Doc No: CS6763-GAK1Q-DGD-V1.3EN

Version: V1.3

MT6177 RF Design Notice

Version Info

Ver.	Data	Content
V0.1	2017.02.10	1st MT6763+MT6177 customer design note release
V0.2	2017.02.24	Updated function spec./ref. design/notice
V0.3	2017.04.12	Updated freq/port/Sawless/DCR notice
V0.31	2017.05.04	Updated limitation of BPI control (RXAGC and TXTPC)
V0.32	2017.05.08	Updated MT6177 TX port allocation
V0.33	2017.05.11	Updated VRF/VPA layout rule Updated MIPI CLK/DATA shunt C
V0.34	2017.05.12	Updated Transceiver Introduction Ball MAP
V1.0	2017.09.08	Updated PMIC output Capacitance Updated LNA Port Assignment in Reference Design for CA Updated LNA Port for Operated Freq. Updated RX isolation notice for NonCA
V1.1	2017.09.22	Updated MT6177 TX Port Allocation Updated LNA Port for Operated Frequency (2G must be assigned in PRX1~PRX8) Added IQ layout guide Updated VPA Output Capacitance Notice
V1.2	2017.10.	Updated VPA Output Capacitance Notice Modified LB SAWless description
V1.3	2018.1.5	Update UHB supported freq. range to <3600MHz Update the VPA Output Capacitance Notice for MT6356 Update Common Placement Guide Update RX SAWless for 2G/TDS/LTE Add Matching Suggestion for Harmonic CAs Update JPN SKU of “LNA Port Assignment and Area Requested Band list”

Topic

- MT6177 vs. MT6176
- MT6177 function block
- LTE CA overview
- MT6177 reference circuit
- Connection between MT6763 (BB)/MT6356 (PMIC) and MT6177
- MT6177 RF layout guide

MT6177 vs. MT6176

MT6177 vs. MT6176

- MT6177 and MT6176 main features:

	MT6176	MT6177
Radio mode	6M(2G/WCDMA/TDSCDMA/FDD-LTE/TDD-LTE/C2K)	6M(2G/WCDMA/TDSCDMA/FDD-LTE/TDD-LTE/C2K)
LTE feature	CAT6 2DL CA	CAT7 2DL CA, 2UL CCA (MT6763T) CAT6 2DL CA (MT6763)
Sawless RX for TDD	NA	2GHB/TDS/LTE B34,B39
TX port	10 (4LB/4MB/2HB)	10 (4LB/3MB/3HB)
PRX port	14	14 (7 Groups)
DRX port	14	14 (7 Groups)
FDD+TDD CA	Yes (FDD at PCC/TDD at SCC)	Yes
3.5GHz band (B42)	NA	Yes
600MHz band (B71)	NA	Yes
E-LNA BYPASS mode	NA	Yes
RXIQ SE/DIFF type	DIFF	Single-ended
HPUE (APT Boost)	Yes	Yes
DPD	Yes (LTE)	YES (WCDMA/LTE/C2K)
IQ input/output	16RX+4TX+4TXdet	8RX(SE)+4TX+4TXdet
Package	TFBGA, 196balls, 6.2x6.2x0.9mm, pitch 0.4mm	FCCSP, 156balls 5mmx5.4mm (27mm2)

MT6177 Function Block

MT6177 Transceiver RF Overview

Key features:

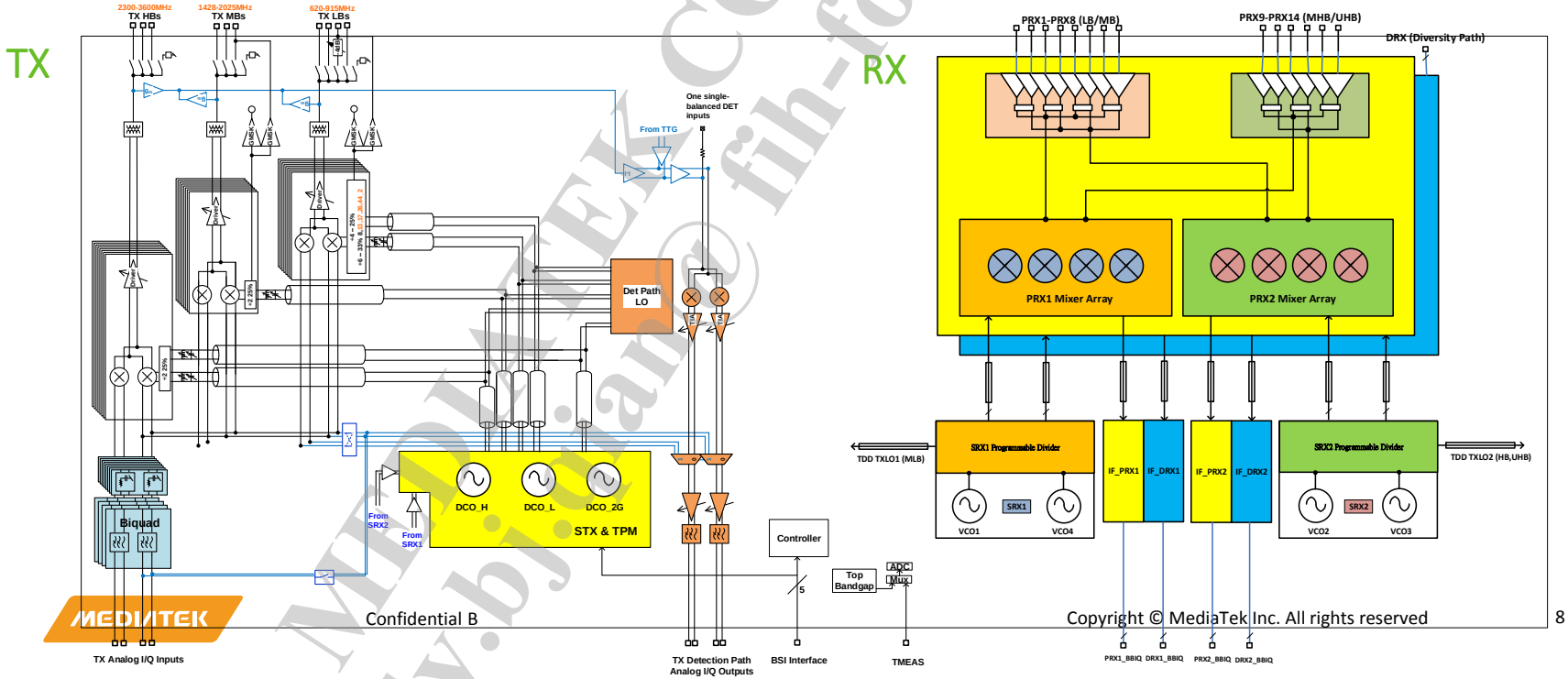
- Full multi-mode RF solution (C2K/GGE/WCDMA/TDSCDMA/LTE/LTE-CA)
  - Carrier aggregation
  - Multi-band LTE/WCDMA/TD-SCDMA/GGE/C2K
  - 64QAM UL/64QAM DL (HSPA+/LTE)
  - C2K/2G/3G/4G co-banding
  - RxD support (14 RxD ports)
  - Supports SRLTE
- Low supply current & operation directly from dual DC-DC converters
- Temperature measurement sub-system

Transmitter:

- Direct conversion (LTE/3G/8-PSK) and DFM for GMSK
  - Dedicated power detection circuits for power control over specific power range
  - 10 TX ports (4LBs, 3MBs, 3HBs)

Receiver:

- Hybrid direct-conversion (4G/3G/C2K)/low-IF (GGE, DC-HSDPA) receiver
  - 14+14 RX ports (8LMBs, 4MHBs, 2H/UHBs)
  - 4 RXIF IQ outputs
- 2 SRX and 1 STX



MT6177 Band Support

- Multi-band LTE/WCDMA/TD-SCDMA/GGE/C2K

Band Names					Frequency (MHz)		Support					
LTE	WCDMA	TD-SCDMA	C2K	GSM/EDGE	UL	DL	FDD LTE	TDD LTE	WCDMA	TD-SCDMA	C2K	GSM/EDGE
1	I		BC6		1920-1980	2110-2170	●		●		●	
2	II		BC1	PCS 1900	1850-1910	1930-1990	●		●		●	●
3	III			DCS 1800	1710-1785	1805-1880	●		●			●
4	IV		BC15		1710-1755	2110-2155	●		●		●	
5	V		BC0	GSM 850	824-849	869-894	●		●		●	●
6					830-840	875-885	●					
7					2500-2570	2620-2690	●					
8	VIII			E-GSM 900	880-915	925-960	●		●			●
9	IX				1749.9-1784.9	1844.9-1879.9	●		●			
10					1710-1770	2110-2170	●					
11	XI				1427.9-1447.9	1475.9-1495.9	●		●			
12					699-716	729-746	●					
13					777-787	746-756	●					
14					788-798	758-768	●					
17					704-716	734-746	●					
18			BC10		815-830	860-875	●				●	
19	XIX				830-845	875-890	●		●			
20					832-862	791-821	●					
21					1447.9-1462.9	1495.9-1510.9	●					
22					3410-3490	3510-3590	●					
23					2000-2020	2180-2200	●					
24					1626.5-1660.5	1525-1559	●					
25					1850-1915	1930-1995	●					
26					814-849	859-894	●					
27					807-824	852-869	●					
28					703-748	758-803	●					
29					N/A	717-728	●					
30					2305-2315	2350-2360	●					
31					452.5-457.5	462.5-467.5						
32					N/A	1452-1496	●					
33					1900-1920	1900-1920		●				
34		a			2010-2025	2010-2025		●		●		
35					1850-1910	1850-1910		●				
36					1930-1990	1930-1990		●				
37					1910-1930	1910-1930		●				
38					2570-2620	2570-2620		●				
39		f			1880-1920	1880-1920		●		●		
40		e			2300-2400	2300-2400		●		●		
41					2496-2690	2496-2690		●				
42					3400-3600	3400-3600		●				
44					703-803	703-803		●				
45					1447-1467	1447-1467		●				
65					1920-2010	2110-2200	●					
66					1710-1780	2110-2200	●					
67					N/A	738-758	●					
68					698-728	753-783	●					
69					N/A	2570-2620	●					
70					1695-1710	1995-2020	●					
71					663-698	617-652	●					

MT6177 TX Port Allocation

TX port	Band	Note
TX0_LB1	B5,B8,B12,B13,B17,B18, B19, B20,B27,B28, B71	638-915MHz
TX0_LB2	Same as LB1	
TX0_LB3	GSM LB	
TX0_LB4	X	
TX0_MB1	B11,B21	1428-2025MHz
TX0_MB2	B1,B2,B3,B4,B25,B34,B39,B66	
TX0_MB3	GSM HB	
TX0_HB1	Same as HB2 (for nonCA only)	2300-3600MHz
TX0_HB2	B7,B30,B38,B40,B41	
TX0_UHB	B22,B42	

- For CA case, TX allocation must follow above table

LNA Port Assignment and Area Requested Band list

- ❑ 93MD can't support TX UL NCCA
- ❑ B44 can't support (no RFFE)
- ❑ HH CA can't support (7+38, 40+42, 7+40, 7+42, 40+41) (no RFFE)
- ❑ LL CA can't support (5+29, 20+28, 8+28, 18+28, 26+28) (no RFFE)
- ❑ 93MD can't support LAA band (5-6GHz) (HW limitation)
- ❑ JPN SKU: B3@PRX10 for 3+42, 3+11, 3+21 CA
- ❑ Special case: (ref page 12)
  - ❑ B32 at HB ports, NF will slightly degrade at MHB ports
  - ❑ B39 at PRX8 for special CA operation (China SKU single ant)

- Please follow the rule to change LNA port:
  - Bands only support non-CA: follow LNA frequency range
  - Bands with CA: intra-group changeable
  - The sensitivity can't benefit from diversity gain and the system has MP risk and higher power consumption if not following this rule.
  - PRX & DRX MUST be in the same LNA Group
    - PDRX1~PDRX8: MLB group
    - PDRX9~PDRX14: MHB group

Version_20171219								HB/UHHB		MB/HB(2)		MB/HB(1)		LB/MB(4)		LB/MB(3)		LB/MB(2)		LB/MB(1)	
Area	2G	3G	4G	4G Roaming	UL intra-band CA	DL intra-band CA	DL inter-band CA	PRX14	PRX13	PRX12	PRX11	PRX10	PRX9	PRX8	PRX7	PRX6	PRX5	PRX4	PRX3	PRX2	PRX1
China	2/3/5/8	1/2/5/8/34/39/BC0	1/3/**5**/7/8/**34**/38/39/40/41	4/8/17/20		CCA: 1, 3, 7, 38, 39, 40, 41 NCCA: 3, 40, 41	1+3, 1+5, 3+5, 39+41,	2	7	1	4	40	41(38)	39	3	34 39 2G MB	44	26(5/BC0) G850	20	8 G900	17
China Rich	2/3/5/8	1/2/5/8/34/39/BC0	1/3/**5**/7/8/**34**/38/39/40/41	4/8/17/20	CCA: 3, 38, 39, 40, 41	CCA: 1, 3, 7, 38, 39, 40, 41 NCCA: 3, 40, 41	1+3, 1+5, 3+5, 3+41, 39+41,	2	7	1	4	40	41(38)	39	3	34 39 2G MB	44	26(5/BC0) G850	20	8 G900	17
EU	2/3/5/8	1/2/5/8	1/3/7/8/20/28/32/38/40/42	2/4/5/12/17	CCA: 3, 7, 38	CCA: 1, 3, 7, 38, 40 NCCA: 3, 7, 38	1+3, 1+7, 1+8, 1+20, 1+28, 1+38, 1+40, 1+41, 3+7, 3+8, 3+20, 3+28, 3+32, 3+38, 3+40, 3+41, 7+8, 7+20, 7+28, 7+32, 8+20, 20+32, 20+38 Low priority: B42, B42 ICA 7+38, 7+40, 20+28, 8+28	42	7	1 4	32	40	41(38)	3 DCS	2 PCS		28	5 G850	20	8 G900	12(17)
India	2/3/5/8	1/2/5/8	1/3/5(26)/20/28A/28B/40/41		CCA: 3, 5	NCCA: 1, 3, 5, 40 CCA: 3, 5, 40	1+3, 1+40, 1+41, 3+5, 3+28, 3+40, 3+41, 5+40, 8+40 Low priority: 40+41, 28+41, 8+41	2		1		40	41		3	2G MB	28A 28B	26(5) G850	20	8 G900	
APAC_India_Africa	2/3/5/8	1/2/5/8/BC0	1/3/5(26)/7/8/20/28A/28B/38/40/41	2	CCA: 3, 5, 7	CCA: 3, 5, 7, 40 NCCA: 1, 3, 5, 7, 40	1+3, 1+7, 1+8, 1+20, 1+40, 1+41, 3+5, 3+7, 3+8, 3+20, 3+28, 3+38, 3+40, 3+41, 5+7, 5+40, 7+8, 7+20, 7+28, 8+40, 28+38 Low priority: 40+41, 7+38, 28+41, 8+41	2	7	1		40	41		3	2G MB	28A 28B	26(5/BC0) G850	20	8 G900	
US	2/3/5/8	1/2/4/5/8/BC0/BC1/BC10	2/4/5/12/13/14/17/25/26/29/30/41/66/71	1/3/7/8/20/28/38/39/40	CCA: 41	CCA: 2, 5, 41, 66 NCCA: 2, 4, 5, 12, 25, 41, 66	2+4, 2+5, 2+12, 2+13, 2+17, 2+29, 2+30, 2+66, 4+5, 4+7, 4+12, 4+13, 4+17, 4+29, 4+30, 5+30, 5+66, 12+30, 12+66, 13+66, 25+26, 25+41, 26+41, 29+30, 29+66, 30+66, 2+71, 4+71, 66+71 Low priority: 4+66, 5+29, 30+71	30	7	1	66(4)	40	41(38)	3 DCS	25(2/BC1) PCS	39	28A 28B 29	26(5/BC0/BC10) G850	20 71	8 G900	12(17) 13 14
LATAM	2/3/5/8	1/2/5/8	1/2/3/4(66)/5/7/12/28/38			CCA: 3, 7 NCCA: 3, 7, 66 Low priority: 28 NCCA/CCA	2+4, 2+5, 2+7, 2+28, 3+7, 3+28, 4+5, 4+7, 4+12, 4+17, 4+28, 7+28, 7+66 Low priority: 4+66		7	1	66(4)		38	3 DCS	2 PCS		28	5 G850		8 G900	12
JPN (TBD)	2/3/5/8	1/3/5/6/8/11/19/BC0/BC6	1/3/5/8/9/11/18/19/21/26/28B/41/42	7/12/17/38/39/40	CCA: 41, 42	CCA: 41, 42 NCCA: 41, 42	1+3, 1+8, 1+11, 1+18, 1+19, 1+21, 1+26, 1+28, 1+41, 1+42, 3+8, 3+11, 3+19, 3+21, 3+28, 3+41, 3+42, 8+11, 8+42, 11+18, 11+28, 11+42, 19+21, 19+42, 21+28, 21+42, 28+41, 28+42, 41+42	42	7	1(BC6)	40	3(9)	41(38)	3	11 21	39 2G MB	28B	26(5/18/19/BC0) G850		8 G900	12(17)

