

A Table-Based Asymmetric System Mixer Model*

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Abstract — This paper introduces a new behavioral system mixer model that is based on measurement of the asymmetric intermodulation (IM) products at the output port of a mixer under varied frequency and power stimulus conditions. The new model, termed the Global Mixer Model (GMM), simulates mixer performance under varied signal conditions, and overcomes limitations due to symmetric assumptions made in commonly available system mixer models. A GMM generated for a microwave mixer is demonstrated using both a custom simulator, also developed with this work, as well as a commercial simulator.

I. INTRODUCTION

Mixers are frequency translation devices that are widely used in communication, radar and electric warfare systems. Mixer performance depends on the power level and the frequency of the input and local oscillator (LO) signals [1]-[3]. Because of the multiple degrees of freedom, mixers are difficult and time consuming to accurately characterize and model. Furthermore, the nonlinear devices inside the mixer circuits not only produce the desired translated signal, but also a multitude of harmonics and intermodulation (IM) products that make the modeling task even more difficult.

Generally, there are two ways to model mixers: circuit-level modeling and behavioral system modeling. Circuit-level modeling uses models for the internal components that comprise the mixer circuit. This must include accurate device models for the nonlinear components used. Examples of such treatments are given by Maas for diode mixers [4]-[5], and Rosário et al. for MESFET mixers [6].

Behavioral system modeling treats the mixer as a black box, using the external parameters of the mixer to describe its performance. This is of great importance, because often a system engineer has little circuit level information, yet requires accurate mixer system simulations. Electronic Design Automation (EDA) software packages, such as Agilent's Advanced Design SystemTM (ADS), Microwave OfficeTM from Applied Wave Research (AWR), and SerenadeTM from Ansoft, provide behavioral system mixer models. The models either depend on polynomial functions or data files,

such as intermodulation table (IMT) files [8] to predict mixer performance. A conventional IMT file is a 2-dimensional table representing the relative amplitudes of the various frequency components, or spurs, appearing at the output of a mixer for a single specific set of input (f_{RF}) and LO (f_{LO}) frequency and power conditions according to the equation:

$$f_{spur} = |m \times f_{RF} \pm n \times f_{LO}| \quad (1)$$

This paper proposes a new behavioral mixer model which utilizes an efficient indexing scheme to store, recall and interpolate performance using a potentially large number of measured datasets. The model helps evaluate or optimize the mixer's performance in a system simulation from many different (power and frequency) perspectives.

The new mixer model is termed the Global Mixer ModelTM (GMM). The GMM has two parts: the indexing scheme file and the measured data files. Each of the measured data files has a record in the indexing scheme file. The data files are recalled based on the stimulus condition of the measurement taken, i.e. relying on the power and frequency of the input signal and the power and frequency of the LO drive. The data files comprise multiple IMT files, spanning a range of input and LO levels and frequencies.

To generate the input files the authors developed an automated procedure for measuring the amplitudes of the IM products in the output spectrum of mixers under swept single-tone input and LO stimulus conditions. The automatic measurement was implemented using a ME7810A prototype frequency translation device system from Anritsu [3]. The measurement procedure stores IM measurements systematically in multiple IMT files. The indexing file is created as well. Fig. 1 illustrates the indexing process. The indexing scheme behaves as the coordination system which can retrieve the IMT data tables according to the stimulus conditions. Each IMT file corresponds to a distinct sum or difference frequency output spectrum under a specific stimulus condition.

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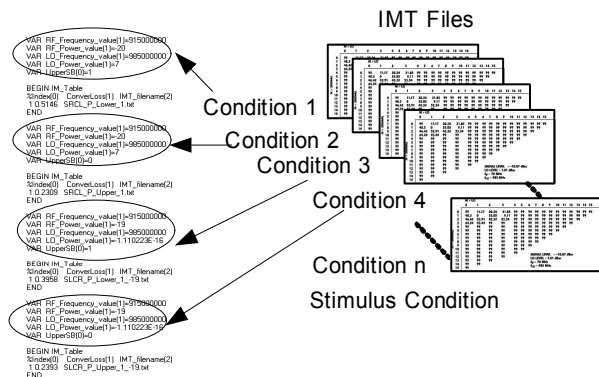


Fig. 1. Indexing Scheme of the GMM mixer model. Multiple asymmetric IMT files are accessed using this scheme.

