Original scientific paper

Implementation Aspects of Radio Spectrum Monitoring and Surveillance System in the VHF/UHF Frequency Band

Verica B. Marinković-Nedelicki, Jovan D. Radivojević, Predrag M. Petrović, and Aleksandar V. Lebl

***Abstract* — The radio system for very/ultra high frequency (VHF/UHF) spectrum monitoring and signal processing used in direction finding is presented in this paper. This main system function is based on the implementation of a 6-channel VHF/UHF radio signal receiver. The multicoupler unit allows selection of the desired signal frequency band for the analysis in the receiver. The system implementation is verified according to the user requirements. Several measured electrical characteristics of multicoupler unit and receiver are presented just to illustrate their possibilities for the full application. Besides, the menus for both devices management are briefly described.**

***Keywords* — radio surveillance, VHF/UHF receiver, multicoupler unit, direction finding, electrical characteristics.**

I. Introduction

THE tradition of radio surveillance systems development is very long in the Institute IRITEL. IRITEL solutions in this area cover a wide frequency range including HF, VHF and UHFbands separately or all together [1]-[8]. The basic equipment of these direction finding solutions are radio signal receivers [2], [4], [5], [6], [8]. An integral part of the receiveris also a demodulator in addition with the signal processing unit [8], [9]. IRITEL applies antenna multicoupler units together with a radio signal receiver to allow more antennas to be used inorder to increase system flexibility [1], [3], [7], [8]. Reference [7] is probably the most important one for the system presentedin this paper when considering antenna multicoupler units.

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A brief survey of companies which produce multicoupler units and RF signal receivers suitable for direction finding maybe found in [3], [5], [6], [8]. Companies with such solutions are Win Radio, Thales and Rohde&Schwarz [10]-[14]. Thales solutions are 6-channel direction finding systems covering the frequency range till 3.8GHz and multicoupler units inthe range till 30MHz allowing antenna input signal distributionto a higher number of outputs [10], [13]. Win Radio has a set of easily portable direction finding solutions covering various frequency bands [11]. Direction finding at Rohde&Schwarz is realized using small, light-weight receivers in the range till 6GHz while a multicoupler unit switches one antenna input to eight outputs for frequencies between 225MHz and 400MHz [12], [14]. A number of other suppliers also have direction finding systems. One such example is the Morcom company, whose direction finding systems are suitable for stationary, vehicle-mounted or transportable deployment, but the solution does not incorporate multicoupler units [15]. References [3], [5], [6] contain a detailed explanation why these solutions are not completely suitablefor our applications. Besides a several times higher price, the second dominant reason why similar solutions available at the world market are not suitable is that no one of these solutions may satisfy the specific user requests when considering the number of input and output signals and the connections between them.

In this paper we present the solution of a very high frequency/ultra high frequency (VHF/UHF) radio surveillancesystem. Section II presents in brief the structure of the system. Its two constituent components are, then, described in Sections III (antenna multicoupler unit) and IV (wideband 6-channel VHF/UHF radio receiver). Some important results of performed measurements on both system elements are presented in Section V. Conclusions are given in Section VI.

The complete system has been developed and tested in IRITEL. It is verified for application to Serbian army Military forces.

This paper is an expanded version of contribution [16]. New elements in the paper are a more detailed insight into device appearance, a display of some system management menus and a presentation of more measured system electrical characteristics which are compared to the expected limiting values. These three new elements support readers' confidence to the system function in real, very demanding, exploiting conditions.

II. Radio Surveillance System Fundamental Structure

Fig. 1 presents IRITEL's VHF/UHF direction finding system. The system is successfully presented at the military exhibition PARTNER 2019 in Belgrade, as illustrated in Fig. 1. The system consists of two units: 1) ARK 3600 – an antenna multicoupler unit and 2) a wideband 6-channel VHF/UHF radio receiver. ARK 3600 is placed under and inside the corresponding antenna. VHF/UHF radio receiver is placed in a separate rack. Selected received signals from a desired antenna set are sent from ARK 3600 to VHF/UHF radio receiver to perform the main functions intended for direction finding.

