

# Measurements and Models of a Power Amplifier Suitable for 802.16.1

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Purpose:

This is a response to Document IEEE 802.16.1p-00/09r1, which requested input regarding parameters of typical power amplifiers for use in 802.16.1 systems.

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# Measurements & Models of a Power Amplifier Suitable for 802.16.1

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- ◆ Measurement & Modeling Approach
- ◆ Application to Example PA
- ◆ Frequency Dependency Issues

# Behavioral Modeling Approach

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Measure AM-AM & AM-PM responses  
(single tone)



Fit to Saleh model  
(gain & phase as functions of signal amplitude)



Use Bessel series expansions of  $G$  and  $\varphi$  to  
compute envelope transfer function  $h$

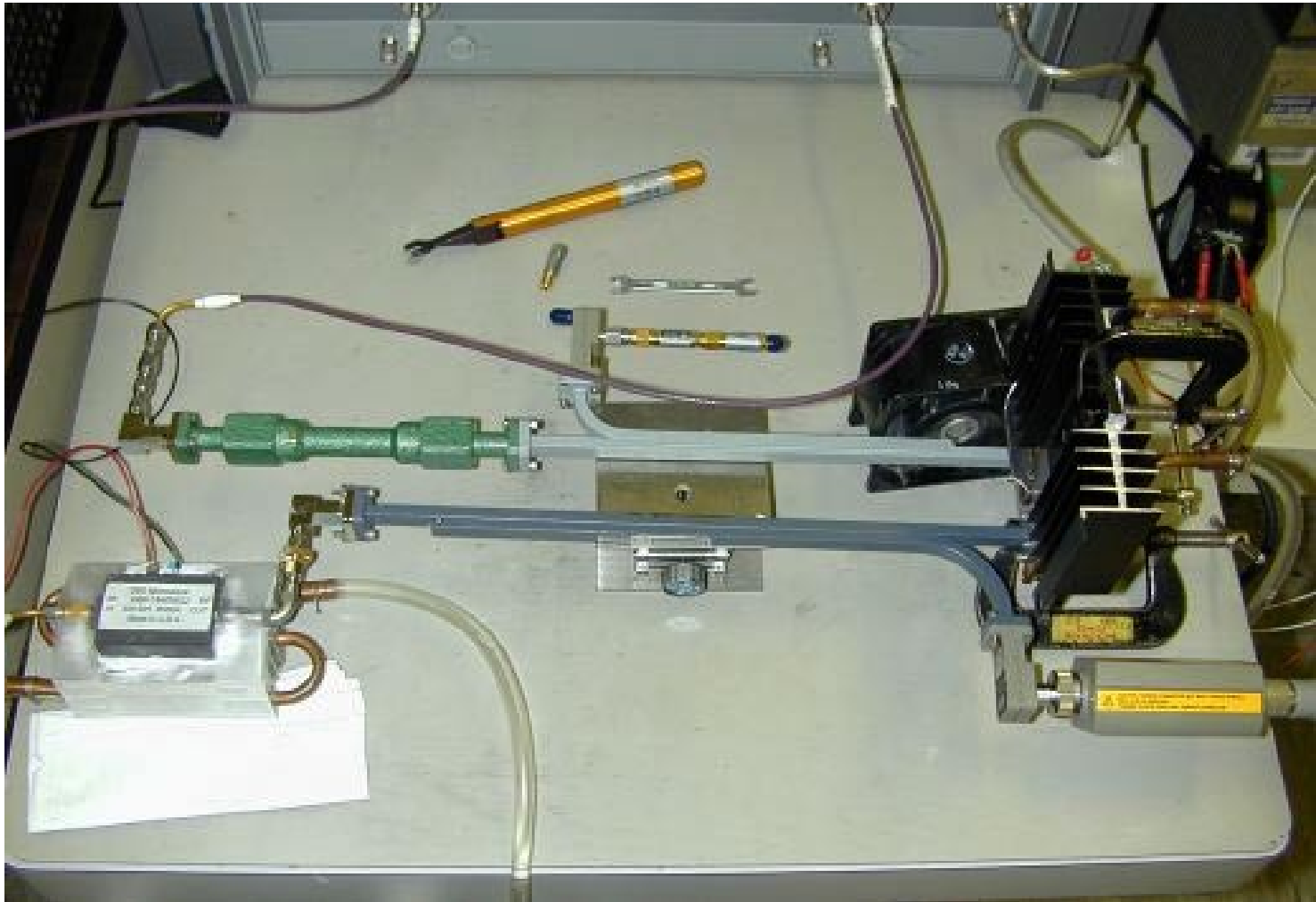


Compute ACPR & EVM from  $y(t) = h(x(t))$

# Example PA Parameters

|                                 |           |
|---------------------------------|-----------|
| Frequency range of measurements | 28-29 GHz |
| Gain (1)                        | 29.3 dB   |
| $P_{1\text{dB out}}$ (2)        | 29 dBm    |
|                                 |           |

# Measurement Set-Up



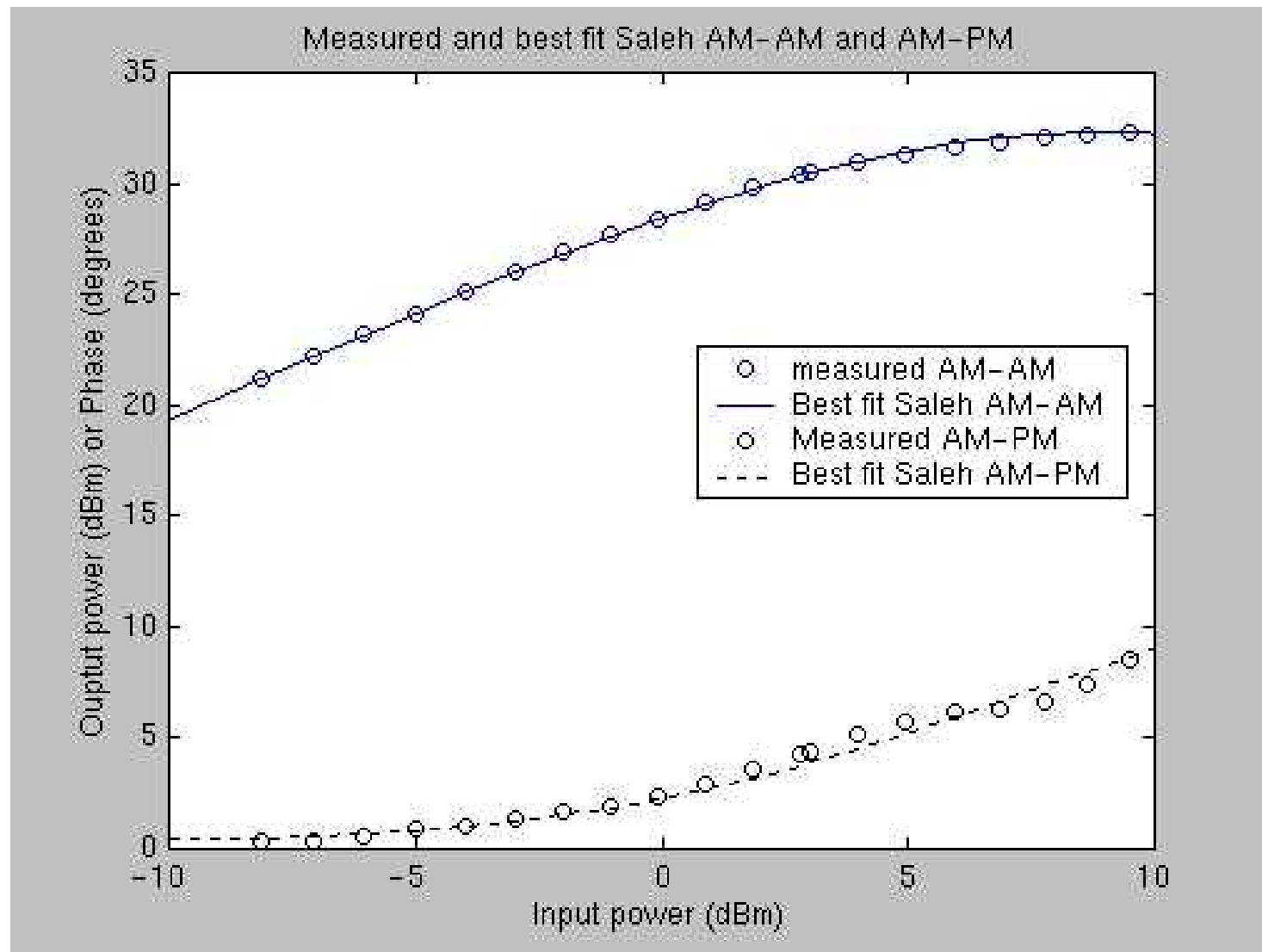
# Saleh Model

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$$G(r) = \frac{\alpha_1 * r}{1 + \beta_1 * r^2}$$

