RF Design Final Spring 2005

Name: _____

LAST 4 NUMBERS in Student Number: _____

Do NOT begin until told to do so
Make sure that you have all pages before starting
Open notes, NO CELL PHONES/WIRELESS DEVICES
DO ALL WORK ON THE SPACE GIVEN
Do NOT use the back of the pages, do NOT turn in extra sheets of work/paper
Multiple-choice and true/false answers should be within 5% of correct value or within 0.5 dB
Show all work, even for multiple choice

ACADEMIC INTEGRITY:
Students have the responsibility to know and observe the requirements of The UNCC Code of Student Academic Integrity. This code forbids cheating, fabrication or falsification of information, multiple submission of academic work, plagiarism, abuse of academic materials, and complicity in academic dishonesty.

Unless otherwise noted:

$F\{\}$ denotes Fourier transform
$F^{-1}\{\}$ denotes inverse Fourier transform
ω denotes frequency in rad/s
$*$ denotes linear convolution
$x^*(t)$ denotes the conjugate of $x(t)$

Useful constants, etc:

$e \approx 2.72$
$1/e \approx 0.37$
$\sqrt{3} \approx 1.73$
$\sqrt{7} \approx 2.64$
$\ln(2) \approx 0.69$
$\log_{10}(2) \approx 0.30$
$\log_{10}(10) \approx 1.0$
$\log_{10}(e) \approx 0.43$

$\pi \approx 3.14$
$\sqrt{2} \approx 1.41$
$\sqrt{5} \approx 2.22$
$\sqrt{10} \approx 3.16$
$\ln(4) \approx 1.38$ &
$\log_{10}(3) \approx 0.48$ &
$\log_{10}(0.1) \approx -1$
$\cos(\pi / 4) \approx 0.71$

$\cos(A) \cos (B) = 0.5 \cos(A - B) + 0.5 \cos(A + B)$
$e^{j\theta} = \cos(\theta) + j \sin(\theta)$

5 Points each

1. The wavelength in a material with $\varepsilon_r = 4$ at 150 MHz is

   a) 1 m b) 3 m c) 30 cm d) none above

2. The noise figure of a filter with insertion loss of 10 dB is

   a) -10 dB b) 0 dB c) 10 dB d) none above

3. A power of 1 watt in a 100 ohm system is equivalent to

   a) 1 Vrms b) 10 Vrms c) 100 Vrms d) none above

4. The impedance of a 80 ohm, 1/2 λ length, transmission line terminated by a 1 pF capacitor at 1 GHz is

   a) –j 160 Ω b) j 80 Ω c) ∞ Ω d) none above

5. The impedance of a 80 ohm, 1/4 λ length, transmission line terminated by a 2 pF capacitor at 1 GHz is

   a) –j 160 Ω b) j 80 Ω c) ∞ Ω d) none above

5 Points each

6. A single-conversion receiver has an LO frequency of 110 MHz, an IF frequency of 20 MHz and high-side injection. The desired RF frequency of the receiver is:

   a) 90 MHz b) 110 MHz c) 130 MHz d) none above

7. A single-conversion receiver has a desired RF frequency of 2000 MHz with an LO frequency of 2100 MHz. The image frequency of the receiver is:

   a) 1900 MHz b) 2100 MHz c) 2200 MHz d) none above

8. A dual-conversion receiver has a first LO frequency of 1100 MHz with high-side injection, and a first IF frequency band of 100-200 MHz. The receiver RF frequency is:

   a) 900-1000 MHz b) 1000-1200 MHz c) 1200-1300MHz d) none above

9. The output noise power of a receiver with 64 dB gain, 10 dB noise figure, 100 MHz preselector bandwidth, and 10 MHz IF bandwidth is

   a) -24 dBm b) -30 dBm c) -60 dBm d) none above

10. The effective (or equivalent) input noise power of a receiver with 70 dB gain, 10 dB noise figure, and 1 MHz bandwidth is

    a) -70 dBm b) -84 dBm c) -104 dBm d) none above

5 Points each

11. The gain of the ideal isotropic radiator antenna antenna is (to within 0.5 dB)

    a) 0 dBd b) -2 dBd c) 2 dBd d) none above

12. The gain of an antenna becomes larger as the antenna aperture increases.

    a) True b) False

13. The free-space loss between two 3 dBi antennas at 2 GHz and separation of 5 km is (to within 2 dB)

    a) 87.2 dB b) 97.3 dB c) 106.5 dB d) none above

14. In an urban environment, signal power between antennas would decrease by 24 dB with each doubling in antenna separation for parameter n = 4.

