# NYCU RF Design Mid-Term Exam 2024/04/29

1. (10%) The typical characteristic of output light power P vs. input current I of laser diodes under forward bias is shown in Fig. 1, where $I_{th}$ is the threshold current. This diode can be directly amplitude-modulated from a RF signal source through a bias-T network. The modulation index m is typically defined as

$$m = \frac{I_{ac}}{I_{dc} - I_{th}}$$

Where $I_{ac}$ is the ac current, $I_{dc}$ is the DC bias current. Assume the dynamic resistance equal to 5Ω with $I_{th}$=20mA and $I_{dc}$=50mA, Please plot the schematic and find the power setting of the RF signal source for m=80%.

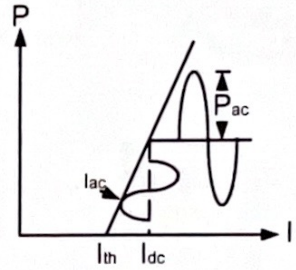


Fig. 1

2. (20%) A load $R_L$=200Ω is wanted to match the rf source with Rs=50Ω internal impedance. Two methods of wide-band matching are considered. One is to use the ideal transformer, which is lossless and is generally used as a calibrator in transmission measurement. The other is to use a resistive network, however with certain loss. Please answer the following questions:
   (a) Find the turn ratio of primary to secondary=1:n for power matching,
   (b) Find the scattering parameters for the transformer with characteristic impedances at input port and output port equal to Rs and $R_L$, respectively,
   (c) Replace the transformer by a simple two-resistor matching network and find the value of resistors,
   (d) Find the Insertion loss.

3. (20%) The block diagram in Fig. 3(a) is the well-known Hartley image-rejection mixer. The RF input contains both desired signal and image noise as

$RF\ Signal = A_{RF}\cos(\omega_{RF}t) + A_{im}\cos(\omega_{im}t)$. Assume $\omega_{RF} < \omega_{LO} < \omega_{im}$.

(a) Can you obtain the desired signal at IF port? (b) If not, how to modify the block diagram?

(b) If Fig. 3(a) is replaced by Fig. 3(b), how to feed the quadrature outputs of local oscillator up to the two mixers? Explain the reason.

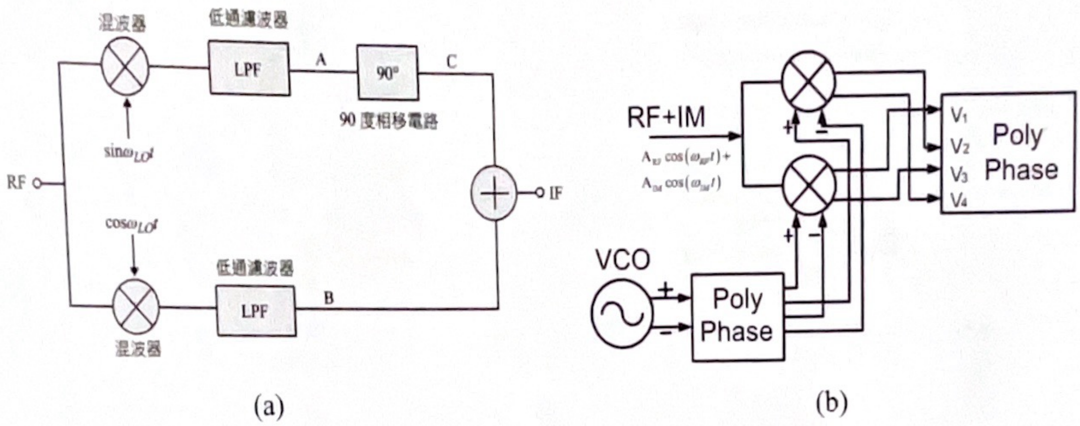


Fig. 3

4. (10%) The blocks of receiver and the related gain and noise figure are shown in Fig. 4.
   (a) Please verify the percentages of LNA and mixer to overall NF,
   (b) Find the tolerance of LNA gain for upper limit 8.5dB of overall NF.

