Extraction of Frequency Response of Receiver Input Filter from Characteristic of Receiver Susceptibility to Third-Order Intermodulation

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***Abstract*—Techniques for experimental evaluation of the amplitude-frequency characteristic of a radio receiver input filter on basis of the measured frequency characteristic of the receiver susceptibility to two-signal (or three-signal) third-order intermodulation are developed: the known technique based on the fitting of parameters of the filter's theoretical model is generalized to deal with a switchable input filter having a high shape factor of the amplitude-frequency characteristic; two new techniques which do not require solving the optimization problem are proposed. The developed techniques are validated experimentally by examination of two radio-receiving paths with different types of the preselection filter: with narrow-band tunable filter and with wide-band switchable filter. The techniques are useful for synthesis of a receiver's behavioral model (describing the intermodulation and other nonlinear effects) on basis of experimental data.**

Keywords—receivers; parameter extraction; systems engineering and theory; radio interference

I. Introduction

In order to estimate the ability of interference-free operation of a radio receiver in complicated electromagnetic environment, it is necessary to have information about the selectivity of its input filter. The importance of such information is proved, for example, by the fact that the frequency response (i.e., the amplitude-frequency characteristic, AFC) of the receiver input filter is an input parameter (given data) of the standardized procedure for computation of intermodulation interference levels [1].

Nevertheless, the lack of knowledge about the selectivity of the receiver input filter is a commonly encountered problem in practice of electromagnetic compatibility (EMC) analysis. The parameters of the input selectivity may not be provided in the receiver specification, or they may be provided with little detail (e.g., only for one value of the unwanted signal frequency offset relative to the receiver tuning frequency) which is not enough for estimation of interference. In such situations, one has to use approximate analytical models describing the input filter AFC or to estimate this AFC by experiment.

The input filter selectivity may differ significantly not only for receivers of the same frequency band, but even for the same receiver operating at different frequencies (e.g., the input filter bandwidth of the AOR AR5000 receiver is tripled and the shape of the input filter AFC is changed drastically as a result of changing the receiver tuning frequency from 999.999 MHz to 1000 MHz [2]). Therefore, the known analytical models of the input filter (e.g., the worst-case frequency cull model derived from statistical data [3], semi-empirical model [4]) may be inadequate for the receiver under consideration, and they should be applied carefully (strictly speaking, only after experimental check of their validity for the particular receiver). Besides, analytical models of the input filter may contain unknown parameters (e.g., the bandwidth at one or several levels, maximum attenuation [1, p.2, p.7], [5, p.70]), and one also needs the experiment in order to estimate the values of these parameters.

As a rule, the AFC of the receiver input filter can not be measured directly by the following reasons: the input part of a receiver is often produced as a single component (in this case, it is impossible to connect the measuring equipment), the connection of the measuring equipment impedance changes the operating conditions of the radio-receiving path (so, the measurement results will be corrupted).

A technique for extraction of the input filter AFC from the measured frequency characteristic of the receiver susceptibility (FCRS) to two-signal third-order intermodulation (FCRS-2xIM3) is proposed in [6]. The technique is based on fitting of parameters of the filter's theoretical model and it has two great advantages: the measurement of FCRS-2xIM3 is standardized [7] and it can be performed for any receiver, even for a receiver which does not have the intermediate frequency (IF) output. But this technique is usually not applicable to receivers in which the preselection filter (PSF) is implemented as a bank of wide-band switchable filters.

Another technique for extraction of the input filter AFC from the FCRS-2xIM3 is based on the iterative algorithm [8], now found to be impractical because of divergent iteration.

The objective of this paper is to develop universal techniques for extracting the AFC of the receiver input filter from measured external characteristics of the receiver.

