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Title	Models for Signal Clipping in Evaluation of MBWA		
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Re:	Performance Evaluation by System and Link Level Simulation		
Abstract	This document proposes a mathematical models for clipping effect and power back-off for the use by the simulation of MBWA proposals.		
Purpose	Discuss and adopt.		
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Models of Signal Clipping for the Evaluation of MBWA

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präsentiert von

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Introduction

Non-linear effect of power amplifier results in

- Clipping of signals \Rightarrow distortion of the transmitted signals and adjacent channel interferences.
- Methods to compensate the loss due to non-linear characteristics
- Back-off of the transmit power \Rightarrow linear characteristic, but less power

Amplifier

Base band signal

$$S(t) = I(t) + jQ(t) \quad (1)$$

RF signal

$$s(t) = I(t) \cos \omega t - Q(t) \sin \omega t = \Re[S(t)e^{j\omega t}] \quad (2)$$

where ω is the RF frequency.

Model of Amplification:

Power amplifier

$$P_{out}(t) = G[P_{in}(t) = S^2(t)] \quad (3)$$

Signal amplifier

$$S_A(t) = F[S(t)] \quad (4)$$

Hard Clipping

The clipped signal has the envelop

$$S_A(t) = \begin{cases} S(t) & \text{for } |S(t)| \leq A \\ A \cdot e^{j\theta(t)} & \text{for } |S(t)| > A \end{cases} \quad (5)$$

when normalized by \sqrt{g} , where

- g : power gain of the amplifier,
- $S(t)$: input signal,
- $\theta(t) = \text{arg}[S(t)]$,
- $A > 0$: ceiling of the output amplitude,
- $S_A(t)$: normalized output signal.

Back-off against Hard Clipping

- Metric for saturation $r := S_m/A$
 - $S_m = \max\{|S(t)|; t \in [0, T]\}$,
 - $r^2 - 1$: saturated power fraction
 - Linear $r \leq 1$; Clipping $r > 1$.
- S_m^2 : maximum input power within the observation window
- A^2 : maximum output power of the amplifier.
- Δ : amplitude amount of back-off

$$r' := (S_m - \Delta)/A = r - \Delta/A \leq r \quad (6)$$

- Complete back-off achieves $r' = 1$. In general,

$$S_m - \Delta \leq A \Leftrightarrow r' \leq 1$$

Soft Clipping

$$S_A(t) = \begin{cases} S(t) & \text{for } |S(t)| \leq A \\ (A + b(S - A)) \cdot e^{j\theta(t)} & \text{for } |S(t)| > A \end{cases}$$

where

- $b(x) = \alpha \cdot (1 - e^{-\beta \cdot |x|})$ characterizes the non-linear region,
- α determines the size of non-linear region and
- β determines the speed of (never !) reaching the
- upper bound $A + \alpha$.

Back-off against Soft Clipping

- Metric for soft saturation

$$r_s := \frac{S_m}{A + \alpha \cdot (1 - e^{-\beta|S_m - A|})}$$

- Relation $r_s \leq r$ holds for $\alpha \geq 0$
- Range between linear and "clipping":

$$A < \max_{|S(t)|, t \in [0, T]} |S_A(t)| < A + \alpha$$

$\Rightarrow 1/(1 + \alpha/A) < r_s < 1$: Soft-clipping.

- Back-off with $1 \leq r' \leq r$,

$$\Delta = (r - r') \cdot A \leq (r - 1) \cdot A \quad (7)$$

- Corresponding soft metric

$$r'_s = \frac{r'}{1 + (\alpha/A) \cdot (1 - e^{-\beta A \cdot |r' - 1|})} \quad (8)$$

