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Measurement Based Behavioural Modeling of Components under Modulated Large-Signal Operating Conditions

Jan Verspecht, Frans Verbeyst, Marc Vanden Bossche

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Network Measurement and Description Group

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Innovating the HP Way

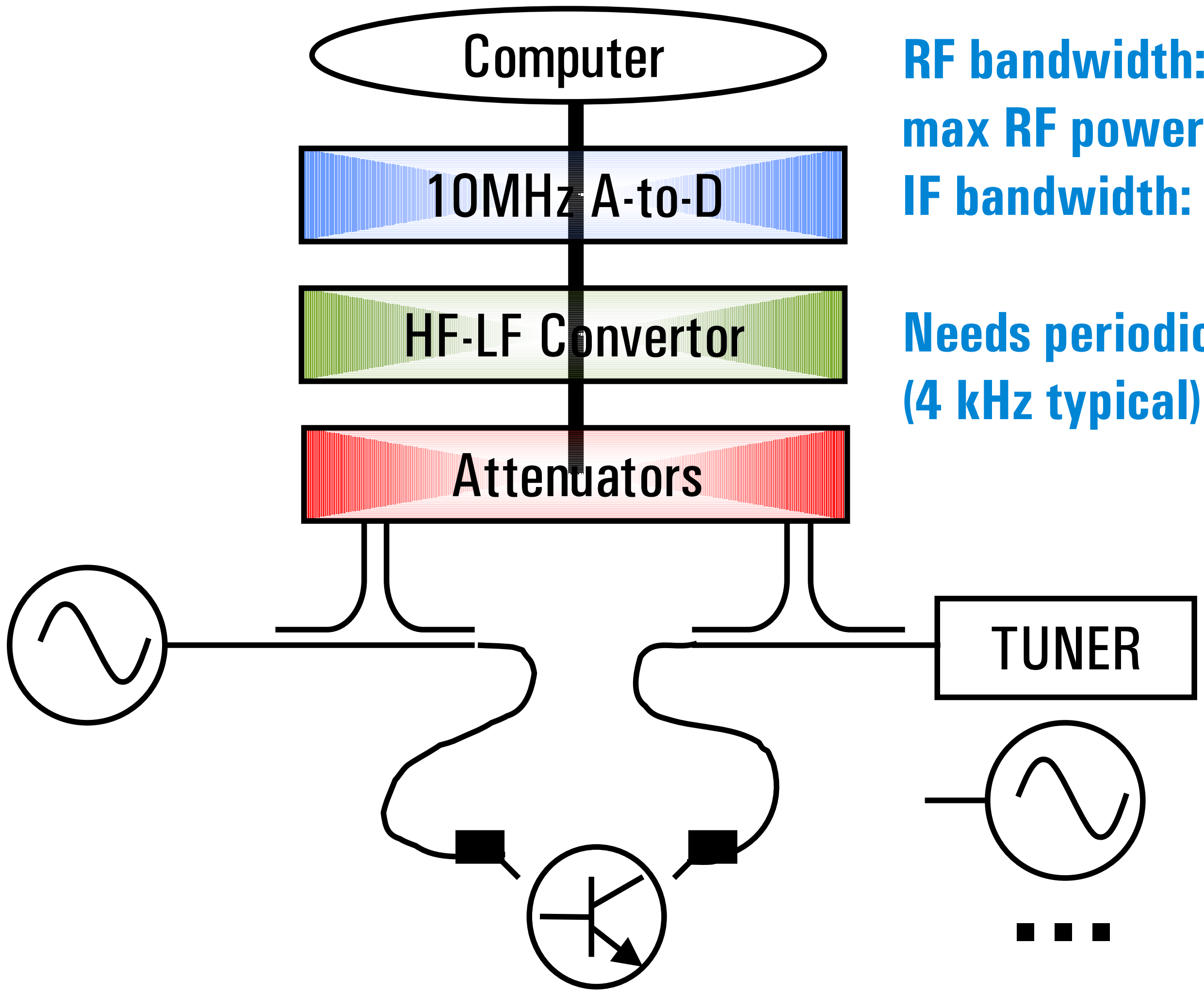
Overview

- Introduction
- Measurement Aspects
- Modeling Aspects
- Conclusion

Introduction

- Large-signal effects can not be neglected:
  ACPR, nonlinear match, harmonics, intermodulation
- Our goal is to develop a coherent modeling and measurement approach to deal with these problems
- The idea is to build models which are based upon measurements performed under realistic operating conditions
- Approach called “Large-Signal Network Analysis”
- Our demonstration vehicle is an RFIC:
  1.9 GHz MMIC amplifier aimed for CDMA applications

The NNMS Modulatus



RF bandwidth: 600MHz - 20GHz
max RF power: 10 Watt
IF bandwidth: 8 MHz

Needs periodic modulation
(4 kHz typical)

