上 海 交 通 大 学 试 卷B

（ 2019 至 2020 学年 第 2 学期 ）

班级号________________________ 学号______________ 姓名 ________

课程名称 通信基本电路与实验/ Communication Circuits 成绩 ______

IMPORTANT NOTICE:

The variable “ID” equals to your student ID number throughout the test.

For example: if your student ID number is 5170309360, then ID=5170309360

1. Fill in the blanks:

1) The effects of nonlinearity include:_____________________； _________________；
_______________________； ____________________

2) A low-noise amplifier senses a -80 dBm signal at 2.420 GHz and two -30 dBm interferers at 2.430 GHz and 2.440 GHz. For simplicity, assume 50-Ω interfaces at the input and output. If the IM products must remain （ID mod 3 ＋13 ） dB below the signal，the IIP3 should be ____________ (dBm).

3) For a RLC circuit shown in Fig. 1, if $L = 0.8\mu\mathrm{H}$, $Q_0 = ((\mathrm{ID}\ \mathrm{mod}\ 3\ + 3\ ) * 20)$, $C_1 = C_2 = 20\mathrm{pF}$, $C_i = 5\mathrm{pF}, R_i = 10\mathrm{k}\Omega, C_0 = 20\mathrm{pF}, R_0 = 5\mathrm{k}\Omega$. Thus, the resonance frequency is___________, resonance impedance is____________, loaded quality factor Q_L is________________,and 3-dB bandwidth B is _____________________.

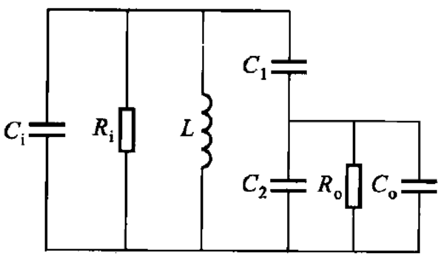

Fig. 1

4) Let Δf = (ID mod 20 - 10) MHz. Suppose that a signal with a carrier frequency of 2.4 GHz is applied to a downconversion receiver, and the LO frequency is 2.4 GHz + Δf. We call this signal is _____-side injected. The IF frequency of this receiver is _______, and the image frequency is _________.

5) Let P_{in} = (ID mod 10 – 5) dBm. For a given power amplifier, let assume its 1-dB compression point is P_{in} and the corresponding P_{out} is 20 dBm as shown in Fig. 2. When working at this 1-dB compression point, the power gain of this PA is ________, and the power gain for the linear component is ________. The input power at the third intercept point (IP3) for the same system is about _______.

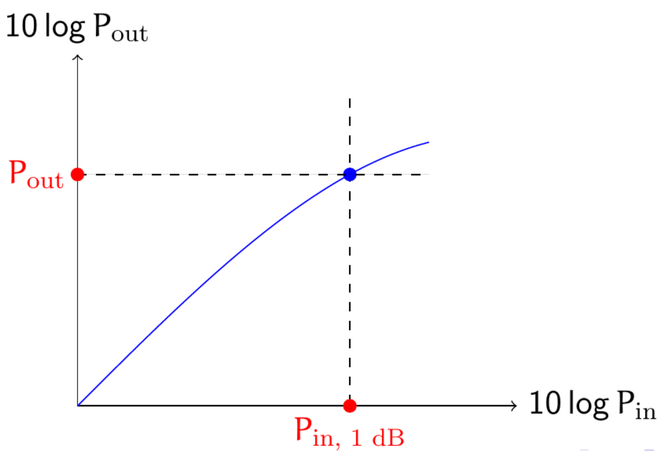

Fig. 2

2. Calculations:

1) As shown in Fig. 3, a 900-MHz GSM transmitter delivers a power of 1 W to the antenna. The receiver is 2m away and the 1.8-GHz signal is attenuated by 10 dB as it propagates across this distance. On the receiver side, suppose NF_1 denote the noise figure of the LNA stage where NF_1 = 2 dB. Here, each noise figure is computed with respect to the output impendence of the previous stage. For LNA and BPF, the voltage gains are A_1 = (ID mod 3 + 6) dB and A_2 = 4 dB. The system is under matched conditions.

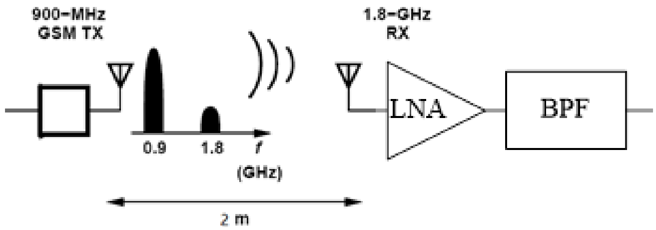

Fig. 3

a) Calculate the necessary noise figure of BPF (NF_2) such that the overall noise figure is no more than 3 dB.

b) Give thermal noise models for at least two devices.

c) Draw the structure of a direct-conversion transmitter and give reasonable LO, baseband frequencies.

d) For the transmitter, explain the effect of feedthrough and its harm.

e) Draw an advanced direct-conversion transmitter by using a frequency divider. Is there still harmful effect of feedthrough? Why?

f) In order not to desensitize a 1.8-GHz receiver having P_{1dB} = -25 dBm, how much should the second harmonic of the signal be suppressed (dB)?

2) Suppose four Bluetooth users operate in a room as shown in the figure. User 4 is in the receive mode and attempts to sense a weak signal transmitted by User 1 at 2.410 GHz. At the same time, Users 2 and 3 transmit at 2.420 GHz and 2.430 GHz, respectively. We start with a simple receiver that only has an antenna and a LNA.