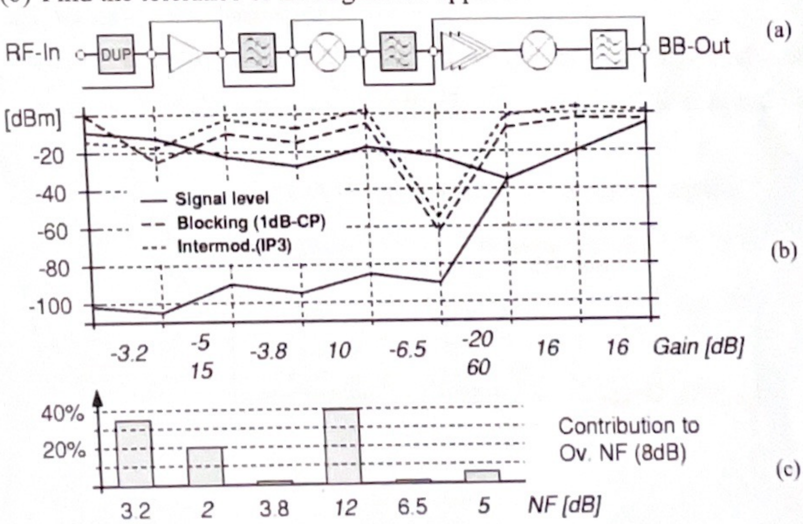


Fig. 4

5. (20%) The nonlinear behavior model of amplifier is often described as

$$Y(t) = k_1 x(t) + k_2 x^2(t) + k_3 x^3(t) + \ldots$$

Where x(t) is the input, Y(t) is the output, and $k_1$, $k_2$ and $k_3$ are the linear and nonlinear coefficients, respectively.

(a) Please compare the differences between one-tone and two-tone tests on $P_{1dB}$ and IIP3.

(b) The CMOS differential amplifier as shown in Fig. 5. Please find the coefficients $k_1$, $k_2$ and $k_3$ in the response of output current $i_{d1}$ to input voltage $v_i$,

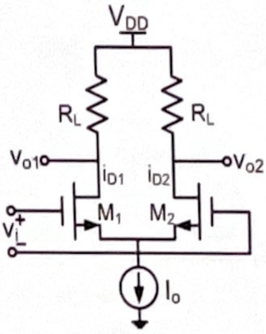

Fig. 5

*Input small signal* $v_i = v_{GS1} - v_{GS2}$

*Drain currents satisfy square law as*

$$i_D = \frac{\mu C_{ox}}{2}\left(\frac{W}{L}\right)(v_{GS} - V_T)^2$$

*and*

$$i_{D1} + i_{D2} = I_O$$

$$g_m = \sqrt{I_O \mu C_{ox}\left(\frac{W}{L}\right)} \triangleq \sqrt{\kappa I_O}$$

$$(1-x)^{1/2} \cong 1 - \frac{x}{2} - \frac{1}{8}x^2 - \frac{1}{16}x^3 \ldots, x^2 \leq 1$$

6. (20%) The standards of frequency bands (I), receiver blocking levels (II), and transmitter spurious (III) for DCS-1800 are listed as follows.

(I) Frequency Band:

- 1710 MHz to 1785 MHz: Up Link;
- 1805 MHz to 1880 MHz: Down Link.

(II) Blocking characteristics

The blocking characteristics of the receiver are specified separately for in-band and out-of-band performance as identified in the following Table-A and Table-B.