II. DESCRIPTION OF THE GMM MODEL

The indexing scheme file follows the widely used microwave data interface file format (MDIF) [7]. MDIF uses data blocks that are separated by BEGIN and END statements. Each data block can be indexed through variable information that is started with VAR reserve word for MDIF file format. Fig. 2 shows an excerpt from the indexing file. The file contains two data blocks that are confined between the BEGIN and END statements. In the data block, the conversion loss value (ratio value) and the IMT file name are given. Each data block has an index that is composed of five variables, which specify the stimulus condition and other considerations.

```

VAR RF_Frequency_value(1)=915000000
VAR RF_Power_value(1)=-20
VAR LO_Frequency_value(1)=985000000
VAR LO_Power_value(1)=-1.110223E-16
VAR UpperSB(0)=1

BEGIN IM_Table
%Index(0) ConverLoss(1) IMT_filename(2)
1 0.3936 SLCR_P_Lower_1_-20.txt
END

VAR RF_Frequency_value(1)=915000000
VAR RF_Power_value(1)=-20
VAR LO_Frequency_value(1)=985000000
VAR LO_Power_value(1)=-1.110223E-16
VAR UpperSB(0)=0

BEGIN IM_Table
%Index(0) ConverLoss(1) IMT_filename(2)
1 0.2360 SLCR_P_Upper_1_-20.txt
END

```

Figure 2. Excerpt of an MDIF indexing file

A traditional IMT data file stores the IM products of single-tone input signal and the LO signal in a triangle

table, with the LO harmonic order increasing horizontally while input signal harmonic order increasing vertically [1]. A single IMT file only stores the sum or difference intermodulation products, its conventional use assumes the mixer is symmetrical, i.e. the corresponding sum and difference intermodulation products have the same amplitude. However, this is not always true according to measurements [8]. To address this limitation of the IMT file format, the GMM uses a variable to point out whether the sum products or difference products are inspected, just like the index variable (UpperSB) in the example MDIF shown in Fig. 2. That is, a pair of IMT files is used to more accurately represent sum and difference product amplitudes.

III. SIMULATION USING THE GMM MODEL

To evaluate the advantages of the proposed GMM, a simulator was developed to access the model and extract information from the model. The simulator reads the indexing files as well as the measured data files according to different requirements. The data is then sent to MatlabTM [9] for data graphing.

One can explore the performance of the mixer in different ways. The user can choose to view the measured data either under sweeping conditions or in static condition. One can also choose to view one IM frequency component in the output spectrum three-dimensionally, or compare the trends of several spurs under the same sweeping parameter. When the specified condition matches a condition for which stored measured data is available the simulation exactly reproduces the measured data. Multidimensional linear interpolation is used when the data for the specified condition is not in the measurement set. More complex interpolation methods (e.g. spline) could also be implemented.

To exemplify the process, measurements on a commercial mixer were made and the measured data was arranged according to the GMM requirement. In this example, the power levels of the input and LO signals were swept and the frequencies were kept constant. The measurement setup is illustrated in Table I. As one can see, the mixer is used as a down-converter. All the results shown use the GMM to reproduce measured data, hence, no measured-to-simulated comparisons are possible or necessary.

TABLE I
MEASUREMENT SETUP OF THE EXEMPLIFIED DATASET

	Frequency	Power
LO Drive	985 MHz	1 – 10 dBm
RF Signal	915 MHz	-15 – 5 dBm

In the first example shown in Fig. 3, the output spectrum is shown cascaded for several static stimulus conditions. The LO signal has a power level at 7 dBm while the RF signal at -15, -10 and 0 dBm respectively. The results show that power levels of the difference components are quite different from that of the sum components. For example, when RF is at -10 dBm, the IF component (70 MHz) has a power level of -15.37 dBm compared to the sum component (1900 MHz) whose power level is -22.31 dBm. However, this difference cannot be observed in the simulated spectrum using only one IMT file [8]. The GMM model addresses the limitation of the traditional IMT file format by using two IMT files (one for the sum, one for the difference components) simultaneously and improves the accuracy of the simulation.

