Automatic Generation of Starting Values for the Simulation of Microwave Oscillators by Frequency Domain Techniques

M. Filleböck, M. Schwab and P. Russer

***Abstract*—In this paper a new approach to the start-up problem inherent to the large-signal analysis of autonomous circuits in the frequency domain is presented. By insertion of a simple network, depending on one parameter, the oscillator is damped to the stability limit where a linear analysis yields good results. The steady state of the undamped oscillator is then obtained by a continuation method corresponding to the successive removal of the damping network. With this procedure the degenerate solution may be excluded in a straightforward manner.**

I. Introduction

The rapid progress in modern MMIC-technology makes high demands on the accuracy of CAD design tools. Available numerical methods for the large-signal analysis of microwave oscillators are methods of the harmonic balance type [1,2] and algorithms based on power series [3]. All these approaches have in common that the problem of computing the steady state is transformed into the problem of solving a system of nonlinear algebraic system equations. For autonomous systems the unknowns of these equations are typically the oscillating or fundamental frequency and the Fourier coefficients of the state variable waveforms. Common methods to solve the non-linear algebraic system equations are the Newton algorithm, relaxation methods and minimization of an objective function [1]. In any case these iterative algorithms require a set of starting values for the unknowns lying within the region of convergence of the solving algorithm.

Microwave oscillators are generally designed with high-Q resonant circuits causing poor convergence properties or even no convergence if the fundamental frequency is not predicted accurately. An initial estimate for the frequency of oscillation is usually obtained by linear analysis [4,2] or by trial and error methods [5]. The large-signal analysis of autonomous systems performed with starting values not sufficiently close to the time-periodic solution will yield the degenerate solution or will not converge if modifications to exclude the degenerate solution were made. Rizzoli et al. proposed a straightforward approach to free-running oscillator analysis based on the harmonic balance algorithm coupled with a mixed-mode Newton iteration where the fundamental frequency is included as an optimization variable [1,2]. The harmonic-balance system equations were modified in order to exclude the bias point as a solution. Furthermore a finite output power of a significant harmonic is used to perform a preliminary iteration to start up the final iteration [1,2]. Chang et al. incorporated the Kurokawa oscillation condition in the system equations to avoid the degenerate solution [5].

The approach in this paper is not based on the, not generally valid, approximation of the steady state solution of the actual oscillator but on the exact solution of the oscillator damped to the stability limit. The steady state solution of the actual oscillator is then obtained by a continuation method. The algorithm can be incorporated in any large-signal analysis program and performed automatically before the iteration process is started.

The authors are with Lehrstuhl f. Hochfrequenztechnik, Technische Universität München, Arcisstr. 21, D - 8000 Munich 2, Fed. Rep. Germany.
IEEE Log Number 9207405.

II. Continuation Methods

The description of various physical problems can be reduced to a set of nonlinear system equations of the form $\mathbf{E}(\mathbf{x}) = 0$. Since in general an analytical solution is not available, the solution is obtained numerically by iteration algorithms requiring a set of starting values sufficiently close to the solution. An estimation of starting values turns out to be a serious task.

The basic idea of continuation methods is to substitute a problem $\mathbf{E}(\mathbf{x}) = 0$, which cannot be solved directly, by a problem

$$\mathbf{F}(\mathbf{x}, \eta) = 0, \tag{1}$$

where η is an independent continuation parameter and $\mathbf{F}(\mathbf{x}, \eta = 0) = \mathbf{E}(\mathbf{x})$. $\mathbf{F}(\mathbf{x}, \eta)$ is chosen in a way that a solution $(\mathbf{x_0}; \eta_0)$ of $\mathbf{F}$ is known or can be estimated easily. Starting from this first solution $(\mathbf{x_0}; \eta_0)$, the continuation problem is to calculate further solutions $(\mathbf{x_1}; \eta_1), (\mathbf{x_2}; \eta_2)...$ until one reaches the target point at $\eta = 0$. This way the modified problem $\mathbf{F}(\mathbf{x}, \eta) = 0$ is transferred step by step into the original problem $\mathbf{E}(\mathbf{x}) = 0$.

The parameterization of the original problem establishes an embedding which is called artificial for arbitrary choices of the continuation parameter η. Within a natural embedding η can be associated with a physical parameter. The advantage of the latter is that the computed solution branch $\mathbf{F}(\mathbf{x}, \eta) = 0$; $\eta_0 \geq \eta \geq 0$ is of physical interest in many cases.