Summary

- Choose target saturation metric r' or r'_s
- Measure current saturation metric

$$r = \frac{\max\{S(t') | t' \in [t, t + T)\}}{A} \quad (9)$$

or

$$r_s = \frac{\max\{S(t') | t' \in [t, t + T)\}}{A + \alpha} \quad (10)$$

- Determine the input transmit signal

$$S_A(t) \sqrt{g} \cdot (r'/r) \quad (11)$$

where $r', r > 0$, or

$$S_A(t) \sqrt{g} \cdot (r'_s/r_s) \quad (12)$$

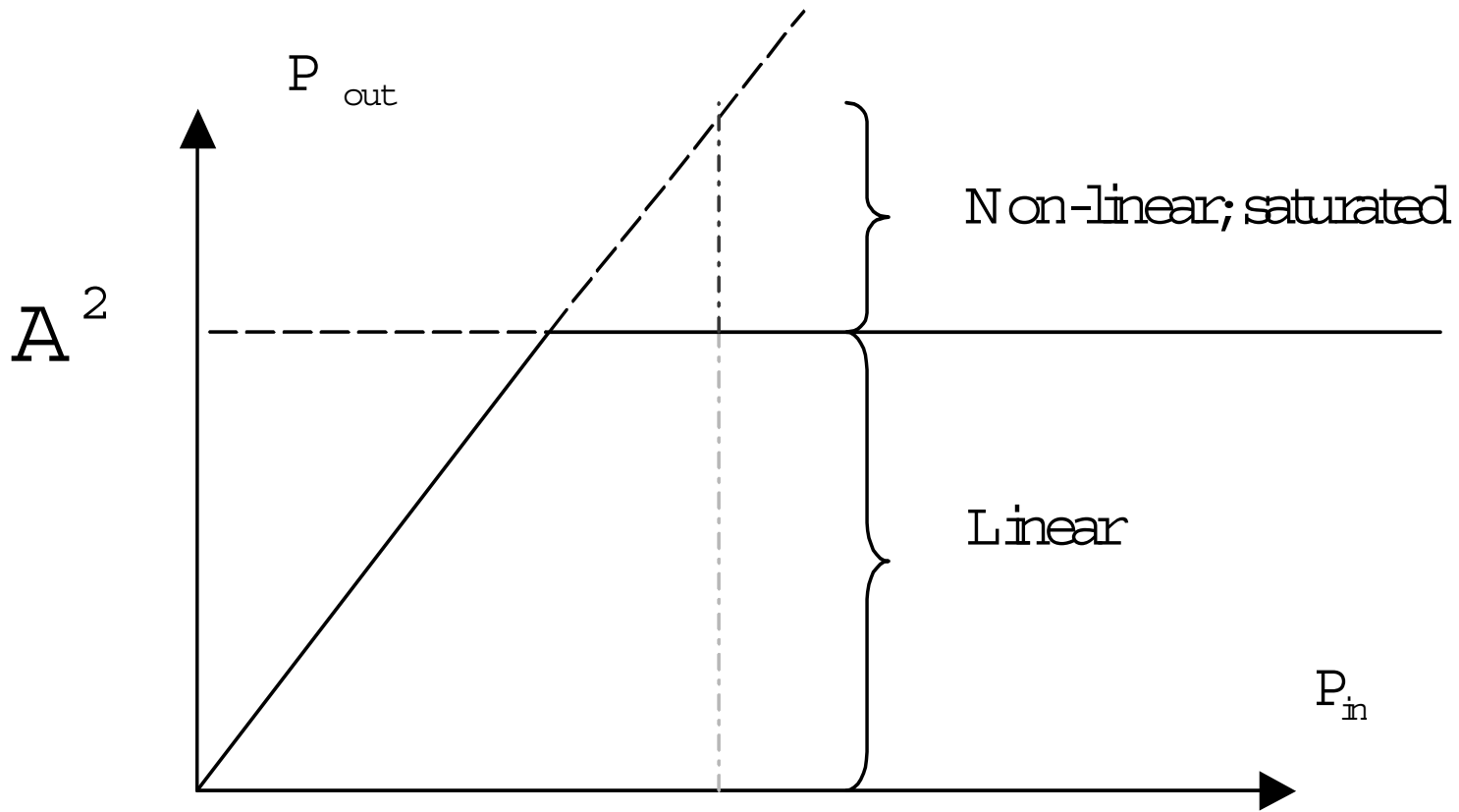


Fig.1 : Non-linear model with hard saturation

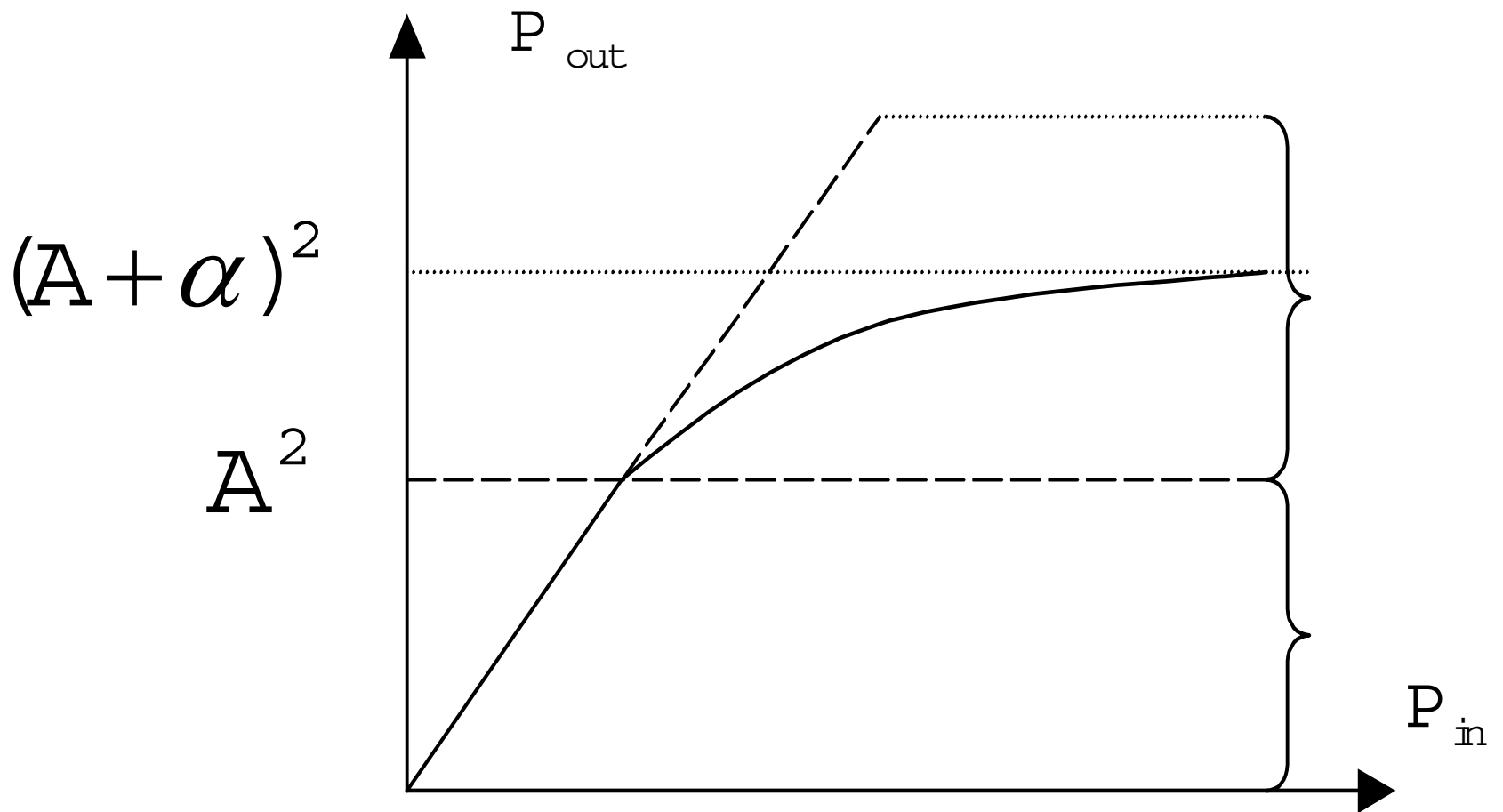


Fig 2 : Non-linear model with soft saturation