SAWless Rx

- SAWless is only for China/India/Apac SKU
- 2G ARX can't support SAWless
- MLB SAWless ports (PRX6):
  - 2G: DCS1800, PCS1900 (PRX6)
  - TDSCDMA: B34, B39 (PRX6)
  - LTETDD: B34, B39 (PRX6+DRX6)
- LB SAWless ports (PRX1):
  - 2G: GSM850, GSM900 (PRX1)
- SAWless Rx can't support E-LNA. (OBB test will fail)
- Need to apply MB BPF before PRX6/DRX6 for OBB test
- Need to apply LB BPF before PRX1 for OBB test
  - HMB can't place at PRX2 and PRX3 if with LB SAWless
- Need to check "MT6177 isolation design notice"

LNA Port for Operated Frequency

- PRX1/DRX1~PRX8/DRX8: for LB/MB 600M~2.025GHz
  - 2G must be assigned in PRX1~PRX8
- PRX9/DRX9~PRX12/DRX12: for MB/HB 1.805GHz~2.69GHz
  - Special Case:
    - (B32 at HB ports, NF will slightly degrade at MHB ports)
- PRX13/DRX13~PRX14/DRX14: for HB/UHB 2.35GHz~3.8GHz
  - Special Case:
    - (B39 at PRX8 for special CA operation (China SKU single ant))
    - When B2 is at PRX14, It is for nonCA only. CA_B2 must be assigned at PRX7.
- Sawless Port: Support 2G (1800/1900) and TDS/LTETDD (B34,B39) at PRX6(2G/TDS/LTE)+DRX6(LTE)

LNA Port Usage - Port Arrangement for Diversity Path

- In order to keep diversity path operation correct, the PRX and DRX port assignment needs to follow the rule as follows
- Mixer Group Concept
  - **PRX1~PRX8 and DRX1~DRX8 are MLB mixer groups**
  - **PRX9~PRX14 and DRX9~DRX14 are MHB mixer groups**
- Rule of diversity path port selection
  - DRX must be in the same mixer group as PRX
    - Example:
      - B3 primary path is assigned to PRX5 which is belong to MLB mixer group
      - Therefore, B3 diversity path must be assigned within DRX1~DRX8
        - Example: DRX3 is ok, and DRX5 is also ok
      - In this case, B3 DRX is not allowed to be assigned to DRX9~DRX14
        - Example: DRX9 is forbidden
  - **It is strongly suggested to assign the DRX in the same number as PRX**
    - Example:
      - If B3 primary path is assigned to PRX7, it is strongly suggested to assign the B3 diversity path to DRX7

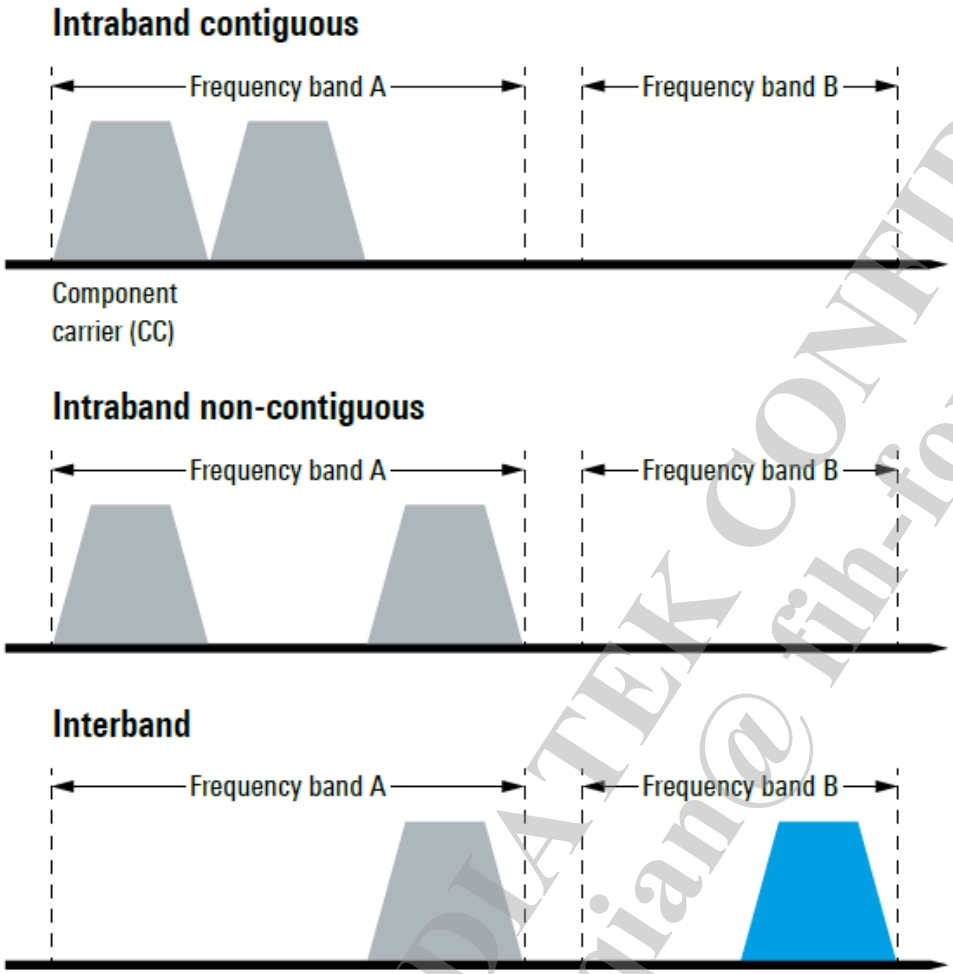
LNA Port Usage - CA operation

- In order to get the best CA performance and make sure that the function is correct, please follow the band assignment of reference design
- Rule
  - There are 7 LNA groups
  - The band should be assigned in the same group as the reference design for CA operation
  - Example:
    - For China SKU, B3 should be assigned in LB/MB(4) for CA operation
      - Because according to the reference design, B3 is assigned to PRX7 or PRX8
  - Special case:
    - B2 at PRX/DRX9~PRX/DRX14 does not support CA operation

Version_20170726								HB/UHHB		MB/HB(2)		MB/HB(1)		LB/MB(4)		LB/MB(3)		LB/MB(2)		LB/MB(1)	
Area	2G	3G	4G	4G Roaming	UL intra-band CA	DL intra-band CA	DL inter-band CA	PRX14	PRX13	PRX12	PRX11	PRX10	PRX9	PRX8	PRX7	PRX6	PRX5	PRX4	PRX3	PRX2	PRX1
China	2/3/5/8	1/2/5/8/34/39/BC0	1/3/**5**/7/8/**34**/38/39/40/41	4/8/17/20		CCA: 1, 3, 7, 38, 39, 40, 41 NCCA: 3, 40, 41	1+3, 1+5, 3+5, 39+41,	2	7	1	4	40	41(38)	39	3	34 39	44	26(5/BC0)	20	8	17

LTE CA Overview

CA Categories

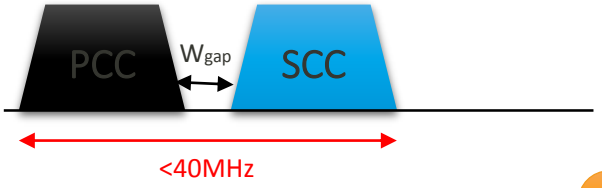


	RF FE	RF LNA	RF SRX
CCA	Same as non-CA	1	1
NCCA CC's gap is small			
NCCA CC's gap is large	Same as non-CA	1	2
Inter band CA	Diplexer or QPX	2	2

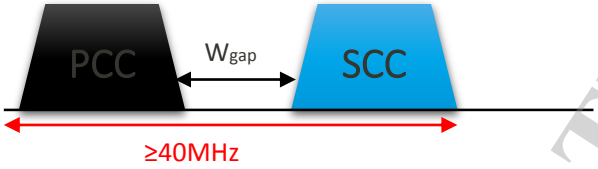
Receive Path for DL CA

1. Contiguous CA

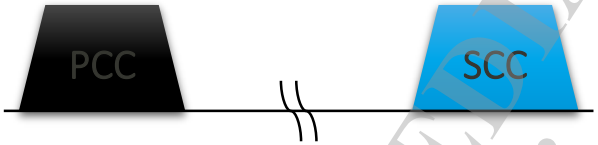
2. Non-contiguous CA (W_{gap} is small.)

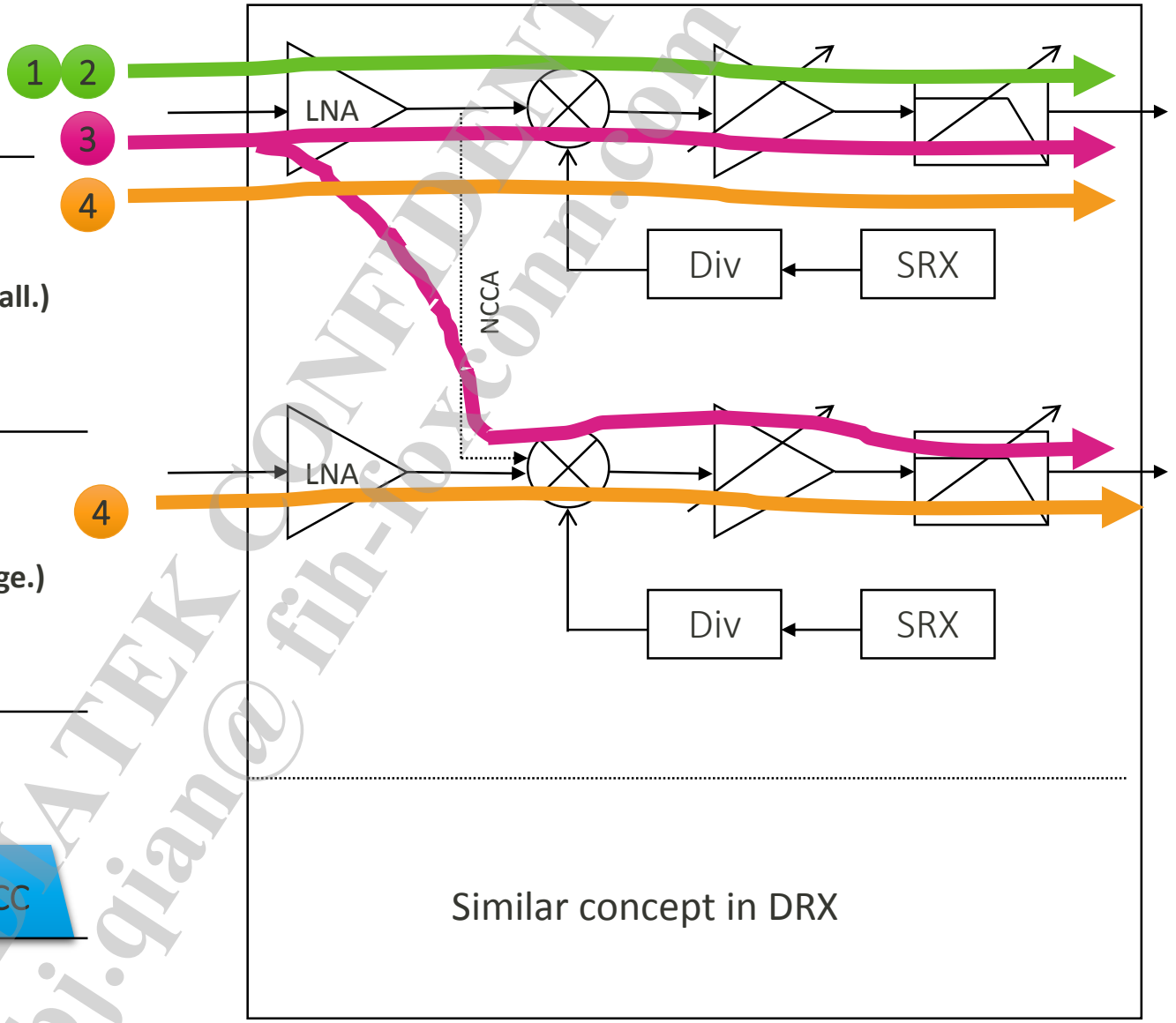


3. Non-contiguous CA (W_{gap} is large.)



4. Inter-band CA



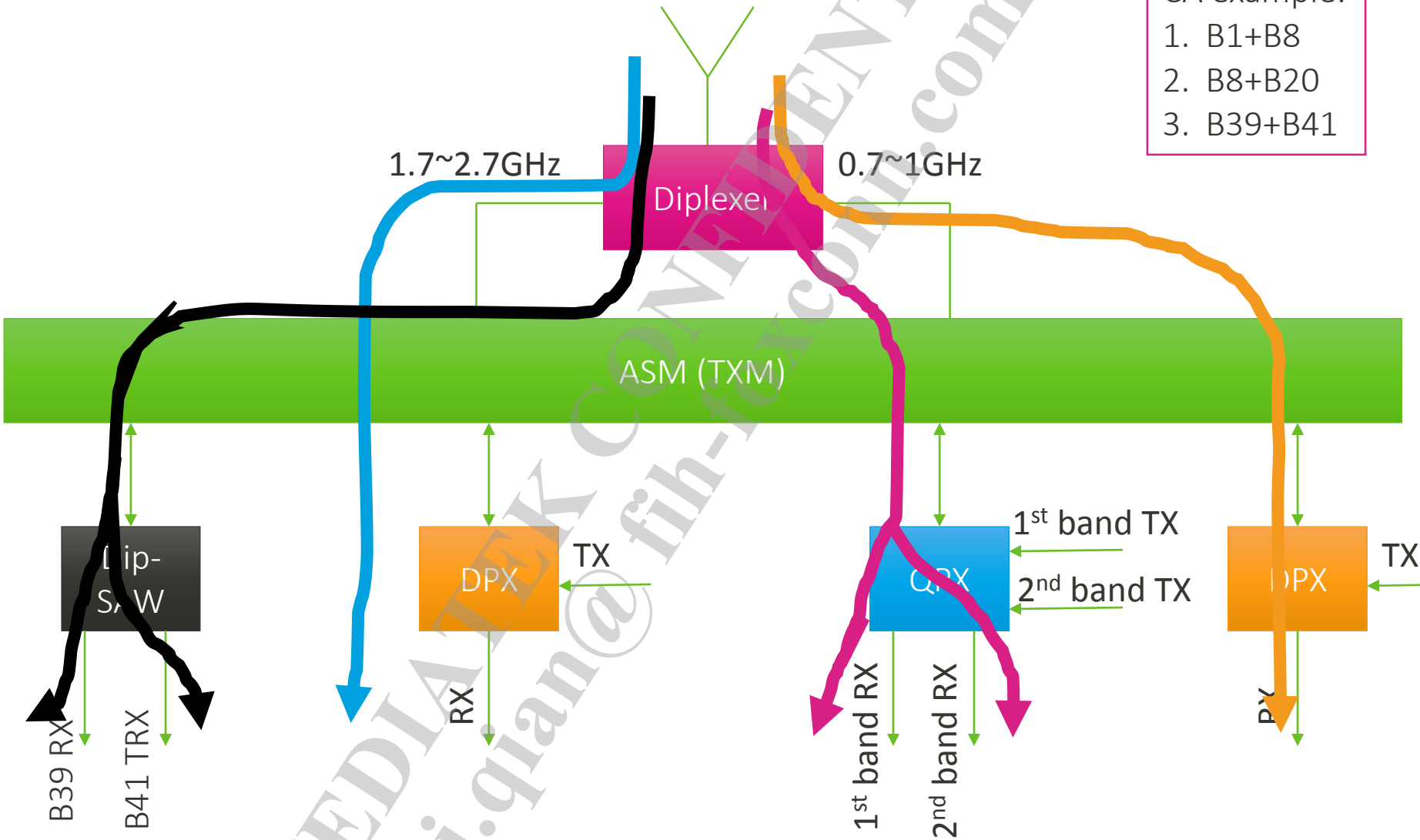


Inter-band CA Combination

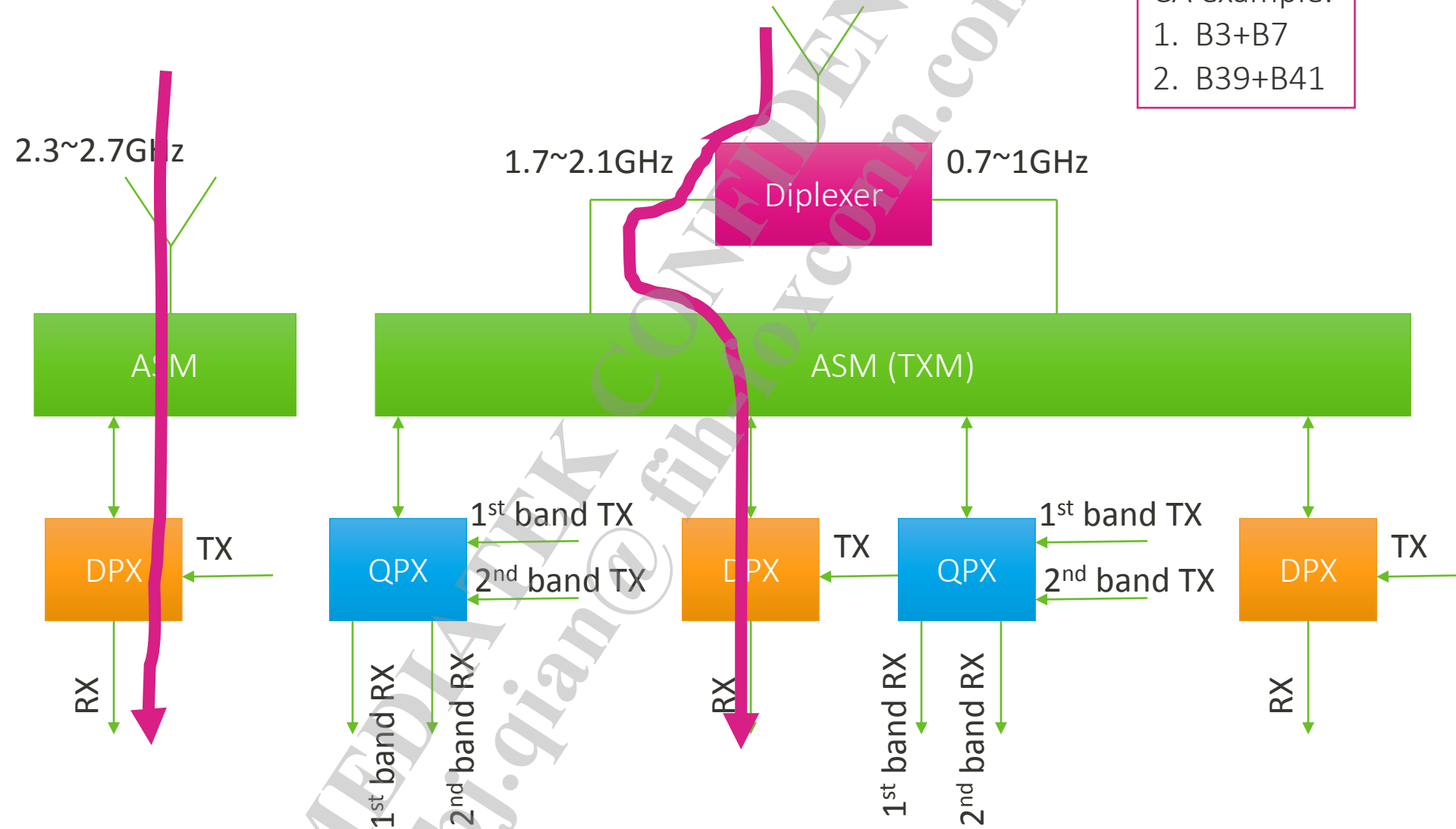
Inter-band CA type	Method
UH-LMH	Diplexer
H-H	This combination is N/A now
H-M	Separate ant
H-L	Diplexer
M-M	QPX
M-L	Diplexer
L-L	QPX