    a) True b) False

15. An 11-stage ring oscillator with propagation delay of 0.5 ns would oscillate at a frequency of:

    a) 22 MHz b) 45 MHz c) 90 MHz d) none above

5 Points each

16. Reducing the bias current of a differential pair by a factor of ½ will, in most cases, decrease the output intercept point by

    a) 0 dB b) 3 dB c) 6 dB d) none above

17. A duplexer can be used to couple a receiver and transmitter to an antenna.

    a) True b) False

18. The sensitivity of a receiver, assuming 20 dB S/N is required, with 70 dB gain, 11 dB noise figure, 30 dBm output third order intercept, and 2 KHz IF bandwidth is

    a) -80 dBm b) -90 dBm c) -110 dBm d) none above

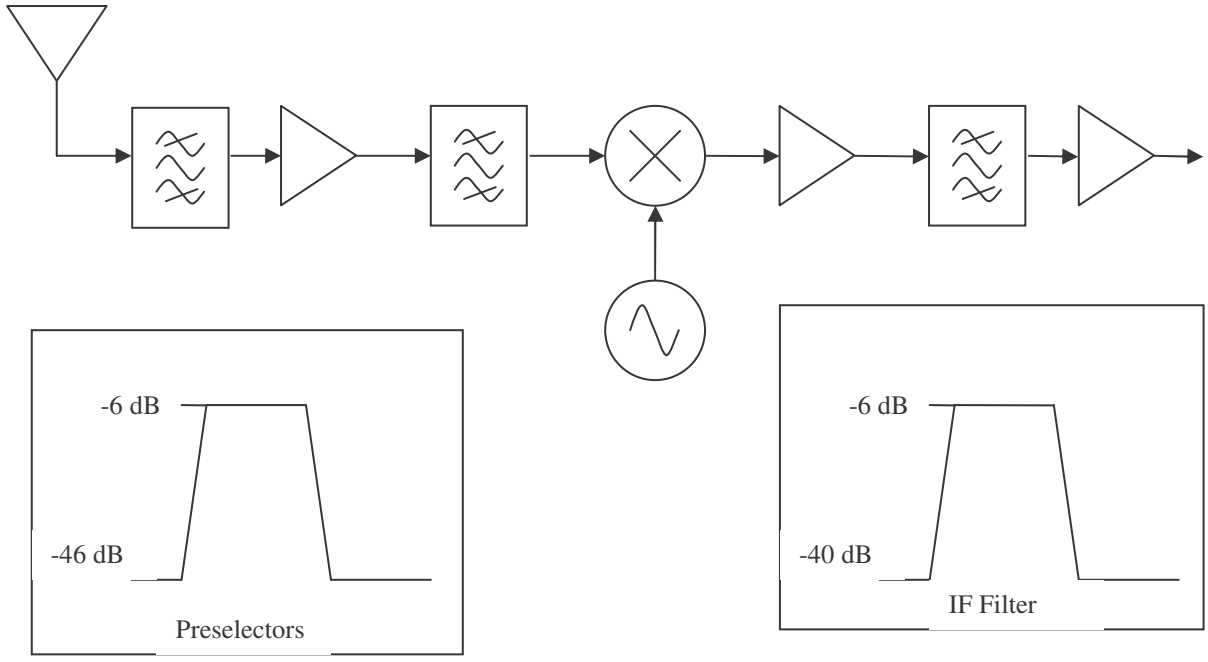
19. The spur-free dynamic range of a receiver front-end with 70 dB gain, 14 dB noise figure, 10 MHz preselector bandwidth, 30 dBm output third order intercept, and 1 MHz IF bandwidth is

    a) 40 dB b) 60 dB c) 70 dB d) none above

20. For an amplifier with third order output intercept of 50 dBm, when the two-tone output power level is 20 dBm, the power level of the third-order distortion products at the output is

    a) -30 dBm b) -40 dBm c) -50 dBm d) none above

The following questions address the receiver below.