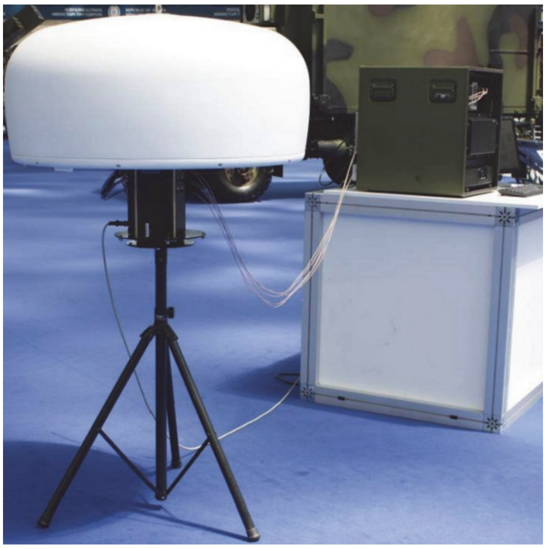


Fig. 1. VHF/UHF direction finding system.

III. ARK 3600 Structure

A block-scheme of antenna multicoupler unit ARK 3600 is presented in Fig. 2, [7]. Its main functions are: the reception of signals from the radio-goniometry antennas and signal distribution/switching towards a 6-channel receiver, selection of signal groups from one of three frequency bands available in the antenna set as well as one of two omni-directional signals for further signal/radio-goniometry processing.

A direction finding antenna system consists of three 5-element and two omnidirectional antenna systems. 5-element systems operate in a frequency band f1-f2, f1-f3 and f3-f4, respectivelywhile two omnidirectional systems operate in the frequency bands f1-f3 and f3-f4. The elements of antenna system are designated as ANTij, where i (i=1,2,3) represents the ordinary number of the antenna system and j (j=1,2,...,5) represents the ordinary number of the antenna signal in one system of antenna signals. The total number of these antenna signals is 15 as also the number of calibration signals (CALIN11,..., CALIN35) intended for ARK3600 self-testing purposes. Calibration signals are generated in a separategenerator of ARK 3600 according to their selection in the CONTROL MODULE.

The modules included in ARK3600 are multiplexers 2 to 1 (MUX2/1), filters (FIL), amplifiers (AMP), multiplexers 3 to1 (MUX3/1) and CONTROL MODULE. The function of eachof these modules is clear from its name and block-scheme. In a physical sense, multiplexer 2 to 1, filter and amplifier, which correspond to the one combination of indices ij are realized as one module (at one printed circuit board). Designations of these modules are LNA1, LNA2 and LNA3.

Besides antenna systems with directional signals used for radio-goniometry function, omni-directional signals are also processed in ARK 3600. Two omni-directional signals are generated: OMNI1 in the frequency band f1-f3 and OMNI2 in the frequency band f3-f4 (Fig. 2). Further processing of these signals is similar to directional antenna signals processing.