III. The System Equations

Piecewise harmonic balance approaches and the FATE algorithm [6] are based on the network representation shown

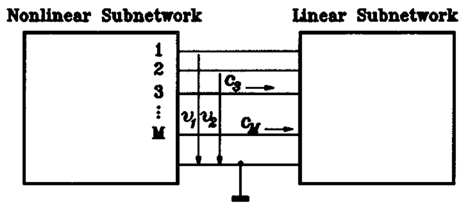


Fig. 1. Schematic network representation.

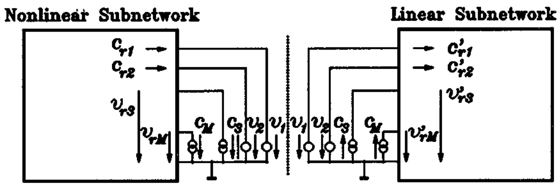


Fig. 2. Separation of the linear and nonlinear network parts.

in figure 1. The oscillator network is divided into two stable subnetworks. The nonlinear subnetwork is described in the time domain by the state equations, the linear subnetwork is described in the frequency domain.

Both subnetworks are connected at M ports. In a subsequent step M linear independent port voltages and currents are substituted by voltage and current sources and the oscillator network is divided up into two parts, see figure 2. We describe the voltage and current sources by the vector $\mathbf{s} = (\mathbf{v}, \mathbf{c})^T$. The system responses to the sources at the ports are represented by the vector $\mathbf{r} = (\mathbf{c_r}, \mathbf{v_r})^T$ in the nonlinear subnetwork and by $\mathbf{r}'$ in the linear subnetwork respectively.

In harmonic balance approaches Kirchhoff's laws are formulated in the frequency domain at the common ports of the subnetworks leading to system equations in terms of vanishing harmonic balance errors. In steady state, all Fourier coefficients of $\mathbf{r}$ and $\mathbf{r}'$, which are described by truncated Fourier series, coincide. The circuit state is completely described by the vector of Fourier coefficients $\tilde{\mathbf{S}}$ of the vector $\mathbf{s}$ and the fundamental frequency of oscillation. The free phase of the limit cycle may be fixed by setting the phase at one port to an arbitrary but fixed value, e.g. by setting the imaginary part of the Fourier coefficient of the fundamental at the first port $\tilde{S}_1^{im}$ to zero. By introducing the fundamental frequency ω_0 as a state variable. the number of unknowns equals the number of system equations.

The system equations are given by

$$\mathbf{E}(\tilde{\mathbf{S}}, \omega_0) = 0, \tag{2}$$

where $\mathbf{E}$ is a nonlinear function and $\tilde{\mathbf{S}}$ represents the Fourier coefficients of the sources at the M ports.

The formulation of Kirchhoff's laws in the time domain, as it is performed in the FATE-algorithm, leads also to system equations of the above form, which can be solved by algorithms of the Newton-Raphson type [6].

To start the iteration, a set of $M(2K+1)-1$ starting values for the Fourier coefficients of the sources and an accurate estimate for the fundamental frequency ω_0 is needed, where M is the number of interconnecting ports and K the number of relevant harmonics. In the following we will show how to overcome the problem of generating starting values by a continuation method with natural embedding.

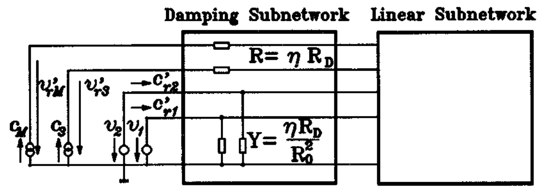


Fig. 3. Linear and damping subnetwork.

IV. The Modified Network

In a strongly damped oscillator network sufficiently close to the primary Hopf bifurcation point, all signal amplitudes in steady state are small. Therefore, linearizing the network in this point and considering only the fundamental frequency component leads to an accurate approximation of the steady state solution.

The basic idea of modifying the oscillator network is to find some parameter, transferring the oscillator into a network close to the primary Hopf bifurcation point, where a linear small-signal approximation yields accurate results.

In this section we will discuss the choice of this parameter, the estimation of the fundamental frequency and the amplitude and phase relations of the Fourier coefficients of the sources at the network ports. By using this approximation as an initial value for the large-signal analysis, the steady state solution for the damped oscillator is determined and this way a starting point for the continuation is given.

