MULTI-HARMONIC DC-BIAS NETWORK BASED ON ARBITRARILY WIDTH MODULATED MICROSTRIP LINE

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Abstract—In this work, we present a novel DC-bias network for multi-harmonic microwave circuits based on an arbitrarily width-modulated microstrip line. The arbitrary shape of the width-modulated microstrip line is obtained by using multiple microstrip taper sections. The method is illustrated through the design of four different DC-bias networks blocking from 1 to 4 harmonic components of a 2.5 GHz signal. The designs with an optimum shape for the arbitrarily width-modulated microstrip line have been manufactured and measured, obtaining a good agreement between the simulated and measured behavior.

1. INTRODUCTION

Over the last years, the increasing demand of low cost compact microwave systems with high functionality and low DC-power consumption [1, 2], has motivated the development of different techniques for the harmonic optimization of microwave circuits [3–8]. Circuits with an optimized harmonic content require DC feeding networks that avoid the power transfer to the DC-source at these harmonics. For circuits that are implemented in microstrip technology, generally these feeding networks are based on structures with radial stubs [9–11]. Nevertheless, radial stub based structures which are used to implement a feeding network with a high number of blocking bands tend to have a very narrowband blocking behavior which increases

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considerably the sensibility to model and manufacture errors. As an alternative to microstrip radial stub based networks, DC-biasing through resistors or RF-chokes can be considered [12]. With the latter, a wideband behavior can be obtained covering the frequency range of the harmonic content to be blocked. Due to the lack of good models that characterize the frequency behavior of these components in the whole frequency range of interest, their usability as bias networks in microwave circuits with an optimized harmonic content is limited.

For the design of multiband microwave filters, the usability of width modulated microstrip lines has been shown in [13–20], where for the shape of the width-modulation known functions as for example sinusoidal [13], gaussian [16, 18], chirped sinusoidal or fourier transform based functions [14, 15, 17, 19, 20] have been proposed.

In this work, we present a new type of multiharmonic DC-bias network, based on an Arbitrarily Width-modulated Microstrip Line (AWMML). The shape of the width-modulation is optimized to obtain a high input-impedance at the desired frequency bands. The arbitrarily width modulated microstrip line is formed by a large number of tapered microstrip sections of the same length, which are optimized in order to obtain a bias-network with the desired frequency response.

The paper is organized as follows. In Section 2, the structure of an arbitrarily width-modulated microstrip line constituted by a large number of tapered microstrip sections is presented, together with the used optimization process in order to obtain the desired frequency response. In Section 3, different optimized multi-harmonic DC-bias networks are analyzed through microwave schematic simulations using distributed elements models for the microstrip taper sections as well as through Method of Moments (MoM) based electromagnetic simulations. The blocking behavior of the different bias networks is studied in Section 4, analyzing their influence in the behavior of a microstrip line when they are connected to the latter. In Section 5, the measured behavior of the different manufactured networks is shown and compared with the simulated results.

2. ARBITRARILY WIDTH-MODULATED MICROSTRIP LINE

The structure of an arbitrarily width-modulated microstrip line is shown in Fig. 1. The AWMML is formed by a large number of tapered microstrip sections of length $\Delta L = \frac{L}{N}$ (Fig. 1(a)) with L the total length of the AWMML and N the number of sections (Fig. 1(b)). In order to obtain a continuous width modulating function, the begin-width $w_{n,1}$ of a particular tapered microstrip section is the same as
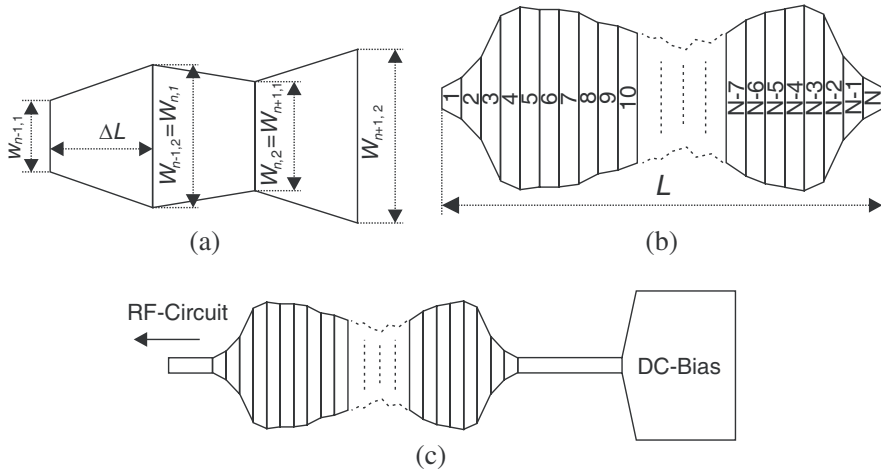
Figure 1. Bias network based on an AWMML. (a) Connection of tapered microstrip sections. (b) Arbitrarily Width-Modulated Microstrip Line. (c) Structure of the bias network.

the end-width $w_{n-1,2}$ of the previous section (Fig. 1(a)). The structure of the bias network is obtained by completing the AWMML, on the RF-side with a small microstrip line in order to asure an easy connection to the high-frequency part of the microwave circuit, and on the DC-side with a transmission line and a wider microstrip section for the mounting of resistors, capacitors and the DC-feed cable. During the optimization process of the AWMML, the length L and the begin- and end-width of every tapered microstrip section are varied in order to obtain the desired frequency response of the bias network.