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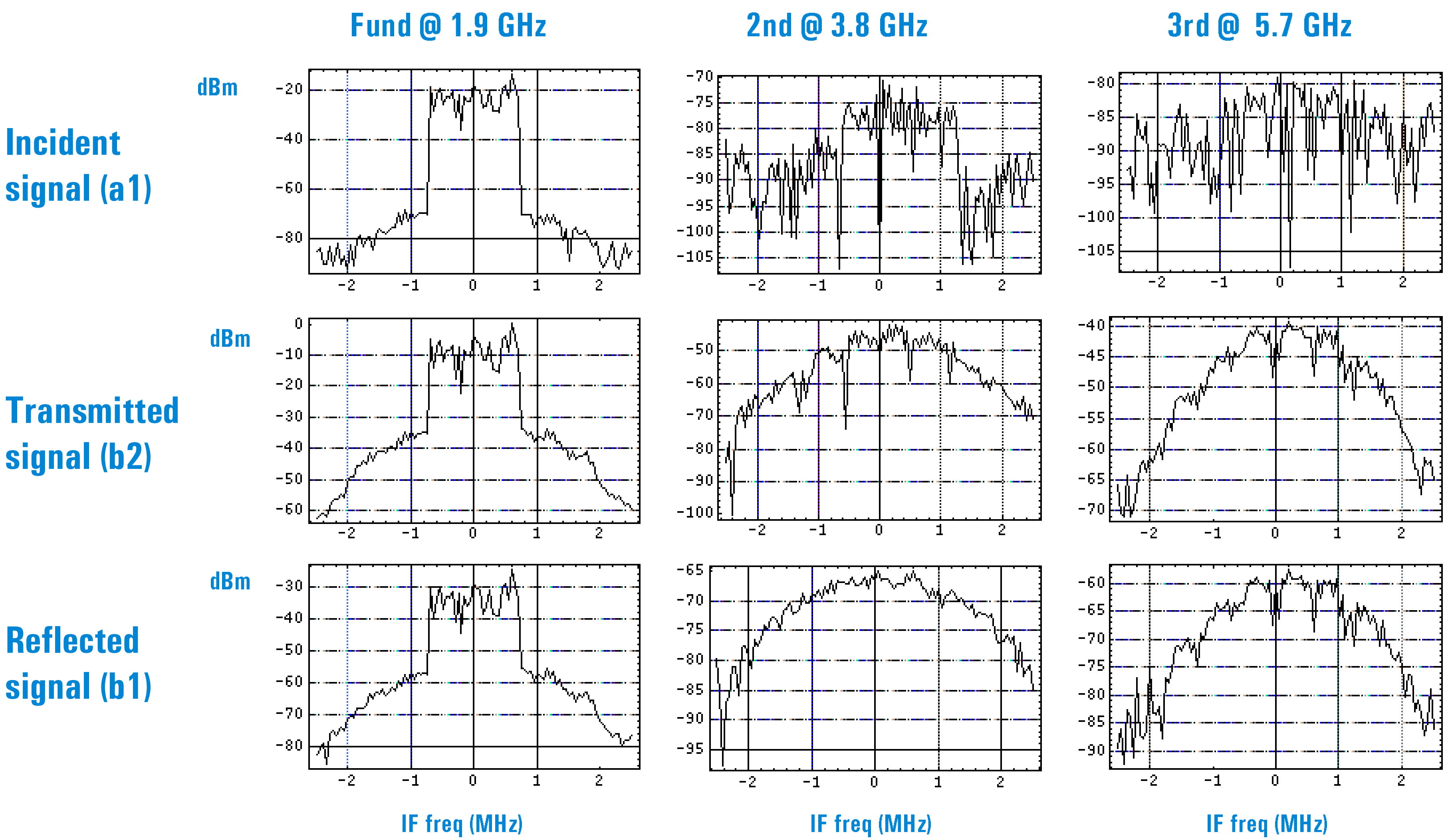
Accuracy of the Measurements

- Coaxial SOLT calibration
- On wafer LRRM calibration
- RF amplitude calibration with power meter
- RF harmonic phase calibration with a SRD diode (characterized by a nose-to-nose calibrated scope)
- IF amplitude and phase calibration traceable to an Agilent Technologies E4406A “Vector Signal Analyzer”