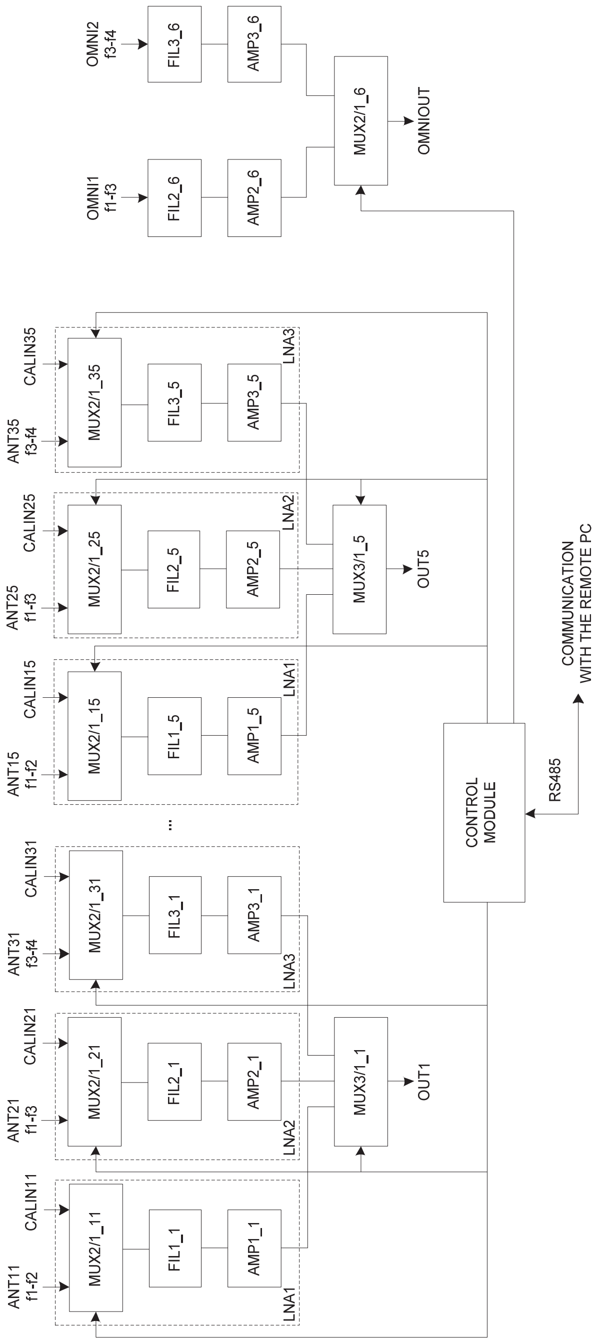


Fig. 2. Block-scheme of antenna multicoupler unit ARK 3600.

Control signals from the block CONTROL MODULE are used to select the signals which have to be transmitted from ARK 3600 inputs to the outputs OUT1 to OUT5, i.e., OMNIOUT. These control signals select the corresponding signals on each multiplexer in ARK 3600. Besides this function, CONTROL MODULE also defines the characteristics of calibration signals sent to CAL IN inputs (not presented in detail in Fig. 2) and exchanges commands and data with the remote PC over a RS485 interface.

The rear and front side of ARK3600 are presented in Fig. 3 and Fig. 4. Antenna and calibration inputs (ANT and CALIN) as well as omni-directional signal inputs (OMNI) are obvious in Fig. 3 and the number of these signals corresponds to those emphasized in Fig. 2. The outputs from the system (DF and OMNI-OUT) are placed at the front side according to Fig. 4 and they correspond to the outputs from the block-scheme in Fig. 2. The cables presented in Fig. 3 distribute calibration signals over the two distributing stars on the top of the device.

Management of ARK 3600 is defined using menus presented in Fig. 5 on a remote PC. Menu in Fig. 5a) is intended to select one of three directional antenna systems and one of two omni-directional antenna systems whose signals are transmitted through ARK 3600. Menu in Fig. 5b) defines the characteristics of calibration signals generated in ARK 3600 system.

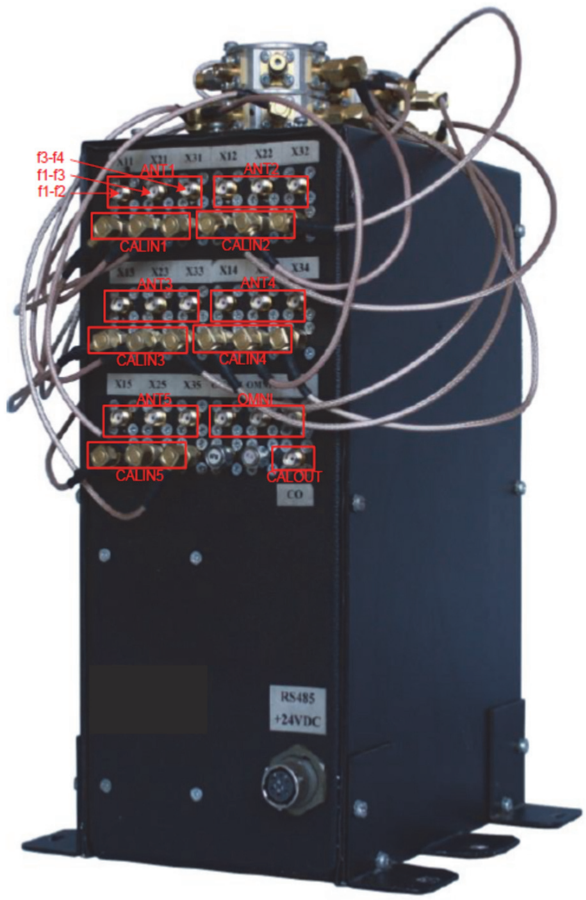
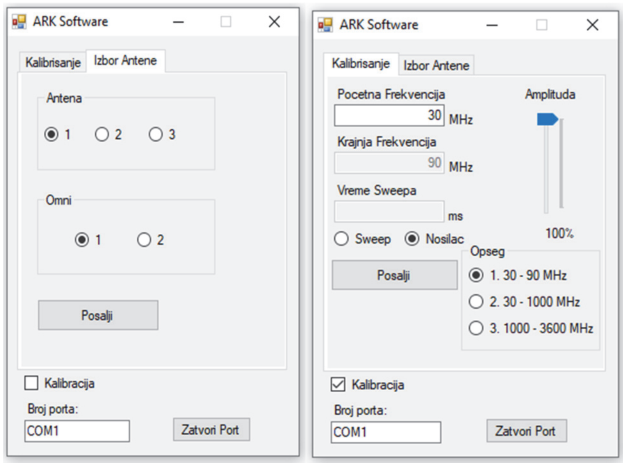


