Validating the AWR X-Parameter Generator using LinzFrame

Martin K. Steiger

University of Applied Sciences Upper Austria, Hagenberg

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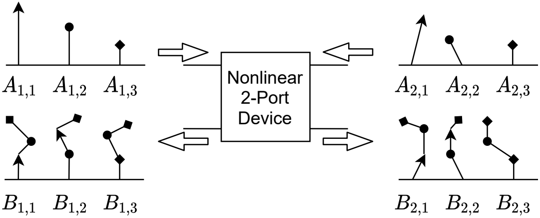
Generating X-Parameters in the Frequency Domain



$$B_{(p,k)} = X^{(F)}_{p,k} P^k + \sum_{\substack{q=1,l=1 \\ (q,l)\neq(1,1)}}^{q=N,l=K} X^{(S)}_{p,k,q,l} A_{q,l} P^{k-l} + \sum_{\substack{q=1,l=1 \\ (q,l)\neq(1,1)}}^{q=N,l=K} X^{(T)}_{p,k,q,l} A^*_{q,l} P^{k+l}$$

Idea: Apply a Large-Signal Tone at Port 1 and sweep an additional Small-Signal Tone with a slight frequency offset Δf for every Port and Harmonic $\Rightarrow$ this leads to Lower and Upper Sidebands around the multiples of the fundamental frequency $k \cdot f_0 \pm \Delta f$

Generating X-Parameters in the Frequency Domain

$$B_{(p,k)} = X^{(F)}_{p,k} P^k + \sum_{\substack{q=1,l=1 \\ (q,l)\neq(1,1)}}^{q=N,l=K} X^{(S)}_{p,k,q,l} A_{q,l} P^{k-l} + \sum_{\substack{q=1,l=1 \\ (q,l)\neq(1,1)}}^{q=N,l=K} X^{(T)}_{p,k,q,l} A^{*}_{q,l} P^{k+l}$$

Algorithm 1: Frequency Domain X-Parameter Extraction ($X^{(F)}$)

```
Large-Signal Tone with f_0 to Port 1
Calculate the unknown Currents and Voltages
Calculate the Scattered Wave B and Incident Wave A using the determined Unknowns
for p = 1, 2, ..., Ports do
    for k = 1, 2, ..., Harmonics do
        B_p = Signal Magnitude of the Scattered Wave B k-th Harmonic at Port p
        A = Signal Magnitude of the Incident Wave at f_0 at Port 1
        X^(F)_{p,k} = B_p / A
    end for
end for
```

Generating X-Parameters in the Frequency Domain

Algorithm 2: Frequency Domain X-Parameter Extraction ($X^{(S)}$ and $X^{(T)}$)

for $p = 1, 2, \ldots,$ Ports **do**
    for $k = 1, 2, \ldots,$ Harmonics **do**
        Large-Signal Tone with f_0 at Port 1, Small-Signal Tone with $kf_0 + \Delta f$ at Port p
        Determine the unknown Currents and Voltages by solving the Circuit Equations
        Calculate the Incident Wave A and Scattered Wave B using the determined Unknowns
        for $q = 1, 2, \ldots,$ Ports **do**
            for $l = 1, 2, \ldots,$ Harmonics **do**
                $B_u =$ upper side-band of B at Port q at $lf_0 + \Delta f$
                $B_l =$ lower side-band of B at Port q at $lf_0 - \Delta f$
                $A_u =$ upper side-band of A at Port q at $kf_0 + \Delta f$
                $X^{(S)}_{p,k,q,l} = B_u / A_u$
                $X^{(T)}_{p,k,q,l} = B_l / A_u$
            end for
        end for
    end for
end for