A. Establishment of a Natural Embedding

There exist various ways to transfer the original oscillator network into a network at the stability limit, e.g. reducing the bias voltage. In the outlined method, a damping network which is dependent on a damping parameter η, is inserted between the two network parts, see figure 3. Since we presumed stability of each network part, no periodic solution can exist for $\eta \rightarrow \infty$. If there exists a periodic solution for the original oscillator network, i.e. $\eta = 0$, there is a critical parameter $\eta_0 > 0$, for which the steady state solution of the parameterized network changes stability. How the frequency of the onsetting oscillation and the amplitude and phase relations of the Fourier coefficients of the fundamental frequency component can be estimated in this bifurcation point, is the task of the next subsection.

B. The Damped Oscillator Network

The nonlinear subnetwork is described in the time domain by its state equations:

$$\frac{d\mathbf{x}}{dt} = \mathbf{f}(\mathbf{x}, \mathbf{s}) \qquad \mathbf{x} \in R^N, \mathbf{s} \in R^M \tag{3}$$

$$\mathbf{r} = \mathbf{g}(\mathbf{x}, \mathbf{s}) \qquad \mathbf{x} \in R^N, \mathbf{s} \in R^M, \mathbf{r} \in R^M, \tag{4}$$

where $\mathbf{x}$ is the vector of state variables and $\mathbf{f}, \mathbf{g}$ are multidimensional nonlinear functions. The vectors $\mathbf{s}$ and $\mathbf{r}$ describe the sources at the ports and the system responses of the nonlinear subnetwork caused by these sources.

The state equations are linearized around the bias point $\mathbf{f}(\mathbf{x_0}, \mathbf{s_0} = 0) = 0$, leading to

$$\frac{d(\mathbf{\Delta x})}{dt} = \left.\frac{\partial \mathbf{f}(\mathbf{x},\mathbf{s})}{\partial \mathbf{x}}\right|_{x_0,s_0} \mathbf{\Delta x} + \left.\frac{\partial \mathbf{f}(\mathbf{x},\mathbf{s})}{\partial \mathbf{s}}\right|_{x_0,s_0} \mathbf{\Delta s} \quad (5)$$

$$\mathbf{\Delta r} = \left.\frac{\partial \mathbf{g}(\mathbf{x},\mathbf{s})}{\partial \mathbf{x}}\right|_{x_0,s_0} \mathbf{\Delta x} + \left.\frac{\partial \mathbf{g}(\mathbf{x},\mathbf{s})}{\partial \mathbf{s}}\right|_{x_0,s_0} \mathbf{\Delta s}. \quad (6)$$

$\mathbf{\Delta x}$, $\mathbf{\Delta s}$ and $\mathbf{\Delta r}$ are the AC components of $\mathbf{x}, \mathbf{s}$ and $\mathbf{r}$. If we denote $\mathbf{X}, \mathbf{S}$ and $\mathbf{R}$ as the Laplace transforms of $\mathbf{\Delta x}, \mathbf{\Delta s}$ and $\mathbf{\Delta r}$, the system equations in the frequency domain are given by

$$p \quad \mathbf{X} = \left.\frac{\partial \mathbf{f}(\mathbf{x},\mathbf{s})}{\partial \mathbf{x}}\right|_{x_0,s_0} \mathbf{X} + \left.\frac{\partial \mathbf{f}(\mathbf{x},\mathbf{s})}{\partial \mathbf{s}}\right|_{x_0,s_0} \mathbf{S} \quad (7)$$

$$\mathbf{R} = \left.\frac{\partial \mathbf{g}(\mathbf{x},\mathbf{s})}{\partial \mathbf{x}}\right|_{x_0,s_0} \mathbf{X} + \left.\frac{\partial \mathbf{g}(\mathbf{x},\mathbf{s})}{\partial \mathbf{s}}\right|_{x_0,s_0} \mathbf{S}, \quad (8)$$

where $p = \sigma + \jmath\omega$ is a complex frequency.