- Some types of diplexer
  - >3.4GHz and <2960MHz
  - >1.7GHz and < 960MHz
  - >1.4GHz and < 960MHz (Japan band)
- Most inter-band CAs are H-L or M-L case
- RXD needs corresponding diplexer SAW

CA RF FE Topology-I



CA RF FE Topology-II



Matching Suggestion for Harmonic CAs

Coefficient	CA Band	Harmonic Relationship	Matching Suggestion
1TX ➔ 3RX	B41+26	B41 TX ➔ B26 3×RX	Apply low-pass type matching for B26 RX
4TX ➔ 3RX	B1+41(38)	B1 4×TX ➔ B41(38) 3×RX	Apply low-pass type matching for B41(38) RX (Between PA and RFIC)
	B3+40	B3 4×TX ➔ B40 3×RX	Apply low-pass type matching for B40 RX ((Between PA and RFIC)
	B25+41	B25 4×TX ➔ B41 3×RX	Apply low-pass type matching for B41 RX (Between PA and RFIC)
3TX ➔ 2RX	B3+41(38)	B3 3×TX ➔ B41(38) 2×RX	Apply low-pass type matching for B41(38) RX (Between PA and RFIC)

MT6177 Reference Circuit

RF Design Note: MT6177 Ref Schematic Check List

NO.	Function	Class	Done	Check Items
1	Common part	A	☐	Use MTK QVL 26MHz TSX, Duplexer, SAW, 2G PA , 3G/LTE PA (support R7/R8/R9) , ASM or TXM
2		A	☐	RX SAW filter, duplexer to ASM or TXM needs to reserve T or Pi-matching network and series DC-block capacitor (If ASM or TXM includes DC-block capacitor, it can be removed.)
3		A	☐	Refer to design note about detailed schematic description.
4	Front end TRX	A	☐	ASM/switch. Connect its power pin to VFE28 (2.8V), not BPI
5		A	☐	All BPI traces to ASM or TXM need to reserve shunt cap
6	MT6177 -	A	☐	**Check the LNA port assignment to follow the reference design and CA combination**
7	RXRF	A	☐	GSM RX can co-band with WCDMA/LTE to lower BOM cost and layout size, but sensitivity will degrade 1~1.5dB.
8	(with DUP)	A	☐	RX trace to RX SAW or duplexer need to reserve single-ended T or Pi-matching network to do RX matching.
9	MT6177 -	A	☐	MT6177 TX trace to PA need to reserve T or pi-matching network.
10	TX RF	A	☐	LTE, WCDMA and EDGE with closed loop power control need to use coupler to MT6177 detector input. Refer to design note; use wide band coupler with attenuator and let the detector input power ranges at 0~-40dBm.
11	(PDET/TMES)	A	☐	LTE/3G PA power can select VCC_PA or VBAT, but it is suggested to use VCC_PA to save power consumption.
12	MT6177 - 26MHz	B	☐	Connect MT6356 CLK buffer output (XO_CEL) to MT6177 XO1 and reserve T or pi-matching network
13	MT6177 – Power	A	☐	Add a LC filter for VIO18 to prevent digital interference.
14	MT6763 -	A	☐	2G PA VAPC can reserve the RC filter (7K//220pF) for some PA, and don't need the voltage divider resistances. Default is 0ohm for RC filter (Phase3 Skyworks/Qrovo TXM).
15	MT6356 – Power	A	☐	Follow PMU's design guide
16	De-sense	A	☐	Reserve EMI filter/bead/filter component for camera, LCM, and MSDC's connector

Topology for 93 Internal Phone (China+EU)

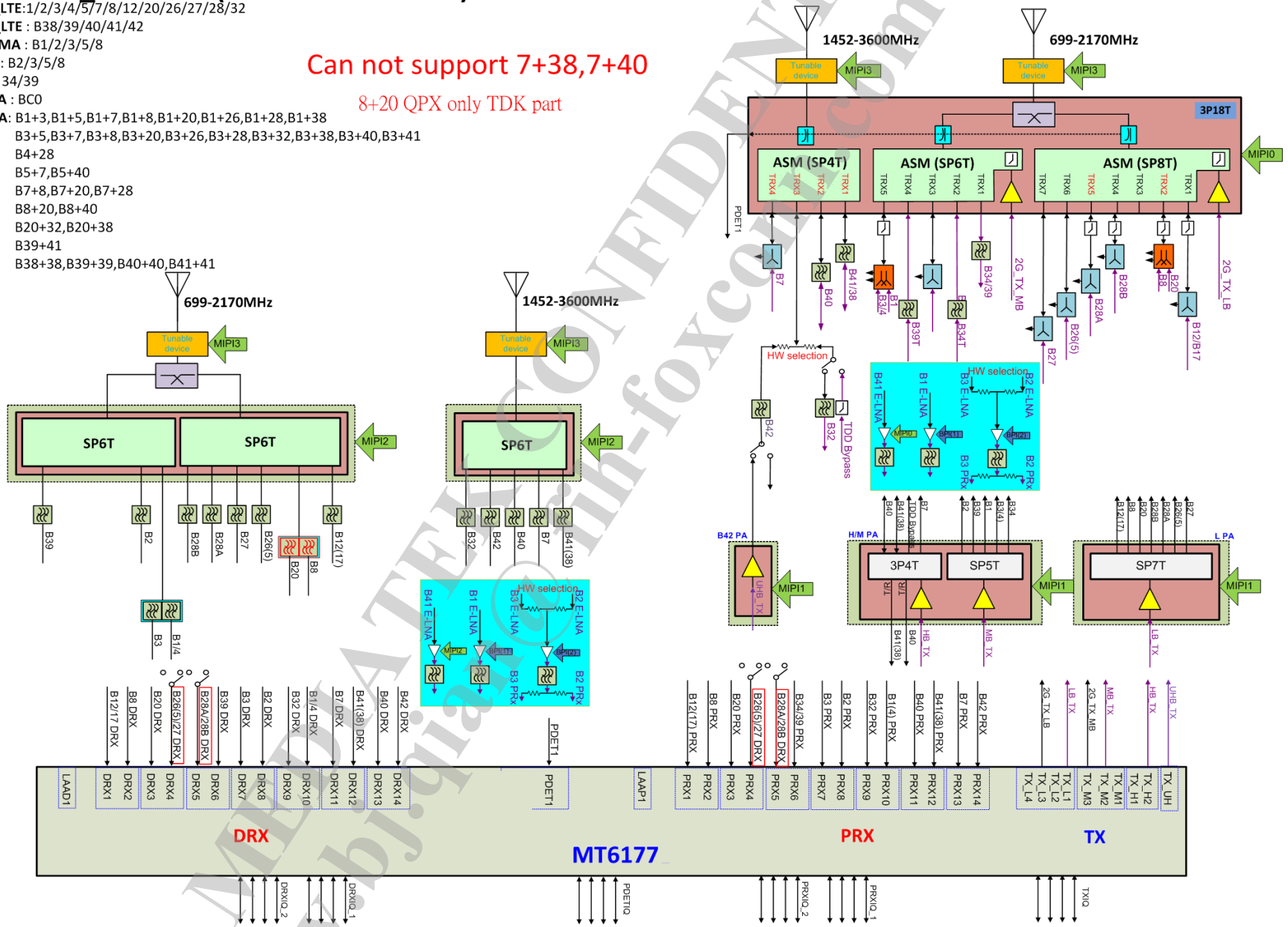
MT6177_EELA SKU(Phase III Dual ANT)

20161004

FDD_LTE:1/2/3/4/5/7/8/12/20/26/27/28/32
TDD_LTE : B38/39/40/41/42
WCDMA : B1/2/3/5/8
GSM : B2/3/5/8
TDS : 34/39
CDMA : BC0
2DLCA: B1+3,B1+5,B1+7,B1+8,B1+20,B1+26,B1+28,B1+38
B3+5,B3+7,B3+8,B3+20,B3+26,B3+28,B3+32,B3+38,B3+40,B3+41
B4+28
B5+7,B5+40
B7+8,B7+20,B7+28
B8+20,B8+40
B20+32,B20+38
B39+41
B38+38,B39+39,B40+40,B41+41

Can not support 7+38,7+40

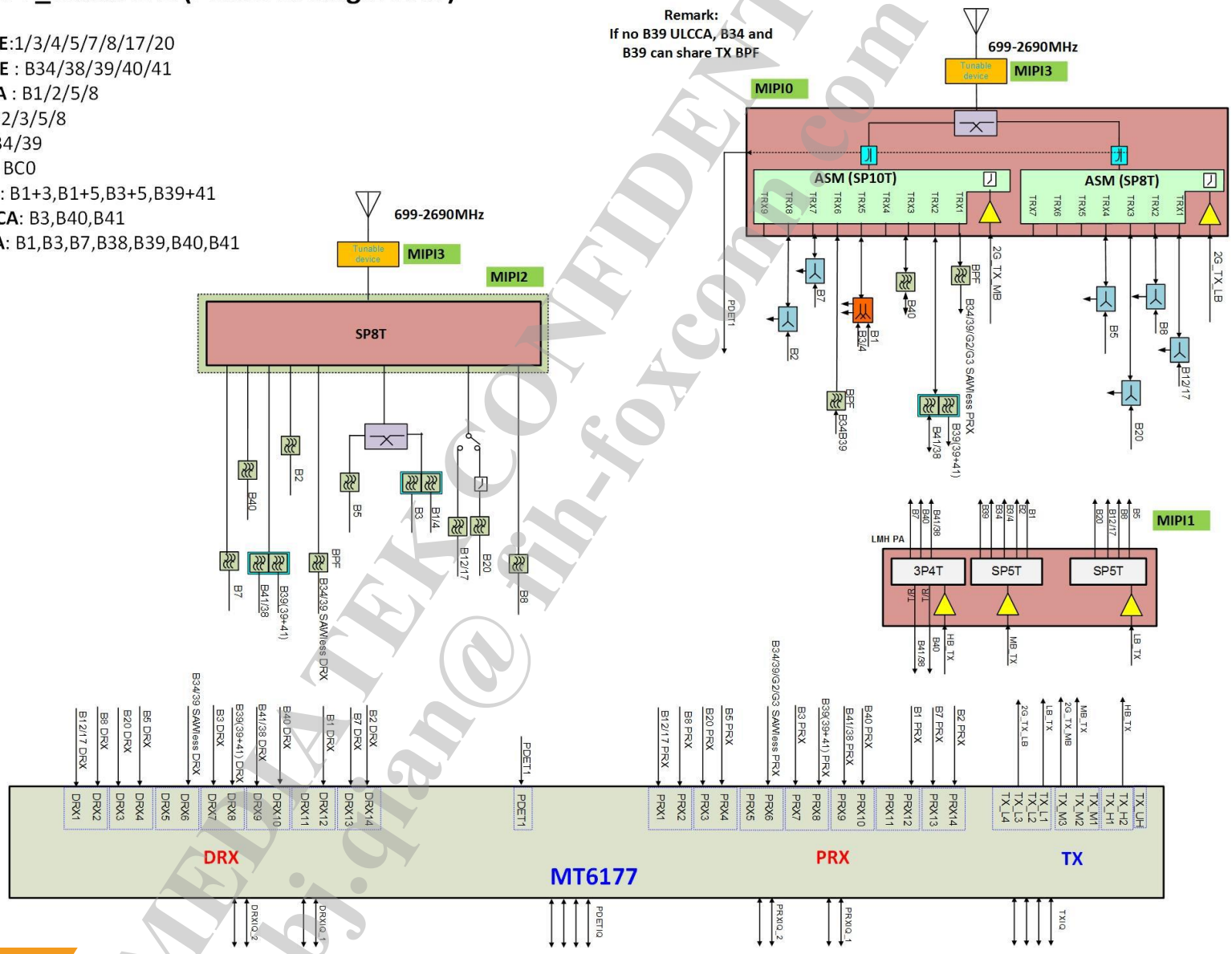
8+20 QPX only TDK part



Topology of MT6177 China SKU

MT6177_China SKU(Phase III Single ANT)

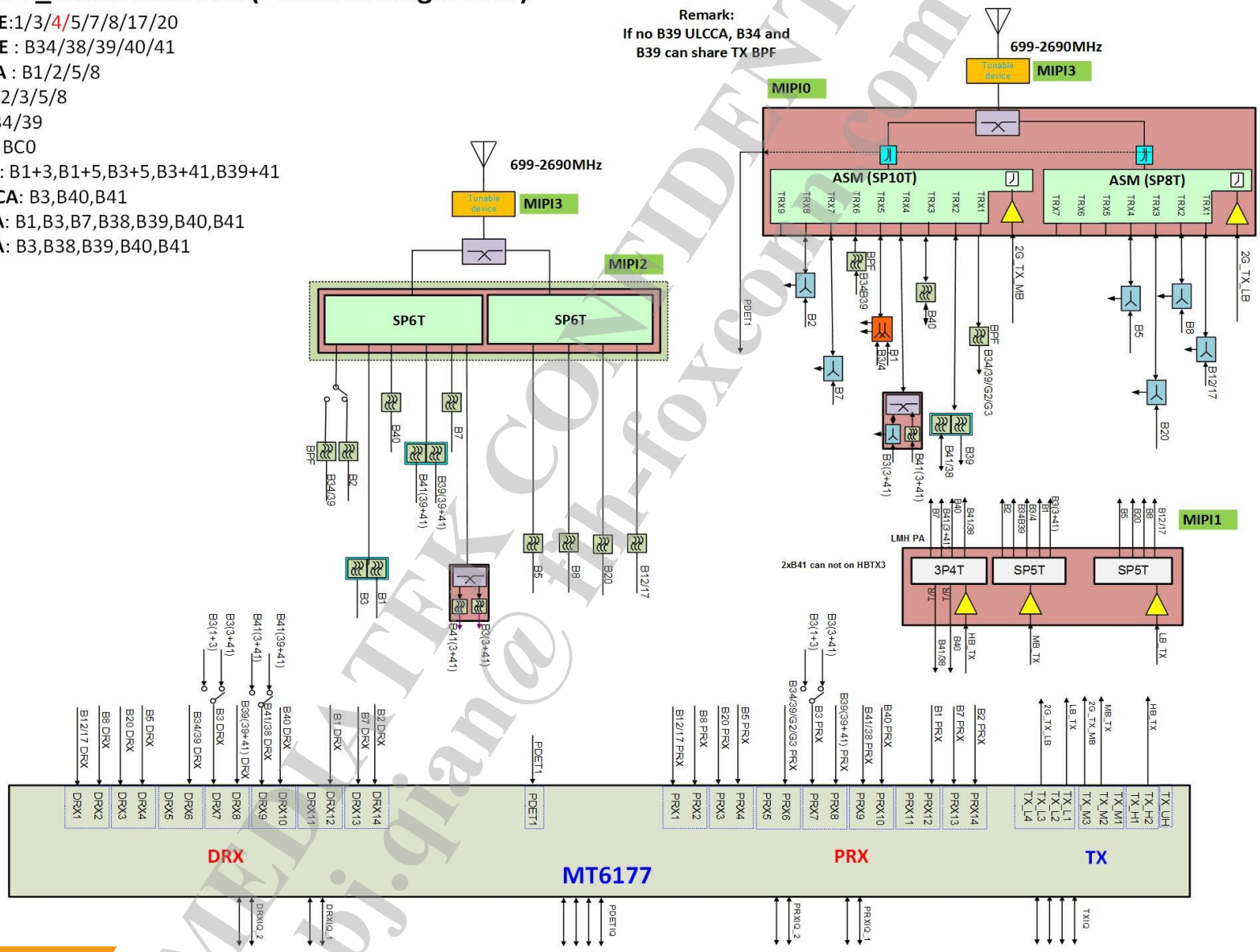
FDD_LTE:1/3/4/5/7/8/17/20
TDD_LTE : B34/38/39/40/41
WCDMA : B1/2/5/8
GSM : B2/3/5/8
TDS : B34/39
CDMA : BC0
2DL ICA: B1+3,B1+5,B3+5,B39+41
2DL NCCA: B3,B40,B41
2DL CCA: B1,B3,B7,B38,B39,B40,B41