5 Points Each

21. The image rejection of the above receiver is most likely

a) 40 dB b) 68 dB c) 80 dB d) none above

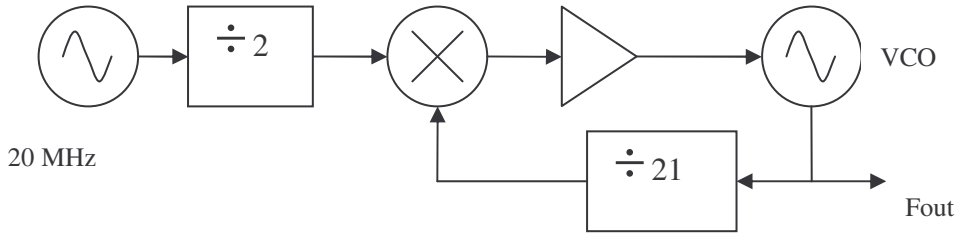
22. The adjacent channel selectivity of the above receiver is most likely

a) 34 dB b) 54 dB c) 60 dB d) none above

23. The noise figure of the above receiver could possibly be 11 dB.

a) True b) False

The following questions address the frequency synthesizer below.



5 Points Each

24. The output frequency Fout is

a) 21 MHz b) 105MHz c) 210 MHz d) none above

25. The frequency step size for the above frequency synthesizer is

a) 0.2 MHz b) 10 Mhz c) 21 MHz d) none above

25 Points

26. You are to design an earth station antenna to receive a signal from a satellite in a geostationary orbit at altitude 40 km above the earth. You may assume that the satellite transmitter has:

    1. a transmit signal power of 1 watt
    2. a frequency of 12 GHz.
    3. a signal bandwidth of 30 MHz

You may also assume that your receiver

1. has a noise figure of 3 dB
2. and that the required signal-to-noise ratio is 10 dB.

Find:

1. the required gain of the receive antenna

   Your answer here:_____

2. the effective area of the receive antenna

   Your answer here:_____

3. the approximate beamwidth of the receive antenna in degrees

   Your answer here:_____

All of your work for this problem must be on the next 2 pages only.

50 points

27. Using parts from the attached data sheets, design a full duplex (FDD, Freq. Division Duplex) IS-95 CDMA radio in the PCS 1900 band with the following performance: (Only design the receiver up to the demodulator, and include a duplexer)

    1. Frequency band:
       Transmit: 1850-1910 MHz, Receive: 1930-1990 MHz
       Set the LO's for 1880 transmit, 1960 receive

    2. Channel Bandwidth: 1.25 MHz
       Adjacent channel rejection (at Fc +/- 1.25 MHz): 80 dB minimum

    3. Receiver noise figure: 10 dB

    4. Image rejection: 70 dB minimum

    5. Receiver output level: 10 dBm at minimum receiver input signal power
       (i.e., at receiver sensitivity). This output is at the final IF frequency.
       A demodulator is NOT required. You may assume 10 dB signal/noise for receiver sensitivity.

    6. Transmitter : you need not design the transmitter, but you must include a duplexer as the first stage of the receiver

After designing the radio,

1. Show a block diagram of your radio design ***with part numbers***.
   The block diagram should be drawn directly above th spreadsheet.
2. Show a spreadsheet for gain, noise figure, P1dB, and OIP3.

(the above 2 items should be placed on the next page)

Also find

3. Receiver sensitivity in dBm at 10 dB S/N

   Your answer here:_____

4. Receiver image rejection

   Your answer here:_____

5. Adjacent channel selectivity/rejection

   Your answer here:_____

6. Receiver Spur-free dynamic range

   Your answer here:_____

7. Transmitter/receiver isolation at Transmitter frequency

   Your answer here:_____

8. Receiver IF frequency

   Your answer here:_____

9. Receiver LO frequency

   Your answer here:_____

9. LO part number

   Your answer here:_____

All of your work for this problem must be on the next 4 pages only.

*Place your final design answers on this spreadsheet And **draw your block diagram above** the spreadsheet. And **show all part numbers** on the spreadsheet **and** on the block diagram.*