In the linearized system, the inner circuit states $\mathbf{X}$ can be eliminated and the behaviour of the subnetwork is described by

$$\mathbf{R} = \mathbf{H_{NL}}\ \mathbf{S} \quad \mathbf{H_{NL}} \in C^{M\times M}, \quad \mathbf{S}, \mathbf{R} \in C^M \quad (9)$$

$$\mathbf{H_{NL}} = \left.\frac{\partial \mathbf{g}(\mathbf{x},\mathbf{s})}{\partial \mathbf{x}}\right|_{x_0,s_0} \left[p \quad \mathbf{I} - \left.\frac{\partial \mathbf{f}(\mathbf{x},\mathbf{s})}{\partial \mathbf{x}}\right|_{\mathbf{x_0},\mathbf{s_0}}\right]^{-1} \times \left.\frac{\partial \mathbf{f}(\mathbf{x},\mathbf{s})}{\partial \mathbf{s}}\right|_{x_0,s_0} + \left.\frac{\partial \mathbf{g}(\mathbf{x},\mathbf{s})}{\partial \mathbf{s}}\right|_{x_0,s_0} \quad (10)$$

$\mathbf{I} \in R^N$ denotes the Identity matrix.

As the source vector may contain voltages and currents, $\mathbf{H_{NL}}$ is a hybrid matrix. If $\mathbf{S}$ contains voltages or currents only, $\mathbf{H_{NL}}$ degenerates to an impedance or an admittance matrix. The linear subnetwork may also be described by a hybrid matrix representation.

$$\mathbf{R'} = \mathbf{H_L} \quad \mathbf{S} \qquad \mathbf{H_L} \in R^{M\times M} \quad (11)$$

In order to damp the oscillator network, resistors depending on the damping parameter η are inserted in series to the current sources and parallel to the voltage sources of the linear subnetwork. For this choice of a damping network (figure 3) the matrix representation for the extended linear subnetwork is given by

$$\mathbf{H_{LD}} = \mathbf{H_L} + \mathrm{diag}\Big[\underbrace{\eta * R_D/R_0^2, \cdots, \eta * R_D/R_0^2,}_{M_V} \underbrace{\eta * R_D, \cdots, \eta * R_D}_{M_C}\Big]. \quad (12)$$

R_D and R_0 are constant, M_V and M_C are the numbers of voltage and current sources at the networkports. The damping parameter is denoted by η. The required equality of the port variables leads to

$$\Big[\mathbf{H_{NL}}(p) + \mathbf{H_{LD}}(p,\eta)\Big] \quad \mathbf{S} = \mathbf{H} \quad \mathbf{S} = 0. \quad (13)$$

A possible way for a starting value estimation is to compute the eigenvalues of the linearized system which are determined by

$$det\Big[\mathbf{H}(\eta, p)\Big] = 0. \quad (14)$$

The eigenvector $\mathbf{S_i}$ related to the complex conjugate pair of eigenvalues $p_i = \sigma_i \pm \jmath\omega_i$ with $\sigma_i > 0$ yields a good approximation for the frequency ω_i of the onsetting oscillation and for the amplitude and phase relations of $\mathbf{S}$ [7]. Obviously, for this computation $\mathbf{H_L}(p)$ has to be given analytically. However, for distributed elements the $\mathbf{H_L}$-matrix is available only along the imaginary axis, i.e. $\mathbf{H_L}(p)$ is given for $p = \jmath\omega$.

In the primary Hopf bifurcation point, i.e. $\eta = \eta_0$, the transients of the onsetting oscillation vanish, that means one pair of eigenvalues meets $p = \pm\jmath\omega$. All other oscillations are dying out as they are related to eigenvalues with a negative real part and are therefore neglected. Only the pair of eigenvalues with $\sigma = 0$ is of interest and can be computed via

$$\det\Big[\mathbf{H}(\eta, p = \jmath\omega)\Big] = 0. \quad (15)$$

These are two encoupled equations in terms of η and ω. The solution of (15) yields ω_0 and η_0. Note that H_L has only to be given for frequencies $p = \jmath\omega$. The corresponding eigenvector, i.e. the amplitude and phase relations of the fundamental frequency component of the port variables are given by (13). Due to the rank defect of the matrix $\mathbf{H}(\eta_0, p = \jmath\omega_0)$, one complex port variable has to be set in order to approximate a steady state solution of the damped network. By setting the imaginary part of the Fouriercoefficient at the first port $\tilde{S}_1^{im}$ to zero the phase of the limit cycle is fixed. A strategy how to set the real part of the Fouriercoefficient at the first port $\tilde{S}_1^{re}$ is presented in the next subsection.