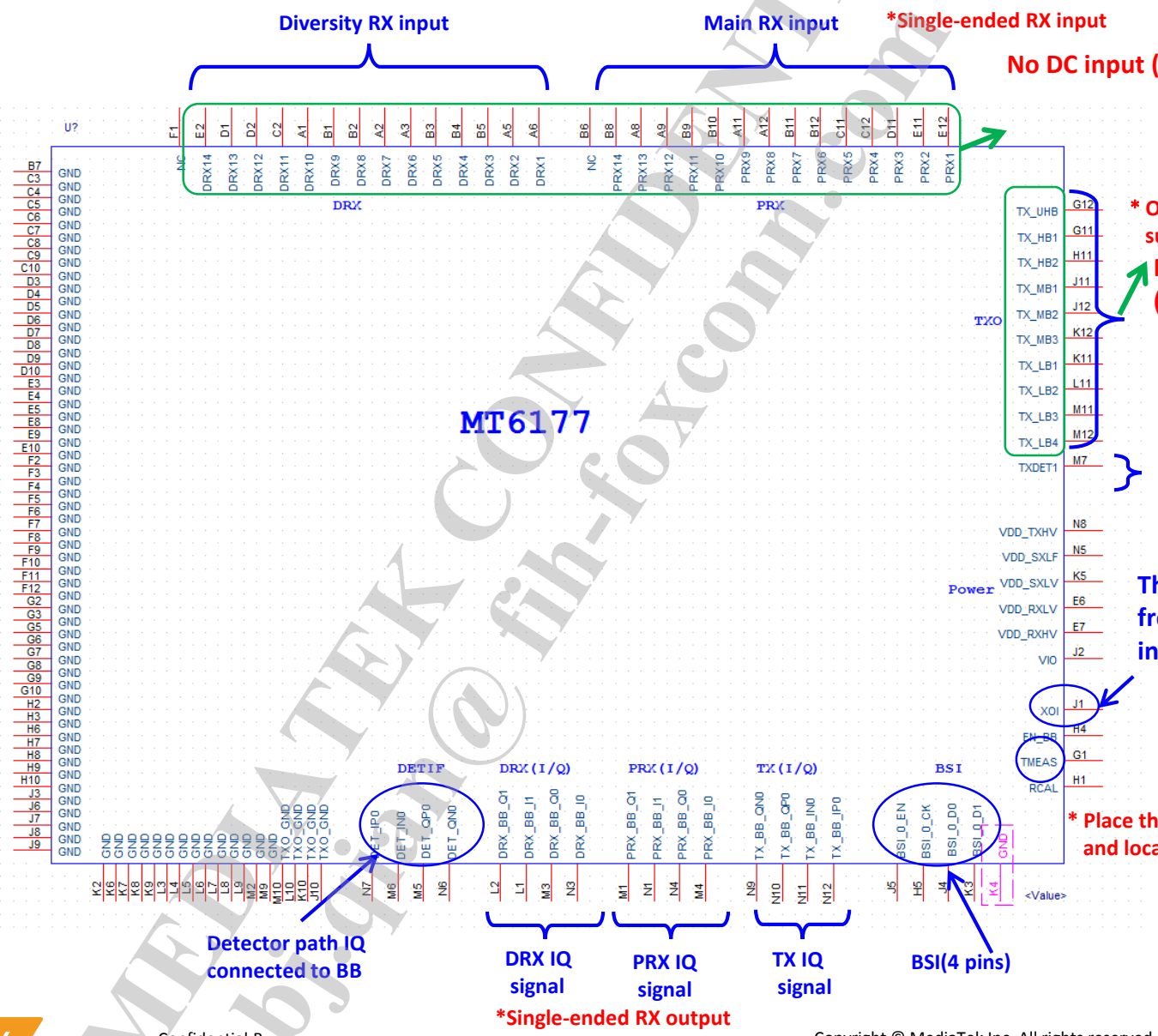
Topology of MT6177 China Rich SKU

MT6177_China Rich SKU(Phase III Single ANT)

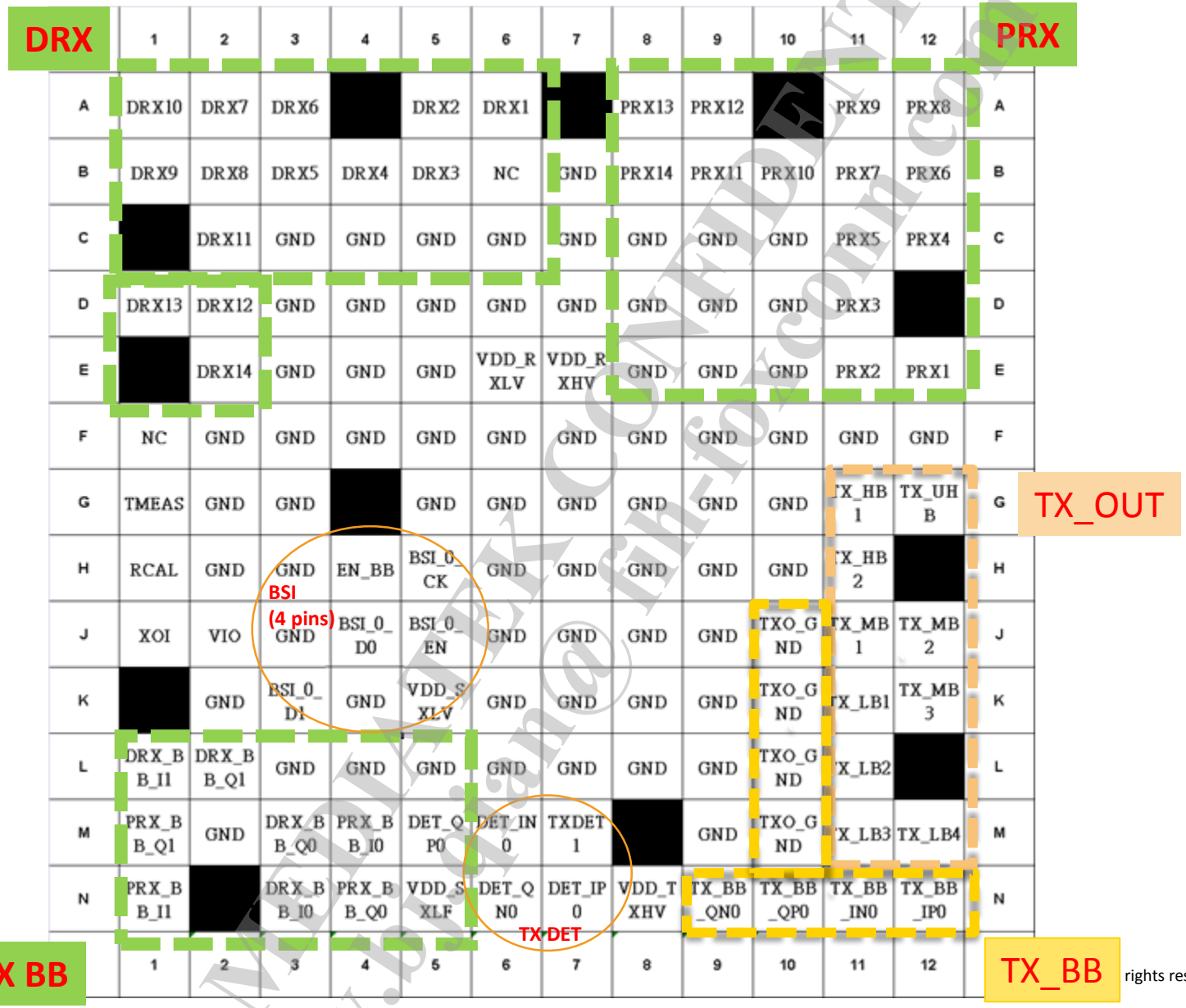
FDD_LTE:1/3/4/5/7/8/17/20
TDD_LTE : B34/38/39/40/41
WCDMA : B1/2/5/8
GSM : B2/3/5/8
TDS : B34/39
CDMA : BC0
2DL ICA: B1+3,B1+5,B3+5,B3+41,B39+41
2DL NCCA: B3,B40,B41
2DL CCA: B1,B3,B7,B38,B39,B40,B41
2UL CCA: B3,B38,B39,B40,B41



RF Design Note – MT6177 Ref. Schematic

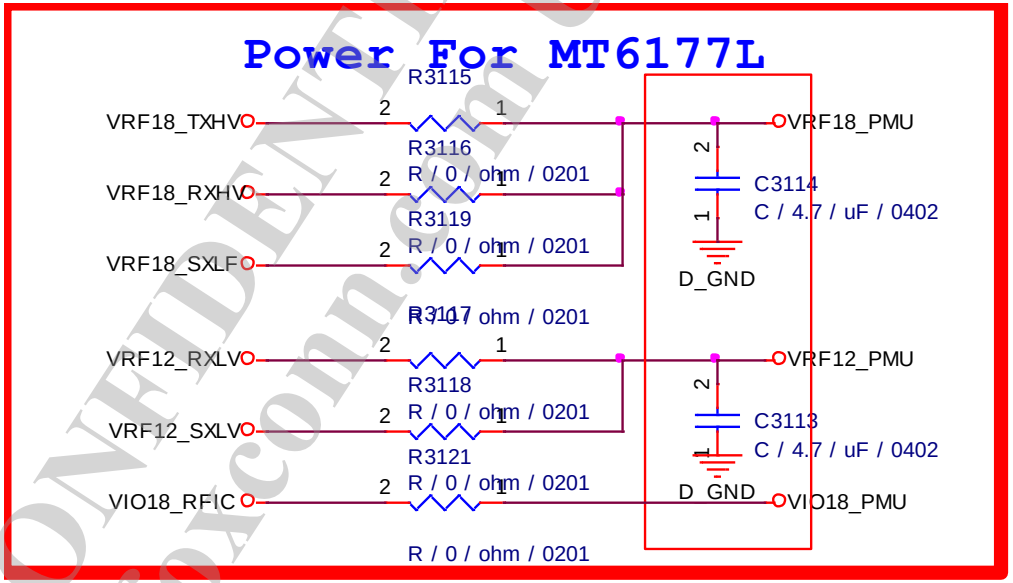


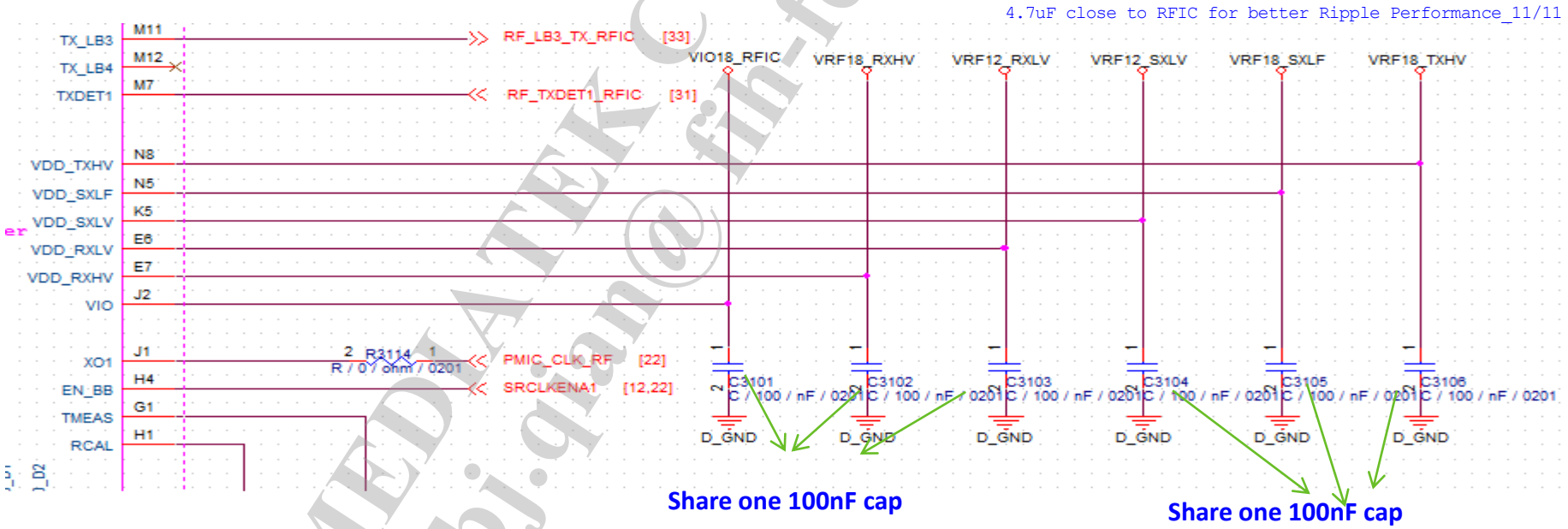
Transceiver Introduction - Ball MAP



Reference Circuit Schematic: Power of MT6177

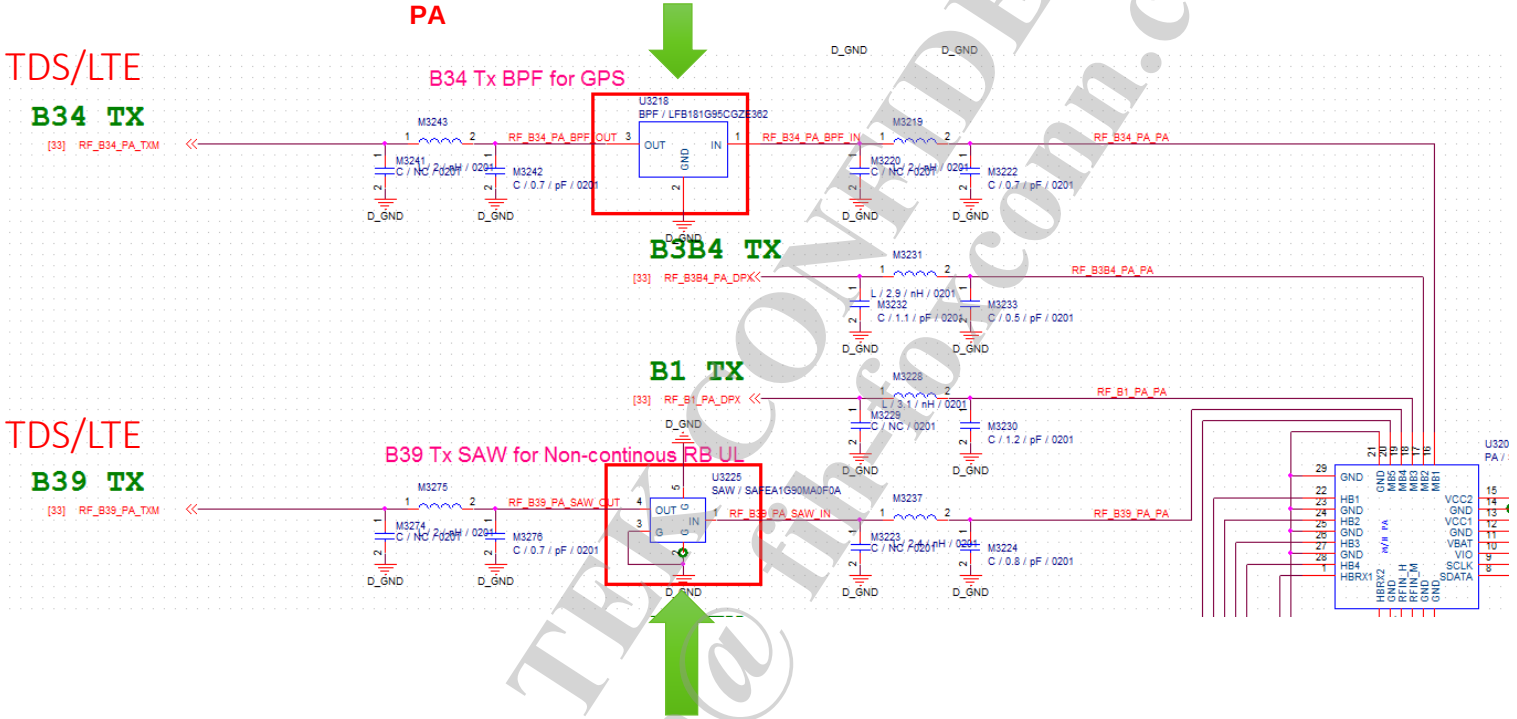
- **Bypass cap should be put close to MT6177.**
- **VRF18 for VDD_TXHV should share one 100nF cap.**
- **VRF18 for VDD_SXLF should have one 100nF cap.**
- **VRF12 for VDD_SXLV should have one 100nF cap.**
- **VRF12 for VDD_RXLV should have one 100nF cap.**
- **VRF18 for VDD_RXHV should have one 100nF cap.**
- **VIO18 for VIO should have one 100nF cap.**
- **Refer to Layout Guide for the location to place the bypass cap and the method to route power.**





MT6177 TX 2UL CCA Notice

- For GPS co-existence case and if the antenna isolation between GPS and B39 is <30dB
- It is suggested not to use "TXM reuse" and use a BPF filter after B34 PA