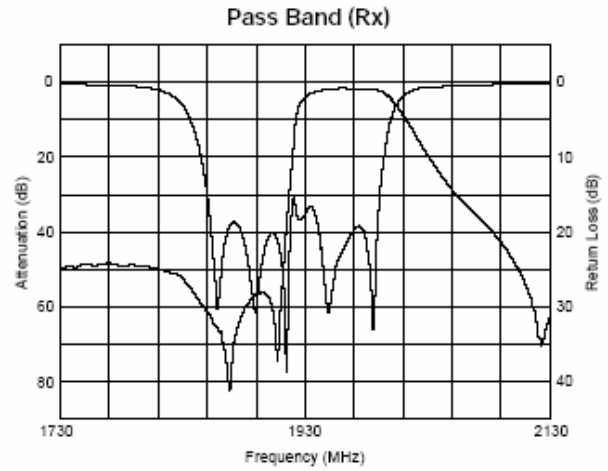
STAGE	Duplexer
gain,dB	
nf,dB	
ip3out, dBm	
1dBout, dBm	
TOTAL	
gain,dB	
nf,dB	
ip3out,dB	
1dBout, dB	

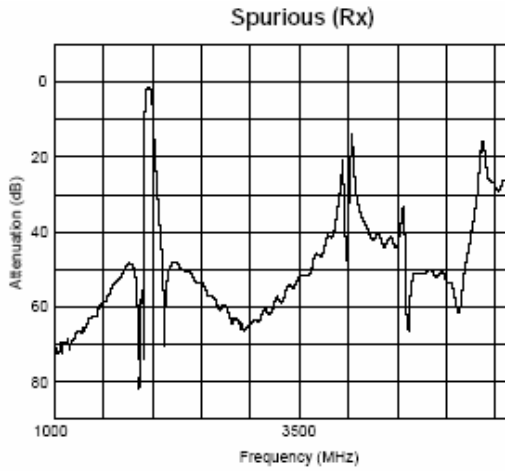
MODEL◆ NO.	FREQ.✪ (MHz)	GAIN (dB) Typical at MHz 100	1000	2000	Note 1 Min.	MAXIMUM POWER (dBm) Output (1 dB Comp.) Typ.	Input (no damage)	DYNAMIC RANGE NF (dB) Typ.	IP3 (dBm) Typ.	VSWR (:1) Typ. In	Out
MAR-1SM	DC-1000	18.5	15.5	—	13.0	+1.5	+13	5.5	+14.0	1.3	1.2
MAR-2SM	DC-2000	12.5	12.0	11.0	8.5	+4.5	+13	6.5	+17.0	1.5	1.4
MAR-3SM	DC-2000	12.5	12.0	10.5	8.0	+10.0	+13	6.0	+23.0	1.5	1.7
MAR-4SM	DC-1000	8.3	8.0	—	7.0	+12.5	+13	7.0	+25.5	1.5	1.9
MAR-6SM	DC-2000	20.0	16.0	11.0	9.0	+2.0	+13	3.0	+14.5	1.7	1.7
MAR-7SM	DC-2000	13.5	12.5	11.0	8.5	+5.5	+13	5.0	+19.0	1.7	1.7
MAR-8ASM	DC-1000	31.5	25	—	20.0	+12.5	+13	3.1	+25.0	1.4	1.8
MAR-8SM	DC-1000	32.5	22.5	—	19.0	+12.5	+13	3.3	+27.0	#	#