C. Steady State Estimation

It has been observed that large-signal analysis algorithms for autonomous systems tend to calculate the degenerate solution. The method of inserting a damping network presented here enables a straightforward solution of this problem. Note that with the insertion of a damping network a solution branch $\tilde{\mathbf{S}}(\eta), \omega(\eta)$ is established, depending on the damping parameter η. This branch describes an oscillatory solution for $0 \leq \eta < \eta_0$ and is determined by the extended system equations

$$\mathbf{E}(\tilde{\mathbf{S}}(\eta), \omega(\eta), \eta) = 0. \quad (16)$$

Usually, the branch is computed by varying η and computing the corresponding $\tilde{\mathbf{S}}(\eta), \omega(\eta)$. To avoid the problem discussed above, one Fourier coefficient of the fundamental is set to an arbitrary but fixed value, say $\tilde{S}_1^{re} = \tilde{S}_1^{st}$ and η is introduced as an optimization variable instead. Starting values for the large-signal analysis are then obtained by calculating the remaining Fourier coefficients of the fundamental via (13) and setting ω to ω_0. Note, that no preassumption has been made except that $\tilde{S}_1^{st}$ is lying on the solution branch defined above. The latter assumption, however, holds in any case if $\tilde{S}_1^{st}$ is chosen sufficiently small. The solution of the modified large-signal analysis program described above, is an $\eta = \eta_{st}$ with

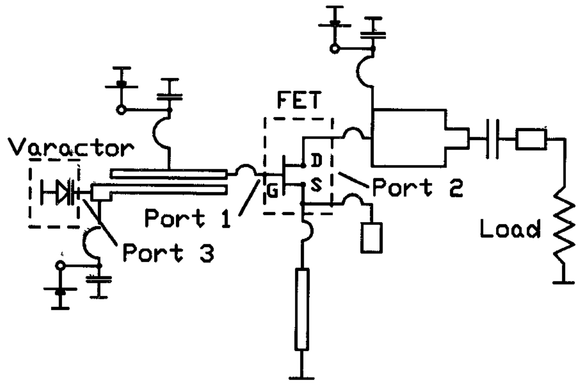


Fig. 4. Varactor tunable GaAs VCO; - - - mark the nonlinear network part.

$0 \leq \eta_{st} < \eta_0$ for which the network has a time-periodic solution with $\tilde{S}_1^{re} = \tilde{S}_1^{st}$.

Starting from the solution of the modified problem with $\eta = \eta_{st}$, the solution of the original problem is found by continuation of the solution branch from $\eta = \eta_{st}$ to $\eta = 0$. By applying the presented method to an example, details such as the appropriate choice of $\tilde{S}_1^{st}$ will be discussed.

V. Example

To demonstrate the feasability of the presented method, starting values for a varactor tunable oscillator were generated according to the strategy described above. The large-signal analysis was performed by the FATE algorithm. The nonlinear and the linear subnetwork have $M = 3$ common ports (figure 4) and the port voltages were substituted by voltage sources. The oscillator was analysed for a varactor tuning voltage of $-2V$. The models for the nonlinear elements were chosen according to [8] and the linear subnetwork was represented by its admittance matrix in the frequency domain.

After linearization of the nonlinear subnetwork in the bias point, the critical frequency and the critical continuation parameter in the primary Hopf bifurcation point were determined to

$$f_0 = 13.7142 \text{ GHz} \quad \eta_0 = 0.364797 \quad (R_D/R_0^2 = 0.001 \text{ S}).$$

This means that a time-periodic solution exists for $0 \leq \eta \leq \eta_0$. In figure 5 the solution path of the frequency of oscillation and the Fouriercoefficient of the port voltage fundamental at the first port, connecting the bifurcation point and the solution of the original problem, is depicted. The task of generating starting values is to estimate any solution lying sufficiently close to the solution path established by varying η from η_0 to $\eta = 0$. With f_0 an estimation for the frequency of oscillation is given. A linear small-signal analysis yields the relation between the Fouriercoefficients of the fundamental at all ports. The estimated Fouriercoefficients of the fundamental at the second and third port may therefore be regarded as linear functions of the Fouriercoefficient at the first port $\tilde{S}_1^{re}$ (figure 6). By setting $\tilde{S}_1^{re}$ to an arbitrary but fixed value $\tilde{S}_1^{st}$, all Fouriercoefficients of the fundamental are determined and the large-signal analysis may be started.