Completeness of the measurements



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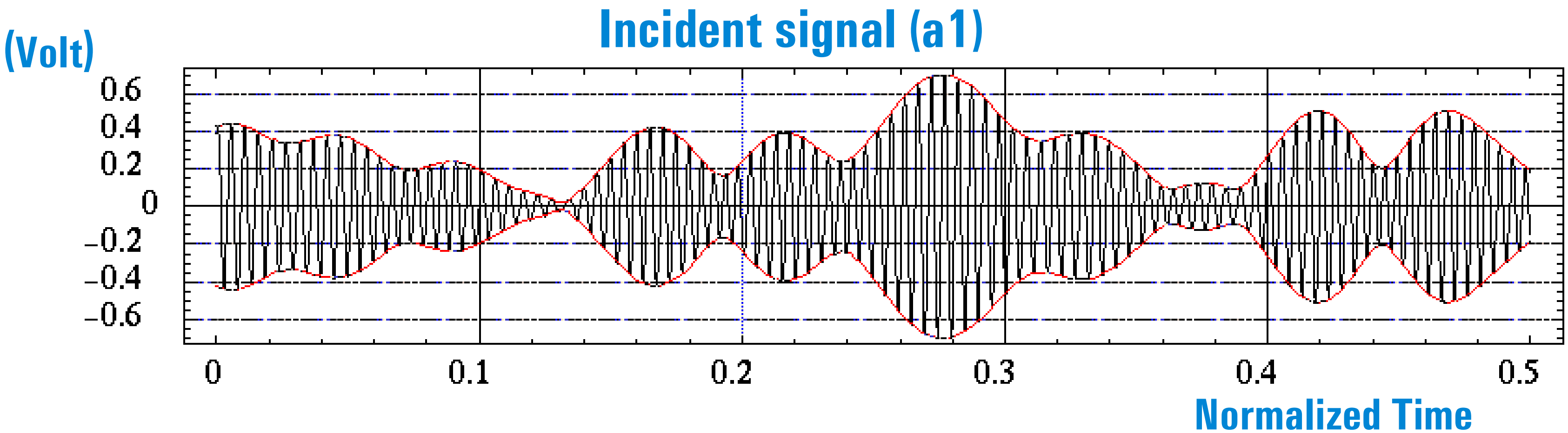
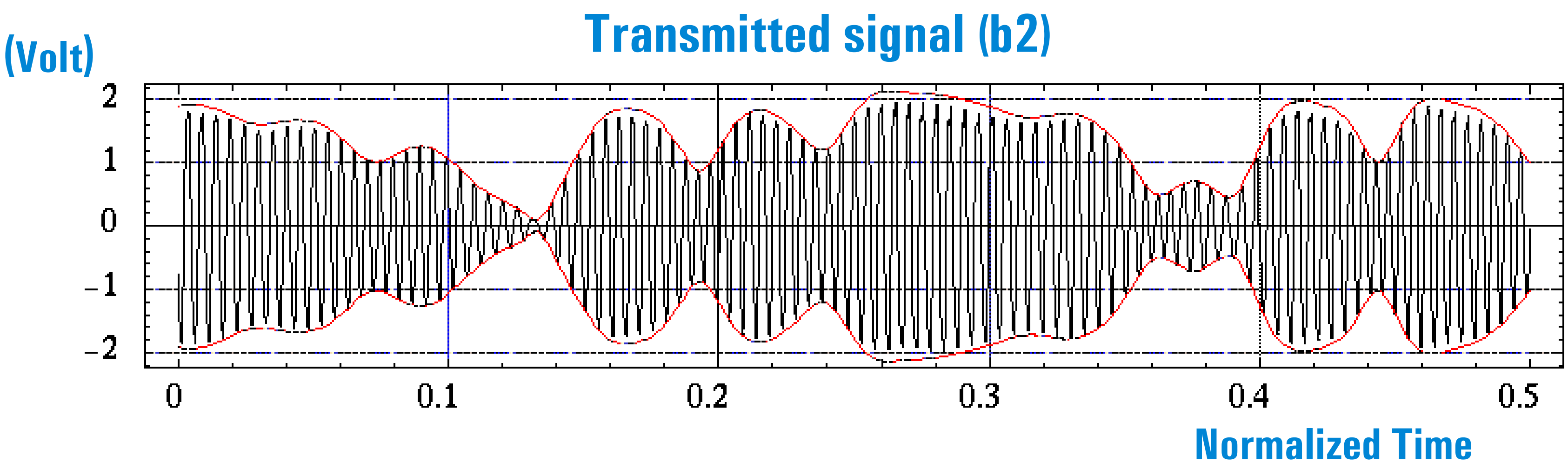
Time Domain Representation