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II. Behavioral Model for Analysis of Receiver Intermodulation

In order to analyze intermodulation interference arising in a receiver, it is useful to represent the receiver as a behavioral model "Filter–Nonlinearity–Filter" (FNF) [5, p.72], [8] (Fig. 1): the first linear filter simulates the frequency selectivity of the receiver input circuit, the memoryless nonlinearity describes the nonlinear properties of the radio-frequency amplifier or of the first mixer, and the second linear filter is a model of the main selectivity implemented, as a rule, in IF path or in digital domain. The advantage of the FNF model is in the following: one is able to synthesize this model (i.e., to extract the model parameters from measured external characteristics of the receiver) even for a receiver the internal structure of which is unknown and the IF output of which is inaccessible (e.g., for a receiver implemented as a single integrated circuit) [8].

If the information about the internal structure of the receiver in not available, it is convenient to normalize the AFCs of the input and output filters ($H_{1U}(f)$ and $H_{2U}(f)$, correspondingly, ref. Fig. 1) to their values at the receiver tuning frequency f_0, i.e., to assume that $H_{1U}(f_0)=1$ and $H_{2U}(f_0)=1$. It is also useful to set the small-signal gain a_1 of the memoryless nonlinearity (MNL) equal to the receiver transfer gain measured from the radio-frequency (RF) input to the IF output; but if the IF output is inaccessible, then it is reasonable (in addition to the normalization of the AFCs) to assume that $a_1=1$, i.e., to operate with signals referred to the receiver input.

Let us represent the instantaneous transfer characteristic of the MNL as a polynomial model:

$$y(x)=\sum_{m=0}^{M} a_m \cdot x^m , \tag{1}$$

where x and y are the instantaneous values of the voltages at input and output of the MNL, M is the degree of the model, and $\{a_m\}$ are the coefficients of the model.

Suppose that the input of the MNL (1) is fed by a sum of L continuous-wave signals

$$x(t)=\sum_{i=0}^{L} X_i \cdot \cos(2\pi f_i + \varphi_i) , \tag{2}$$

where X_i, f_i, φ_i are the amplitude, frequency, and initial phase of i-th component of the input signal, correspondingly.

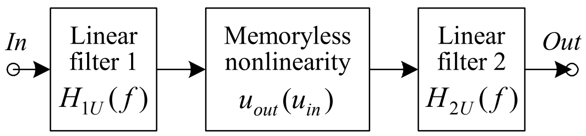

Fig. 1. Behavioral model of a radio receiver.

Consider a K-signal intermodulation (IM) product ($K \le L$) of order N at the output of the MNL (1):

$$y_{(z_1,z_2,\dots,z_K)}(t) \equiv y_{IM}(t) = Y_{IM}\cdot\cos(2\pi f_{IM} + \varphi_{IM}),$$
$$f_{IM}=\sum_{i=1}^{K} z_i f_i , \qquad N=\sum_{i=1}^{K} |z_i| , \tag{3}$$

where $(z_1, z_2, \dots, z_K)$ is a vector of integer coefficients describing the type of the IM product; $Y_{IM}, f_{IM}, \varphi_{IM}$ are the amplitude, frequency, and initial phase of the product (3), correspondingly.

Since the FCRS to intermodulation (FCRS-IM) of any type is measured at small levels of the interference observed at the receiver output (the desired signal which is equivalent to the interference is comparable to the receiver sensitivity), the influence of the nonlinearity of orders $N+2, N+4, \dots$ on the amplitude Y_{IM} of the product (3) can be neglected [5, p.38, p.28], then we have [9]

$$Y_{IM}=\gamma_{IM}\cdot a_N \cdot X_1^{m_1}\cdot X_2^{m_2}\cdot\ldots\cdot X_K^{m_K} ,$$
$$\gamma_{IM}=N!/(m_1! m_2! \dots m_K! \cdot 2^{N-1}), \quad m_i \equiv |z_i|, \quad i=1 \dots K. \tag{4}$$

For receivers known to the author, approximate formula (4) describes the sensitivity-comparable levels of 3-rd order IM products very accurate, and the levels of 5-th order (up to 9-th order in some cases) IM products are described with reasonable accuracy. The amplitudes of the higher-order IM products should be computed by strict formulas [10].