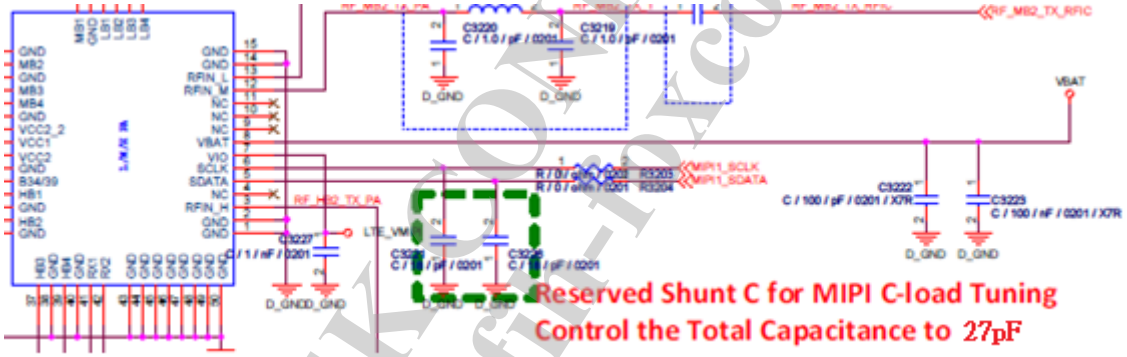


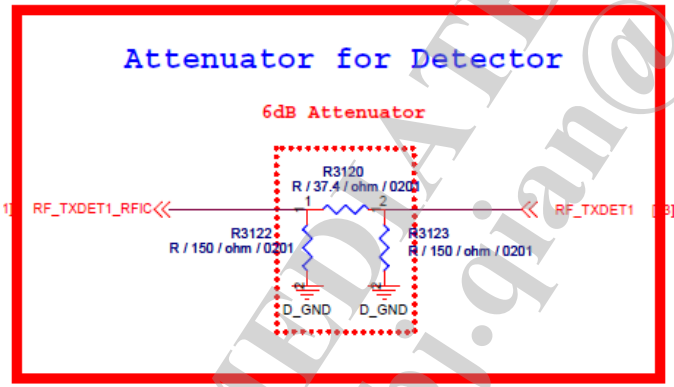
- Apply B39 TX SAW at PA output to pass CIM3 and GPS de-sense
- Power back-off can be used in the B39 CCA small RB case to pass UE-coexistence, and the B39 can use the BPF path (B34 TX co-path)

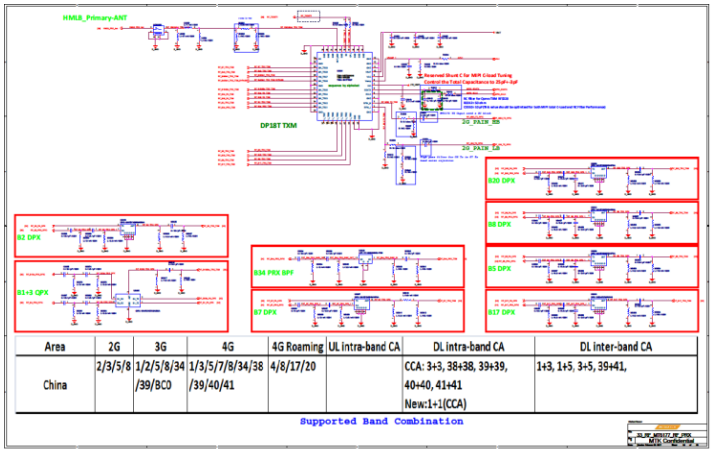
Refer Sch China Single Ant

Area	2G	3G	4G	4G Roaming	UL intra-band CA	DL intra-band CA	DL inter-band CA
China	2/3/5/8	1/2/~~3~~/5/8/34/39/BC0	1/3/**5(~~26~~)**/7/8/**34**/38/39/40/41	4/8/17/20		CCA: 3+3, 38+38, 39+39, 40+40, 41+41 **New:1+1(CCA)**	1+3, 1+5(~~26~~), 3+5(~~26~~), 39+41,

1. TXM(SKY77927)+LMH PA(SKY77643)
2. Detector Attenuator to 6dB for both SKY and Qorvo Phase3 TXM
3. Reserved Shunt C to 27pF for MIPI CLK and DATA

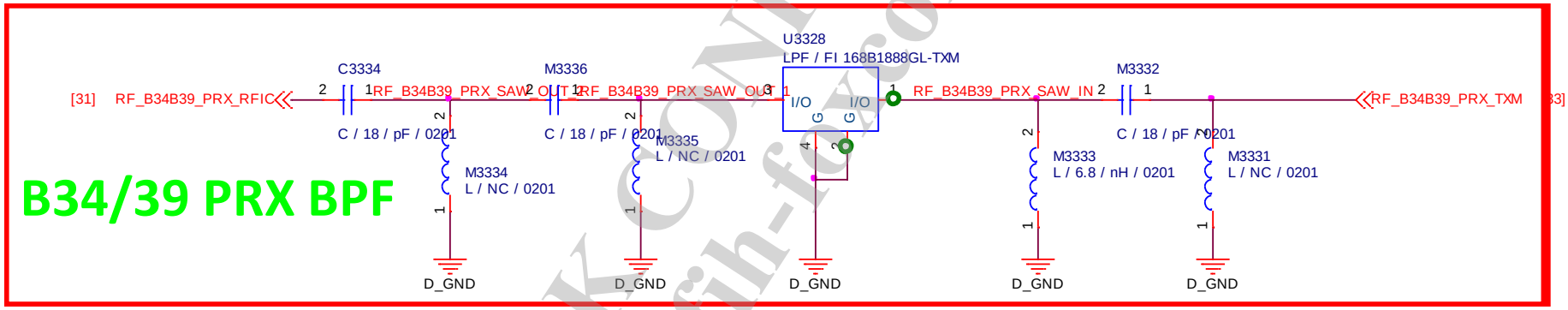


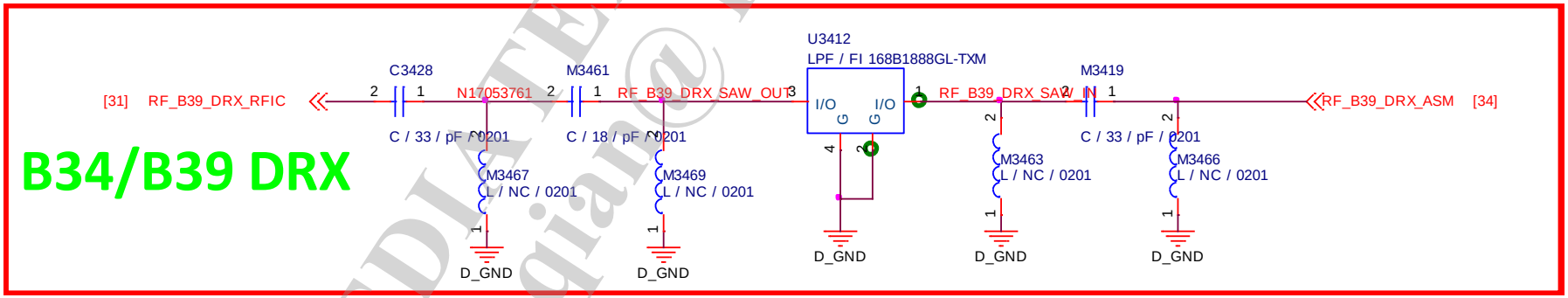




RX SAWless for 2G/TDS/LTE

- SAWless LNA port is PRX6 and DRX6
- PRX/DRX path have to apply BPF to pass OBB test
- PRX6 is for 2G-MB and TDS-B34/39 and LTE-B34/39
- PRX6/DRX6 can support LTE B34/B39 P+D
- 2G ARX can't support SAWless





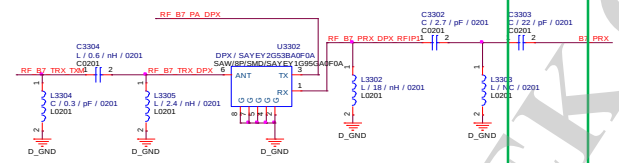
Reference Circuit Schematic: PRX RF

- It is recommended that TX, RX, ANT path layout should keep good isolation in 3G/4G FDD RF
- *Note: Check the DPX for C2K spec or in QVL

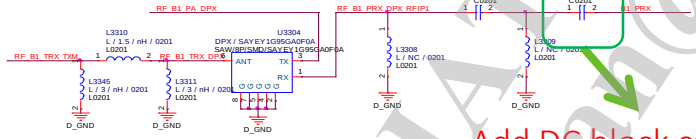
Example for DPX co-banding :