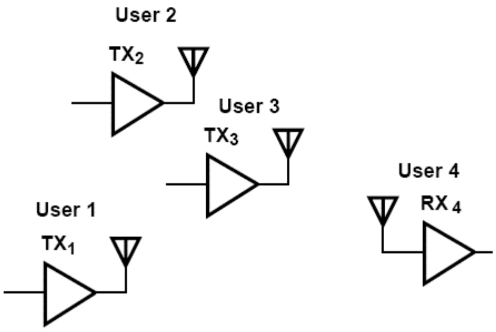

Fig. 4.

a) Explain what will happen if the receiver's LNA possesses nonlinearity.
b) We can place a BPF before the receiver's LNA to filter out unwanted signals. Assume that the power sensed by the receiver at 2.410 GHz and 2.420 GHz is -40 dBm and P2 = (ID mod 4 – 2) dBm, respectively. What is the minimal Q required for this BPF to suppress the adjacent channel signal by 70 dB.
c) We can relax the requirement on the Q by using a single-stage superheterodyne receiver. Please draw a diagram to illustrate, and indicate the purpose for each component.
d) What is the new Q required for the channel selection filter, if the intermediate frequency for the new receiver is set to 40 MHz. Here, we assume all the components are ideal (no unwanted nonlinearity and etc.).

3) Please draw the structure of a heterodyne receiver. Suppose the carrier frequency of the desired signal is $\omega_{in} = 2.4$GHz, and the LO frequency is ω_{LO} =2.42+(ID mod 10) ∗ 0.01GHz.

a) Please explain the "image problem" in heterodyne receiver and estimate the image frequency in this case. You could use drawings to illustrate.
b) How can we suppress the "image"? Please give two possible solutions and draw the corresponding receiver structures.
c) Is oscillator pulling harmful in a heterodyne receiver? Briefly explain the reason.

4) For a parallel RLC circuit, if its resonance frequency is f = 200+(ID mod 5) MHz, capacitance C = 2 pF, resistance R_P = 15 kΩ. The current in the circuit reaches the maximum value of 100 mA at resonance frequency.

a) Calculate the inductance L, Quality Factor Q, and 3-dB bandwidth B.

b) Calculate the amplitude of the voltage at resonance frequency;

c) If the input current is $0.1\cos 2\pi \times 210 \times 10^6 t$ (A), write the expression of the output voltage.

d) How can we guarantee maximum power delivery if we want to load the circuit with another resistor R_L=1.5KΩ? Please give the topologies of at least two circuit networks (the value of each components are not required).

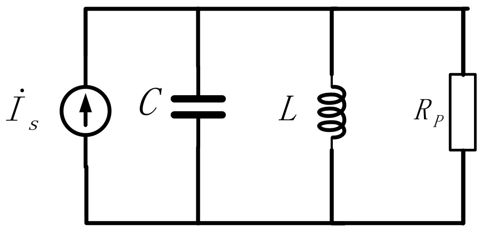

Fig. 5

5) As to the circuit shown in Fig. 6，

a) Please figure out the condition with which the circuit can work as an oscillator (in terms of the multiplication of L_iC_i)

b) Please analyze the equivalent components for each L-C units at resonant frequency;

c) Suppose you have a crystal, how to build a crystal oscillator based on the given structure in figure 6? Please analyze the advantage of crystal oscillator.

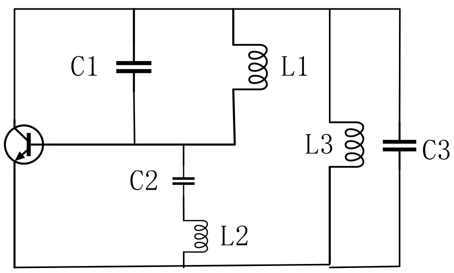

Fig. 6

6) A typical single-ended MOSFET implementation of mixer is illustrated in Fig.7. Here, the MOSFET is used as a switch.

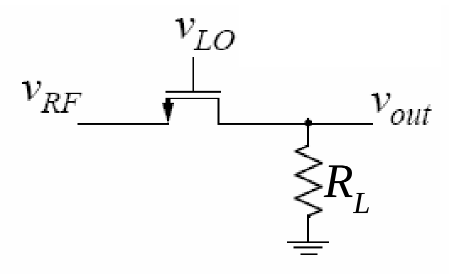

Fig. 7

a) For a sinusoidal input RF signal $v_{RF} = \sin\omega_{RF}t$ and a sinusoidal switch control signal $v_{LO} = \cos\omega_{LO}t$, please derive the output signal v_{out}. For the switch, let us assume it is only turned on when the $v_{LO} > 0.5$.

b) If we take RF as the input and IF as the output, is this system linear? Is this system time-invariant? Please explain your answer

c) Please determine the spectrum at the output.

d) What is the definition of (voltage) conversion gain? Please determine the conversion gain for the mixer shown in Fig. 7.

e) It is known that such a simple design would lead to a phenomenon called "feedthrough". Please explain where it comes from. You could use drawings to illustrate.

f) Please repeat part (a) if R_L is replaced by a capacitor C_L.

7) As to a power amplifier, suppose P_o =5W, V_{DD} =24V, the bias voltage is equal to V_{TH} and the load is equal to 50+(ID mod 3) Ω. The drain current is
$$i_D = \begin{cases} i_{rf}\cos\omega_0 t & i_D > 0 \\ 0 & i_D < 0 \end{cases}$$

a) Please give the value of P_{DC} and η.

b) How to raise the output power by adjust a single parameter? What is the maximum output power and efficiency in this case? Give a practical circuit and its brief explanation to achieve the parameter adjustment.

c) Please give another way to raise the energy efficiency.

d) Are there any effects caused by nonlinearity in this circuit? How does it arise?