Now suppose that the input of the FNF model (ref. Fig. 1) is fed by the signal (2). Then, at the output of the FNF model, the frequency f_{IM} of the product (3) is not changed and the amplitude, in compliance with (4), takes the form

$$Y_{IM}=H_{2U}(f_{IM})\cdot\gamma_{IM}\, a_N \prod_{i=1}^{K}\{H_{1U}(f_i)\, X_i\}^{|z_i|} . \tag{5}$$

If the IM product frequency (3) falls within the passband of the FNF model output filter (e.g., if $f_{IM}=f_0$), then this product passes to the FNF model output without attenuation (ref. Fig. 1).

III. Extraction of Input Filter AFC from Measured Characteristic of Receiver Susceptibility to Two-Signal Third-Order Intermodulation

For two-signal third-order IM (2xIM3) of the types $(z_1,z_2)=(2,-1)$ and $(z_1,z_2)=(-1,2)$, equation (5) takes the form

$$Y_{2\text{xIM3}}=(3/4)\,a_3\,[H_{1U}(f_N)\cdot X_N]^2\cdot H_{1U}(f_F)\cdot X_F ,$$
$$f_N=f_0+\Delta f, \quad f_F=f_0+2\cdot\Delta f, \quad f_{IM}=f_0, \quad H_{2U}(f_0)=1, \tag{6}$$

where f_N is the frequency of a two-tone input signal component nearest to the receiver tuning frequency f_0; f_F is the frequency of an input signal component farthest from f_0; X_N and X_F stand for the voltage amplitudes of the input signal components with the frequencies f_N and f_F, correspondingly; Δf is the difference between f_N and f_0.

In accordance with [7, pp.73-75, pp.176-177], [3, p. 4.46], [11], let us define the FCRS-2xIM3 as a dependence $X_N(f_N)$ such that the following conditions are satisfied: 1) the frequencies f_N and f_F of the input signal components satisfy the relationship (6); 2) the levels of these components are equal: $X_N = X_F$; 3) the level $Y_{2\text{xIM3}}$ of the IM response component at the IF output of the receiver is constant and equal to the susceptibility level Y_0.

Then, as it follows from (6), the frequency characteristic of susceptibility (FCS) to 2xIM3 for the FNF model is

$$X_N(f_N) = \sqrt[3]{X_0 \big/ \{(3/4)(a_3/a_1)\, H_{1U}^2(f_N)\, H_{1U}(f_F)\eta_{FN}\}}, \quad f_F = 2f_N - f_0, \quad \eta_{FN} = X_F/X_N = 1, \quad Y_0 = a_1 X_0, \qquad (7)$$

where X_0 is the level of receiver susceptibility to co-channel interference, as referred to the radio-frequency input.

If the FCRS-2xIM3 $X_N(f_N)$ is measured, then it is possible to find the FNF model parameters involved in (7): the MNL coefficient a_3 and the input filter AFC $H_{1U}(f)$. For this purpose, the susceptibility level X_0 is considered to be given (e.g., measured), and the MNL coefficient a_1 is calculated by the algorithm provided in Section II.

The MNL coefficient a_3 is defined by the technique proposed in [6]. Assuming that $H_{1U}(f) \cong 1$ near to the receiver tuning frequency, we obtain from (7):

$$a_3 \cong X_0 \big/ \{(3/4)(X_{Na}^3/a_1)\eta_{FN}\}, \quad X_{Na} \equiv X_N(f_{Na}), \qquad (8)$$

where f_{Na} is the reference value of the frequency f_N, this value is chosen in the vicinity of the receiver tuning frequency f_0 in such a way that the point X_{Na} falls in the flat region of the FCRS-2xIM3 $X_N(f_N)$.

A coarse estimate of the input filter AFC $H_{1U}(f)$ can be obtained by K_e times changing (expanding) the frequency scale of the FCRS-2xIM3 $X_N(f_N)$ relative to f_0:

$$H_{1U,e}(f) = X_{Na} \big/ X_N(f_0 + (f - f_0)/K_e). \qquad (9)$$

The value of the expansion factor K_e in (9) is taken from the interval [1.3, 2] and adjusted experimentally. For receivers with tunable preselection filter (PSF), the shape factor of which is usually not high, formula (9) yields good result if $K_e = 4/3$. But for receivers with switchable PSF, the shape factor of which is much higher, the values $K_e \in [1.6, 1.9]$ are usually appropriate (ref. Section V). In order to obtain the worst-case model of the input filter, it is reasonable to use (9) with $K_e = 2$.

