Behavioral model of mixer in linear operation

(a quick research update)

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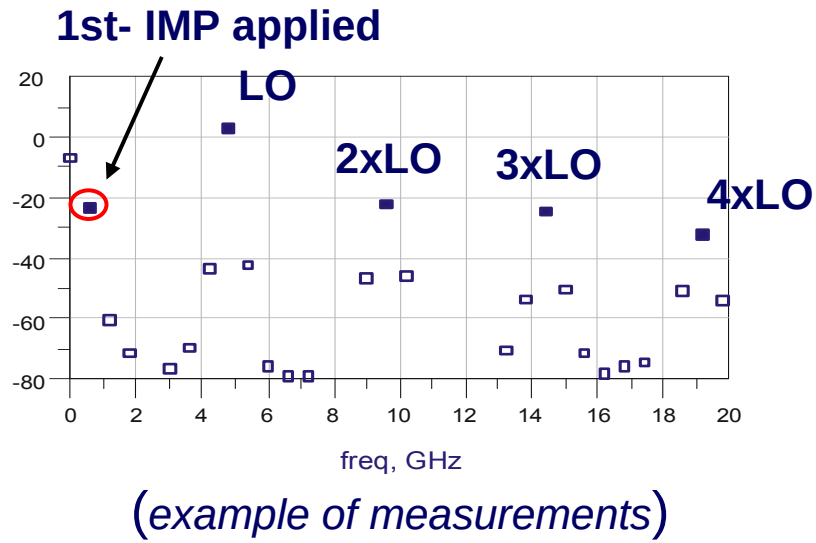
outline

- The use of Conversion Matrix as behavioural modelling of linear mixer
- The use of state-functions for the modelling of weakly nonlinear mixer

The CM as model



(*example of measurements*)

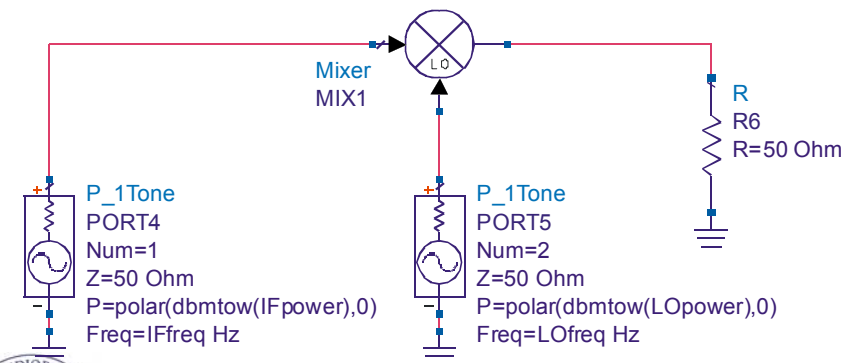
- The basic idea is to extract the CM from LSNA measurements

$$\mathbf{I} = \mathbf{Y} \times \mathbf{V}$$

- The CM represents a linear relationship, between currents and voltages, allowing the representation of the mixer operation in a behavioural way:

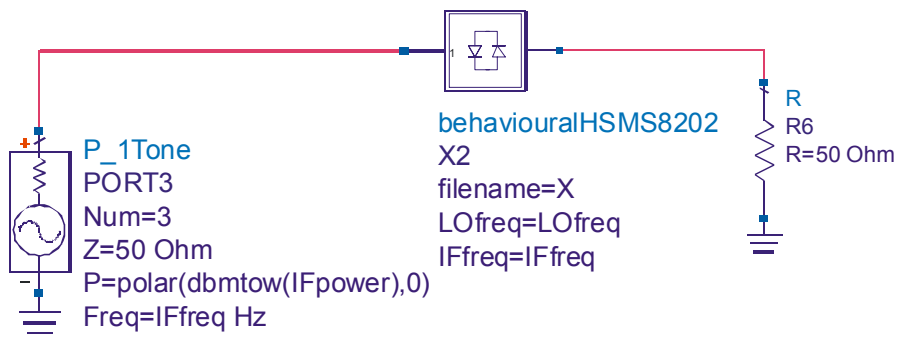
- device based representation –

Two-tone HB analysis

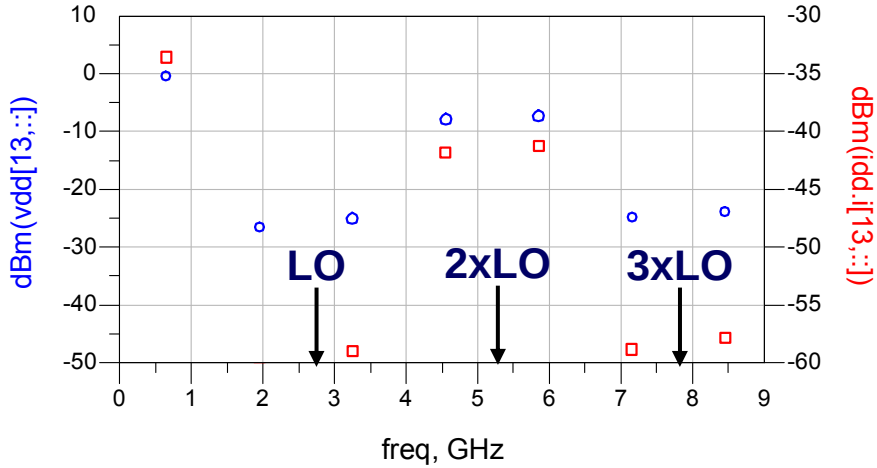


- behavioural representation –

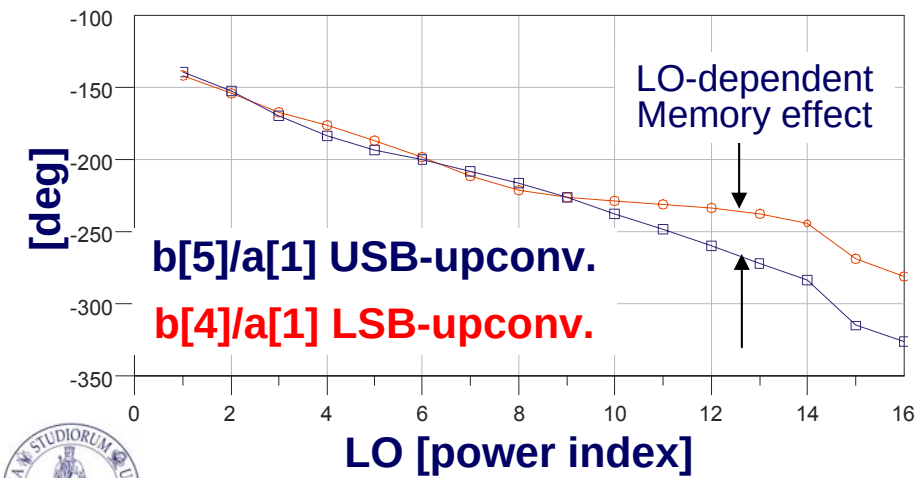
Single tone HB analysis

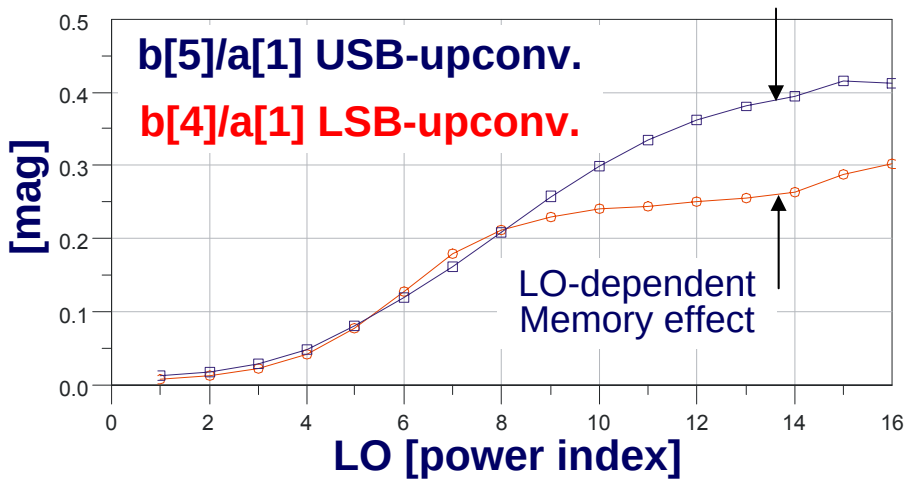


Example of analysis: sub-harmonic mixer



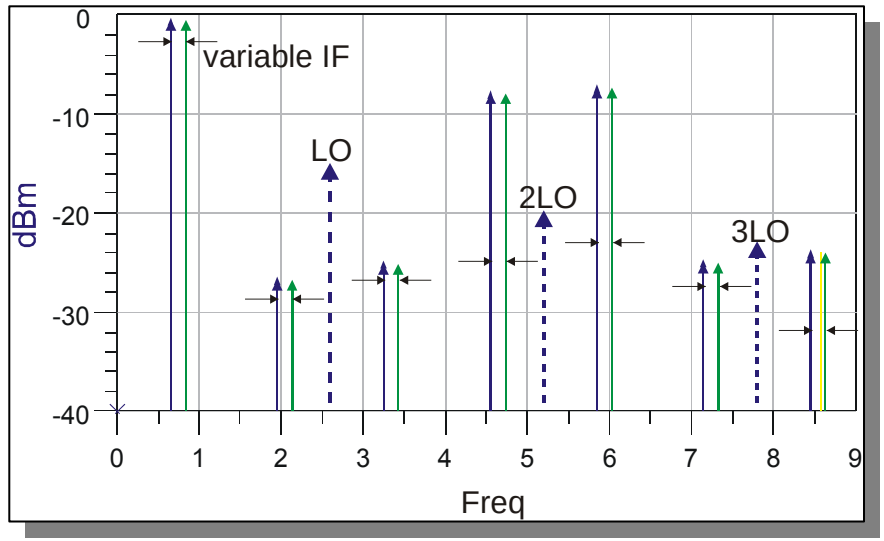
- The analysis now consists in an HB simulation which considers only the small-signal.
- The circuit or the nonlinear cell can be arbitrary complex but, the simulation complexity depends only from the size of the CM (no. harmonics of the LO)





limitation

- The need for an IF-dependent CM would require LSNA systems and calibration procedures able to deal with bandwidth at least 20 MHz.



- ✓ The approach is suitable for the frequency domain analysis of conversion process, the model doesn't require for post processing
- ✓ Limitation: the approach is fully linear, it relates input-output variable in a proportional sense. It doesn't take into account for the absolute amplitude of the RF\IF signal

Behavioural model of weakly nonlinear mixer

- The state functions model can be formulated by a power expansion as:

$$i_{1,2}(t) = \sum_{k=1}^{\dim} \sum_{n=0}^{pow} \left[A_{n,k}^{(1,2)} \left[v_1^{(k)}(t) \right]^n + B_{n,k}^{(1,2)} \left[v_2^{(k)}(t) \right]^n \right]$$