In a first stage, the design of the bias network is implemented with distributed element models for the microstrip components in the schematic simulator of Agilent Advanced Design System (ADS), using the 0.75 mm thick ROGERS 3003 substrate with $\epsilon_r = 3$ and $\tan\delta = 0.0013$ at 10 GHz. For the different designs of the bias networks, $N = 200$ tapered sections have been used for the implementation of the AWMML. In the optimization process a condition of minimum input impedance is imposed at severall frequencies in the different desired blocking bands of the bias networks, which are satisfied through the optimization of the begin- and end-width of the tapered sections together with the length L of the AWMML. Once the AWMML parameters that satisfy the impedance requirements for the imput impedance of the bias network are found, the layout is created from the schematic model, and the behavior of the structure is analyzed

using the ADS MoM simulator. In the next section, this optimization procedure is illustrated through the design of four different bias networks.

## 3. DESIGN AND ANALYSIS OF AWMML BASED BIAS NETWORKS

The flexibility that is obtained when using an AWMML, is illustrated through the design of four different AWMML-based bias networks having blocking bands at a number M of harmonics of 2.5 GHz ($M = 1, \ldots, 4$. During the optimization process of the different bias networks in the schematic simulator, the input impedance Z_{in} of the structures with the DC-terminal connected to ground (Fig. 2), is evaluated in every blocking band at a number of frequencies. A minimum $|Z_{in}|$ of 1 kOhm along a blocking bandwidth of 200 MHz centered at every blocked harmonic component is imposed. The resulting optimized bias networks are illustrated in Fig. 3, with respectively one (Fig. 3(a)), two (Fig. 3(b)), three (Fig. 3(c)), and four (Fig. 3(d)) blocking bands. The input impedance of the designs simulated with
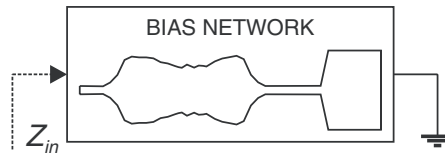
Figure 2. Used configuration for the optimization of the AWMMLbased bias networks.
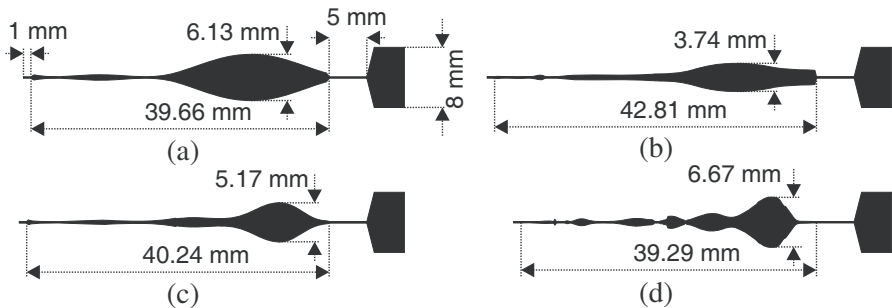
Figure 3. Bias networks based on a AWMML optimized for different blocking bands at: (a) 2.5 GHz. (b) 2.5 GHz and 5 GHz. (c) 2.5 GHz, 5 GHz and 7.5 GHz. (d) 2.5 GHz, 5 GHz, 7.5 GHz and 10 GHz.
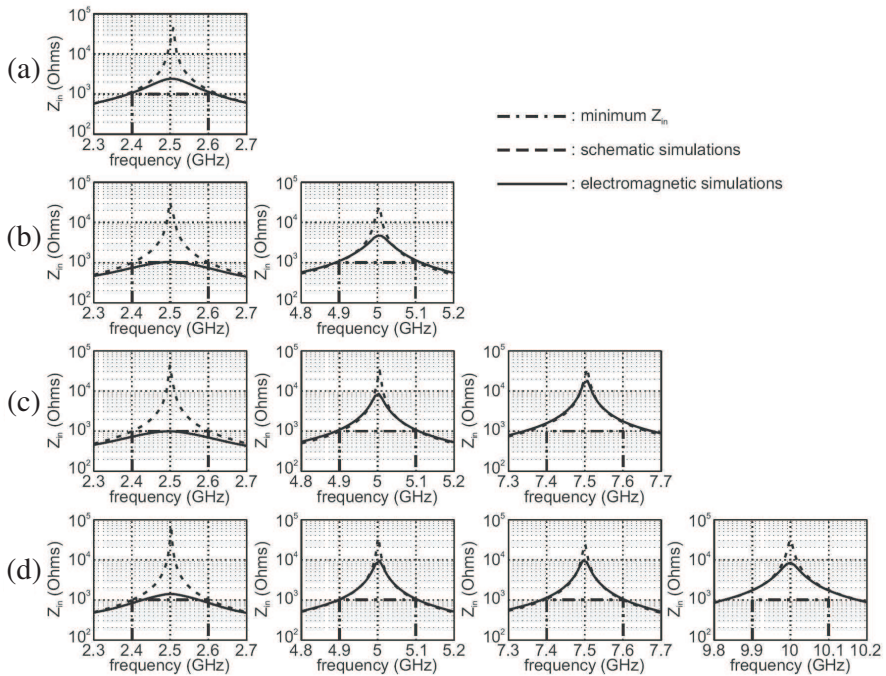
Figure 4. Comparison between schematic and electromagnetic simulations of the designs of Fig. 3.