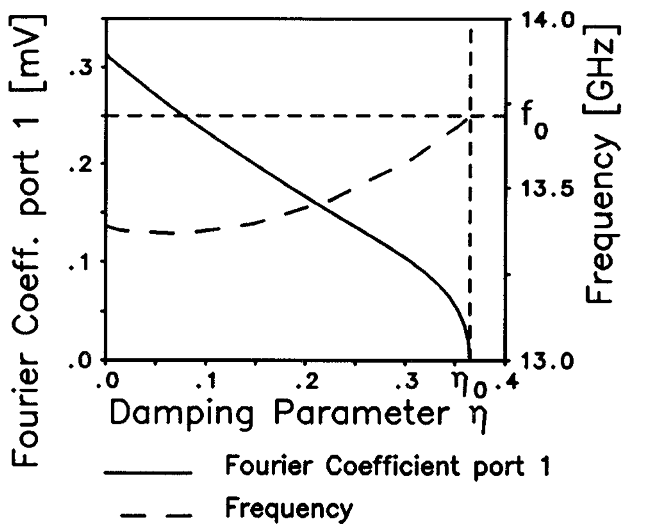


Fig. 5. Solution path of the frequency of oscillation and the Fourier coefficient of the fundamental first port.

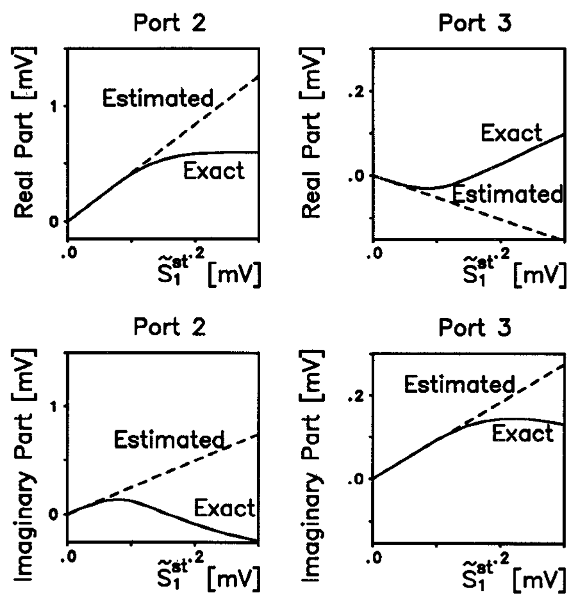


Fig. 6. Estimated and exact values of the Fourier coefficients of the fundamental at the second and third port.

In figure 6 the estimated Fouriercoefficients of the fundamental and the coefficients resulting from the nonlinear large-signal analysis are depicted dependant on $\tilde{S}_1^{st}$. In the case of relatively small amplitudes $\tilde{S}_1^{st}$, the small signal approximation is excellent and the large-signal analysis algorithm converges after one iteration step. For larger choices of $\tilde{S}_1^{st}$, exact and estimated solution do not coincide anymore as the exact solution contains higher harmonics. The FATE algorithm needs more iteration steps, but still converges as the degenerate solution is avoided by setting the Fouriercoefficient of the fundamental at the first port to the fixed value $\tilde{S}_1^{re} = \tilde{S}_1^{st}$. In this case the solution of the iteration is closer to the solution of the undamped oscillator reducing the computational effort for the continuation back to the original problem. Table 1 lists the Fouriercoefficient $\tilde{S}_1^{st}$ determining the amplitude level of the starting values and the solution, the damping parameter η related to the solution with $\tilde{S}_1^{re} = \tilde{S}_1^{st}$ and the number n of iteration steps required to achieve convergence. In any case the deviation of the estimated frequency from the exact solution was less than 2.6%. This value must be regarded with respect to the Q-factor of the resonator, lying in the region of $Q \simeq 30$. Note that the large-signal analysis converged for any choice of $\tilde{S}_1^{st}$ lying on the solution path established by the damping parameter and for small amplitudes $\tilde{S}_1^{st}$ estimated and exact solution almost coincide.

VI. Conclusion

A new algorithm to overcome the start-up problem arising in the analysis of free-running oscillators was presented. By introducing a new network parameter the calculation of the degenerate solution is avoided without any restrictive assumptions concerning the network topology. The algorithm may be coupled with standard large-signal analysis programs such as the piecewise harmonic-balance algorithm and be performed automatically before the actual analysis is started.