Approaches in LinzFrame and AWR

LinzFrame

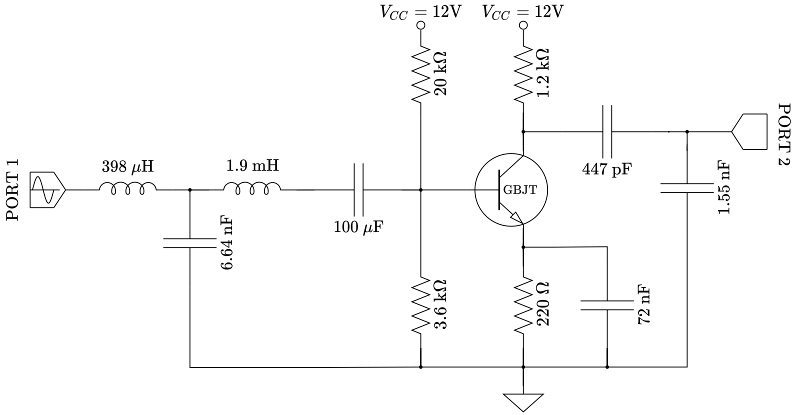
- Frequency Domain Approach
  - Perturbation Methods
  - PDE Approach
- Time Domain Approach (very similar to Perturbation Approach)

Cadence AWR

No specific algorithm is given in the accessible documents. A frequency domain method with harmonic balance is assumed.

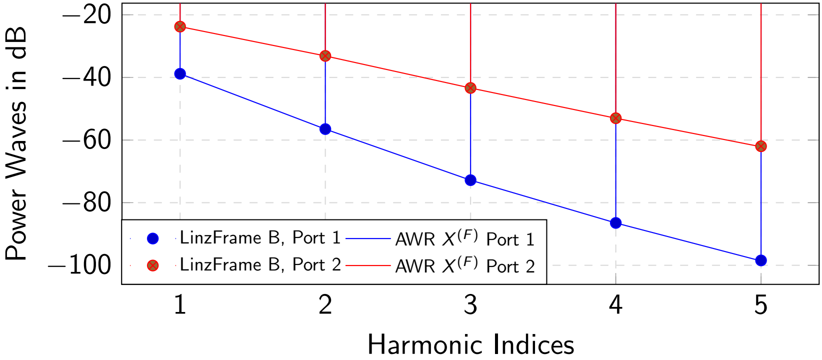
AWR Model Validation using Harmonic Balance (HB)

Prerequisite: HB Implementations provide equivalent Results ✓

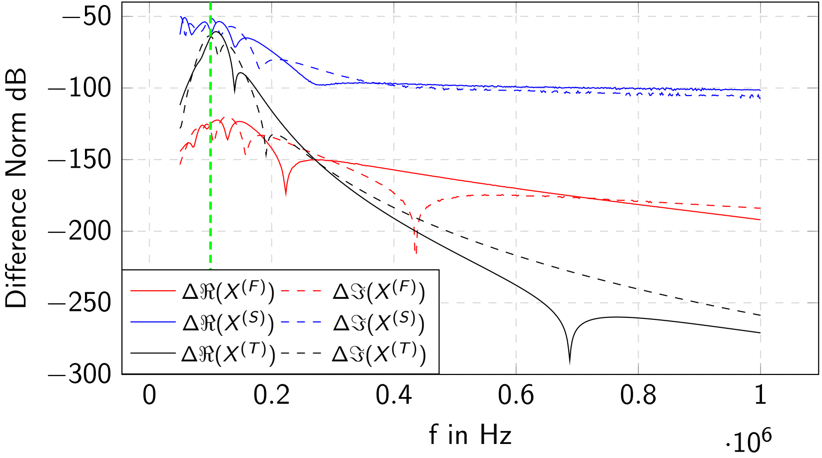


AWR Model Validation using Harmonic Balance (HB)

Idea: Apply a Large-Tone Signal at Port 1 with -30 dBm at 100 kHz and evaluate the Simulation Results in LinzFrame and AWR $\Rightarrow$ when no other Harmonics are present, the Scattered Wave B (determined with HB) should match the $X^{(F)}$ Parameters of the AWR Model



X-Parameter Difference Norm



Since the common emitter amplifier is matched at 100 kHz and has the largest gain there, we also expect the largest X-parameters at this point and thus probably also high deviations from the AWR model