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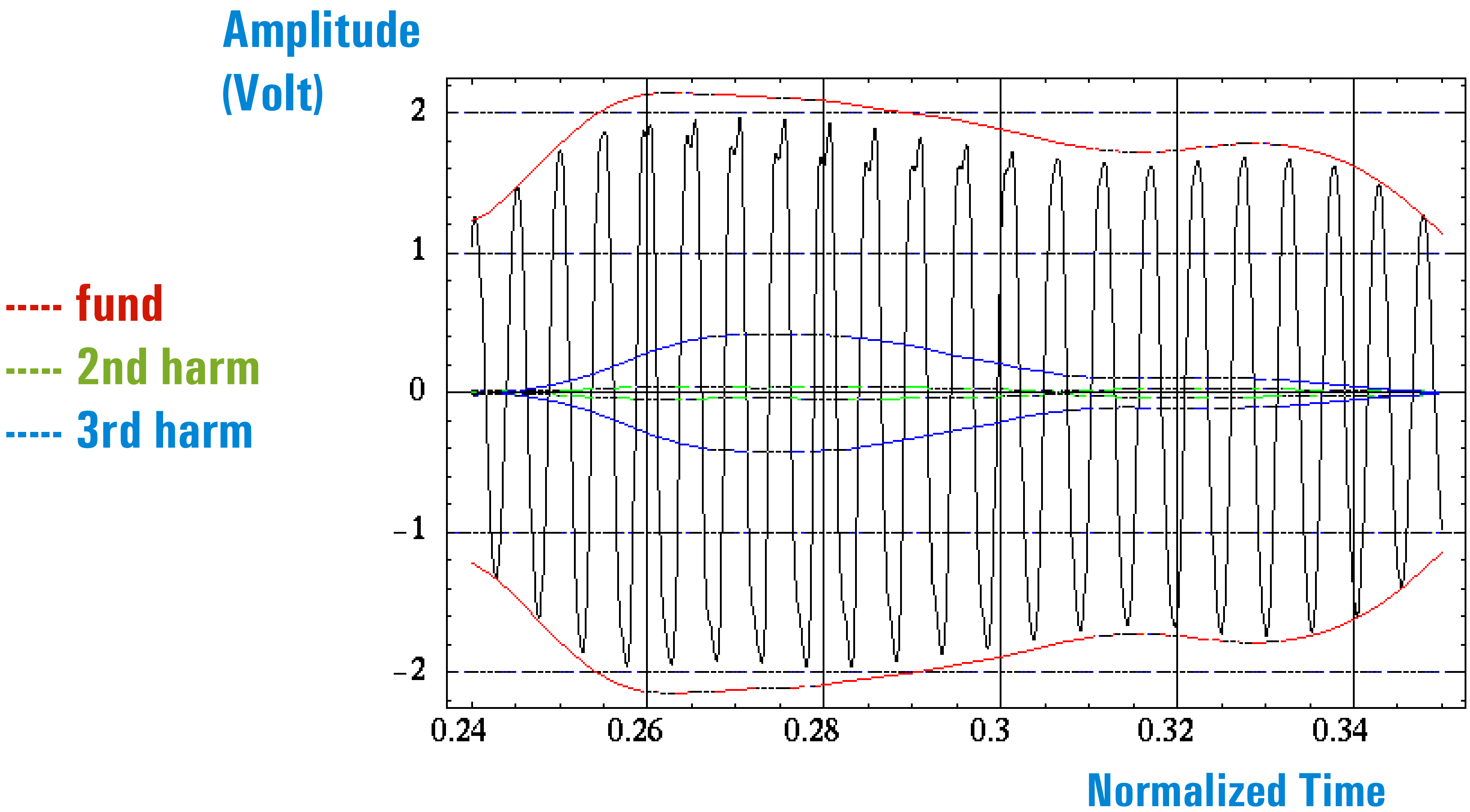
Zoom on the transmitted signal