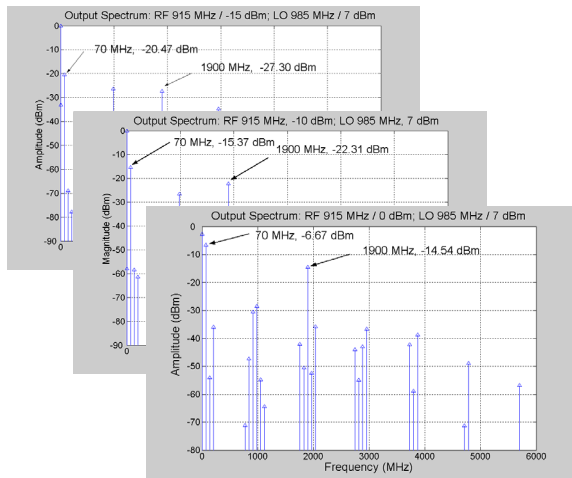


Fig. 3. Static stimulus condition spectral output using the GMM model. Results for 3 different power levels are shown.

Next we use the GMM to analyze the power dependences of the conversion loss (CL). In Fig. 4, the conversion loss of the mixer is plotted against sweeping RF and LO power levels. As one can see, the CL changes little when RF power is low; when RF power exceeds 0 dBm, the CL exhibits power compression. As expected, increasing LO power decreases the CL.

Any single IM product can be simulated versus the sweeping parameters. In Fig. 5 the difference IM product of 3rd LO and 1st RF harmonics are plotted versus sweeping RF and LO power. In Fig. 6, four IM products are plotted versus sweeping RF power. The comparison illustrates the effect of the RF power has on the different IM products.

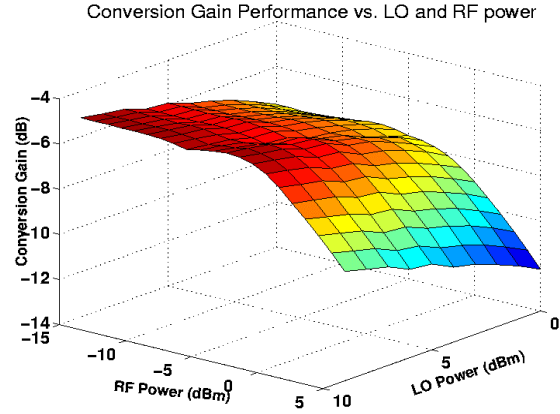


Fig. 4. The performance of the CL vs. RF and LO power levels.

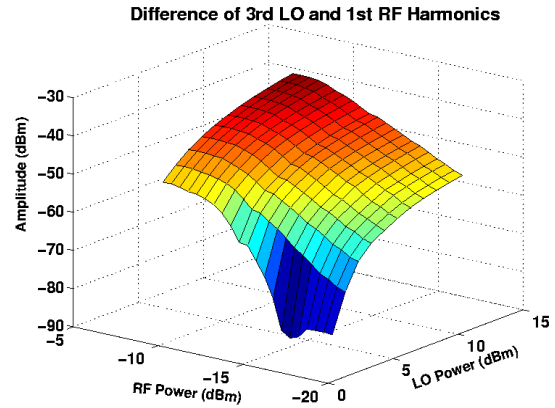


Fig. 5. The difference IM product of 3rd LO and 1st RF harmonics (2040 MHz) vs. RF and LO power levels.