More accurate estimation of the input filter AFC $H_{1U}(f)$ can be obtained by fitting of parameters of the filter's theoretical model [6]: the unknown AFC is approximated by a theoretical AFC $H_{1U,t}(f)$ and the parameter values for $H_{1U,t}(f)$ are found by optimization (i.e., they are adjusted in such a way that the FCRS-2xIM3 $X_N(f_N)$ computed by (7) with the use of $H_{1U,t}(f)$ fits the measured FCRS-2xIM3 as well as possible).

It is proposed in [6] to use the AFC of a multi-stage RLC-circuit which is tuned to the receiver working frequency f_0 as the $H_{1U,t}(f)$ and to perform the two-parameter optimization by adjusting the quality factor Q_t of one RLC stage and the number N_t of the stages. Therefore, the application of the technique given in [6] usually produces good result for receivers with tunable PSF. But, as a rule, this technique is not applicable to receivers with switchable PSF, since such PSF is poorly described by the multi-stage RLC-circuit model. In view of the last situation, it is reasonable to generalize the technique proposed in [6] to the case of any arbitrary theoretical AFC $H_{1U,t}(f)$, e.g., to use the AFC of the Butterworth filter or the AFC of the Chebyshev filter as $H_{1U,t}(f)$. In order to obtain the initial estimation for the optimization, it is helpful to calculate the AFC by the use of (9) assuming $K_e = 1.6$ and then to approximate the result by some theoretical AFC $H_{1U,t}(f)$. An example of application of the technique is considered in Section V.

The need of performing the optimization is a drawback of the theoretical-model fitting technique, because this optimization does not permit to make the process of finding the AFC $H_{1U}(f)$ fully automated.

IV. Extraction of Input Filter AFC from Measured Characteristic of Receiver Susceptibility to Three-Signal Third-Order Intermodulation

For three-signal third-order IM (3xIM3) of the types $(z_1, z_2, z_3) \in \{(1,1,-1), (1,-1,1), (-1,1,1)\}$, equation (5) takes the form

$$Y_{3\text{xIM3}} = (3/2)\, a_3\, H_{1U}(f_N)\, X_N \cdot H_{1U}(f_M)\, X_M \cdot H_{1U}(f_F)\, X_F, \quad f_N = f_0 \pm \Delta f, \quad f_F = f_M + \Delta f, \quad f_{IM} = f_0, \quad H_{2U}(f_0) = 1, \quad \Delta f = |f_N - f_0| < |f_M - f_0| < |f_F - f_0|, \qquad (10)$$

where f_N, f_M, and f_F are the frequencies of the components of a three-tone signal at the receiver input; X_N, X_M, and X_F

are the voltage amplitudes of these components, respectively; Δf is the absolute difference between f_N and f_0.

Let us define the FCRS to 3xIM3 (FCRS-3xIM3) as a dependence $X_M(f_M)$ such that the following conditions are satisfied: 1) the frequencies f_N, f_M, and f_F of the input signal components satisfy the relationship (10); 2) the frequency f_N and the level X_N are constant; 3) the levels X_M and X_F are equal: $X_M = X_F$; 4) the level Y_{3xIM3} of the IM response component at the IF output of the receiver is constant and equal to the susceptibility level Y_0.