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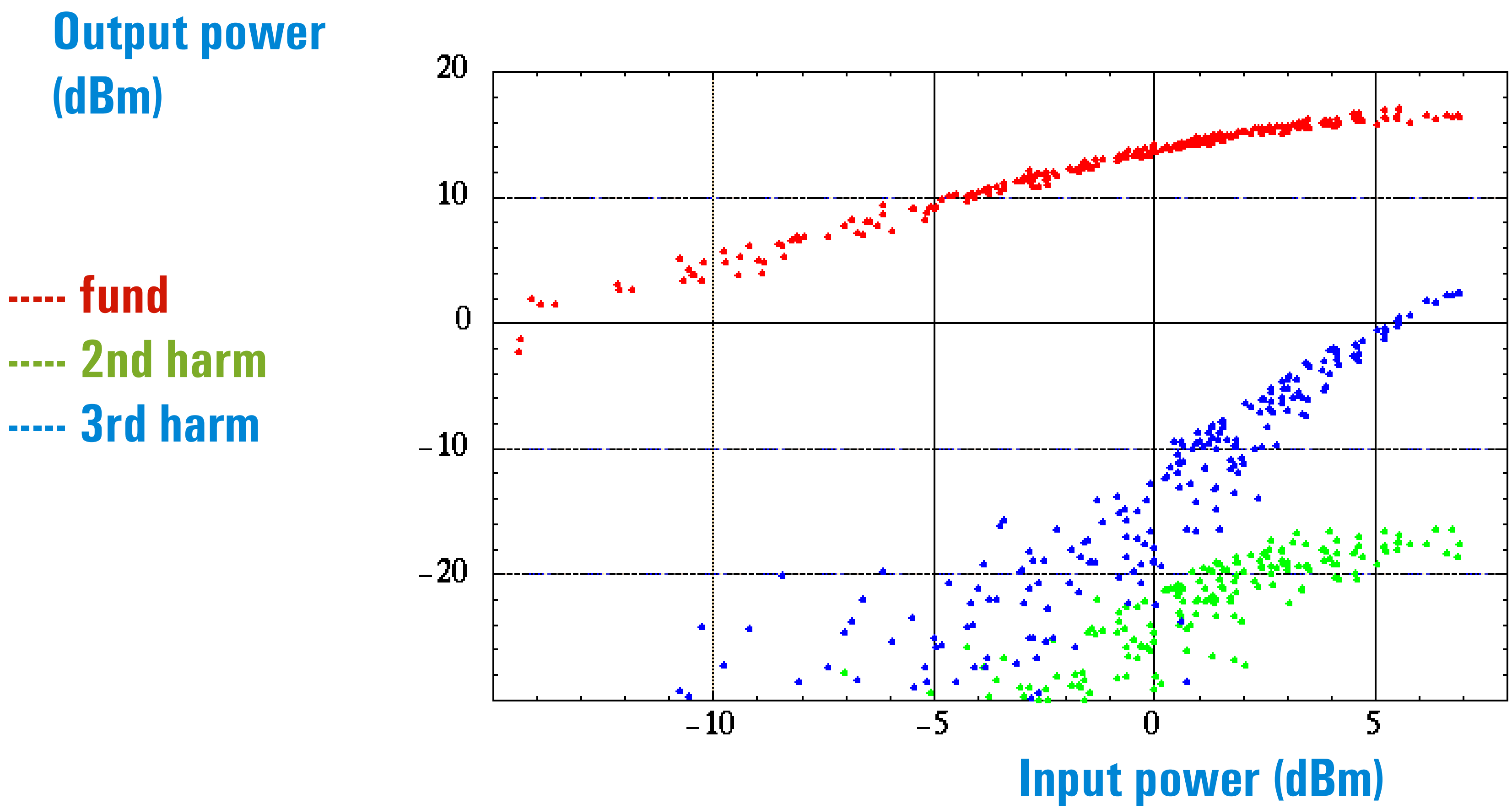
Dynamic Harmonic Distortion: Transmitted Signal



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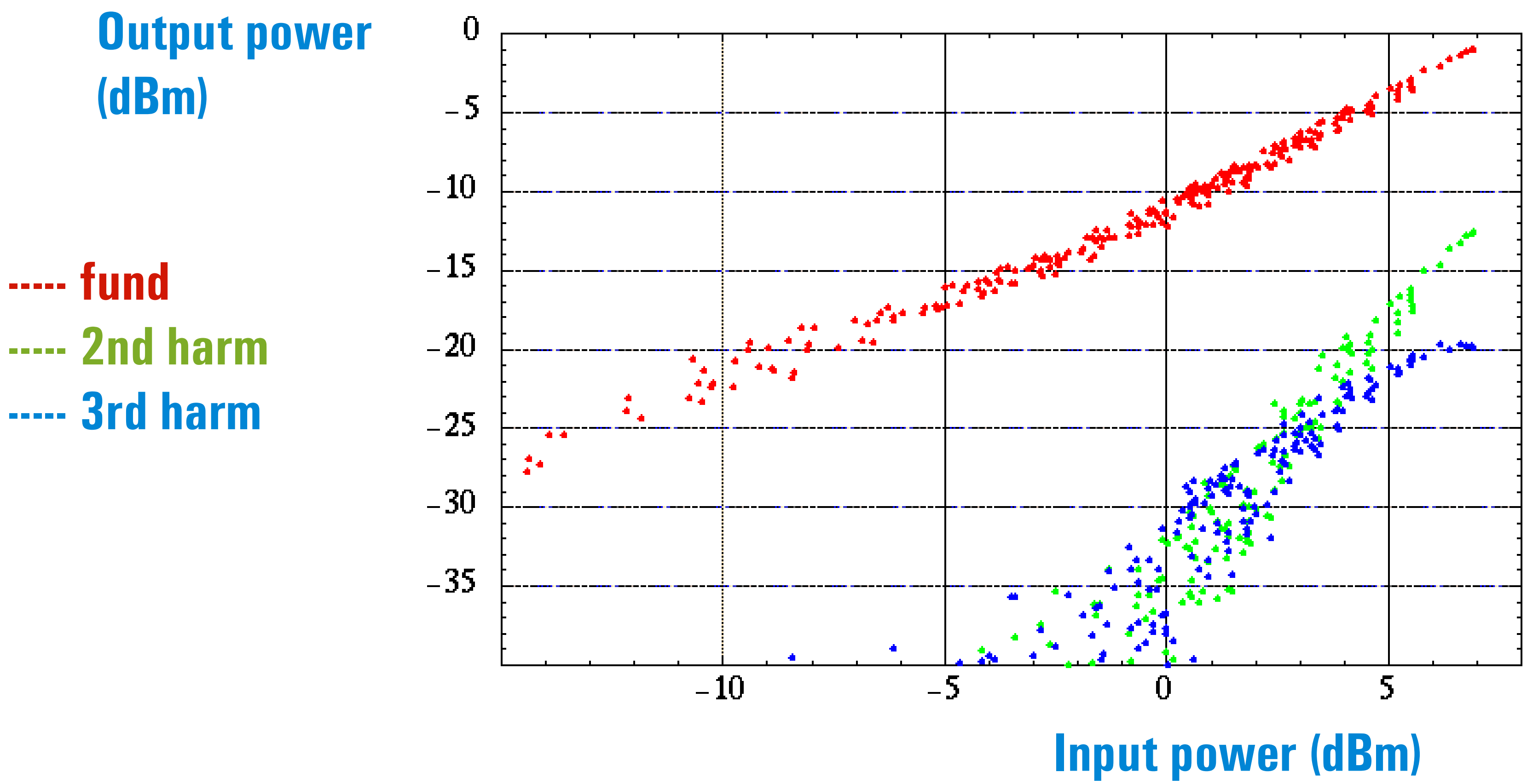
Dynamic Harmonic Distortion: Reflected Signal



