EE 340: Communications Laboratory
Autumn 2021

Lab 5: Non-linearity and its effects in communication systems

Aim of the experiment

To study non linearity and its effects on communication systems
● To observe 2nd order (or even order) non-linearity
– Generation of undesired DC components and
– Unwanted out of band spectral components.
● To observe the effect of 3rd order (or odd order) non-linearity
– In-band spurious signal generation (and signal distortion) at the transmitter.
– Desensitization of the receiver (in the presence of strong interferer).
● To verify desensitization (or gain compression) of a RF receiver caused by saturation.

Legends

Question/Observation: Show it to the TA and explain (carries marks)

Recall/think about something

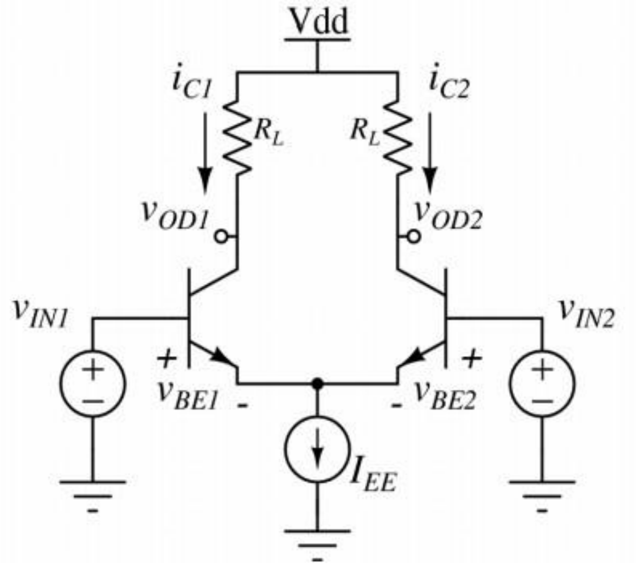
Caution

Additional information -weblink

PART1: Large Signal Model

- Consider BJT differential amplifier, with

$$v_{ID} = v_{BE1} - v_{BE2}$$



Using [large signal BJT model]prove that,

$$i_{C1} = \frac{\alpha I_{EE}}{1+e^{-v_{ID}/v_T}} \; ; \; i_{C2} = \frac{\alpha I_{EE}}{1+e^{+v_{ID}/v_T}}$$

- *Single ended output (v_{BE2} = constant ; $v_{BE1} = v_{ID}/2$)*

$$v_{OD1} = i_{c1} R_L = \frac{A_v}{1+e^{(v_{BE2}-v_{BE1})/v_T}} = \frac{1}{1+ke^{-v_{ID}/2v_T}}$$

Plot the above input-output relation

- *Differential output (with $v_{BE1} = +v_{ID}/2$; $v_{BE2} = -v_{ID}/2$)*

$$v_{OD} = (i_{c1} - i_{c2}) R_L = \alpha I_{EE} R_L \frac{e^{v_{ID}/2v_T} - e^{-v_{ID}/2v_T}}{e^{v_{ID}/2v_T} + e^{-v_{ID}/2v_T}} = A_v \tanh(v_{ID}/2v_T)$$

What is the small signal differential gain of the system?

PART1a : 2nd Order Non-Linearity

For this part of lab, implement single ended output transfer function as shown in previous slide
Following procedure can be used :

- Apply the digital modulated data (as v_{ID}) from the given 'Input.bin' file using 'file_source' block. (use samp_rate = 320kHz)
- Use a multiply constant block and set $\boldsymbol{v_T}$ = 25mV, also use a amplitude slider to control the input signal amplitude. Use slider to vary the signal power/amplitude. Keep default value = 10e-6 and maximum value = 100e-3.
- Use exponential function in 'transcendental' block to mathematically model the single ended transfer function as discussed in last slide.
- Keep k=0.9 .
- By varying the slider, observe the unwanted in-band components and undesired components in the band adjacent to the desired signal band itself.

- ✓ Is it possible to remove these unwanted out-of-band spectral components for narrowband signals (explain)?
- ✓ Can you locate and justify out-of-band IM2 components the observed location of unwanted spectral components?
- ✓ How fast do the unwanted spectral component change with respect to the desired component. For example, if signal increases by 10 dB, how much is the change in 2nd order components (explain why?).

PART1b : 3rd Order Non-Linearity

2nd order non-linearity, can be eliminated with differential signaling.

- So implement the differential model to eliminate 2nd order non-linearity, so as to observe ONLY 3rd order non-linearity effect clearly.
- Use **tanh(x)** function in 'transcendental' block to model this system and apply given modulated data from file with amplitude slider(as done in part1a). Use slider to vary the signal power or amplitude. Keep default value = 10e-6 and maximum value = 30e-3.
- Keeping A_v = 1 for the model
- By varying the slider, observe the unwanted in-band components and undesired components in the band adjacent to the desired signal band itself.

But this time effects of 2nd order nonlinearity like DC component are eliminated.

- ☑ Can these in-band components inside and in vicinity to the desired signal spectrum be removed easily as compared to previously seen out of band?
- ☑ Can you justify the observed location of unwanted spectral components?
- ☑ How fast do the unwanted spectral component change with respect to the desired component (for some change in input power). Explain why?

PART2a: Desentization

3rd ordered nonlinearity leads to Desentisation of receiver.

- So, we need to use the differential model (tanh(x) function) for this part of experiment.
- This time fix the amplitude of the desired modulated signal from the file.
- Add a sinewave tone representing an **interferer** to the output of signal and apply this to the input of the transcendental block with tanh(x) function.
- Make sure that interferer is very close to the desired signal spectrum (sinewave frequency can be set in the range 45kHz to 75kHz).
- Increase interferer amplitude from 0.01 to 1 by a slider.
- You should observe that the desired signal amplitude decreases as you increase the interferer amplitude.

This saturation of the receiver is called desensitization and is basic principle behind jamming of the receiver.

Can 2nd order non-linearity also cause desensitization of the receiver(use small signal polynomial approximation to analyze this)?