Fig. 3. The rear side of ARK 3600.

Fig. 4. The front side of ARK 3600.



a) b)

Fig. 5. ARK 3600 network management over communications port: a) antenna selection tab; b) calibration tab

IV. VHF/UHF Receiver Structure

The 6-channel VHF/UHF receiver is implemented for electromagnetic spectrum surveillance and control and for broad-band, fast scanning radio-goniometry in VHF/UHF frequency band. Its block scheme is presented in Fig. 6. Necessary external connections between the receiver modules and between the sole radio receiver and other devices are also presented in this figure. Such connections are also emphasized in Fig. 6.

There are four separate oscillators in the module LOCALOSCILLATOR. Two of them generate a signal of variable frequency (outputs with the designation f_{var}). The third and the fourth oscillator (the outputs with the designations f_{fix1} and f_{fix2}) generate the signals of stable, mutually different, frequencies. CONTROL BLOCK defines the frequency changes of two variable oscillators. The first of them is intended for the first 5 channels in the receiver while the second one generates a sinusoidal signal for the 6th channel. Opposite to variable oscillators, the fixed frequency oscillators generate signals for all 6 channels. All 6 receiver channels have the same structure; the only difference is that the 6th channel receives a separate signal of variable frequency.

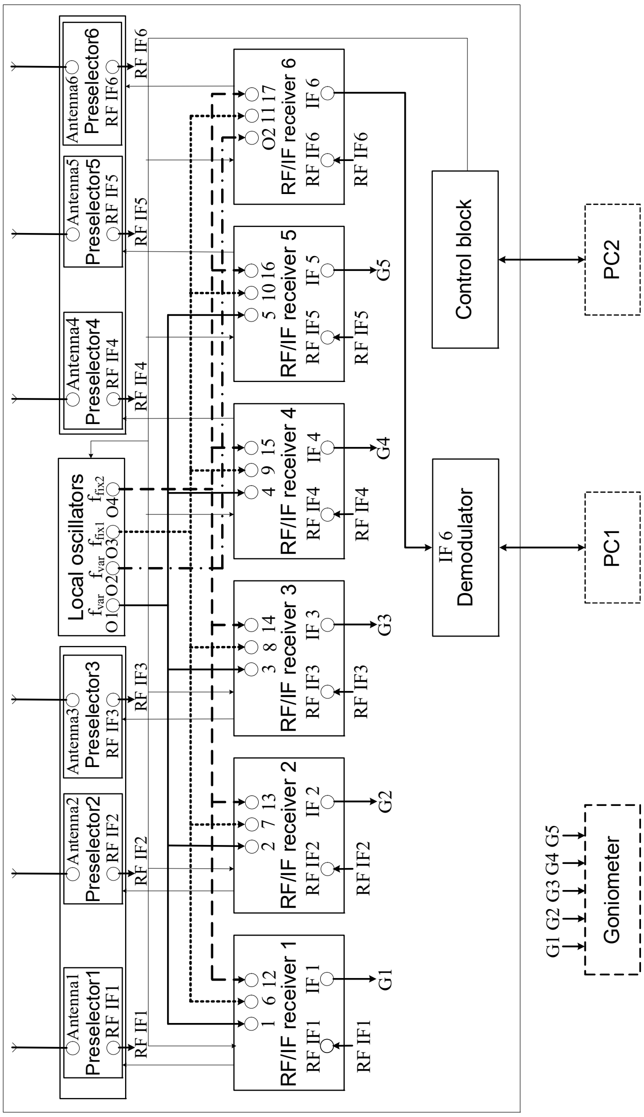


Fig. 6. Block-scheme of the VHF/UHF receiver.

Antenna signal is received in the system over the connectors Antenna1,..., Antenna6. This input RF signal then passes the input filter bank, which is designated as Preselector1,..., Preselector6 (Fig. 6). The filter purpose is to extract the part of the input signal in the desired frequency band. The selection of the desired filter in preselector is realized using the command from the corresponding RF/IF receiver. The signals from the presector output (RF IF1,..., RF IF6) are transmitted to the RF/IF receiver input. One of the RF/IF receiver functions is to transfer an input signal to the intermediate frequency (IF) at the output designated as IF. The outputs from the first five IF outputs (IF1,..., IF5) are used for signal processing in a goniometer (signals designated as G1,...,G5 in the Fig. 6). A goniometer is a separate device (processor) independent of VHF/UHF receiver.

As stated before, electromagnetic spectrum surveillance andcontrol are realized in the VHF/UHF receiver. This action is realized in such a way that the signal from the output IF 6 of the RF/IF receiver 6 is processed in the demodulator block. Signal processing in the demodulator is supported by the program in the computer PC1 where the application SDRSharp for RF signal demodulation is installed.

The Control block of the VHF/UHF radio receiver controls and supervises the operation of all 6 RF/IF receivers and local oscillators. Indirectly, these blocks are under the control of the separate computer PC2.

The rear and front side of VHF/UHF receiver are presented in Fig. 7 and Fig. 8. The switched antenna signals from ARK 3600 are coming to the rear side according to Fig. 7. The realized connections between the system modules (6 receiver modules, block of oscillators, demodulator, then preselectors to receiver modules) are obvious in Fig. 8.

Fig. 7. The rear side of VHF/UHF receiver.

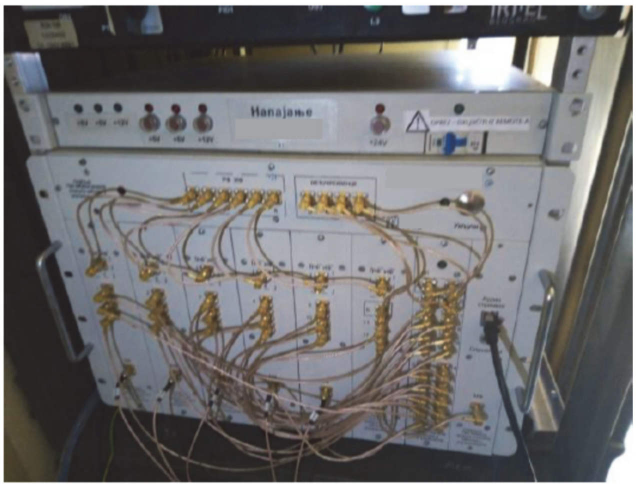


Fig. 8. The front side of VHF/UHF receiver.

The characteristics of signals used to allow RF signal reception are defined from the menu presented in Fig. 9. It is necessary to precisely select the receiving frequency (in

1Hz steps), the signal gain at RF and IF (in 1dB steps), to choose the desired preselector filter and whether manual or automatic gain control is applied, and so on. All these signal characteristics may be defined from a distant PC, as in the case of ARK 3600.