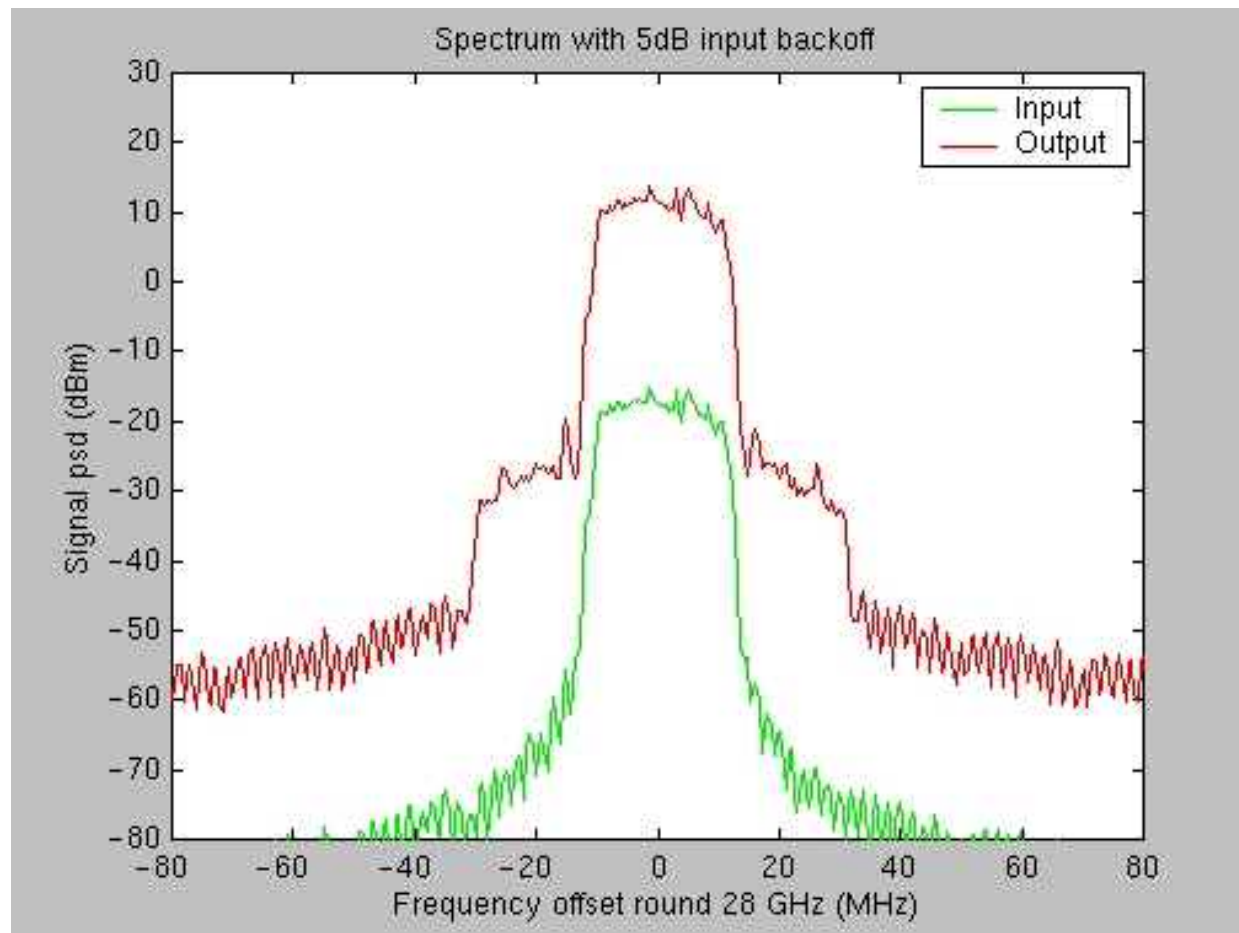
$$\varphi(r) = \frac{\alpha_2 * r^2}{1 + \beta_2 * r^2}$$