Then, as it follows from (10), the FCS to 3xIM3 (FCS-3xIM3) for the FNF model is

$$X_M(f_M) = \sqrt{\frac{X_0}{\frac{3}{2}\frac{a_3}{a_1} H_{1U}(f_N)\, H_{1U}(f_M)\, H_{1U}(f_F)\, X_N\, \eta_{FM}}}, \quad (11)$$
$$\eta_{FM} = X_F / X_M = 1, \qquad Y_0 = a_1 X_0.$$

If the value of Δf is small (e.g., if the value of the frequency f_N is chosen at the boundary of the receiver 60 dB passband), then the approximations $H_{1U}(f_N) \cong 1$ and $H_{1U}(f_M) \cong H_{1U}(f_F)$ are valid. By taking into account these approximations, the AFC of the input filter can be expressed from (11) as follows:

$$H_{1U}(f_{MF}) \cong \frac{1}{X_M(f_M)} \sqrt{\frac{X_0}{(3/2)(a_3/a_1)\, X_N\, \eta_{FM}}}, \quad (12)$$
$$f_{MF} = (f_M + f_F)/2 = f_M + \Delta f/2.$$

The optimization is not required here, which is the advantage of the proposed technique (12) in comparison with the theoretical-model fitting technique (ref. Section III). The need to perform the simple but non-standard three-signal measurements is a drawback of the technique (12).

V. Validation of Developed Techniques

In order to validate the developed techniques, the FCRS-2xIM3 $P_N(f_N)$ and FCRS-3xIM3 $P_M(f_M)$ of the AOR AR5000 receiver were measured (Fig. 2) by the instrumentality of the automated double-frequency test (DFT) system [12]. To decrease the measurement time, the receiver response was analyzed at the output of the second IF path (10.7 MHz). In order to examine two typical circuit implementations of the input filter [13], [14], the measurements were executed at two values of the receiver tuning frequency: 130 MHz (the receiving path with the narrow-band tunable filter is used in this case) and 1 GHz (the path containing the wide-band switchable filter is used in the receiver at this frequency) [2]. Only the case of $f_0 = 1$ GHz (in which the agreement of the computed and measured results is worse) is reported below because of limited volume of the paper.

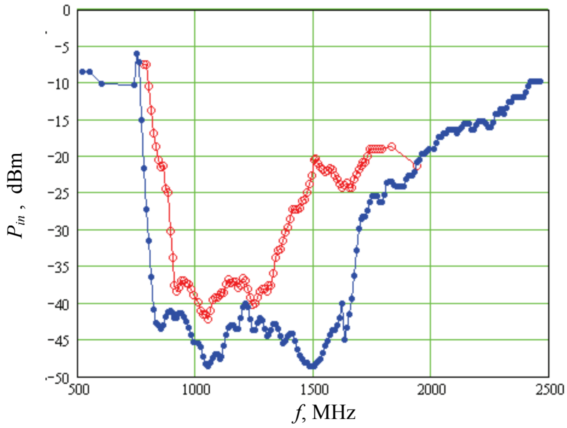

Fig. 2. Measured frequency characteristics of susceptibility (FCS) of the AOR AR5000 receiver to two-signal (red line) and three-signal (blue line) third-order intermodulation (IM3). Parameters of the measurements: the receiver tuning frequency is 1 GHz; susceptibility level referred to the second IF output is -72 dBm. Parameters of the three-tone measurements: the frequency and amplitude of the fixed component of the input signal are 1000.8 MHz and -35 dBm, correspondingly. Note: the desired-signal channel at 1 GHz can not be observed in the plot because it is intentionally skipped during the measurements [7] and the measured characteristics are interpolated (the bandwidth of the first IF path is about 22 MHz at the level of -30 dB [2], the measurement step in frequency is 10 MHz).