Band	2G	WCDMA	LTE	C2K
B2/1900	1900	B2	B2	BC1*
B3/1800	1800	B3	B3	-
B5/850	850	B5	B5	BC0*
B8/900	900	B8	B8	-

B7 TRX

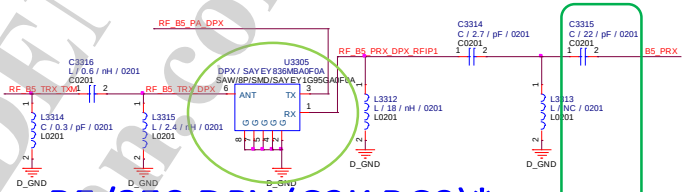


B1 TRX



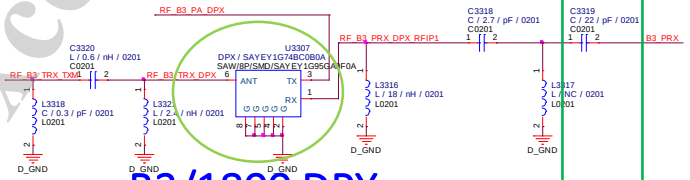
Add DC block cap at MT6177 input

B5 TRX



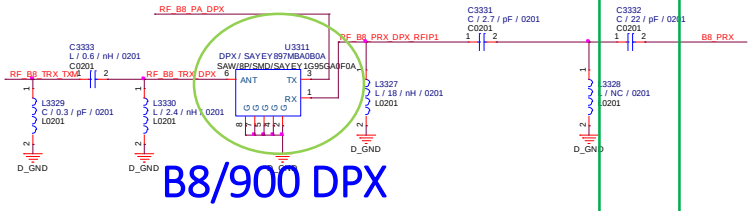
B5/850 DPX (C2K BC0)*

B3 TRX



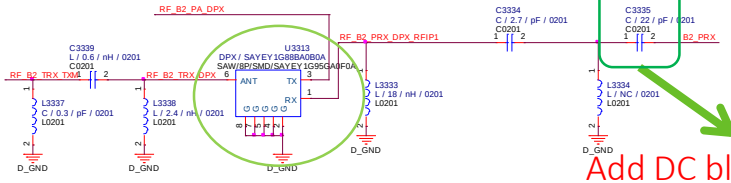
B3/1800 DPX

B8 TRX



B8/900 DPX

B2 TRX

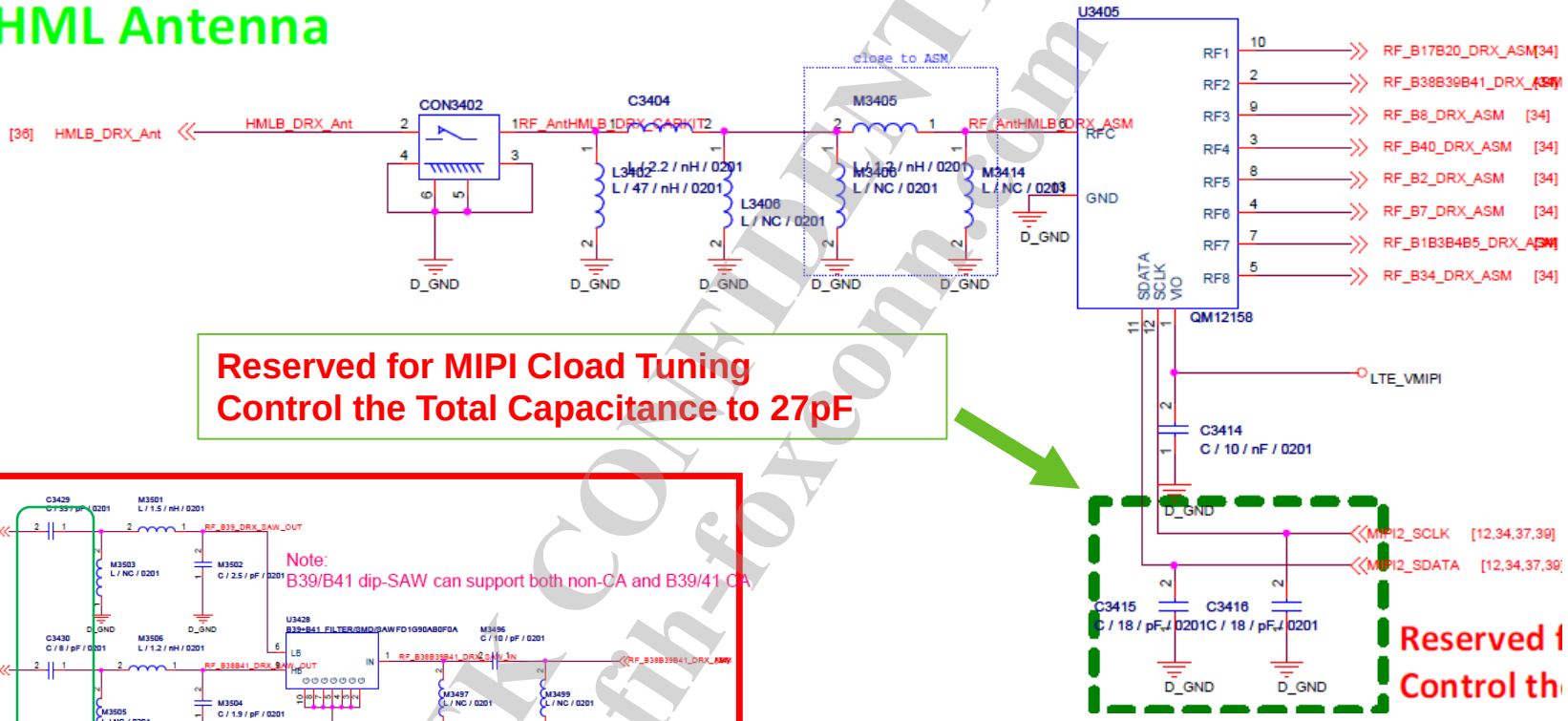


B2/1900 DPX (C2K BC1)*

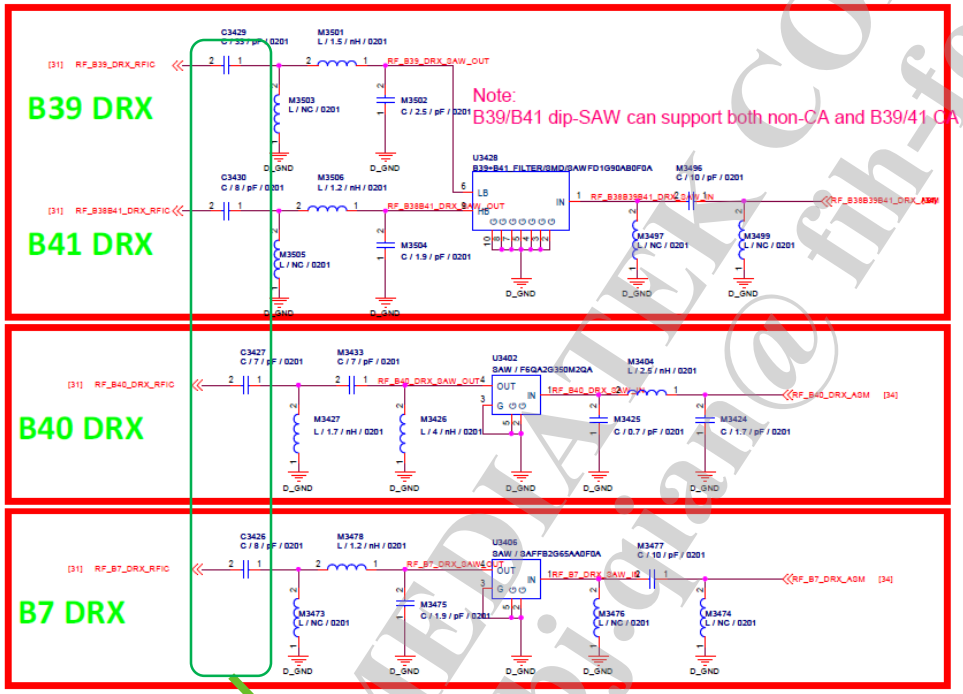
Add DC block cap at MT6177 input

Reference Circuit Schematic: 4G DRX RF

DRX HML Antenna

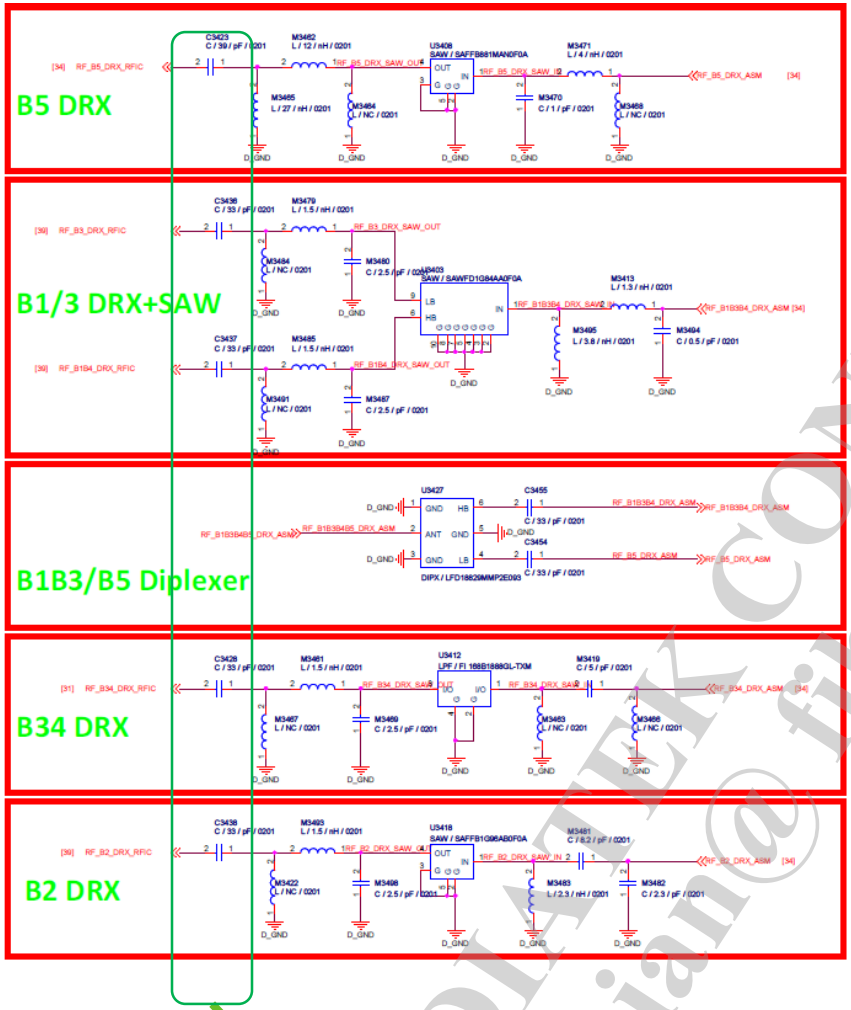


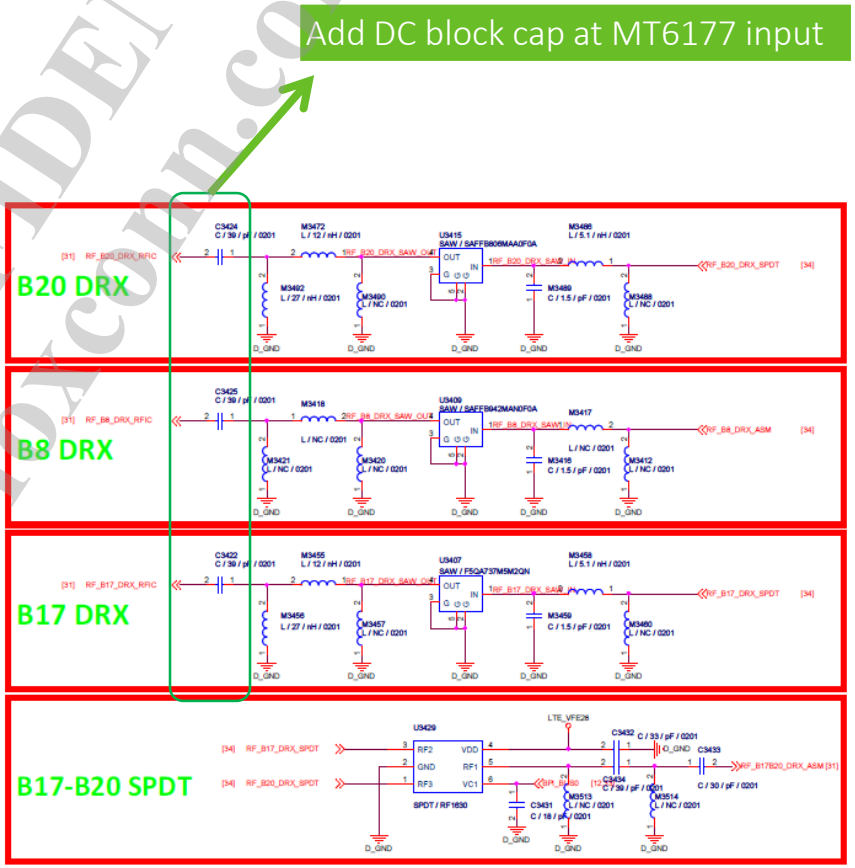
Reserved for MIPI Cload Tuning
Control the Total Capacitance to 27pF



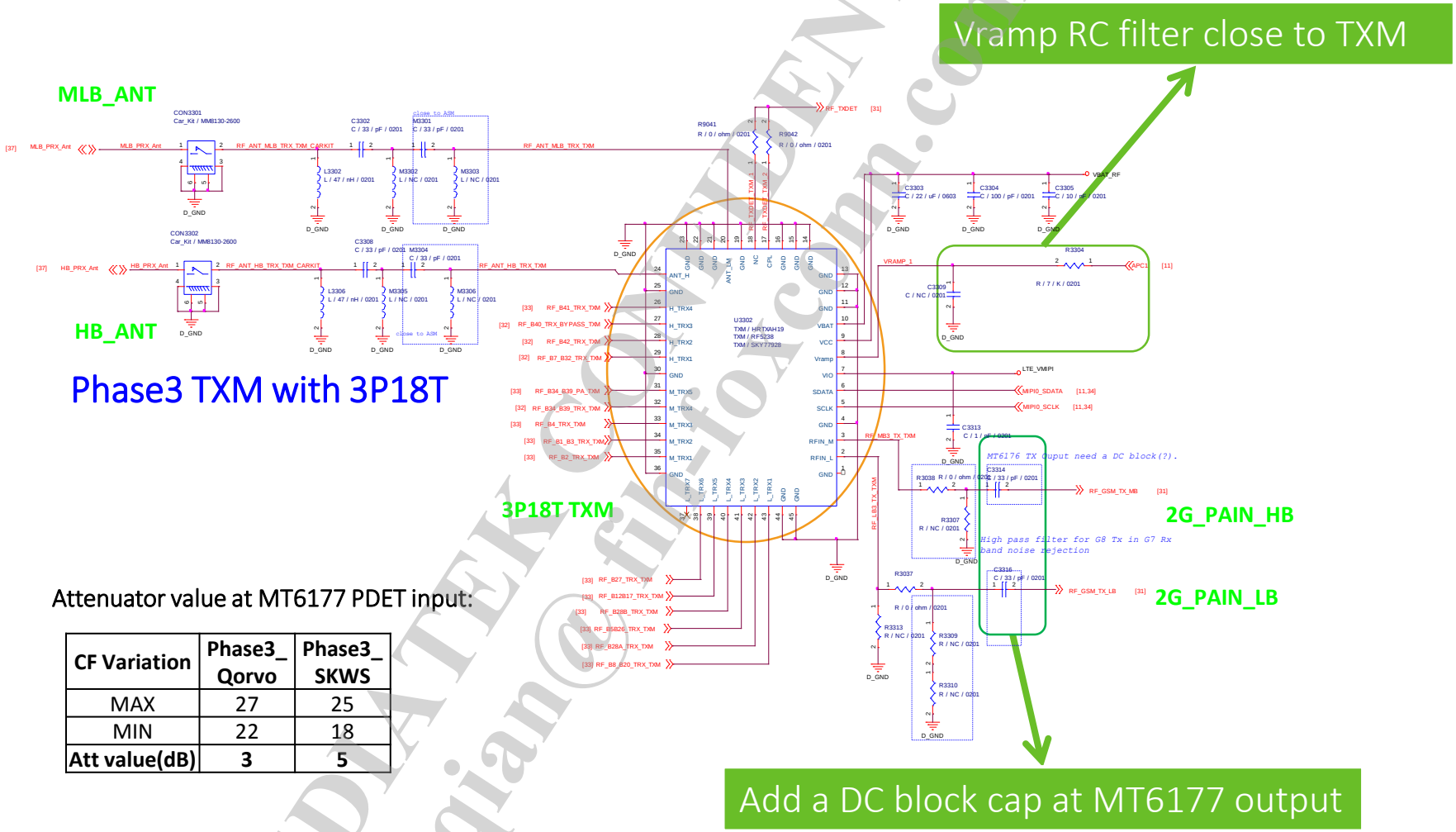
Add DC block cap at MT6177 input

Reference Circuit Schematic: 4G DRX RF





Reference Circuit Schematic: TXM

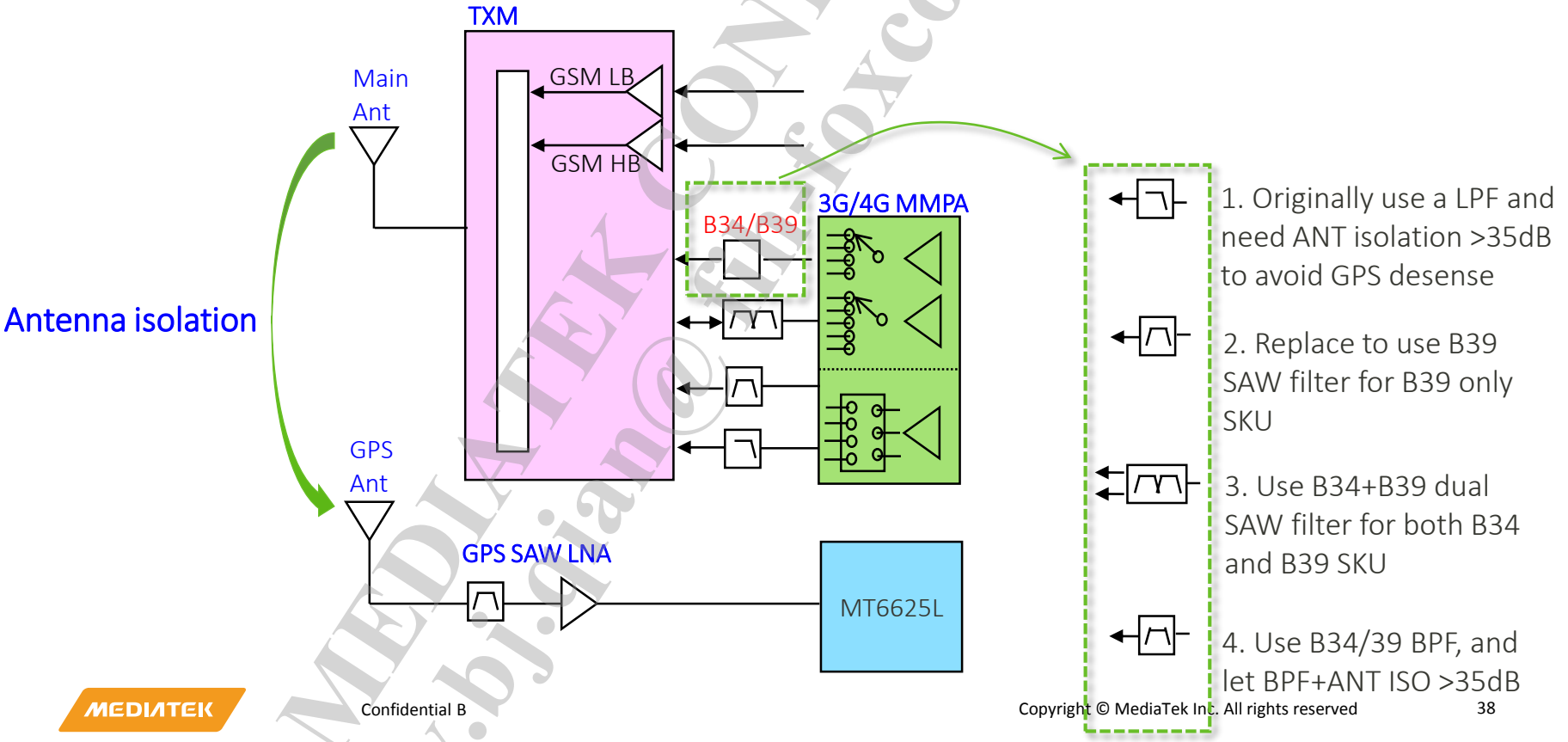


Attenuator value at MT6177 PDET input:

CF Variation	Phase3_ Qorvo	Phase3_ SKWS
MAX	27	25
MIN	22	18
Att value(dB)	**3**	**5**

LTE B34/B39 to GPS De-sense Solution

- B34/39 not TXM reuse case:
  - Antenna isolation between GPS and B34/39 + Band-Pass Filter after B34/39 PA > 35dB
    - Use B39 SAW filter (ex: SAFEA1G90MA0F0A) for B39 only SKU
    - B34+B39 dual SAW filter (ex: SAWEN1G90PA0F0A) for both B34 and B39 SKU
    - Use BPF (ex: LFB181G95CT9E362) + antenna isolation 14dB



Connection between MT6763 (BB)/MT6356 (PMIC) and MT6177

Interface (MT6293 Part) M6763-MT6177

- Interface: M6763-6177
  - Connect to 6177
    - BSI: 5pins
    - PRX_IQ: BB0/BB1 (SE) 4pins
    - DRX_IQ: BB0/BB1 (SE) 4pins
    - TX_IQ: BB0(P+N) (DIFF) 4pins
    - DET_IQ: DET0 (DIFF) 4pins
    - SRCLKENA
  - Total PIN Count
    - 5(BSI)+8(RXIQ)+4(TXIQ)+4(DET_IQ)+ 1(SRCLKENA)

    ➔22

**RF PIN Count: 22

	MT6293	
Function Block	Default function	
BSI	RFIC_BSI_0_EN	RFIC_BSI_0_EN
	RFIC_BSI_0_CK	RFIC_BSI_0_CK
	RFIC_BSI_0_D0	RFIC_BSI_0_D0
	RFIC_BSI_0_D1	RFIC_BSI_0_D1
	RFIC_BSI_0_D2	RFIC_BSI_0_D2
ABB RXBB	PRX_BB_I0	PRX_BB_I0
	PRX_BB_Q0	PRX_BB_Q0
	PRX_BB_I1	PRX_BB_I1
	PRX_BB_Q1	PRX_BB_Q1
	DRX_BB_I0	DRX_BB_I0
	DRX_BB_Q0	DRX_BB_Q0
	DRX_BB_I1	DRX_BB_I1
	DRX_BB_Q1	DRX_BB_Q1
ABB TXBB	TX_BB_IP0	TX_BB_IP0
	TX_BB_IN0	TX_BB_IN0
	TX_BB_QP0	TX_BB_QP0
	TX_BB_QN0	TX_BB_QN0
ABB TXDET	DET_IP0	DET_IP0
	DET_IN0	DET_IN0
	DET_QP0	DET_QP0
	DET_QN0	DET_QN0
SRCLKENA	SRCLKENA	SRCLKENA

Interface (MT6177 Part) M6763-MT6177

- Interface: M6763-6177
  - Connect to MT6763
    - BSI: 4pins (BSI_o_D2 is GND)
    - PRX_IQ: BB0/BB1 (SE) 4pins
    - DRX_IQ: BB0/BB1 (SE) 4pins
    - TX_IQ: BB0(P+N) (DIFF) 4pins
    - DET_IQ: DET0 (DIFF) 4pins

Category	Pin Name				Description
	Name	Default	I/O	GPIO/RF pin	
	TXDET1		I	RF	TX detection path input
BB I/O	PRX_BB_Q0		O	BB	RX1 BB Q output
	PRX_BB_I0		O	BB	RX1 BB I output
	PRX_BB_Q1		O	BB	RX2 BB Q output
	PRX_BB_I1		O	BB	RX2 BB I output
	DRX_BB_Q0		O	BB	RX1 diversity BB Q output
	DRX_BB_I0		O	BB	RX1 diversity BB I output
	DRX_BB_Q1		O	BB	RX2 diversity BB Q output
	DRX_BB_I1		O	BB	RX2 diversity BB I output
	TX_BB_IPo		I	BB	TX BB I input
	TX_BB_INo		I	BB	TX BB I input
	TX_BB_QNo		I	BB	TX BB Q input
	TX_BB_QPo		I	BB	TX BB Q input
	DET_IPo		O	BB	TX detection path I output, test pin 0
	DET_INo		O	BB	TX detection path I output, test pin 1
	DET_QPo		O	BB	TX detection path Q output, test pin 2
	DET_QNo		O	BB	TX detection path Q output, test pin 3
BSI Interface and CLK Input	BSI_o_EN		I	GPIO	BSI enable
	BSI_o_CK		I	GPIO	BSI clock
	BSI_o_Do		I/O	GPIO	BSI input/output data
	BSI_o_D1		I/O	GPIO	BSI input/output data
	BSI_o_D2		I/O	GPIO	BSI input/output data
	XOI		I	RF	26MHz input
	EN_BB		I		Global static controller enable
	TMEAS		I	DC	Temperature measurement
	RCAL		O	DC	External resistor calibration pin
Voltage Supply	VDD_RXHV		VDD	RF	DCDC 1.8V supply for RX
	VDD_RXLV		VDD	RF	DCDC 1.2V supply for RX
	VDD_TXHV		VDD	RF	DCDC 1.8V supply for TX and STX
	VDD_SXLV		VDD	RF	DCDC 1.2V supply for STX
	VDD_SXLF		VDD	RF	DCDC 1.8V supply for STX
	VIO		VDD	RF	Always on 1.8V for digital
	TXO_GND		GND	RF	TX output ground
	GND		GND	RF	RF ground