Acknowledgment

The authors wish to thank Prof. Dr. P. Rentrop and Dr.-Ing. T. Göller for many helpful discussions. The hybrid integrated GaAs-VCO-oscillator was designed by Dipl.-Ing. V. Güngerich. This work was supported by the Deutsche Forschungsgemeinschaft DFG.

References

[1] V. Rizzoli, A. Neri, P. Ghigi, F. Mastri, *Simulation and Design of Nonlinear Microwave Circuts: An Overview of Frequency-Domain Techniques for the Treatment of Oscillators*, Integrated Nonlinear Microwave and Millimeterwave Circuits (INMMC '90) Digest, p. 123–136, Duisburg 1990

[2] V. Rizzoli, A. Costanzo, A. Neri, *Harmonic-Balance Analysis of Microwave Oscillators with Automatic Suppression of Degenerate Solution*, Electronics Letters, Vol. 28 No. 3, pp. 256–257, 30th January 1992

[3] G. W. Rhyne, M. B. Steer, B. D. Bates *Frequency-Domain Nonlinear Circuit Analysis Using Generalized Power Series*, IEEE Trans. Microwave Theory and Technics, Vol. 36 No. 2, pp. 379–387, February 1988

[4] B. Roth, A. Beyer, *Integrated Microwave Oscillators in Design and Simulation*, Integrated Nonlinear Microwave and Millimeterwave Circuits (INMMC '90) Digest, p.137–151, Duisburg 1990

[5] C.-R. Chang, M. Steer, S. Martin, E. Reese, *Computer-Aided Analysis of Free-Running Microwave Oscillators*, IEEE Trans. Microwave Theory and Technics, Vol. 39 No. 10, pp. 1735–1745, October 1991

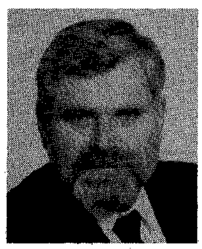
[6] M. Schwab, *Determination of the Steady State of an Oscillator by a Combined Time- Frequency- Method*, IEEE Trans. Microwave Theory and Techniques, Vol. 39, pp. 1391–1402, Aug. 1991

[7] D. Hente, R.H. Jansen, *A Frequency Domain Continuation Method for the Analysis and Stability Investigation of Nonlinear Microwave Circuits*, IEEE Proc., Pt. H, 133, p. 351–362, 1986

[8] V. Güngerich, M. Schwab, P. Russer, *Nonlinear Design and Experimental Results of a Low-Noise Varactor Tunable Oscillator using a coupled Microstrip Resonator*, IEEE MTT-S Digest, p. 549–552, Albuquerque 1992.

Marion Filleböck was born in Pfronten, Germany in 1966. She received the Dipl.-Ing. degree in 1990 from the Technische Universität München. In 1991 she was with JMI-Institute in Tokyo, Japan. Since 1991 she has worked as a Research Assistant at the Technische Universität München on the nonlinear computer-aided design of oscillator circuits.

Martin Schwab was born in München, Germany in 1961. He received the Dipl.-Ing. degree in 1988 and the Dr.-Ing. degree in 1992 from the Technische Universität München where he worked as a research Assistant on the nonlinear computer-aided design of oscillator circuits from 1988 to 1992. Since February 1992 he has been with Siemens AG München.



Peter Russer was born in Vienna, Austria in 1943. He received the Dipl.-Ing. degree in 1967 and the Dr. techn. degree in 1971, both from the Technische Universität in Vienna. From 1968 to 1971 he was an Assistant Professor at the Technische Universität in Vienna. In 1971 he joined the Research Institute of AEG-Telefunken in Ulm, where he worked on fiber-optic communication, high speed solid-state electronic circuits, laser modulation and fiber-optic gyroscopes. Since 1981 he has held the chair of Hochfrequenztechnik at the Technische Universität München. Since October 1992 he has been on leave to join the Ferdinand von Braun Institut für Höchstfrequenztechnik in Berlin as director. His current research interests are methods for computer aided design of microwave circuits, integrated microwave and millimeterwave circuits, microwave oscillators, microwave applications of superconductors and optical communications. Peter Russer is the author of more than 90 scientific papers in these fields. He is IEEE Senior Member, and member of the German Informationstechnische Gesellschaft and the Austrian and German Physical Societies. In 1979 he received the NTG award and in 1990 the Peter Johns Prize. From 1987 to 1989 he was chairman of the German MTT/AP Joint Chapter. In 1990 he was Visiting Professor at the University of Ottawa.