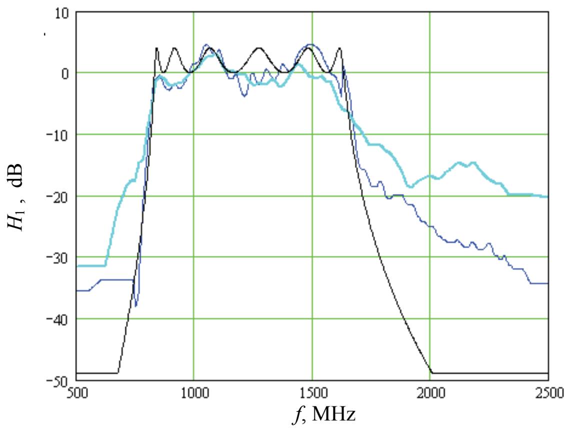

Fig. 3. Calculated amplitude-frequency characteristic (AFC) of the input filter of the AOR AR5000 receiver – the results of processing the FCS to IM3 (ref. Fig. 2) by different techniques: by transforming the FCRS-3xIM3 in accordance with (12) (ref. Section IV) (blue line); by scaling the FCRS-2xIM3 in accordance with (9) in which Ke = 1.8 (cyan line); by fitting the parameters of a theoretical model (ref. Section III) (black line). The fitted theoretical model is as follows: the Chebyshev type I filter of order 12, the passband is 830…1630 MHz at the level of -3 dB, the passband gain ripple is 4 dB, the maximum attenuation is 53 dB.

The AFC of the receiver input filter is computed by the developed techniques (Fig. 3). In order to recalculate the power P into the voltage amplitude X and vice versa, the load resistance of 50 Ohm is used. The MNL coefficients are obtained as follows: $a_1 = Y_0 / X_0 = 27.2$ V/V is computed as a ratio of the standard response -72 dBm to the receiver sensitivity -100.7 dBm, $a_3 = 2345\ \mathrm{V}^{-2}$ is calculated by formula (8) in which $f_{Na} = 990$ MHz.

In order to estimate the accuracy of the developed techniques, the following characteristics are calculated on basis

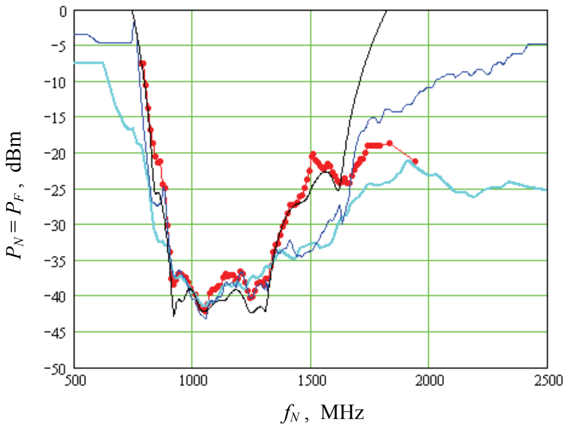

Fig. 4. Frequency characteristic of susceptibility of the AOR AR5000 receiver to two-signal third-order intermodulation – the results of measurement (red line) and computation on the basis of different estimations of the input filter AFC (colors of the lines are the same as in Fig. 3).

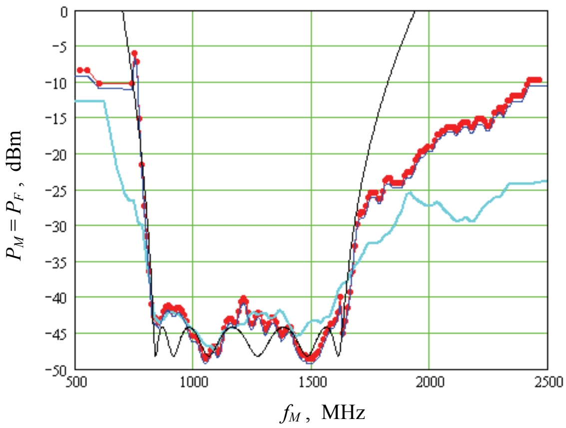

Fig. 5. Frequency characteristic of susceptibility of the AOR AR5000 receiver to three-signal third-order intermodulation – the results of measurement (red line) and computation on the basis of different estimations of the input filter AFC (colors of the lines are the same as in Fig. 3).