+7 dBm LO, up to +1 dBm RF

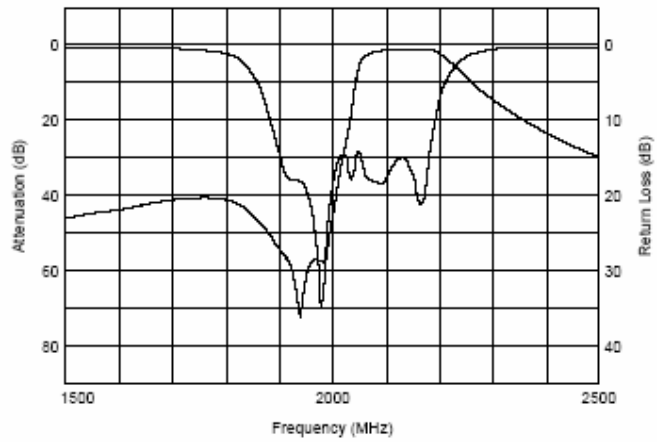
ADE/ADEX

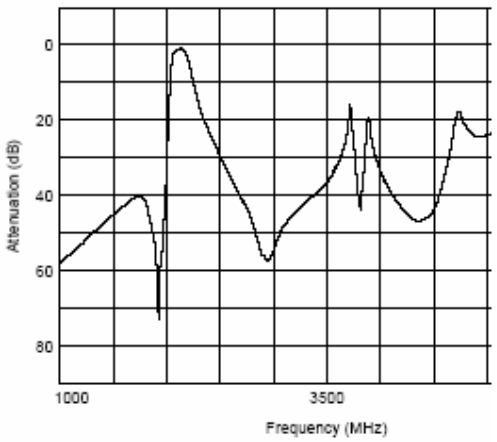
◆ MODEL NO.	FREQUENCY MHz LO/RF f_L-f_U	IF	CONVERSION LOSS dB Mid-Band –	σ	Max.	Total Range Max.	LO-RF ISOLATION dB L Typ.	Min.	M Typ.	Min.	U Typ.	Min.	LO-IF ISOLATION dB L Typ.	Min.	M Typ.	Min.	U Typ.	Min.	IP3@ center band Typ. (dBm)
ADE-1**	0.5-500	DC-500	5.0	.10	6.5	7.8	70	50	55	35	45	30	65	45	40	25	30	20	15
ADE-1ASK**	2-600	DC-600	5.3	.10	6.5	7.5	55	45	50	30	40	25	50	40	45	24	35	18	16
ADE-2ASK**	1-1000	DC-1000	5.4	.10	6.8	9.5	55	45	45	30	36	20	50	40	32	22	22	12	12
ADE-2	5-1000	DC-1000	6.67	0.26	8.0	9.5	60	40	47	25	32	22	62	35	45	25	32	20	20
ADE-3G**	2300-2700	DC-400	5.6	.10	—	7.0			36 (typ.)		25 (min.)				26 (typ.)		17 (min.)		13
ADE-3GL**	2100-2600	DC-600	6.0	.25	—	8.8			34 (typ.)		25 (min.)				20 (typ.)		7 (min.)		17
ADE-4**	200-1000	DC-800	6.8	.10	8.5	8.5	60	45	53	40	45	30	45	30	40	22	35	20	15
ADE-5**	5-1500	DC-1000	6.6	.10	7.5	9.3	50	40	40	25	33	23	50	40	30	20	20	10	15
ADE-6**	0.05-250	DC-200	4.6	.05	7.0	8.4	62	49	40	30	40	20	58	44	45	24	25	15	10
ADE-11X**	10-2000	5-1000	7.1	.10	8.2	9.8	62	45	36	20	27	18	60	45	37	20	38	20	9





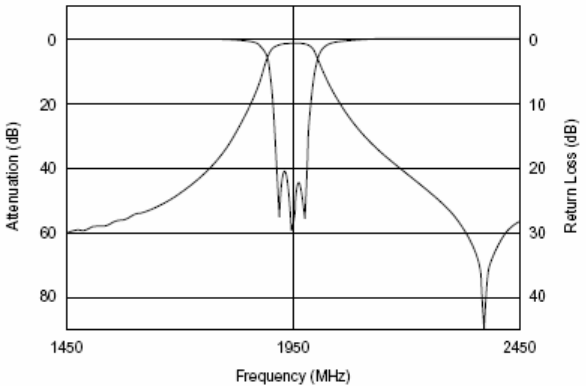
Part Number	fo (Tx) (MHz)	Bandwidth (Tx) (MHz)	IL at BW (dB max.)	Attenuation (dB min.)	fo (Rx) (MHz)	Bandwidth (Rx) (MHz)	IL at BW (dB max.)	Attenuation (dB min.)
K91G88LEHAB	1880	60	3.4	40 (1930 to 1990MHz)	1960	60	4.1	50 (1850 to 1910MHz) 0 to +35 degree C
K91G88LEHAC	1880	60	3.4	40 (1930 to 1990MHz)	1960	60	4.6	53 (1850 to 1910MHz) -35 to +85 degree C



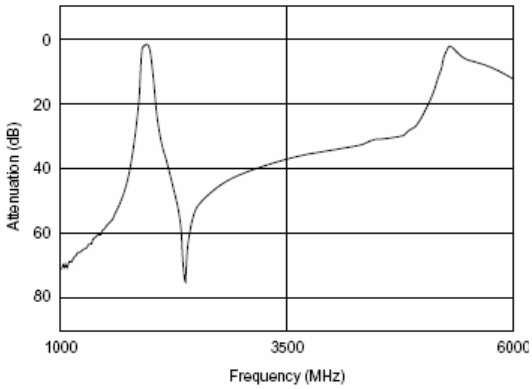


Part Number	fo (Tx) (MHz)	Bandwidth (Tx) (MHz)	IL at BW (dB max.)	Attenuation (dB min.)	fo (Rx) (MHz)	Bandwidth (Rx) (MHz)	IL at BW (dB max.)	Attenuation (dB min.)
YK61G95LBJCA	1950	60	1.5	44 (2110 to 2170MHz)	2140	60	1.8	54 (1920 to 1980MHz)
YK61G95LBNCB	1950	60	1.4	43 (2110 to 2170MHz)	2140	60	2.2	48 (1920 to 1980MHz)