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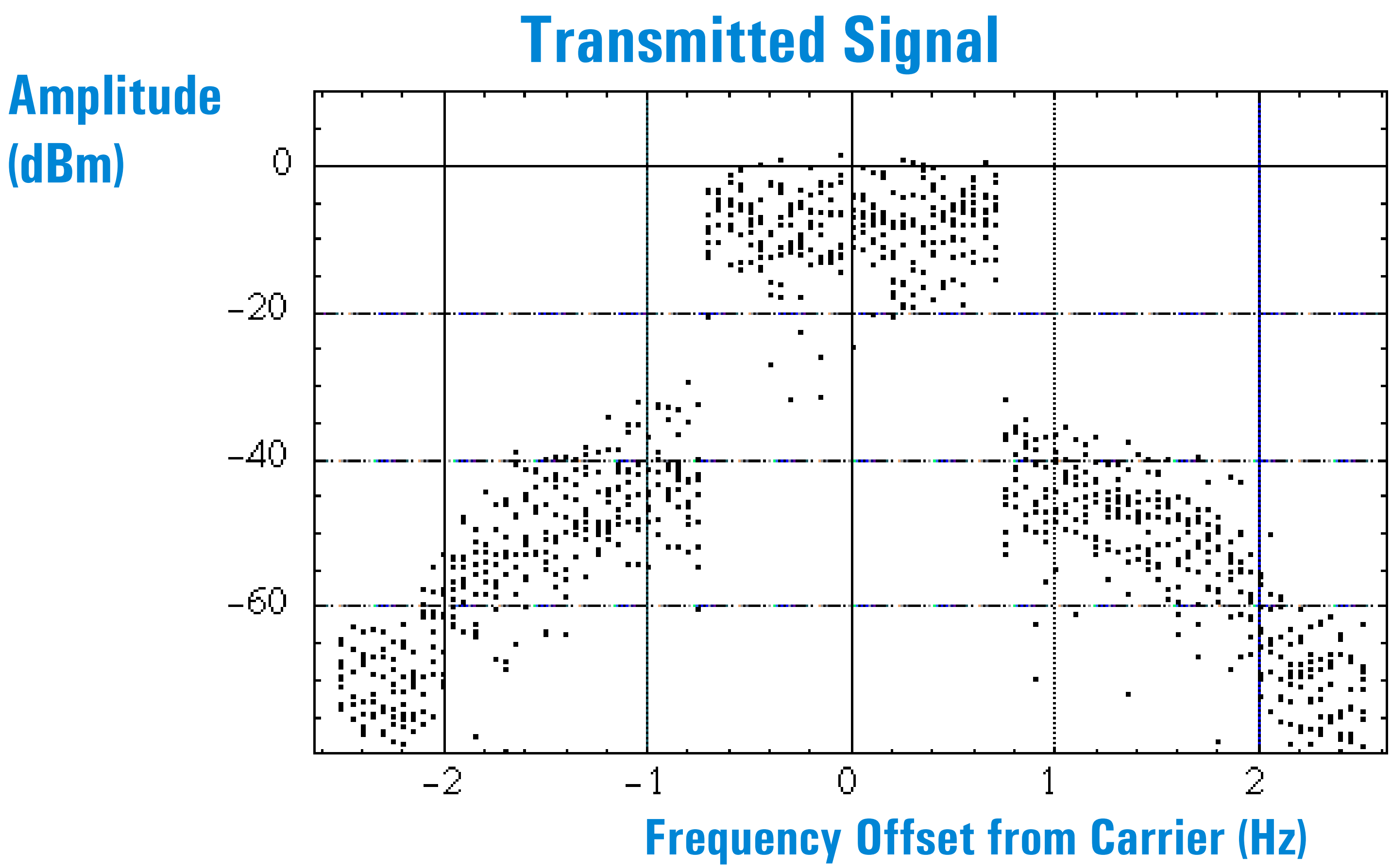
Emulate CDMA statistics using many periodic pseudo-random sequences