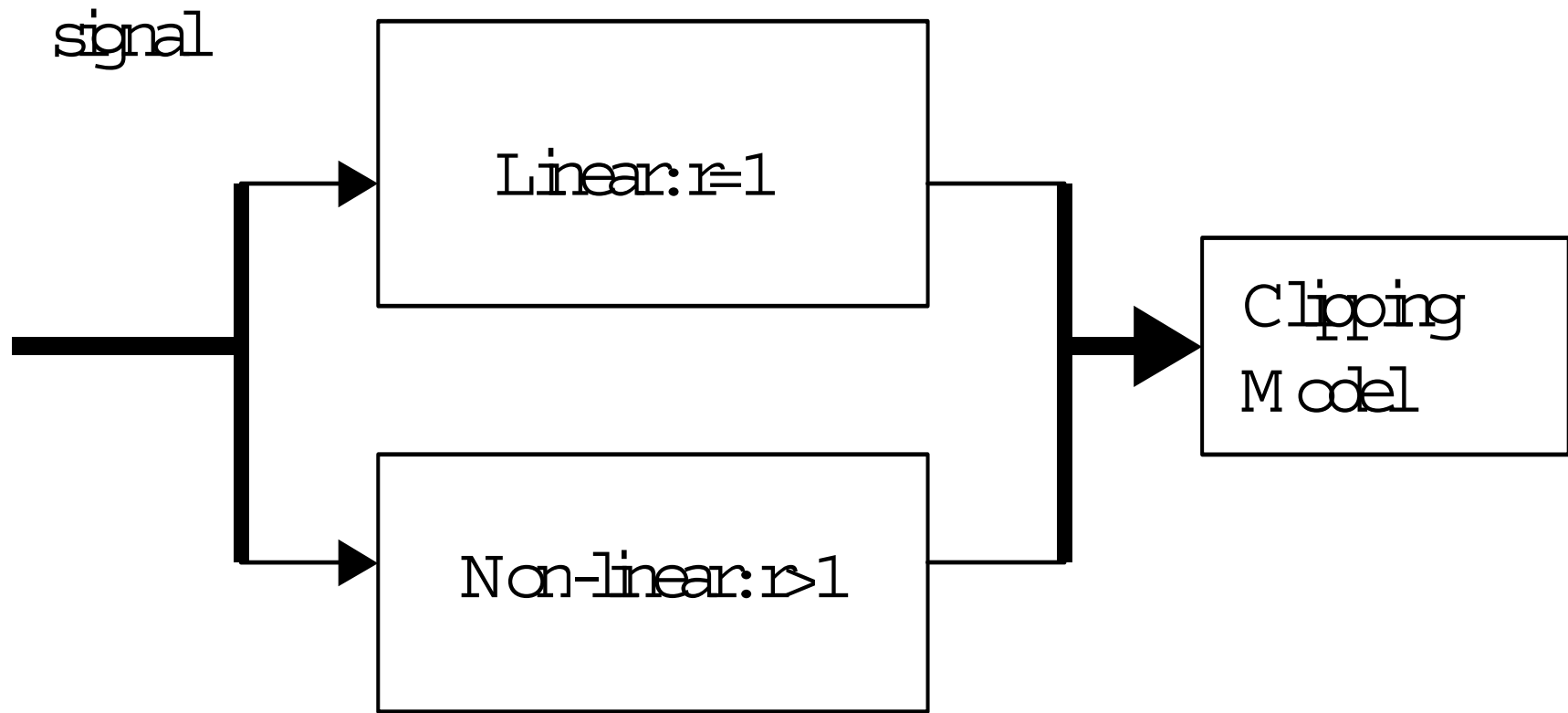


Fig 3 : Model for the study of loss due to clipping

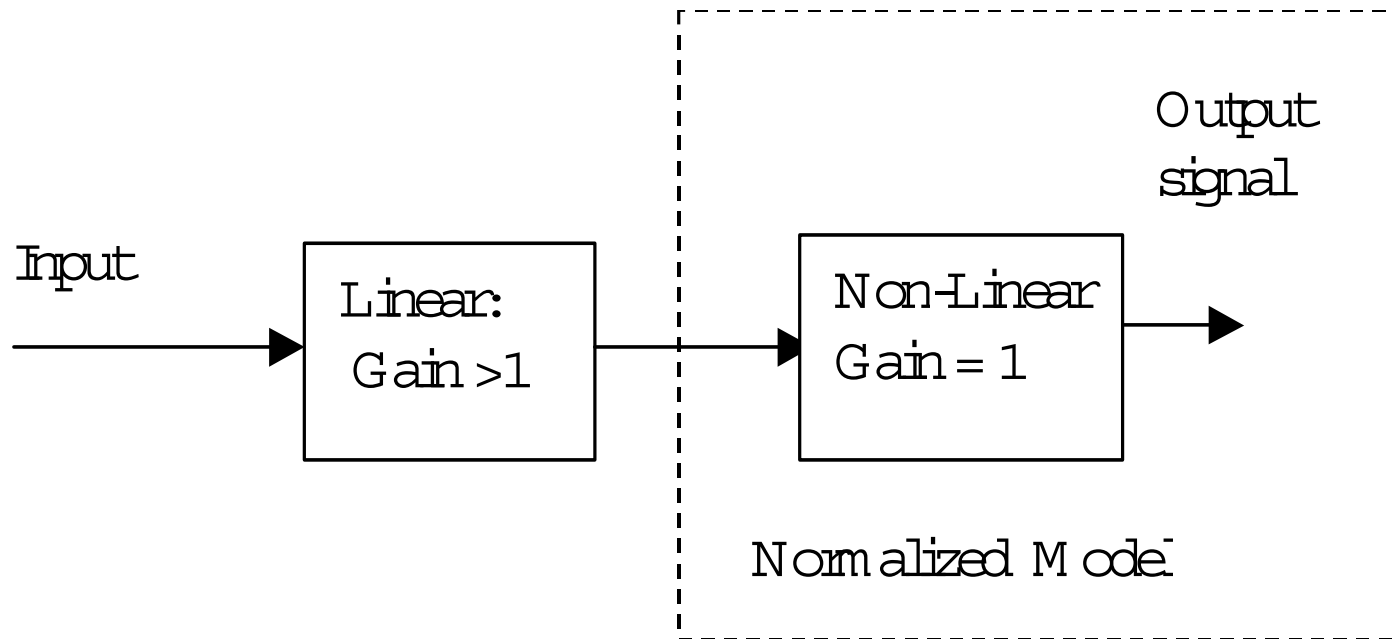


Fig.4 : Model of normalized amplifier