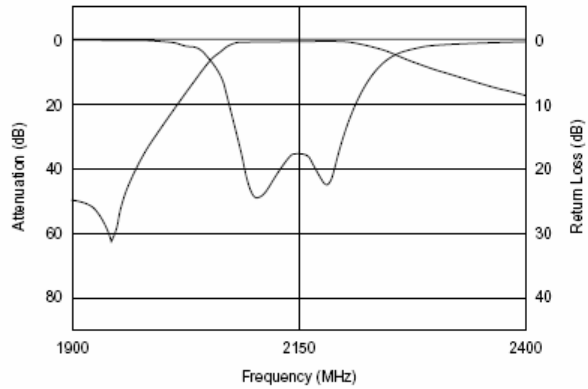
Pass Band: DFCH31G95HDHAA



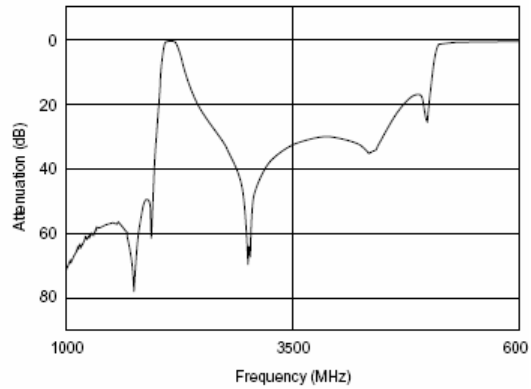
Spurious: DFCH31G95HDHAA



Pass Band: DFCH32G14HDHA



Spurious: DFCH32G14HDHA

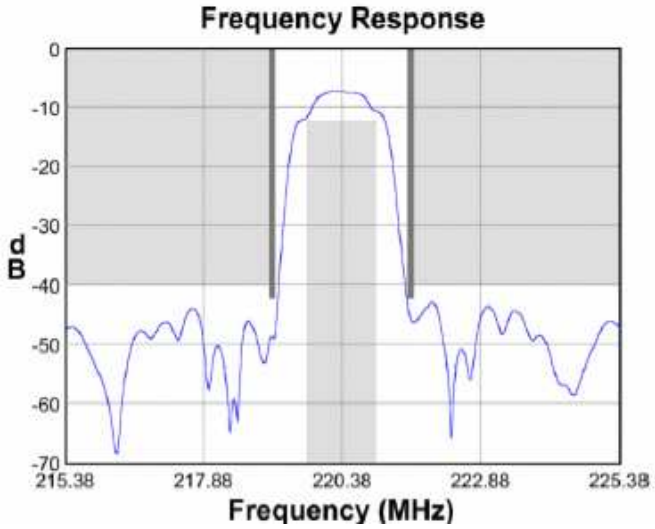


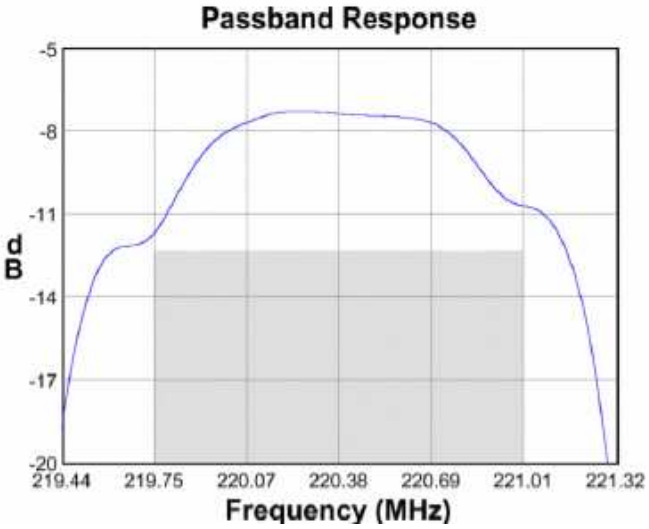
SAWTEK
a TriQuint company

ıta Sheet

Part Number 855
220.38 MHz SAW Fi

Typical Performance (at +25°C)