- Being *dim* the maximum degree of the derivative to be considered to obtain the single-valued function, namely the dimension of the state-space.
- while *pow* the maximum degree of the power expansion

state-functions model

- The trajectory is firstly measured by the LSNA, then the coefficients of the following state-functions are evaluated

$$i_{1,2}(t) = \sum_{k=1}^{\dim}\left(\sum_{n=0}^{N} A_n^{(k)} \left|V_{1,n}\right| (2\pi f_n)^{k-1} \cos\left(2\pi f_n t + \varphi_{1,n} + (k-1)\frac{\pi}{2}\right) + \sum_{n=0}^{N} B_n^{(k)} \left|V_{2,n}\right| (2\pi f_n)^{k-1} \cos\left(2\pi f_n t + \varphi_{1,n} + (k-1)\frac{\pi}{2}\right)\right)$$

- Being $\left|V_{1,n}\right|, \varphi_{1,n}, \left|V_{2,n}\right|, \varphi_{2,n}$ the phasors amplitudes and phases measured at port 1 and 2 respectively at frequency f_n.
- While $A_n^{(k)}$ and $B_n^{(k)}$ the unknown to be evaluated, by either fitting or a closed-form procedure.

Case study: gate pumped HEMT

- Pro: The model remove the restriction of previous approach (absolute amplitude) allowing the analysis of a frequency conversion process in weakly nonlinear regime.
- Con: the IF-dependent description appears quite cumbersome, if not impractical