NYCU RF Design Mid-Term Exam 2022/05/02

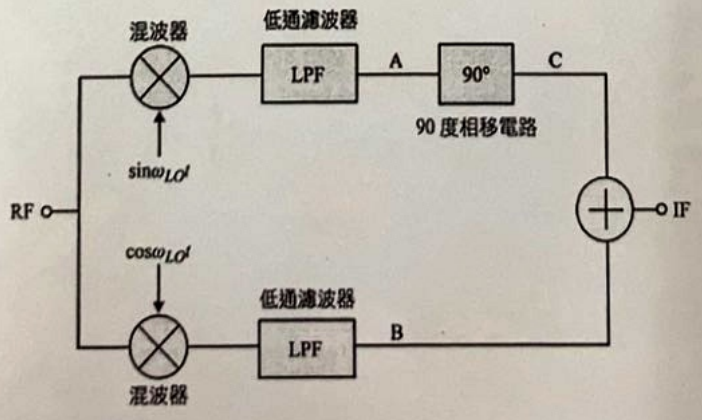
1. (10%) In ETSI about receiver characteristics, the requirements are given in terms of power levels at the antenna connector of the receiver. Equipment with integral antenna may be taken into account by converting these power level requirements into field strength requirements, assuming a 0 dBi gain antenna. Please verify the fields strengths E(dBuV/m) related to the power levels P (dBm) under 50 ohms impedance by the following formula

E = P+ 20logf(MHz) + 77.2

Where f is the operating frequency.

2. (30%) A load R_L=200Ω is wanted to match the rf source with Rs=50Ω internal impedance. Two wide-band matching circuits are considered. One is the transformer, which is lossless and the other is the resistive network with certain loss. With the transformer matching please find (a) the turn ratio of transformer, (b) the scattering parameters for the transformer with characteristic impedances at input port and output port equal to Rs and R_L, respectively, and (c) the insertion loss which is the ratio of output power to incident power in dB. Similarly, replace the transformer by a simple two-resistor network and find (d) the value of resistors, (e) the scattering parameters, and (f) insertion loss.

3. (10%) The picture in the following is the well-known Hartley image rejection mixer. The RF input contains both desired and image $RF\ Signal = A_{RF}\cos(\omega_{RF}t) + A_{im}\cos(\omega_{im}t)$. *Assume* $\omega_{RF} < \omega_{LO} < \omega_{im}$. Can you obtain the desired signal? Explain the reasons.



4. (30%) Please verify the following equations for the n-stage cascaded rf circuit

(a) (5%) Total noise figure

$$F_{total} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \ldots + \frac{F_{n+1} - 1}{G_1 G_2 .. G_n}$$

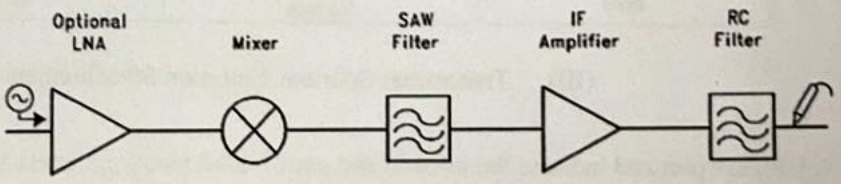
(b) (10%) Output IP2 及 IP3

$$IP2 = -20\log\left[\sum_{i}^{n}\sqrt{\frac{1}{IP2_i G_{i+1} G_{i+2} \cdots G_n}}\right]$$

$$IP3 = -10\log\left[\sum_{i}^{n}\sqrt{\frac{1}{IP3_i G_{i+1} G_{i+2} \cdots G_n}}\right]$$

where G_i、$IP2_i$、$IP3_i$、and F_i are the i^{th} stage gain, output IP2, output IP3, and noise figure.

(c) (15%) A rf link budget is shown in the figure. Assume input power -93dBm, Find input total NF, total output OIP3, and total output power。



NF (dB)	3 (2)	13 (20)	3 (2)	10 (10)	3 (2)
Gain (dB)	10 (10)	15 (31.6)	-3 (0.5)	20 (100)	-3 (0.5)
OIP3 (dBm)	10 (10)	7.5 (5.624)	100 (10^{10})	20 (100)	100 (10^{10})

5. (20%) The frequency bands, receiver blocking levels, and transmitter spurious 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 tables.

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

(I) Frequency Band

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.										

(II) Blocking Level

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

(III) Transmitter Spurious Emission Measurement 4.3.3.1

(a) Please plot and indicate the in-band and out-of-band blocking levels as a function of offset frequency Δf according to table (I) and (II) for MS at f_o=1805 and 1880MHz.

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

(c) The phase noise of local oscillators is also constrained by the spurious emission, especially near the transmitter-receiver 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 (III). Please calculate the required phase noise for the transmitter at edge 1785MHz.

(d) Furthermore, indicate which one among those offsets is the most stringent under the Leeson model of $(\Delta f)^{-2}$ shaping of phase noise.