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Modeling in the "Modulation Domain"

- Signals are described as time-dependent phasors
- IQ representation for the fundamental and the harmonics
  - $a_{11}(t)$ = fundamental of incident signal at port 1
  - $b_{21}(t)$ = fundamental of transmitted signal at port 2
  - $b_{13}(t)$ = 3rd harmonic of reflected signal at port 1

- There is a relationship between the $a_{ij}(t)$'s and $b_{ij}(t)$'s

The Describing Function

- For this application we make a static assumption (the validity is verified by the NNMS data)

$$b_{ki}(t) = F_i\left(a_{11}(t)\right)$$

- Theory of the Describing Functions:

$$b_{ki}(t) = \left(I_{ki}\left(\left\|a_{11}(t)\right\|\right) + jQ_{ki}\left(\left\|a_{11}(t)\right\|\right)\right)P(t)^i$$

$$P(t) = e^{ji\varphi\left(\left\|a_{11}(t)\right\|\right)}$$

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Fitting the Measured Data

- We start from sets of couples

$$(a_{11}(t_n), b_{ki}(t_n))$$

- Apply phase normalization and split Re and Im part

$$(\|a_{11}(t_n)\|, \mathrm{Re}(b_{ki}(t_n)P^{-i})) \longrightarrow I_{ki}$$

$$(\|a_{11}(t_n)\|, \mathrm{Im}(b_{ki}(t_n)P^{-i})) \longrightarrow Q_{ki}$$

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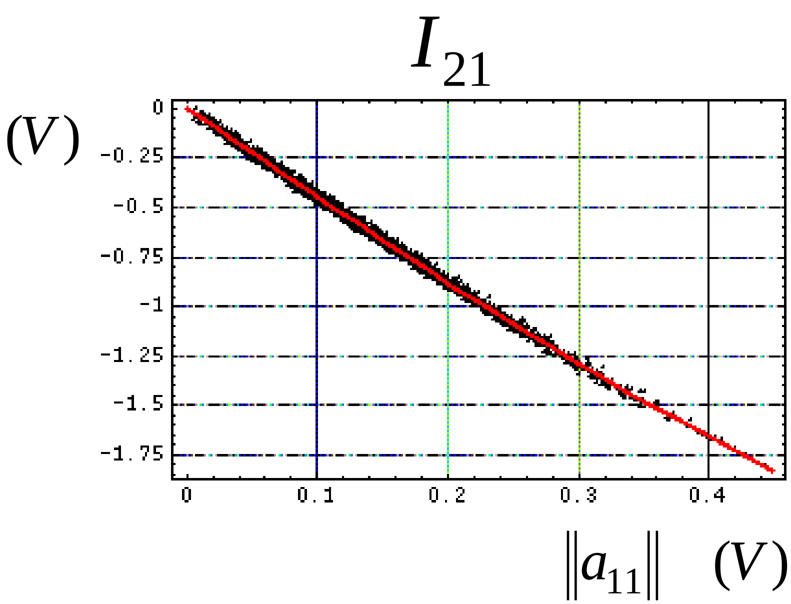
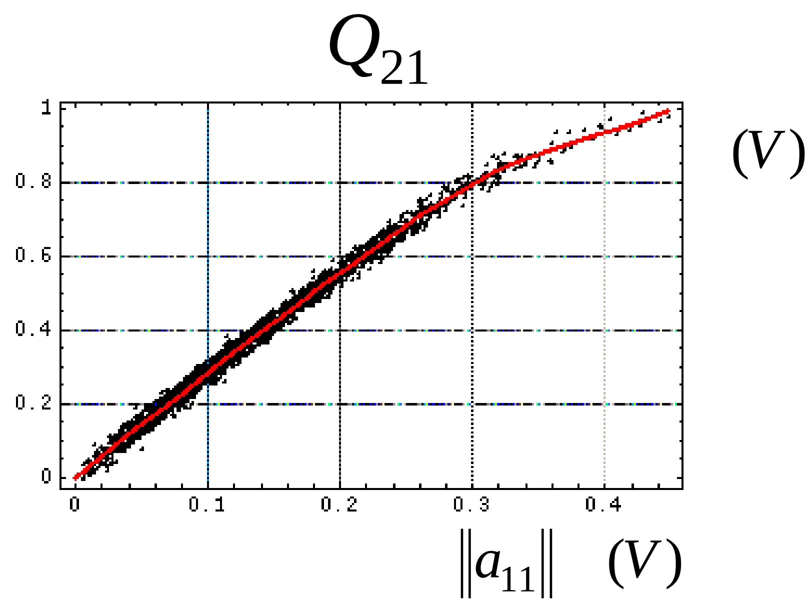
Apply Fitting Technique