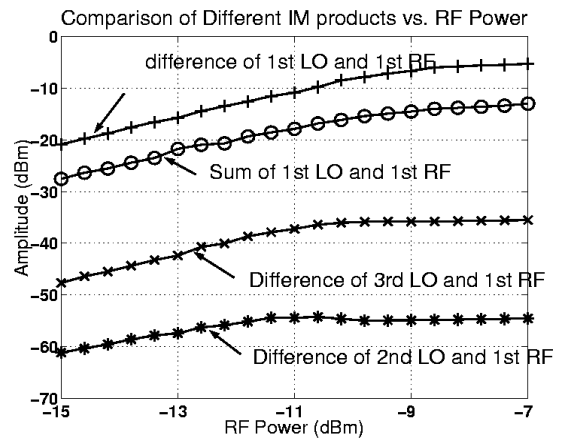


Fig. 6. Comparison of four IM products versus sweeping RF power.

IV. INTEGRATION WITH COMMERCIAL CAE SOFTWARE

Although a simulator developed at The University Of South Florida was used to present the model heretofore, it can also be integrated with commercial EDA packages. As one example, integration within a ADS™ harmonic balance simulation schematic in Fig. 7. The *MixerIMT2* model of ADS is used in the harmonic balance simulation. This model utilizes IMT data files provided to predict the mixer performance. The ADS Data Access Component (DAC) is setup to access the GMM model based on the specified index [7]. Fig. 8 presents the simulated conversion gain under swept LO power and swept RF power. The GMM can also be incorporated with other simulation packages after some interface work. For example, to integrate with the Microwave Office™ CAE package, an eXtensible Markup Language (XML) interface can be developed to access the indexing file of the GMM model. However, to the authors' knowledge commercial EDA system mixer models will not currently allow for taking advantage of the asymmetric IM simulation aspect of the GMM. Hence, a code-based implementation will provide the most flexible utilization of the GMM.

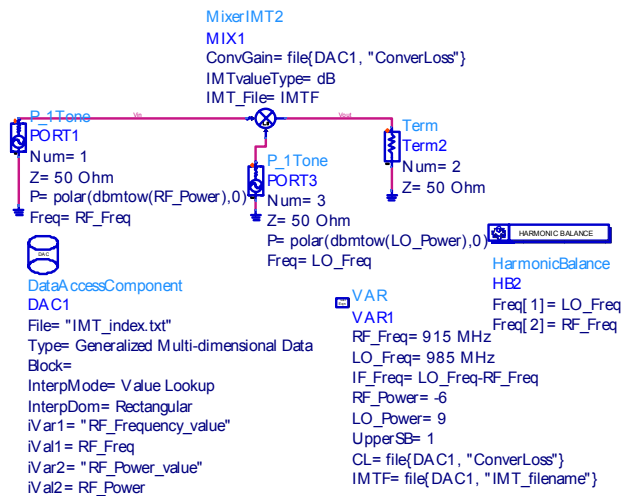


Fig. 7. Simulation schematic of the ADS example using the GMM model.

V. CONCLUSION

A novel table-based system mixer model was developed that utilizes multi-dimensional IM data.

Also developed along with this new model were an automated IM measurement procedure for creating the input files, and a custom simulator that allows simulation of asymmetric mixer spectra. The so-called Global Mixer Model “GMM” allows the multi-dimensional, dynamic and asymmetric nature of mixer output spectra to be properly included in design analyses and optimizations.

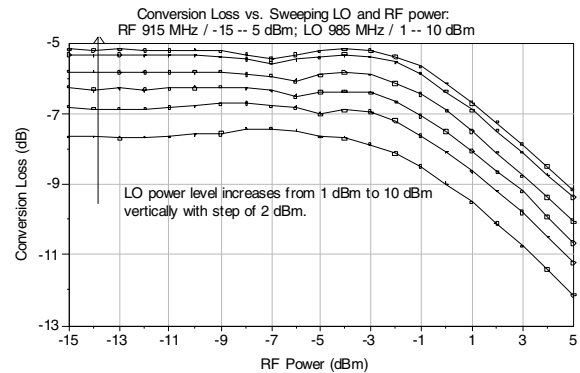


Fig. 8. Simulated conversion gain vs. swept LO and RF power levels using ADS™.

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