the ADS schematic simulator, using distributed element models for the microstrip components, are shown in Fig. 4.

Once the design has been obtained in the schematic simulator, the layout is exported and simulated with the MoM based ADS electromagnetic simulator. Small differences between the results obtained with the schematic simulator and the MoM simulator are corrected by changing the length L and thus ΔL of the AWMML structure. The input-impedance of the corrected designs obtained through electromagnetic simulations are compared with the results obtained with the schematic simulator in Fig. 4. Note that although the maximum values of Z_{in} calculated with the electromagnetic simulations are lower than the ones simulated with the schematic models, a sufficiently high impedance is obtained in all the blocking bands.

4. BLOCKING BEHAVIOR OF THE BIAS NETWORKS

The way the bias network affects a microwave circuit is studied using
the configuration of Fig. 5, where the RF-side of the bias network is
connected to a microstrip line and the DC-side is connected through a
resistor R_{DC} to ground.

The configuration of Fig. 5 is obtained by creating in the MoM-
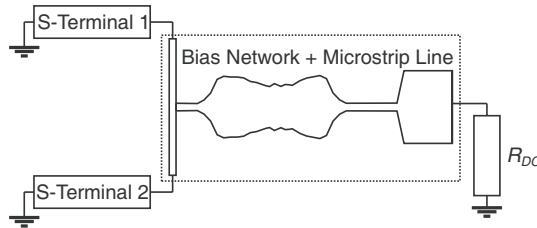
Figure 5. AWMML based bias network connected to a microstrip line
and to a DC-feed resistor R_{DC}.
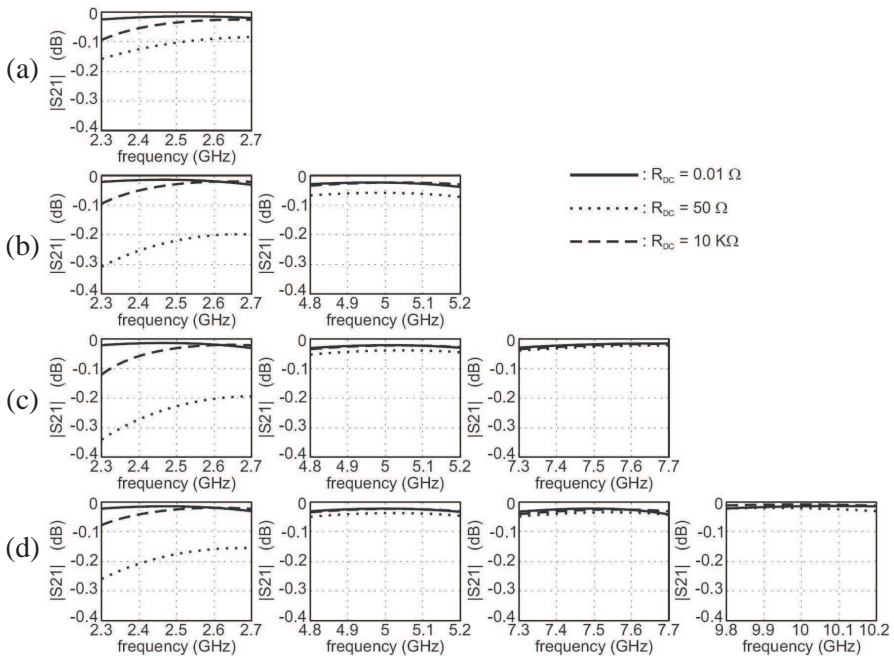
Figure 6. S-parameter $|S_{21}|$ for R_{DC} values $0.01\,\Omega$, $50\,\Omega$, and $10\,\text{k}\Omega$,
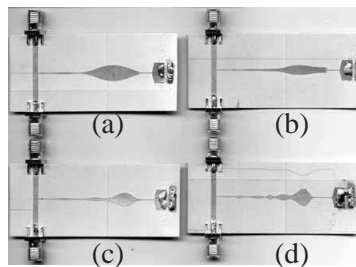corresponding with the designs of Fig. 3.