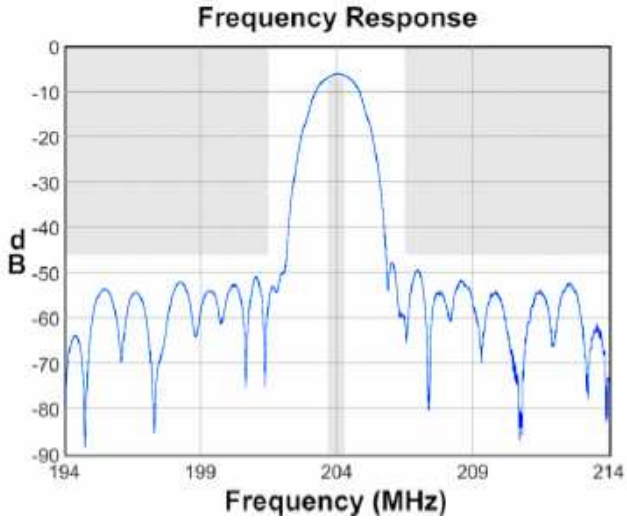


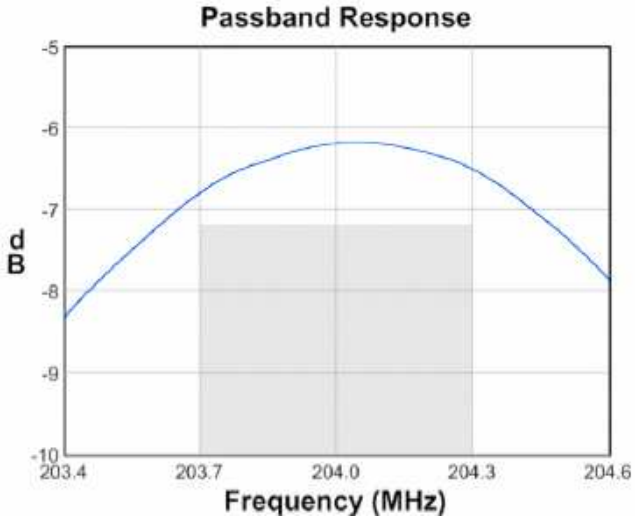
SAWTEK
a TriQuint company

eliminary Data Sheet

Part Number 8557
204 MHz SAW Fil

Typical Performance (at +25°C)





WIDE BAND 250 to 2120 MHz

VOLTAGE CONTROLLED OSCILLATORS

MODEL NO.	FREQ. (MHz)		POWER OUTPUT (dBm)	TUNE VOLTAGE (V)		PHASE NOISE (dBc/Hz) SSB@ offset frequencies: Typ.				PULLING (MHz) pk-pk @12 dBr	PUSHING (MHz/V)	TUNING SENSITIVITY (MHz/V)	HARMONICS (dBc)		3 dB MOD. BANDWIDTH (kHz)	POWER SUPPLY	
						1 kHz	10 kHz	100 kHz	1 MHz							Voltage (V)	Current (mA)
	Min.	Max.	Typ.	Min.	Max.					Typ.	Typ.	Typ.	Typ.	Max.	Typ.	Nom.	Max.
POS-500W	250-500		+10.0	1	16	-79	-100	-120	-140	1.5	0.2	17–23	-25	-18	100	12	25
POS-800W	400-800		+8.0	0.5	18	-71	-93	-115	-137	3.0	0.5	18–50	-26	-18	100	10	25
POS-900W	500-900		+7.0	1	20	-75	-95	-115	-135	2.0	0.3	16–40	-26	-20	100	12	25
POS-1000W	500-1000		+7.0	1	16	-73	-93	-113	-133	6.0	1.5	30–42	-26	-20	100	12	20
POS-1400A	975-1400		+13.0	1	20	-65	-95	-115	-135	14	2.0	25–30	-16	—	4000	8	30
POS-2000A	1370-2000		+11.8	1	20	-73	-97	-117	-137	12	3.0	30–45	-24	-12	4000	8	30
POS-2120W	1060-2120		+8.0	0.5	20	-70	-97	-117	-137	27.0	2.5	35–120	-11	—	1000	12	28