BPI/MIPI Table

- PA_VM0, PA_VM1 mux with MIPI4
- BPI_OLAT2, BPI_OLAT3 mux with MIPI3
- BPI_BUS0~BPI_BUS17 can be controlled by RX_AGC (E-LNA control)
- BPI_BUS28, BPI_BUS29 can be controlled by TX_TPC (Can't apply for E-LNA)

	M17			
Function Block	Default function	2017'02'23	Default setting	Aux Func.0
BPI	BPI_RFFE0	BPI_BUS0	BPI	GPIO76
	BPI_RFFE1	BPI_BUS1	BPI	GPIO75
	BPI_RFFE2	BPI_BUS2	BPI	GPIO74
	BPI_RFFE3	BPI_BUS3	BPI	GPIO73
	BPI_RFFE4	BPI_BUS4	BPI	GPIO72
	BPI_RFFE5	BPI_BUS5	BPI	GPIO71
	BPI_RFFE6	BPI_BUS6	BPI	GPIO70
	BPI_RFFE7	BPI_BUS7	BPI	GPIO69
	BPI_RFFE8	BPI_BUS8	BPI	GPIO55
	BPI_RFFE9	BPI_BUS9	BPI	GPIO56
	BPI_RFFE10	BPI_BUS10	BPI	GPIO57
	BPI_OLAT0	BPI_BUS11	BPI	GPIO78
	BPI_OLAT1	BPI_BUS12	BPI	GPIO54
	BPI_ANT0	BPI_BUS13	BPI	GPIO53
	BPI_ANT1	BPI_BUS14	BPI	GPIO77
	BPI_ANT2	BPI_BUS15	BPI	GPIO52
	PA_VM0	BPI_BUS28 (Mux MIPI4)	BPI	GPIO80
	PA_VM1	BPI_BUS29 (Mux MIPI4)	BPI	GPIO79
	BPI_OLAT2	BPI_BUS16 (Mux MIPI3)	MIPI	GPIO65
	BPI_OLAT3	BPI_BUS17 (Mux MIPI3)	MIPI	GPIO66
MIPI	MIPI0_SCLK	MIPI0_SCLK	MIPI	GPIO64
	MIPI0_SDATA	MIPI0_SDATA	MIPI	GPIO63
	MIPI1_SCLK	MIPI1_SCLK	MIPI	GPIO62
	MIPI1_SDATA	MIPI1_SDATA	MIPI	GPIO61
	MIPI2_SCLK	MIPI2_SCLK	MIPI	GPIO68
	MIPI2_SDATA	MIPI2_SDATA	MIPI	GPIO67
	MIPI3_SCLK	MIPI3_SCLK	MIPI	GPIO66
	MIPI3_SDATA	MIPI3_SDATA	MIPI	GPIO65
	MIPI4_SCLK	MIPI4_SCLK	BPI	GPIO80
	MIPI4_SDATA	MIPI4_SDATA	BPI	GPIO79

BPI/MIPI Usage for Internal Phone

6293 Pin name	BPI	Net name	China+EU RF DTB	China+EU Internal Phone	NA Demo Phone (TBD)
AG5	BPI_0	BPI_BUS0	B42 Tx/Rx SW	B42 Tx/Rx SW	RF
AJ4	BPI_1	BPI_BUS1	B28b<->B28a Rx SW	B28b<->B28a Rx SW	RF
AG6	BPI_2	BPI_BUS2	B5/B26<->B27 Rx SW	B5/B26<->B27 Rx SW	RF
AK3	BPI_3	BPI_BUS3	B32 PRx<->TDD Bypass mode SW	B32 PRx<->TDD Bypass mode SW	RF
AJ6	BPI_4	BPI_BUS4	X	X	RF
AH6	BPI_5	BPI_BUS5	X	X	RF
AJ3	BPI_6	BPI_BUS6	DRDI DET	DRDI DET	RF
AL4	BPI_7	BPI_BUS7	B2/B3 PRx eLNA	B2/B3 PRx eLNA	RF
AG27	BPI_8	BPI_BUS8	B2/B3 PRx eLNA	B2/B3 PRx eLNA	RF
AH27	BPI_9	BPI_BUS9	B2/B3 DRx eLNA	B2/B3 DRx eLNA	RF
AH26	BPI_10	BPI_BUS10	B2/B3 DRx eLNA	B2/B3 DRx eLNA	RF
AL6	BPI_11	BPI_OLAT0		OLAT	OLAT
AH25	BPI_12	BPI_OLAT1		OLAT	OLAT
AK25	BPI_13	BPI_ANT0	TAS	OLAT (TAS)	ANT
AK6	BPI_14	BPI_ANT1	TAS	OLAT (TAS)	ANT
AJ27	BPI_15	BPI_ANT2	TAS	TAS	ANT
AK5	BPI_28	BPI_PA_VM0			SRS+TAS
AK4	BPI_29	BPI_PA_VM1			SRS+TAS

CHINA+EU

port	device	2G	3G	TDS	C2K	LTE	Other
MIPI-0	TXM / eLNA	ASM / PA	ASM	ASM / PA	ASM	ASM	B38/B41 PRx eLNA
MIPI-1	PA1(Sky77651) / PA2(Sky77652) /PA3(QM52042) / PMIC(RF7061)		PA1 / PA2	PA2	PA1 / PA2	PA1 / PA2	PMIC(HPUE)
MIPI-2	DRX ASM / eLNA		ASM	ASM	ASM	ASM	B38/B41 DRx eLNA
MIPI-3	ANT tuner	OLAT (TAS)	OLAT (TAS)	OLAT (TAS)	OLAT (TAS)	OLAT (TAS)	

MT6177 RF Layout Guide

Common Placement Guide

1. Put Battery CONN close to 2G PA to reduce voltage drop in max. output power.
2. The Thermistor sensor placement should be close to PA.
3. (RF trace, Clock) away from high power (PA output), high current (VBAKeep susceptible circuit T, VCC_PA), and high speed circuit (Flash/DRAM) region.
4. Keep PA far away from TRX LNA input trace.
5. Keep RF matching circuit placement similar to the reference design with good impedance control to save the fine-tuning matching effort.
6. The TX port to 3G/4G PA path requires pi-matching circuit for TX power matching.
7. Make high band RX trace as short as possible.
8. Make high band TRX trace as short as possible.
9. MT6177 and PA should be placed at different sides or different shielding spaces.
10. For the harmonic CA case, separate the PA shielding space for LB and HMB PA.
11. Keep matching close to RX LNA port. Reserve shunt component at Duplexer/SAW input/output.

Common Layout Guide for RF

1. RX uses 50ohm single-ended trace. Keep enough space between trace-to-trace and trace-to-ground plane.
2. Keep out the space between the top layer of RX single-ended trace and the ground plane by 3~5 times of L1-L2 thickness.
3. Keep out the second layer of RF trace, RF component's PAD and RX single-ended matching area to minimize capacitance and loss.
4. Keep out the second layer of TCXO to minimize capacitance.
5. Susceptible traces (RF, 26MHz, VAPC and PDET) should be covered by GND plane and surrounded by a wall of GND via or GND trace act of a similar coaxial cable.
6. TX/RX isolation is critical to 3G/4G RX performance. Good isolation depends on good layout.
7. Keep good isolation between 2G TX output and coupling feedback path.
8. Remove broken and small ground plane or add GND via to main GND.
9. In a good board design, drop as many "vias" to ground as possible in the RF circuitry section.

Common Layout Guide for Power

- The width of VCC_PA trace should be at least 50mils from PMIC to 3G/LTE PA and 30 mil in RF room (The DCR should be less than 70mohm, refer to Figure. 1 in next page).
- The width of VRF18 trace should be at least 20mils from PMIC to MT6177 and 15 mil in RF room (The DCR should be less than 120mohm, refer to Figure. 2 in next page).
- The width of VRF12 trace should be at least 12mils from PMIC to MT6177 and 10 mil in RF room (The DCR should be less than 200mohm, refer to figure. 2 in next page).
- VBAT should be at least 80mil from battery connector to 2G PA and 50mil in RF room.
- Give as many vias as possible when switching layers for VCC_PA and VBAT.
- Good power trace layout should be surrounded by ground plane and via.
- Do not let power trace be a loop.
- Do not use a power plane in RF PCB. Loop trace and power plane like an antenna.
- Use a star topology to reduce coupling between various supply pins in a system.
- Do not put power trace in top layer without any shielding.
- Drop through hole GND via surrounding PCB.
- Ground via reduces current return paths. Drop as many GND vias near battery connector and switching layers as possible.
- PA VCC2 must keep away RF trace and signal via. Surround VCC2 with GND plane and use GND via to keep distance with RF trace and signal via.
- Each RF/FE power domain totally output capacitor must meet the capacitor range that descript in PMIC design notice.
- IQ trace must keep away PMIC/VS1 to avoid power noise and de-sense.

VRF PCB Layout Constraint

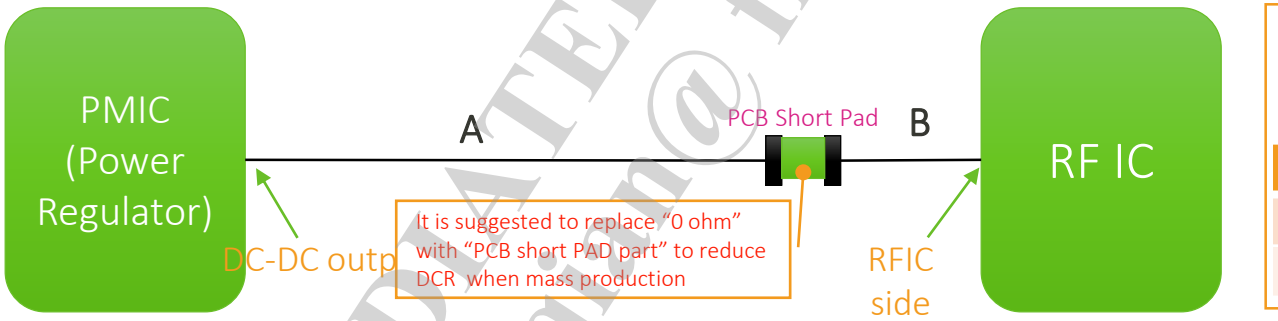
- Power Domain Information and PCB Layout Constraint

Power Domain	PMIC DC Accuracy(mV)	RF IC Min. Voltage(V)	Loading Current(A)	PCB Resistance A+B constraint(mΩ)
VRF12	+/- 12	1.11	0.15	< 200
VRF18	+/- 18	1.75	0.35	<120

- Example of PCB Layout Constraint *1

Power Domain	PCB Resistance A+B constraint (mΩ)	PCB Width (mil)	PCB Length (mil)	Cu Thickness (OZ)
VRF12	< 200	A ≥ 12 ; B ≥ 12	A ≤ 2000 ; B≤ 150	0.5
VRF18	<120	A ≥ 20 ; B ≥ 15	A ≤ 2000 ; B≤ 150	0.5

*1: Reduce the width acceptable at IC fan out, the total PCB resistance should meet constraint. It is suggested that the minimum width is ≥ 12mils, and length is <100mils at IC fan out



PCB Short Pad Part Recommend

Part Size	Width of PCB Short (mils)
0201	12
0402	20

Electrical Equations of PCB Resistance reference:
http://circuitcalculator.com/wordpress/2006/01/24/trace-resistance-calculator

VPA PCB Layout Constraint

- Power Domain Information and PCB Layout Constraint

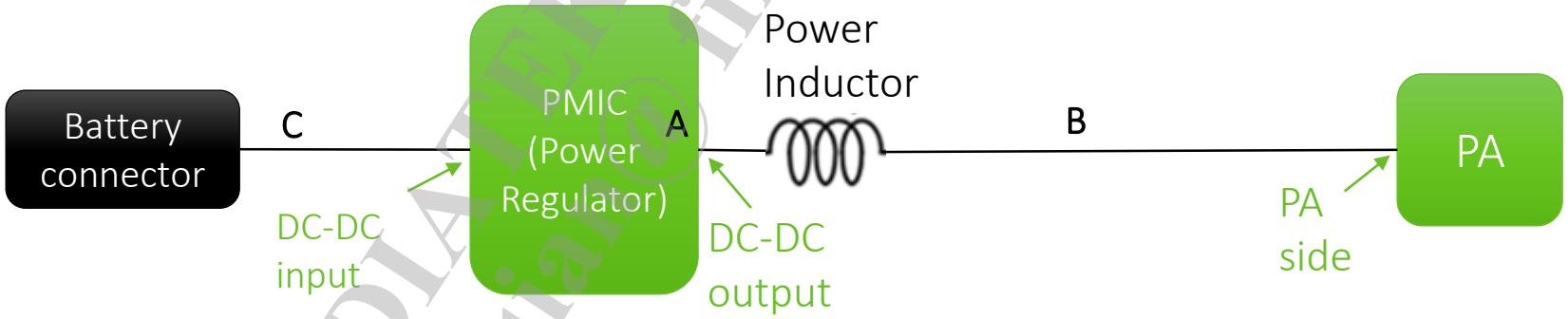
Power Domain	PA*1 Min. Voltage(V)	Loading Current(A)	PCB Resistance A+B+C constraint(mΩ)
VPA	3.15	1.0	< 70

***1**: The minimum voltage indicates the voltage measured at the PA side when VPA sets the output voltage =3.4V in PMIC

- Example of PCB Layout Constraint *1

Power Domain	PCB Resistance A+B+C constraint (mΩ)	PCB Width A/B/C (mil)	PCB Length A/B/C (mil)	Cu Thickness (OZ)
VPA	< 70	≥ 60	≤ 4000	0.5

***1**: Reduce the width acceptable at IC fan out, the total PCB resistance should meet constraint. It is suggested that the minimum width is ≥ 20mils, and length is <100mils at IC fan out



Electrical Equations of PCB Resistance reference:
http://circuitcalculator.com/wordpress/2006/01/24/trace-resistance-calculator

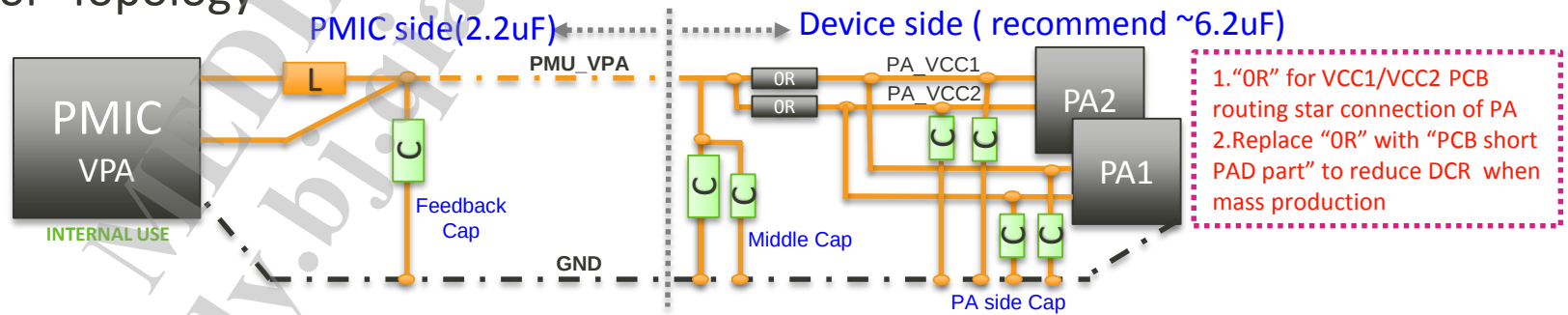
VPA Output Capacitance Notice(1)

- Why define the output capacitor range
  - The PA's transient voltage and timing are more critical
    - Stability ,ripple and transient voltage drop issue If output capacitor is too small
    - Stability and dynamic voltage scaling timing issue If output capacitor is too bigger
- Capacitor Specification Requirement
  - The updated is for dimension of capacitor don't care that accept small than 0603 and only need to follow the absolute effective capacitance shown below table. The electrical performance also be guarantee for the previous capacitance notice.
  - Typical total output capacitance is 2.2uF (Feedback)+ ~6.2uF (Middle +PA)

Item	Typical Cap(uF)	Effective Min Cap (uF) *1	Effective Max Cap (uF) *2	Rated V(V)	Placement Location
Feedback Cap	2.2	**0.7**	**X**	>=6.3	Close PMIC for PMIC FB sense pin
Feedback Cap+ (Middle +PA side Cap)	2.2+~6.2	**4.2**	**7.0**	>=6.3	Feedback Cap Close to PMIC ; Others Close to PAs.