# Fit to Saleh Model



# ACPR & EVM Predictions

$$h(A) = v(A)e^{j\varphi(A)}$$





# ACPR & EVM Simulations for QPSK

| Roll off factor | Input Back off (dB) | Output Back off (dB) | ACPR (dB) | EVM (%) |
|-----------------|---------------------|----------------------|-----------|---------|
| 0.15            | 3.01                | 2.95                 | -30.64    | 11.74   |
| 0.25            | 3                   | 2.91                 | -32.8     | 11.47   |
| 0.35            | 2.97                | 2.89                 | -33.82    | 11.24   |

Table 2: QPSK,  $r_{\max} = 0.8$  V

# ACPR & EVM Simulations for 16 QAM

| Roll off factor | Input Back off (dB) | Output Back off (dB) | ACPR(dB) | EVM (%) |
|-----------------|---------------------|----------------------|----------|---------|
| 0.15            | 5.12                | 4.81                 | -31      | 12.22   |
| 0.25            | 5.11                | 4.79                 | -33.84   | 11.23   |
| 0.35            | 5.1                 | 4.79                 | -34.23   | 10.91   |

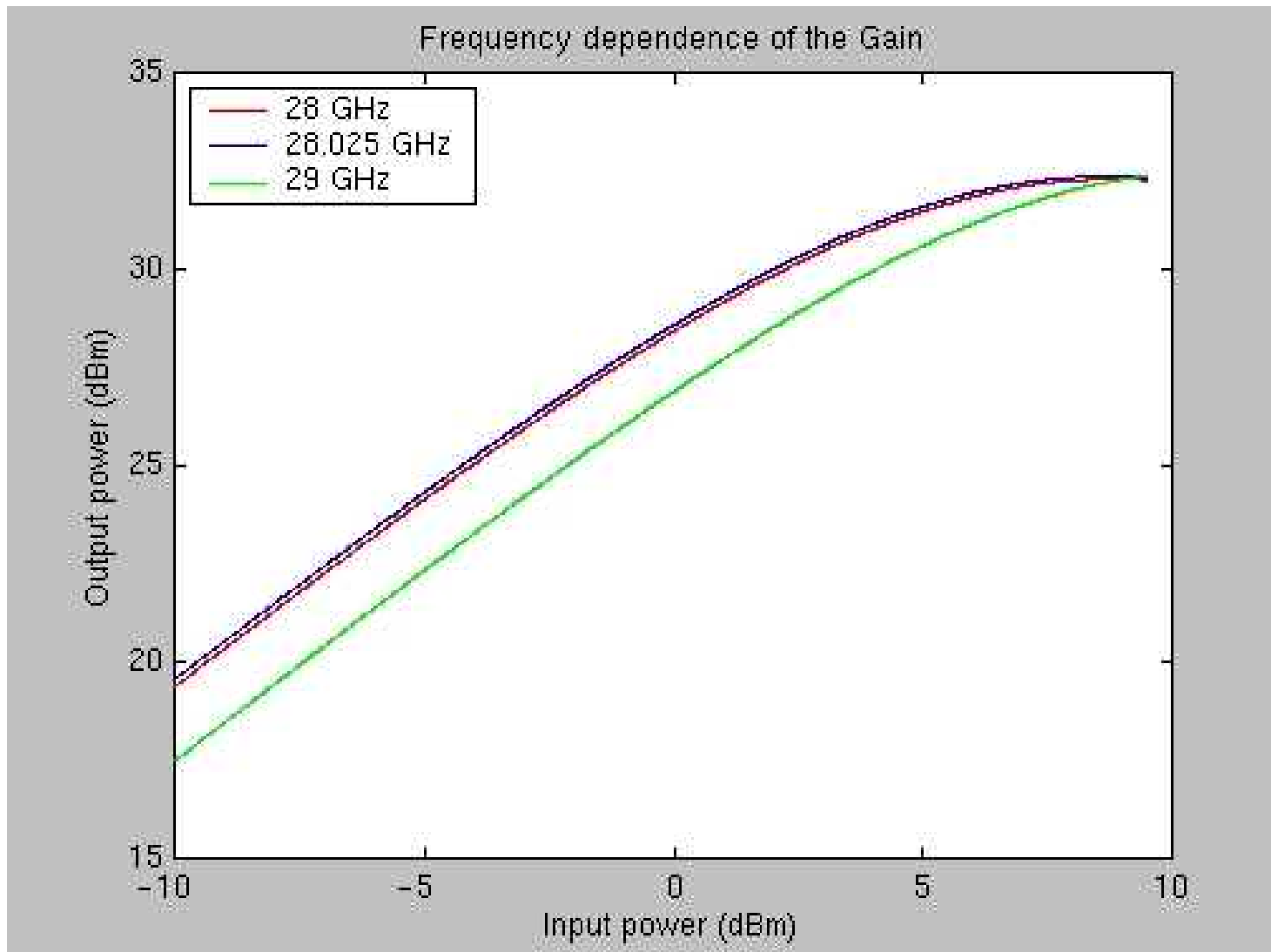
Table 3: 16 QAM,  $r_{\max} = 0.8$  V

# Frequency Dependency Issues

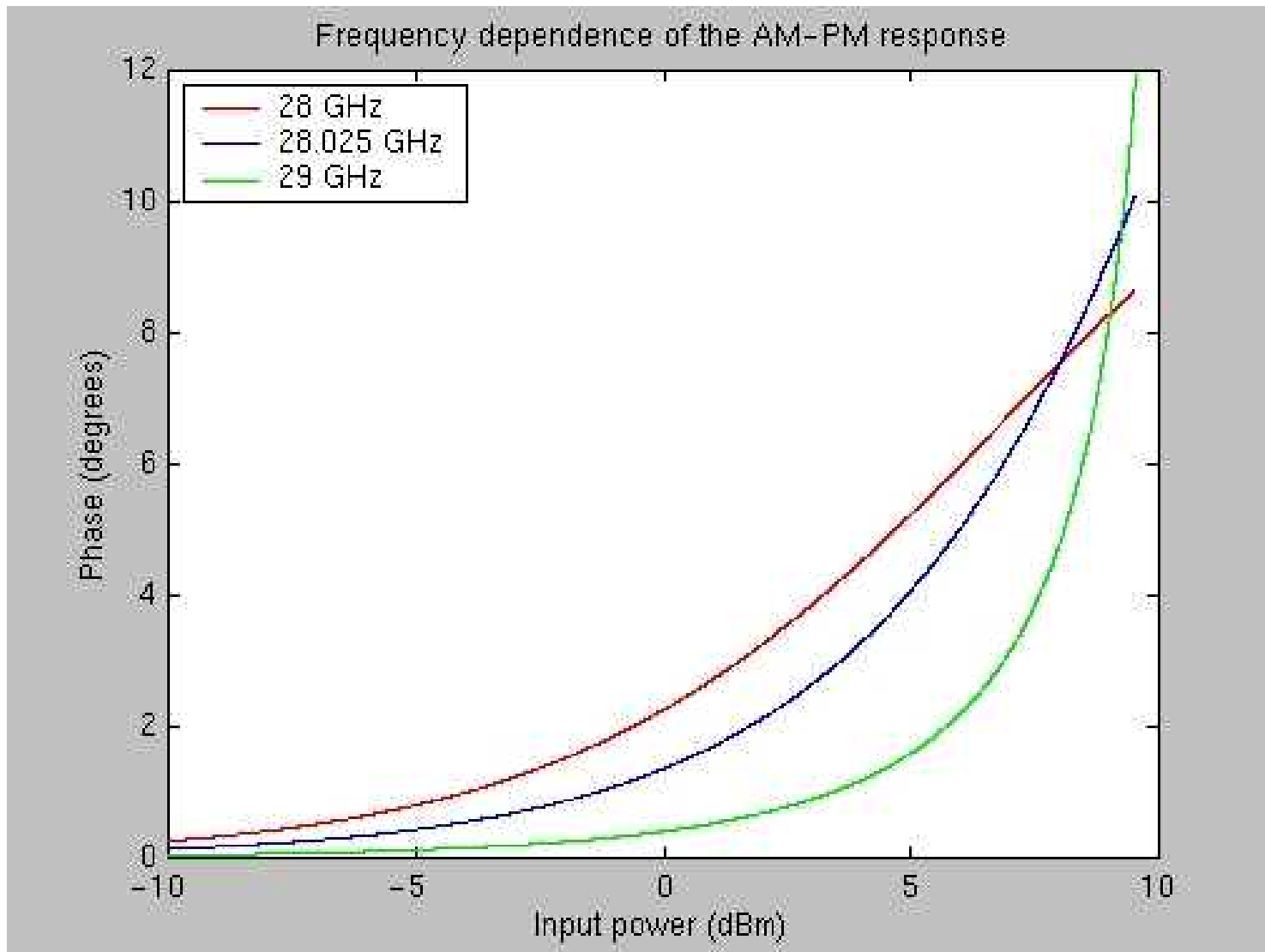
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- ◆ Broadband amplifiers may not have flat gain and phase responses over 500 - 1000 MHz bands
- ◆ Envelope transfer function  $h$  is calculated using signal tone stimulus, but may depend on input waveform due to memory effects
- ◆ Simple frequency response corrections may not work

