radiated disturbance power supply for power P_{out2} with horizontal set antenna and cables unshielded - the measurement verification detector QP

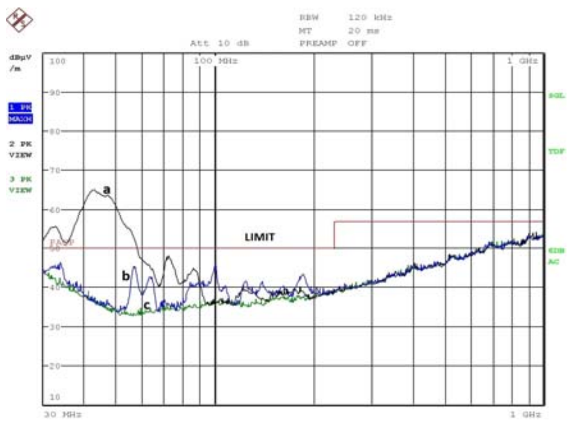

Fig. 14. Emission of radiated disturbance power supply for power P_{out2} with vertical antenna setting, the curve a - wires unshielded, curve b - shielded cables, curve c - background level

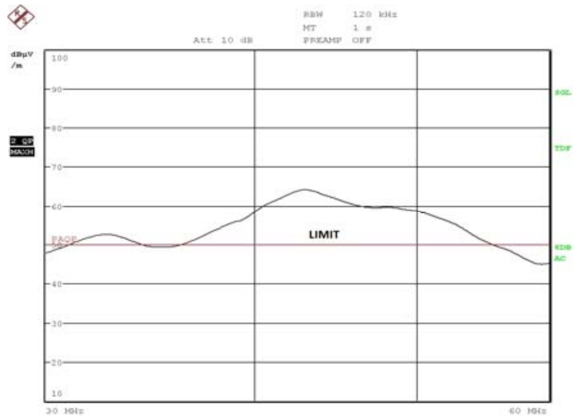

Fig. 15. Emission of radiated disturbance power supply for power P_{out2} on the vertical setting of the antennas and cables unshielded - measurement of the QP detector verification

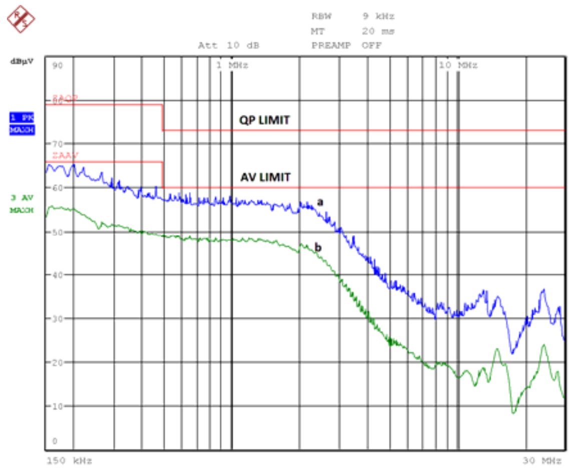

Fig. 16. Emission of conducted disturbances the power supply for the power P_{out1}; curve a - peak detector PK, b - average detector AV, limits for listeners QP and AV

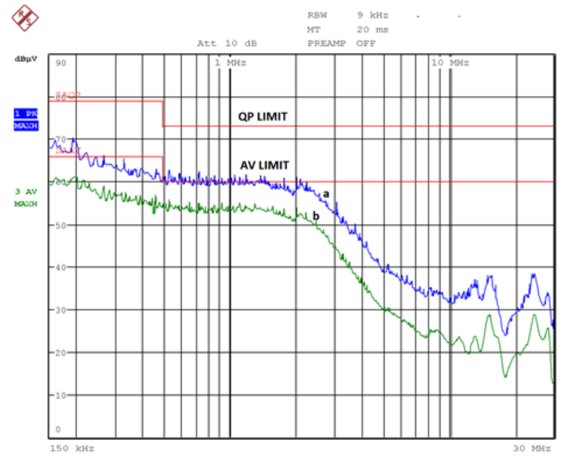

Fig. 17. Emission of conducted disturbances the power supply for the power P_{out2}; curve a - peak detector PK, b - average detector AV, limits for listeners QP and AV

B. The emission of conducted disturbances

In Fig. 16 and 17 are the emission of conducted disturbances the power supply, the measured peak detector and the detector mean value. In addition, given the existing disorder levels in an industrial environment appropriate for the listeners the value of quasi-peak and average values.

Summary

Taking into account the small dimensions of the 42×26×15 mm model power supply, the tested device can be regarded as a point source of radiated electromagnetic disturbances with the [13] antenna distance requirement of 3 m. Power supply and system loads were fed to the power supply and to the load of the system by 1 m cable with and without shield. Assessment of the level of the emission of radiated and conducted disturbances was made based on the standards used for industrial environment [10]. This decision was dictated by the fact that the inverters with parameters similar to the model by far more often are used in industrial devices than in consumer hardware. To improve the study, preliminary measurement of emission of radiated and conductive disturbances was carried out with a measuring receiver using peak (PK) and AV (average) detectors. In the case of exceeding the maximum level of emissions of the current values of the detector for quasi-peak (QP), measurements made with a peak value detector (PK), was repeated measurements with appropriate detector QP (Fig. 9, 11, 13, 15) in the range of frequencies in which the originally observed exceeding permitted level QP.

Initially, the measurements of emissions radiated disturbance from the power supply was carried out for unshielded cables connecting the device to the power source and the load, by exceeding the maximum emission levels for polarization vertical and horizontal antenna, confirmed that verifies the measurement using the detector value of quasi-peak (QP), in the frequency range 30 to 50 MHz (Fig. 8, 10, 12, 14 – curve a).

During the study there were no significant differences in the levels of emissions of the disorders associated with the level of output power supply under test, for both horizontal and vertical polarization antenna measurement.

Exceeding the emission limit values for both polarizations of the antenna was caused by radiated emission not from the object under test, but by irradiation of the power generated by the power supply through the wires connecting the object under test to the source and load. This conclusion is confirmed by the results of the measurement of emissions from the installations for cables made shielded, which screen was connected to ground positions. In this case, all recorded emission levels of the disorder (curve b, Fig. 8, 10, 12, 14) are below the limit values in the graphs as acceptable levels.

There was, however, a reasonable risk that the adapter may generate abnormal in excess of the limits for the emission of disturbances conducted. To this end, made appropriate measurements, the results of which are shown in the Fig. 16 and 17. It is easy to see, that the emission curves are well below the permissible levels in the entire measuring range 150 kHz ÷ 30 MHz The desired spacing from the limit values with a positive test result the emissions radiated disturbances testifies to the correctness of the made project in terms of electromagnetic compatibility requirements. When using longer cable connections between the power supply and, the power bus and the power receiver, make sure that the shielded cable is properly connected on both sides. In the more common situation, place the power supply on the base plate target device, you must ensure that the tracks in accordance with the requirements set out in paragraph 2 and apply the appropriate filters.

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