- For our example we use a piece wise polynomial (3rd order)





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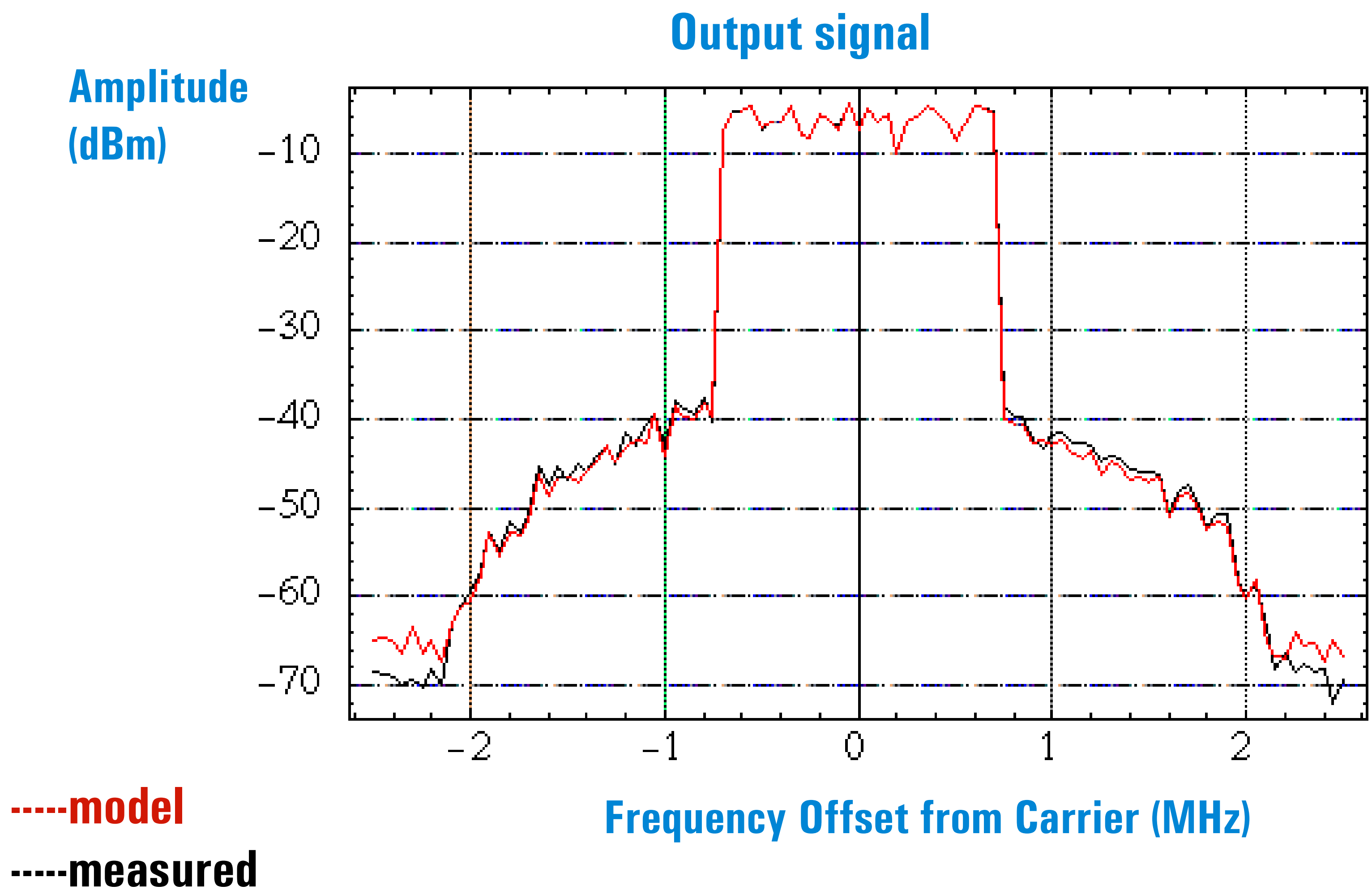
Model Verification - Spectral Regrowth



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Conclusions

- Accurate behavioral models can be extracted, based upon large-signal measurements performed under realistic operating conditions
- The presented modeling and measurement techniques describe spectral regrowth, compression, nonlinear input match, the generation of harmonics,...

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