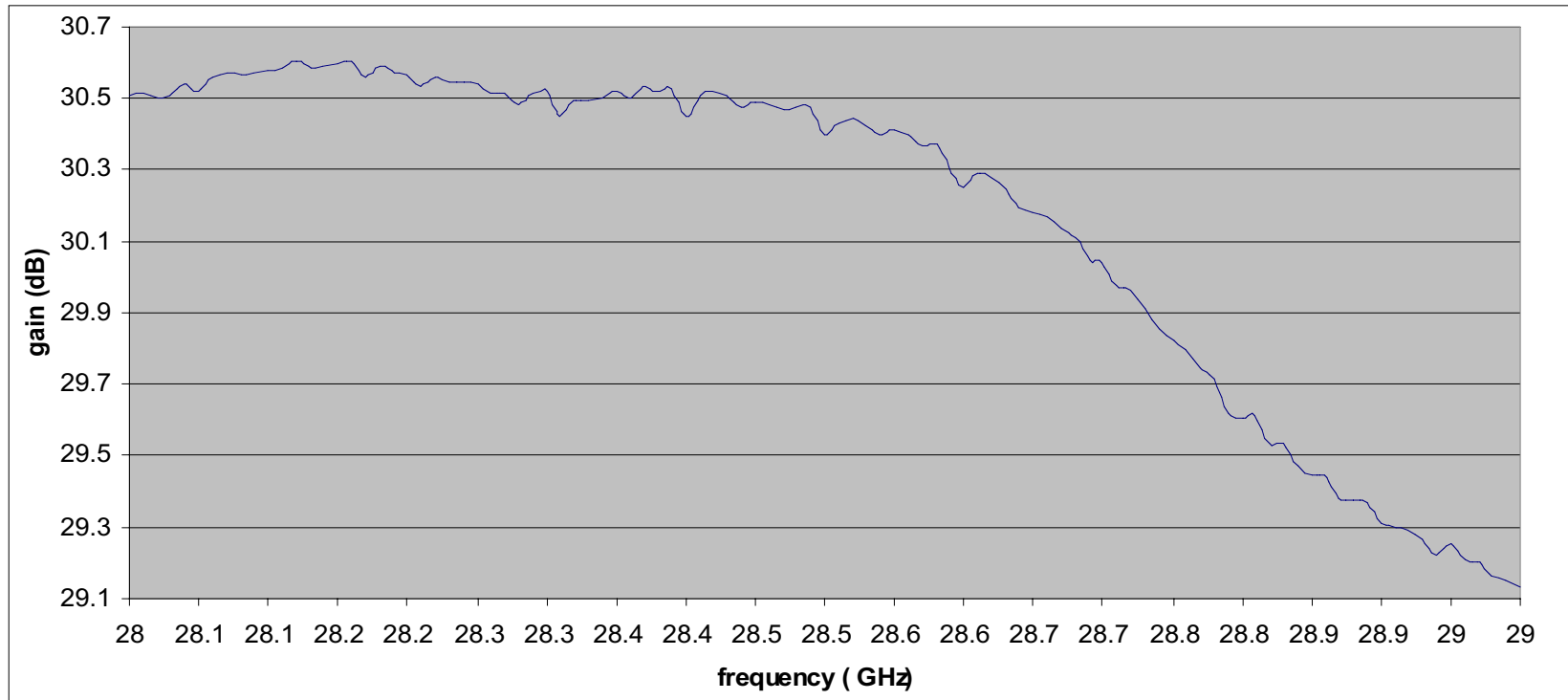
# Frequency Dependence in AM-AM



# Frequency Dependence in AM-PM

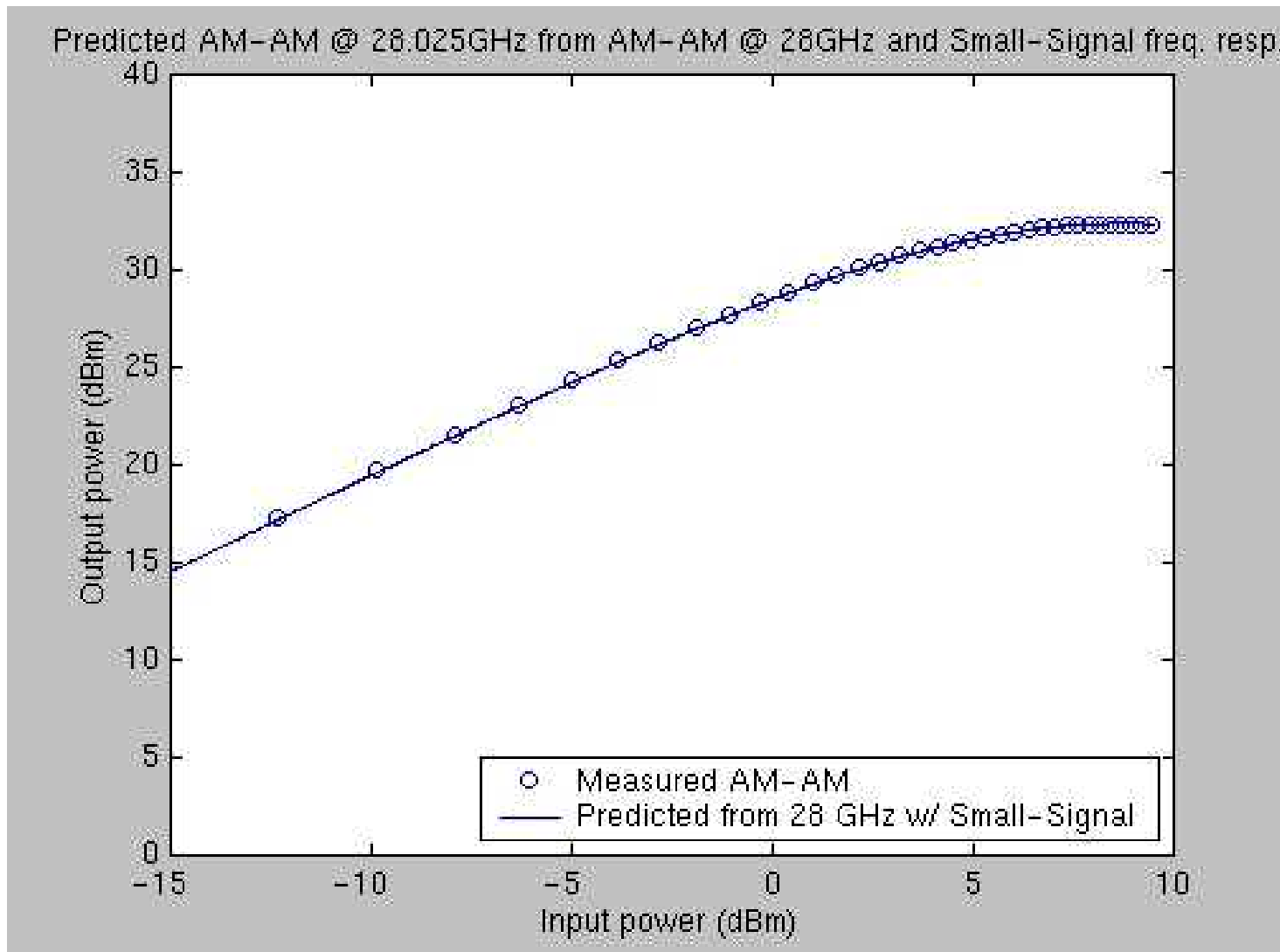


# Small Signal Gain & Simple Correction

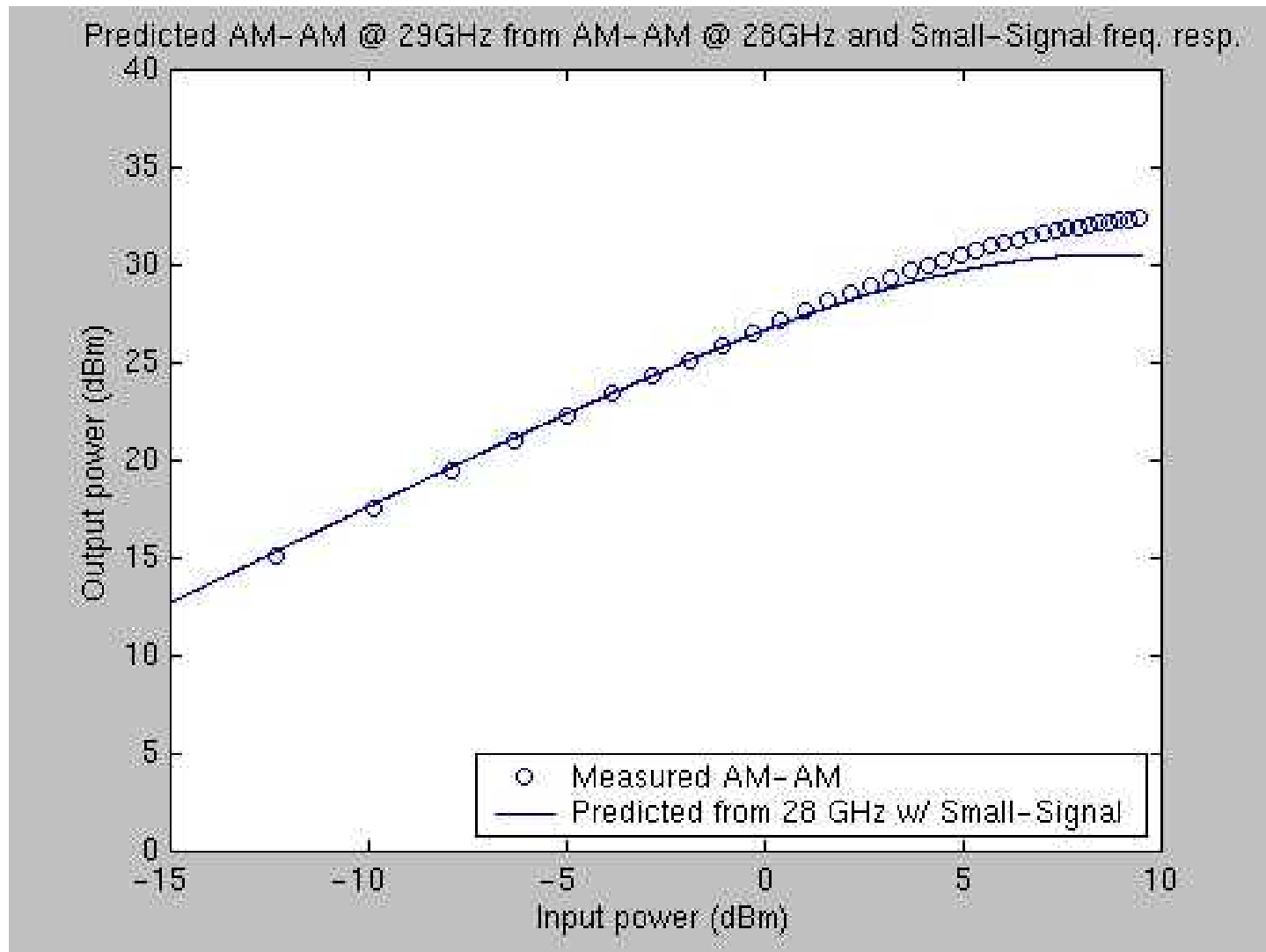


$$G(f) = G(f_0) \frac{g(f)}{g(f_0)}$$

# AM-AM Prediction to 28.025 GHz



# AM-AM Prediction to 29.0 GHz





## Summary

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- ◆ Measured PA behavior (AM-AM & AM-PM) can be used in modeling effort.
- ◆ Saleh model provides independent gain and phase functions that **has been** used to compute output waveform for given input stimulus.
- ◆ Approach does not include memory effects (single tone measurements) and cannot fully correct for frequency dependence within band.
- ◆ ACPR and EVM predictions still need to be validated with measurements.