simulator environment a component, which is characterized through electromagnetic simulations of the layout of the bias network connected to the microstrip line, and imported in the schematic simulator where it is completed with the resistor R_{DC} and the S-parameters analysis ports. A good blocking behavior of the bias network is found when the scattering parameter $|S_{21}|$, measured between the two ports of the microstrip line (Fig. 5), is not affected by variations in the value of R_{DC}.

The result of this analysis is shown in Fig. 6, where the variation of the parameter $|S_{21}|$ in the blocking bands is presented for three different values of R_{DC} (0.01 Ω, 50 Ω, and 10 kΩ). From Fig. 6 it can be seen that the influence of the bias networks on the behavior of the microstrip line leads to a variation in $|S_{21}|$ which is smaller than 0.4 dB for the blocking band at 2.5 GHz, and smaller than 0.1 dB for the blocking bands at higher harmonic components (Fig. 6).

5. EXPERIMENTAL RESULTS

The used configuration of Fig. 5 enables the experimental validation of the designed bias networks. The four AWMML bias networks connected to a microstrip line have been manufactured obtaining the circuits of Fig. 7.

The behavior of the four manufactured bias networks has been analyzed through the measurement of the S-parameter $|S_{21}|$ between the two ports of the microstrip line, for the R_{DC} values 0.01 Ω, 50 Ω, and 10 kΩ. The measured variation of $|S_{21}|$ in the blocking bands is shown in Fig. 8. As can be observed from the measurements of Fig. 8, the influence of the bias networks on the behavior of the microstrip line is very small as predicted by the simulated results of Fig. 6.

Figure 7. Manufactured AWMML based bias networks connected to a microstrip line, corresponding with the designs of Fig. 3.
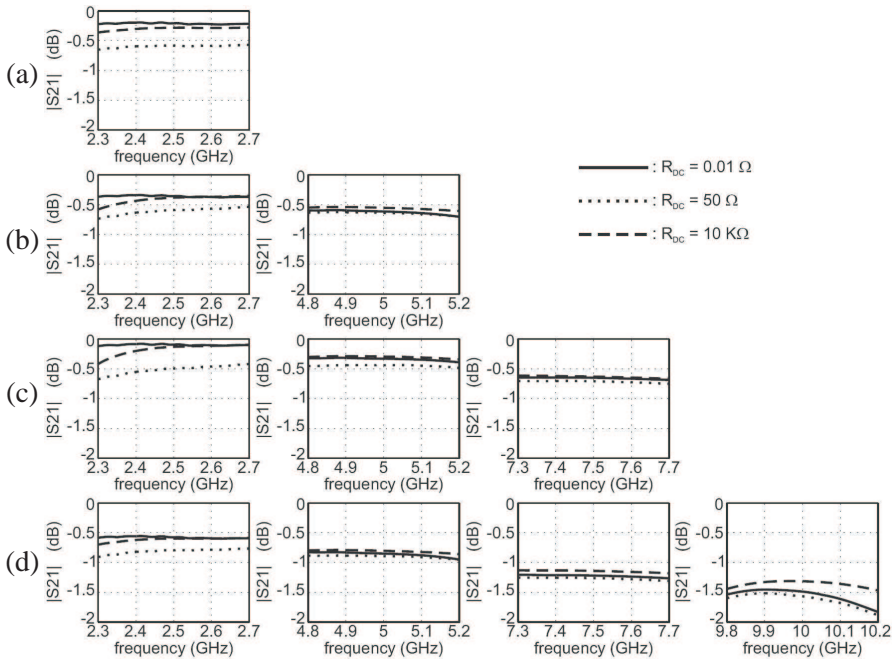
Figure 8. Measured S-parameter $|S_{21}|$ for R_{DC} values $0.01\,\Omega$, $50\,\Omega$, and $10\,\text{k}\Omega$, corresponding with the designs of Fig. 3.

6. CONCLUSIONS

A novel type of multiharmonic bias network based on an Arbitrarily Width-modulated Microstrip Line has been presented. Four different AWMML based networks have been designed for different blocking bands centered at $2.5\,\text{GHz}$, $5\,\text{GHz}$, $7.5\,\text{GHz}$ and $10\,\text{GHz}$. The blocking behavior of the bias networks has been studied when they are connected to a microstrip line. The four designs have been manufactured and measured obtaining a good agreement between experimental and simulated results.

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