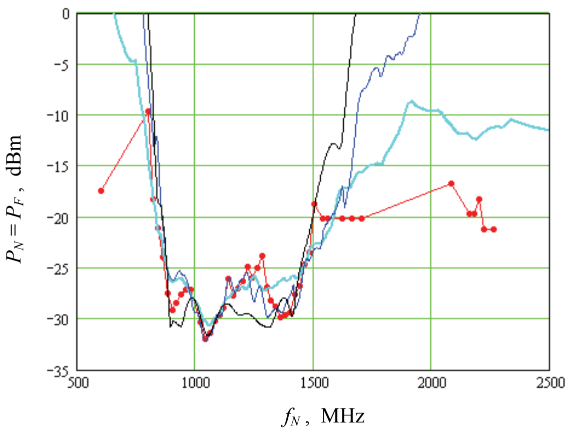

Fig. 6. Frequency characteristic of susceptibility of the AOR AR5000 receiver to two-signal fifth-order intermodulation – the results of measurement (red line) and computation on the basis of different estimations of the input filter AFC (colors of the lines are the same as in Fig. 3).

of the input filter AFC estimations shown in Fig. 3: the FCRS-2xIM3 (Fig. 4) is computed by (7) and the FCRS-3xIM3 (Fig. 5) is computed by (11). The comparison of the calculated and measured FCRS to IM3 (FCRS-IM3) proves the operability and validity of all three developed techniques.

A disagreement between the FCRS-IM3 predictions obtained by fitting the parameters of a theoretical model and by formula (12) is observed in the vicinity of the frequency 1500 MHz in Fig. 4 and in the vicinity of 1800 MHz in Fig. 5. This disagreement is caused by the change of the nonlinearity generating the dominant IM component. The detailed analysis of the receiver circuit showed that the band-pass input filter is implemented in the form of cascade connection of a high-pass filter, first stage of the radio-frequency amplifier (RFA), and low-pass filter. Therefore, the IM3 observed in the vicinity of the mentioned frequencies is generated by the nonlinearity of the first stage of the RFA, but the left branch of the FCRS-IM3 is caused by the nonlinearity of the second stage of the RFA or by the nonlinearity of the first mixer. Thus, the computation of the receiver input filter AFC on basis of the FCRS-2xIM3 may cause the overestimation of the susceptibility level (ref. Fig. 5) and the miss of intermodulation interference as a result. So, for the purpose of EMC analysis, it is preferably to estimate the input filter AFC on basis of the FCRS-3xIM3 by (12) or to use the worst-case estimation, i.e., formula (9) in which $K_e = 2$.

Let us investigate how accurate is the prediction of the FCRS to the other IM responses by using the FNF model. By analogy with FCRS-2xIM3 (ref. Fig. 4), the FCRS to a two-signal fifth-order IM of types $(z_1, z_2) \in \{(3,-2), (2,-3)\}$ (FCRS-2xIM5) is computed with help of (5) and measured (Fig. 6).

In order to find highly dangerous intermodulation responses of the AOR AR5000 receiver, its double-frequency characteristic [12] was measured in the frequency range of 500…3000 MHz. Analysis of the measurement results shows that the second-order intermodulation response of type $f_1 + f_2 - f_{LO1} = f_{IF1}$ is the most dangerous; here f_{LO1} is the frequency of the first local oscillator ($f_{LO1} = 1622.4$ MHz) and f_{IF1} is the first IF ($f_{IF1} = f_{LO1} - f_0 = 622.4$ MHz). Traditionally, this response is not considered as significant for UHF receivers [15]; therefore, the fact of finding it in the AOR AR5000 proves the importance of experimental analysis of a particular receiver and the efficiency of the DFT technology. The results of computation and measurement of the FCRS to this intermodulation response (FCRS-2xIM2) are given in Fig. 7.

With increasing the offset from the receiver tuning frequency, all measured FCRS-IM (ref. Figs. 4, 5, 6, and 7) tend to a constant $P_{\max}$ the value of which falls in the interval –20…–5 dBm. This peculiarity is a result of changing the interference type: the IM interference dominates if the levels of the receiver input signals are less than –20 dBm; the IM is observed together with a one-signal interference (e.g., desensitization or limited effectiveness of shielding) if the levels fall in the range of –20…–5 dBm; in case of the higher levels, one-signal interference dominates despite the fulfillment of the IM frequency relationship. This interpretation is proved by the measured characteristic of the AOR AR5000 receiver susceptibility to one-signal interference (which is not given here due to limited volume of the paper): the maximum level of the susceptibility falls in the range of –20…–5 dBm. Therefore, the upper limit $P_{\max}$ can be taken into account in two ways:

1) First, to analyze and eliminate one-signal interference by the use of the receiver's linear model (which is based on the worst-case approximation of measured FCRS to one-signal interference [3]); as a result, the receiver input signals with levels of –20 dBm or higher will be suppressed. Then, to analyze the IM by the use of the FNF model (ref. Fig. 1).