Table-A Frequency Band for blocking signals

| Frequency band | Frequency range (MHz) DCS 1 800 | |
|---|---|---|
| | MS | BTS |
| in-band | 1 785 - 1 920 | 1 690 - 1 805 |
| out-of-band (a) | 0,1 - 1705 | 0,1 - < 1 690 |
| out-of-band (b) | > 1 705 - < 1 785 | N/A |
| out-of band (c) | > 1 920 - 1 980 | N/A |
| out-of band (d) | > 1 980 - 12,750 | > 1 805 - 12,750 |

Table-B Blocking Level

| Frequency band | GSM 400, P-, E- and R-GSM 900 | | | | | | DCS 1 800 & PCS 1 900 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | other MS | | small MS | | BTS | | MS | | BTS | |
| | dBµV (emf) | dBm | dBµV (emf) | dBm | dBµV (emf) | dBm | dBµV (emf) | dBm | dBµV (emf) | dBm |
| in-band | | | | | | | | | | |
| 600 kHz ≤ \|f-f$_o$\| < 800 kHz | 75 | -38 | 70 | -43 | 87 | -26 | 70 | -43 | 78 | -35 |
| 800 kHz ≤ \|f-f$_o$\| < 1,6 MHz | 80 | -33 | 70 | -43 | 97 | -16 | 70 | -43 | 88 | -25 |
| 1,6 MHz ≤ \|f-f$_o$\| < 3 MHz | 90 | -23 | 80 | -33 | 97 | -16 | 80 | -33 | 88 | -25 |
| 3 MHz ≤ \|f-f$_o$\| | 90 | -23 | 90 | -23 | 100 | -13 | 87 | -26 | 88 | -25 |
| out-of-band | | | | | | | | | | |
| (a) | 113 | 0 | 113 | 0 | 121 | 8 | 113 | 0 | 113 | 0 |
| (b) | - | - | - | - | - | - | 101 | -12 | - | - |
| (c) | - | - | - | - | - | - | 101 | -12 | - | - |
| (d) | 113 | 0 | 113 | 0 | 121 | 8 | 113 | 0 | 113 | 0 |
| NOTE: For definition of small MS, see subclause 1.1 | | | | | | | | | | |

(III) Transmitter Spurious Emission Measurement [4.3.3.1]

Table-C

| Band | Frequency offset (offset from carrier) | Measurement bandwidth |
|---|---|---|
| relevant transmit band | ≥ 1,8 MHz | 30 kHz |
| | ≥ 6 MHz | 100 kHz |

(a) Please plot and indicate the in-band and out-of-band blocking levels as a function of offset frequency $\Delta$f from 0.1MHz to 12750MHz according to Table-A and B for DCS MS at carrier frequency $f_o$=1805 and 1880MHz. [A reference is given in Fig. 6.]

(b) Let the receiver sensitivity equal to -99dBm with S/N=9dB. Please calculate the required phase noise of the local oscillator at each offset frequency $\Delta$f=0.6MHz, 1.6MHz, 3MHz, and 20MHz, due to blocking effect.

(c) The local oscillators are also used in the transmitter mode. The phase noise may be limited by the spurious emission, especially near the band edge. In DCS-1800 the spurious level from transmitter should be less than -71dBm in the band 1805-1880MHz [3GPP TS-0505 4.3.3.1] with output power +33dBm. The measurement bandwidth depends on the offset frequency as listed in the Table-C. Please calculate the required phase noise for the transmitter mode at edge 1785MHz.

(d) Furthermore, indicate which one among questions (b) and (c) is the most stringent, assume the offset shaping $(\Delta f)^{-2}$ of phase noise is under the prediction of Leeson model.

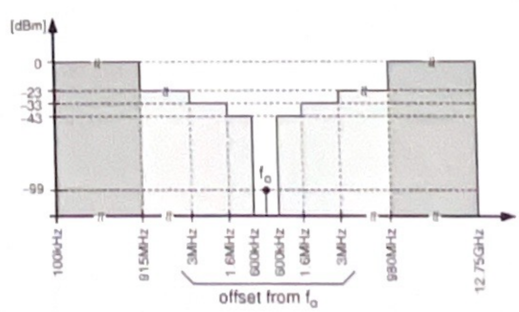


Fig. 6