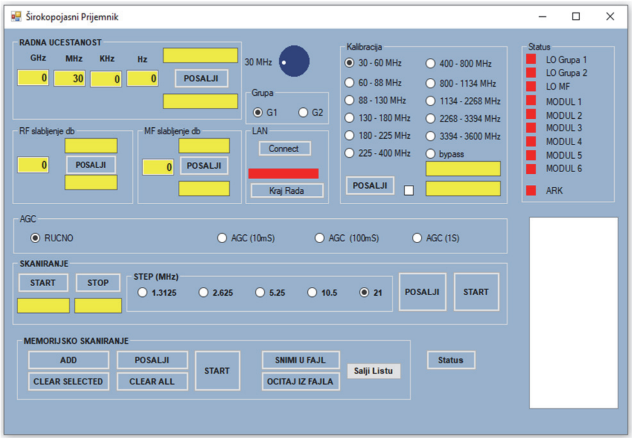


Fig. 9. VHF/UHF receiver network management.

V. The Results of Measurements

The VHF/UHF direction finding system is completely testedand verified for the operation in Serbian army. It has passed the total predefined set of measurements. The measurements have been performed separately for ARK 3600 and VHF/UHFreceiver part. Here some of the results are presented.

The results of measurements for ARK 3600 are presented in Fig. 10 and Fig. 11. Fig. 10 presents the results obtained for Voltage Standing Wave Ratio (VSWR) measured at one input to the system (concretely ANT21 in Fig. 2) while Fig. 11 presents the frequency characteristic of one of the filters (FIL2 from Fig. 2).

The results of measurements for VHF/UHF receiver are presented in Fig. 12 and in tables 1 and 2. Fig. 12 presents the frequency characteristic of one of the preselector filters while Table 1 and Table 2 show the results of the third and second level intermodulation products calculation. The slope of the filter in Fig. 12 calculated on the base of frequencies where attenuations are 3dB and 60dB equals 1.84 and it is obtained according to the formula:

$$S = \frac{BW_{60dB}}{BW_{3dB}} = \frac{f_u - f_l - \Delta f_{l60dB} + \Delta f_{u60dB}}{f_u - f_l - \Delta f_{l3dB} + \Delta f_{u3dB}}, \quad (1)$$

where BW_{60dB} is the filter bandwidth between two frequencies with attenuation 60dB and BW_{3dB} is the filter bandwidth between two frequencies with attenuation 3dB. To determine these two distances in Fig. 12, we have to start from the right side of equation (1). Here f_u is filter upper limiting frequency, f_l is filter lower limiting frequency, $\Delta f_{u60dB}=f_{u60dB}-f_u$ and $\Delta f_{u3dB}=f_{u3dB}-f_u$ are distances of frequencies with attenuation 60dB and 3dB from f_u, $\Delta f_{l60dB}=f_{l60dB}-f_l$ and $\Delta f_{l3dB}=f_{l3dB}-f_l$ are distances of frequencies with attenuation 60dB and 3dB from f_l.

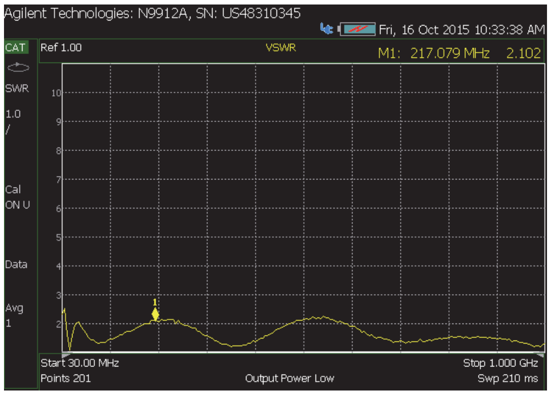


Fig. 10. Voltage Standing Wave Ratio (VSWR) for one of the inputs to ARK3600.

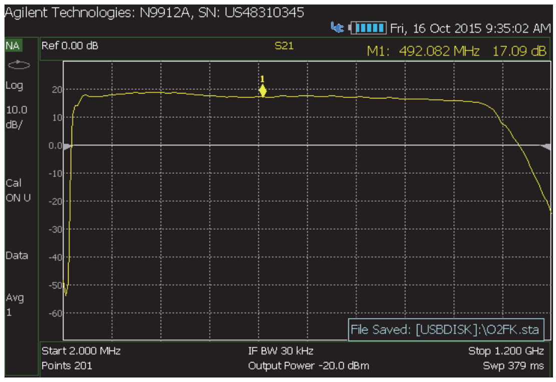


Fig. 11. Filter characteristic as a function of frequency for one of the inputs of ARK 3600.