*1 : -30°C~85°C / DC=0.5~3.6V / AC=0.01Vrms
*2 : -30°C~85°C / DC=2.5~3.6V / AC=0.01Vrms , the capacitance increased when lower DC

- Capacitor Topology



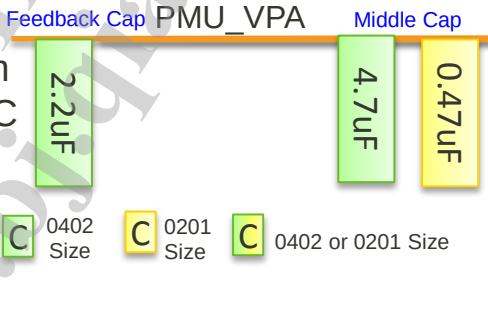
VPA Output Capacitance Notice(2)

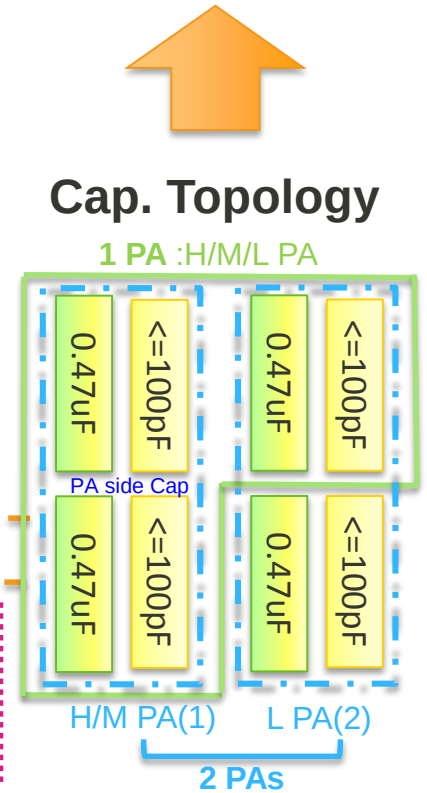
- Example for Capacitors arrangement

Example	Example 1 : PA side 0201 size		Example 2 : PA side 0402 size	
Location	1 PA – Cap/Size	2 PAs– Cap/Size	1 PA – Cap/Size	2 PAs– Cap/Size
PMIC FB Cap	2.2uF/0402	2.2uF/0402	2.2uF/0402	2.2uF/0402
Middle Cap	1. 4.7uF/0402 ; 2. 0.47uF/0201	1. 4.7uF/0402 ; 2. 0.47uF/0201	1. 4.7uF/0402 ; 2. NC/0201	1. 4.7uF/0402 ; 2. NC/0201
PAs side Cap	1. 0.47uF *3/0201 2. <=100pF *3/0201	1. 0.47uF *4/0201 2. <=100pF *4/0201	1. 0.47uF *3/0402 2. <=100pF *3/0201	1. 0.47uF *4/0402 2. <=100pF *4/0201

- Part Reference : http://ds.murata.co.jp/software/simsurfing/en-us/#

Part	Part Number	Rated Voltage(V)	Part Size
0.47uF	GRM033R60J474KE90	6.3	0201
0.47uF	GRM155R60J474ME19	6.3	0402
1.0uF	GRM155R60J105ME19	6.3	0402
2.2uF	GRM155R60J225ME95	6.3	0402
4.7uF	GRM155R61A475MEAA	10	0402





MT6177 IQ Signals

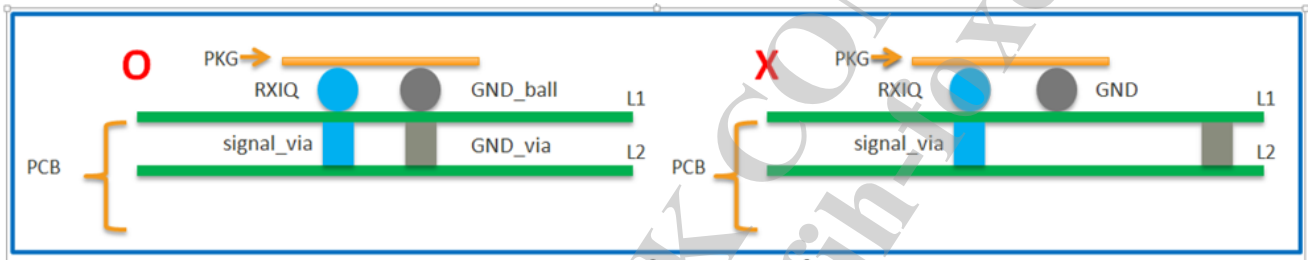
a. All GND ball adjacent RXIQ must be well connected @ L1 (Fig-1)

b. The RXIQ signal must has GND via close to its layer transition (Fig-1)

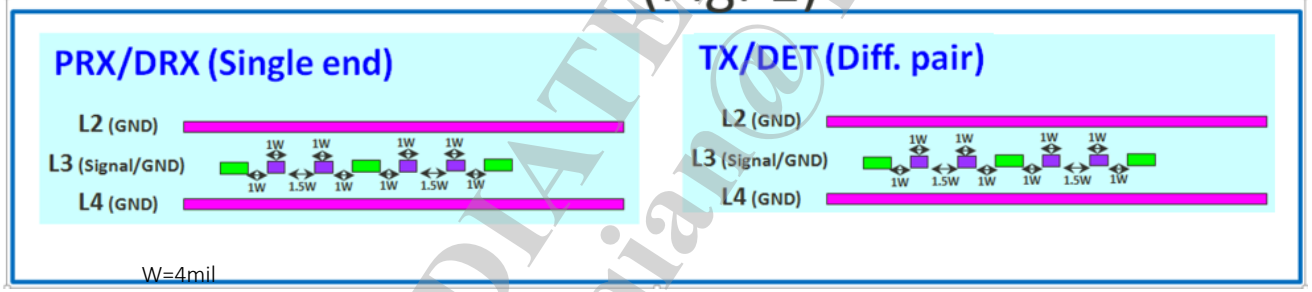
c. All RXIQ signals should have GND shielding by group (adjacent up/down layers) (Fig-2)

d. All TXIQ, RXIQ, DETIQ max PCB loading <15pF (or layout length < 50mm, depending on PCB stack) to avoid signal drooping in band edge

e. Gap between I and Q trace >= 6mil to prevent bad isolation (>65dB) (Fig-2)



(Fig. 1)



(Fig. 2)

MT6177 IQ

Function Block	Default function
ABB RXBB	PRX_BB_I0
	PRX_BB_Q0
	PRX_BB_I1
	PRX_BB_Q1
	DRX_BB_I0
	DRX_BB_Q0
	DRX_BB_I1
	DRX_BB_Q1
ABB TXBB	TX_BB_IP0
	TX_BB_IN0
	TX_BB_QP0
	TX_BB_QN0
ABB TXDET	DET_IP0
	DET_IN0
	DET_QP0
	DET_QN0

MT6177 IQ Signals

Layout not recommended

Figure 1 shows the ABB IQ are routed beneath the PMIC power nets even with ground plane shielding.

But the magnetic coupling from PMIC switching node could cause de-sense issue.

Not Recommended

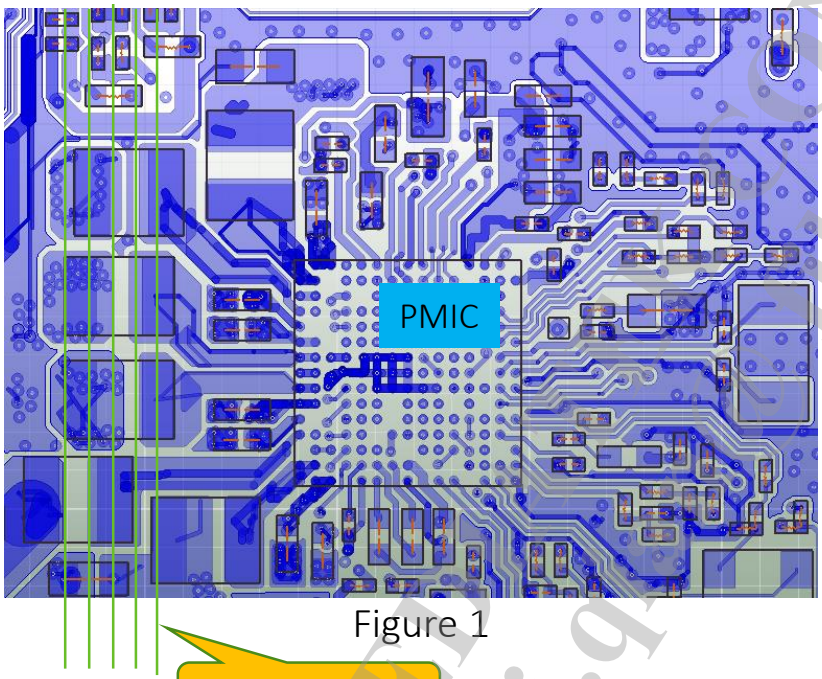


Figure 1

Layout recommended

Figure 2 shows the ABB IQ are routed away from PMIC power nets to avoid de-sense issue.

No overlap between PMIC nets and ABB IQ region.

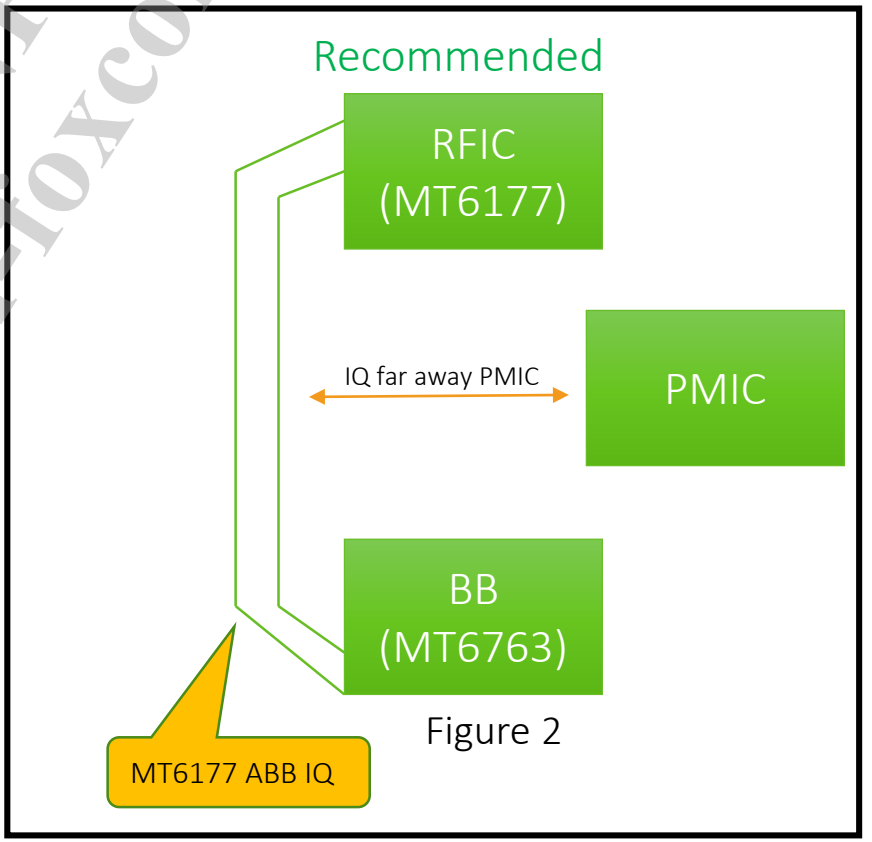


Figure 2

MT6177 IQ Signals

Layout not recommended

Figure 1 shows the PMIC power nets via are routed in the ABB IQ region in the PCB inner layer even with ground shielding

But the low frequency PMIC switching noise could couple to RX IQ and cause de-sense issue.

Not Recommended

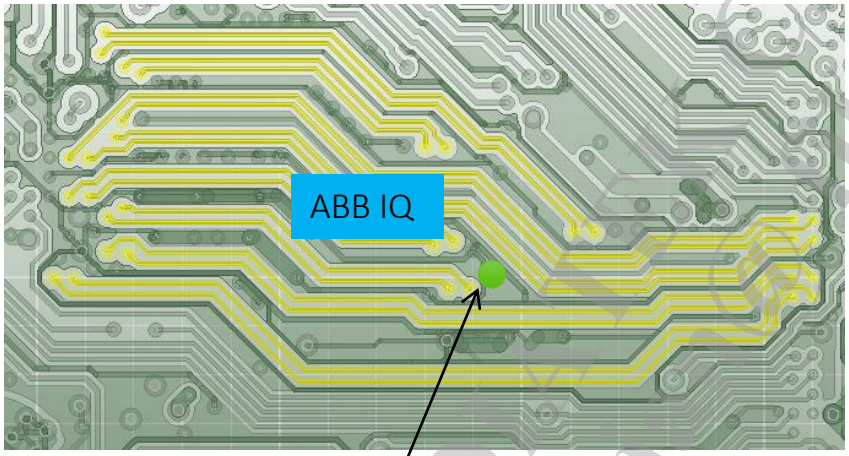


Figure 1

Layout recommended

Figure 2 shows PMIC power nets via are away from ABB IQ region at least 25mil to avoid de-sense issue.

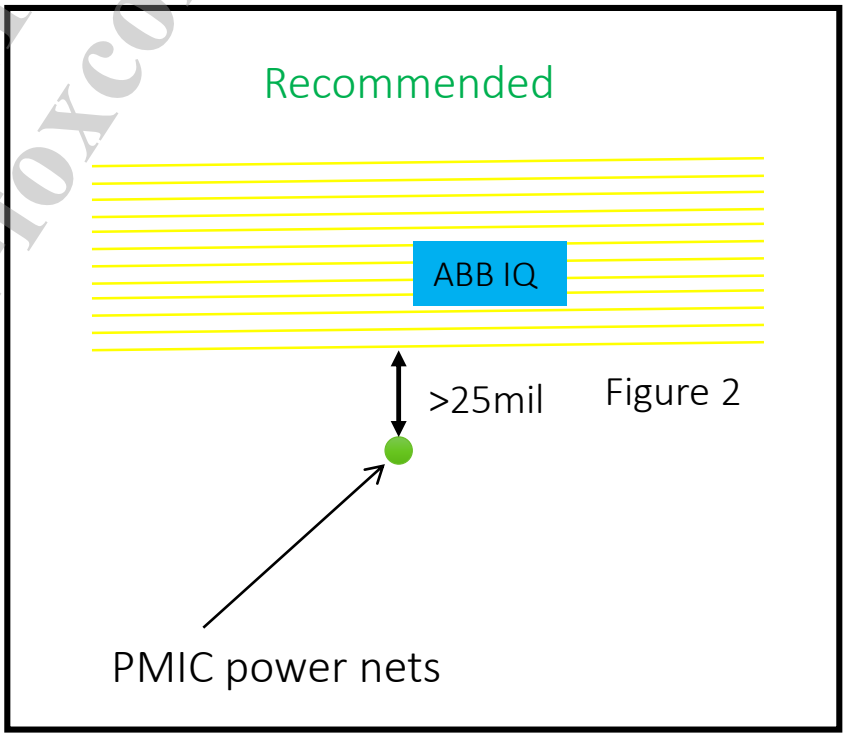


Figure 2

IQ Trace Loading

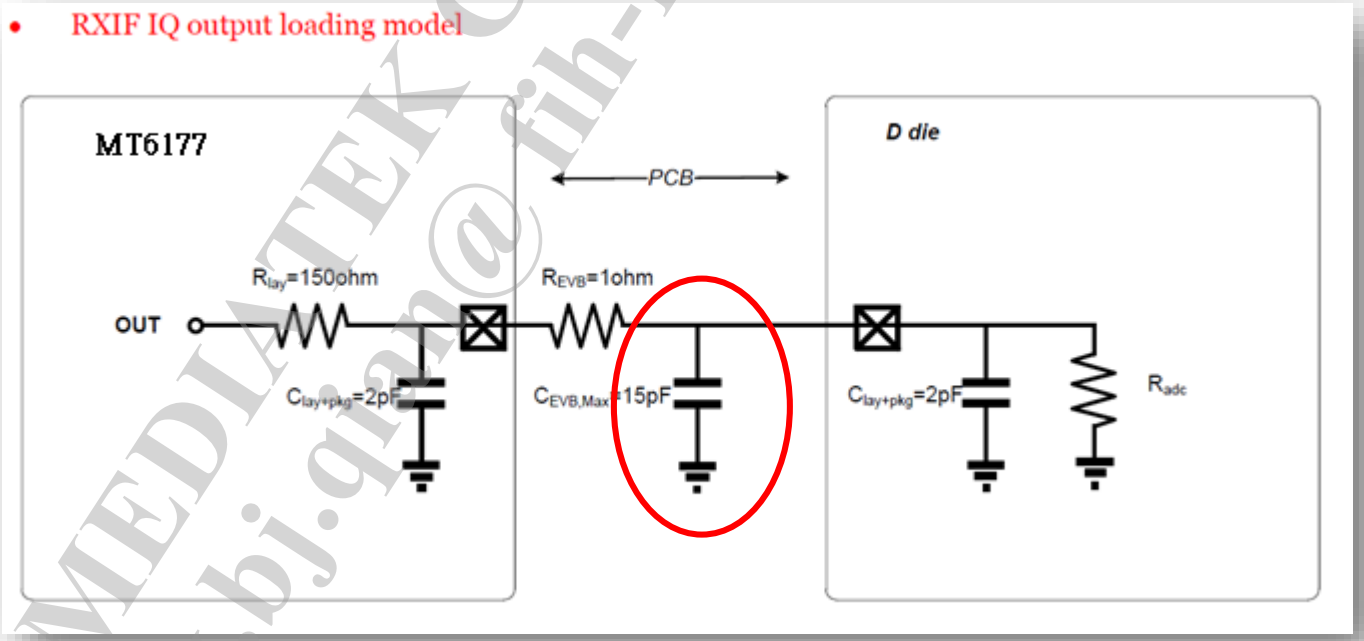
For the applications whose bandwidth are beyond LTE 30MHz, for example NC-CA, we highly recommend that the PCB loading should be small enough (<15pF) to avoid extra drooping in band-edge and performance degradation. Inevitably, in some special case, the PCB IQ traces may be longer and make PCB loading larger, the value would be up to several tens of pF. In these cases, limited performance can only be achieved. For example, the maximal throughput would be degraded.

PCB trace requirement of Rx IF interface:

1. Capacitance loading < 15pF or trace length <50mm (The trace cap/cm is typically around 3pF/cm, depending on PCB stack-up)

2. Mismatch between capacitance of I path and Q path < 10%

3. I to Q isolation: >65dB (The suggested gap between I trace and Q trace: >=6mil)



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