2) To limit the attenuation introduced by the output filter of the FNF model, as proposed in [8].

The presence of the upper limit $P_{\max}$ of the FCRS-IM from which the input filter AFC is extracted may cause the underestimation of the FCRS to a stronger IM product. For example, the computation of the input filter AFC by scaling the FCRS-2xIM3 leads to the underestimation of the FCRS-2xIM2 (ref. Fig. 7): the level $P_{\max}$ of the FCRS-2xIM2 is estimated at –25 dBm but the measured value is –20 dBm. The underestimation is caused by the fact that the dynamic range of the measured FCRS-2xIM3 (20 dB – ref. Fig. 4) is less than the dynamic range of the FCRS-2xIM2 to be predicted (30 dB – ref. Fig. 7). In other words, the input filter AFC extracted by scaling the measured FCRS-2xIM3 takes into account the clipping of the FCRS-2xIM3 at the value of $P_{\max}$, but this clipping is not caused by the input filter and it should not be taken into account in the extracted AFC. In order to avoid the underestimation of the FCRS-IM levels, one can extrapolate the filter's AFC theoretically (e.g., by the use of the theoretical-model fitting technique – ref. Section III and Fig. 3) or extract the AFC from the measured FCRS to the most dangerous IM response (the 3xIM3 response is more dangerous than the 2xIM3 one, therefore the use of (12) without the extrapolation of the AFC leads to satisfactory result in this case – ref. Fig. 7).

VI. CONCLUSION

The results of experiments prove the validity of all three developed techniques for estimation of the receiver input filter AFC. The ability to predict the frequency characteristic of receiver susceptibility to an intermodulation response of arbitrary type and order on the basis of the obtained estimation of the input filter AFC and measured spurious-free dynamic range for this response is also confirmed experimentally.

Only continuous-wave signals are considered in Sections II, III, IV, and V in order to simplify the analysis and to decrease the measurement time. Nevertheless, the developed techniques for estimation of the receiver input filter AFC are still valid in case of modulated signals; this is important if the receiver does not have the IF output port or if the standardized characteristics must be measured [7, p.75].

After the input filter AFC $H_{1U}(f)$ is extracted, one can synthesize the receiver's behavioral model (ref. Fig. 1) which makes it possible to predict the characteristics of the receiver susceptibility to intermodulation of arbitrary types and orders as well as to predict the presence and severity of receiver intermodulation interference for any given electromagnetic environment [1], [3], [8], [16].

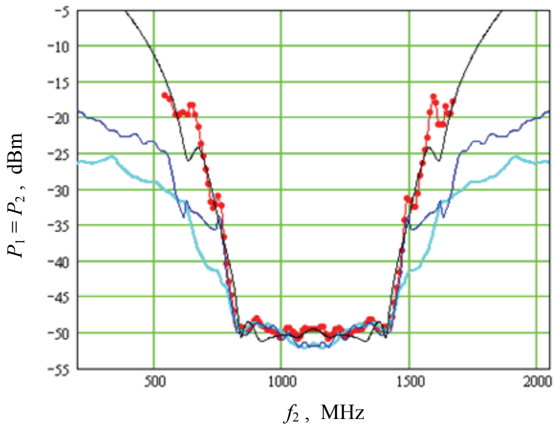

Fig. 7. Frequency characteristic of susceptibility of the AOR AR5000 receiver to two-signal second-order intermodulation – the measured data (red line) and the results of computation by the use of (5) and different estimations of the input filter AFC (colors of the lines are the same as in Fig. 3).

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