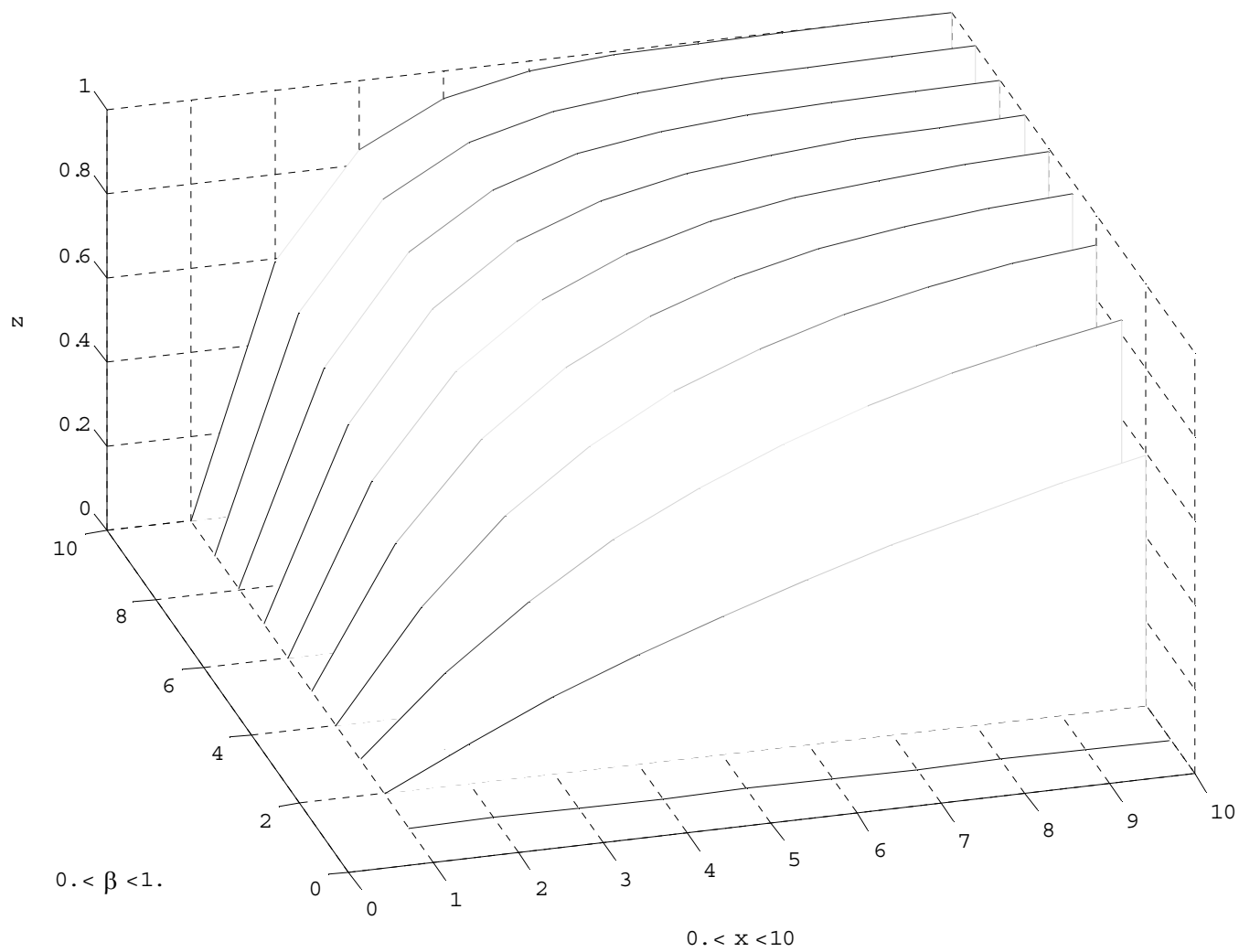


Fig. 5: Non-linear part $b(x)$ of the amplifier characteristic

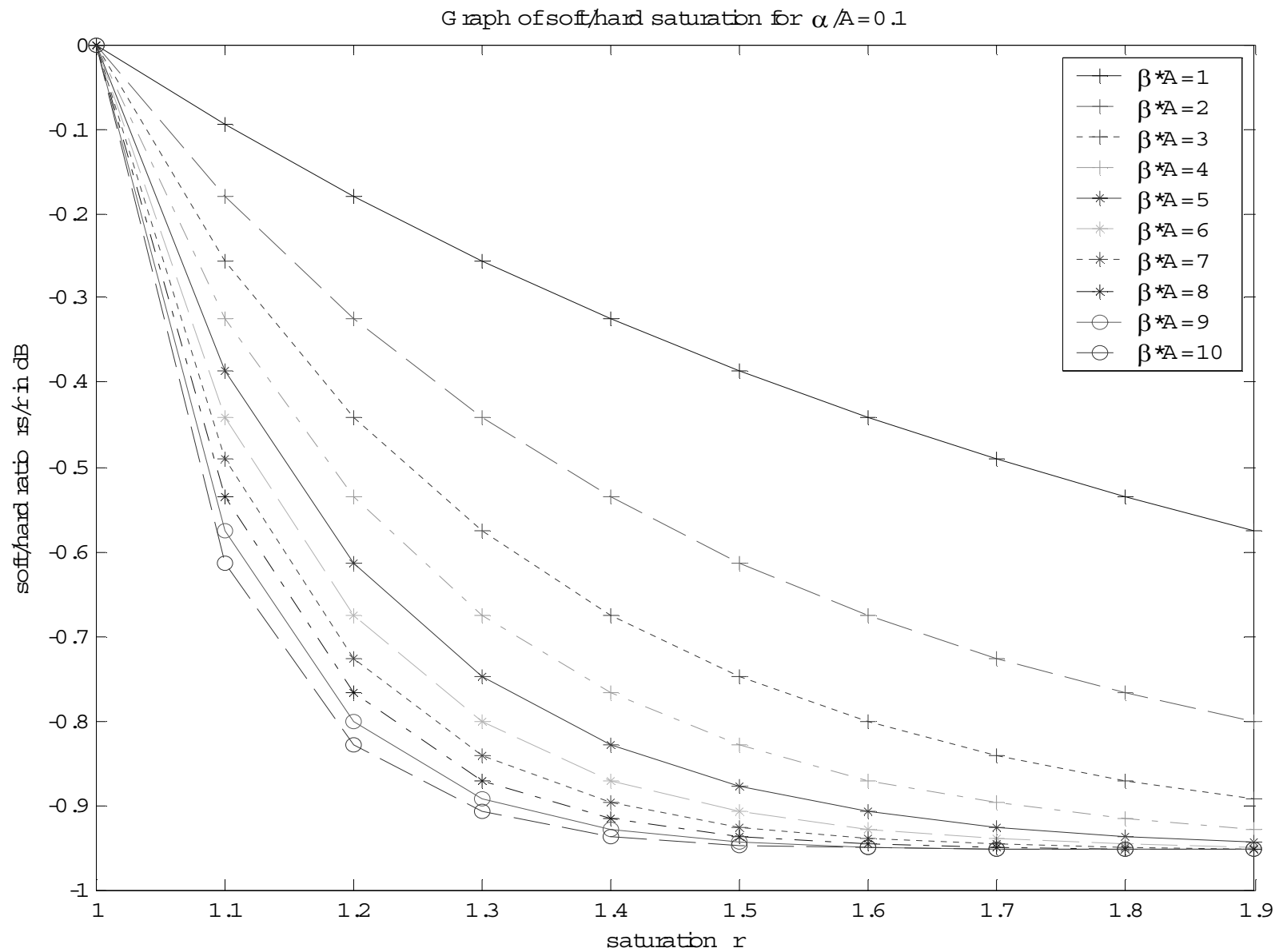


Fig.6: Saturation D istance $10 \cdot \log (r_s/r)$