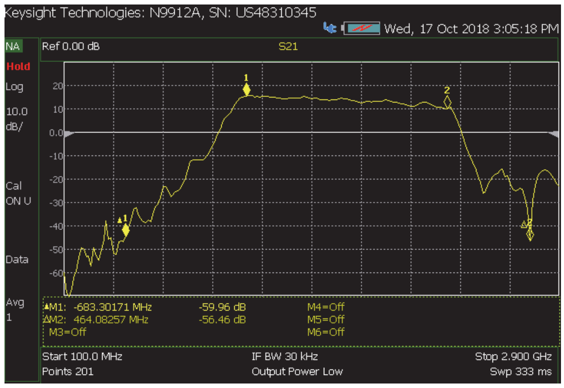


Fig. 12. Filter characteristic as a function of frequency for one of preselector filters at the input of VHF/UHF receiver.

The third level intermodulation products in Table 1 are calculated at the frequencies $f_{ip3} = 2{\cdot}f_2{-}f_1$ starting from the measured signal levels at these three frequencies according to the formula

$$IP3 = P_{in} + \frac{a}{2} \quad (2)$$

where P_{in} is signal level at the frequency f_1 or f_2 and a is the signal level at f_{ip3}. In a similar way, the second level intermodulation products in Table 2 are calculated at the frequencies $f_{ip2} = f_2{-}f_1$ starting from the measured signal levels at these three frequencies according to the formula

$$IP2 = P_{in} + a_1 \quad (3)$$

where a_1 is the signal level at f_{ip2}. Frequencies f_1 and f_2 are selected such that the obtained intermodulation frequency (IF) is in the vicinity of one of the regular frequencies (f_1 or f_2). Thus, it is not possible to attenuate the IF by the channel filter. The acceptable signal level is now the proof of the sufficiently low interference.

TABLE 1: THE CALCULATED THIRD LEVEL INTERMODULATION PRODUCTS AT VHF/UHF RECEIVER

f_1 (MHz)	f_2 (MHz)	f_{ip3} (MHz)	IP3 (dBm)
35	37	39	22
1798	1802	1806	22
3576	3580	3584	21

TABLE 2: THE CALCULATED SECOND LEVEL INTERMODULATION PRODUCTS AT VHF/UHF RECEIVER

f_1 (MHz)	f_2 (MHz)	f_{ip2} (MHz)	IP2 (dBm)
35	76	41	57
1200	2410	1210	57
1790	3590	1800	56

Besides the presented characteristics for both devices, some other measurement results for ARK3600 could also be emphasized: the noise factor in the whole necessary frequency bandwidth is ≤3.4dB, the 1dB compression point is ≥15.3dB and isolation between signal inputs is higher than 75dB and between signal outputs higher than 30dB, and so on.

All transmission characteristics for ARK3600 and VHF/UHF receiver completely satisfy the reference values. As an example, VSWR value in Fig. 10 should be lower than 2.5 for ARK3600. Noise factor, 1dB compression point, isolation between signal inputs and isolation between signal outputs also for ARK 3600 should be less than 8dB, more than 15dB, more than 65dB and more than 30dB, respectively. The filter slope according to Fig. 12 should be lower than 2.5 and the third and the second level intermodulation products according to Table 1 and Table 2 should be greater than 20dBm and 55dBm respectively for VHF/UHF receiver.

VI. CONCLUSIONS

The radio surveillance system for very high frequency (VHF) and ultra high frequency (UHF) spectrum monitoring and signal processing used in direction finding is presented in this paper. The main element in the system is a VHF/UHF receiver and it is supported by an antenna multicoupler unitto select the desired frequency band for signal processing. This development is the extension of IRITEL earlier systems in this area [1]-[9]. The system is verified for its complete production. System management is very simple, over intuitive menus partly described in the paper. Several transmission characteristics are presented just to illustrate system operability.

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