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Contents

Foreword

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1 Scope

The present document is a technical report for "Expansion of LTE_FDD_1670_US to include 1670-1680 MHz Band for LTE in the US" study item, which was approved at 3GPP TSG RAN#59 [2]. The ID assigned to the study item FS_LTE_FDD_1670_US. The objective of this study item is to facilitate and harmonize the characteristics and efficient use of 1670-1680MHz DL duplexed with band 24 UL for LTE FDD deployment in US. In addition to the schedule and status of the study items, the report includes a description of the motivation, requirements, study results and specification recommendations.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications". [SID] RP-090666, "Proposed SI: Extended 850", Alcatel-Lucent, Ericsson, Motorola, NII Holdings, Nokia, Nokia Siemens Networks, ST-Ericsson

[2] RP-130202: " Study Item Proposal: Expansion of LTE_FDD_1670_US to include 1670-1680 MHz Band for LTE in the US ", RAN #59, Feb. 2013

[3] FCC Rules and Regulations 47 C.F.R §27: "Miscellaneous Wireless Communications Services: http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&SID=79c73df3f25987fc1a7bc7da895561df&rgn=div5&view=text&node=47:2.0.1.1.5&idno=47

[4] FCC Order DA 07-5101: "Crown Castle Waiver Order", FCC, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-07-5101A1.pdf

[5] FCC Rules and Regulations 47 C.F.R §2.106: "Table of Frequency Allocations" http://transition.fcc.gov/oet/spectrum/table/fcctable.pdf

[6] FCC Rules and Regulations 47 C.F.R §25.23: "Special requirements for ancillary terrestrial components operating in the 1626.5–1660.5 MHz/1525–1559 MHz bands." http://www.hallikainen.org/FCC/FccRules/2012/25/253/section.pdf

[7] FCC Order DA-10-534, March 26, 2010, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-10-534A1.pdf

[8] FCC Order DA-04-3553, November 8, 2004, http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-04-3553A1.pdf

[9] FCC Order DA 05-30, February 25, 2005, http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-05-30A1.pdf

[10] 3GPP TS 36.104 v12.0.0, "Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception".

[11] 3GPP TS 25.942 v11.0.0, "Radio Frequency (RF) system scenarios".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [x] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [x].

3.2 Symbols

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [x] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [x].

<TBA> <To Be Assigned>

4 Background

Band 24 (L-Band) is standardized in 3GPP Rel-10 LTE under the work item "Adding L-Band (Band 24) LTE for Ancillary Terrestrial Component (ATC) of Mobile Satellite Service (MSS) in North America" (L_Band_LTE_ATC_MSS) UID_470010. The FCC has suspended the license to deploy ATC in both the upper and lower segments of Band-24 downlink in the United States (and the associated build-out requirements, pending further review). As a result, LightSquared has not commenced such deployment in this band, and will not use Band 24 downlink until the FCC and NTIA approve such use. On December 20, 2012, the FCC granted LightSquared an indefinite extension of its ATC build-out requirement, while it considers LightSquared's proposals to resolve concerns regarding potential interference to GPS receivers, including the proposals discussed here (Order in IB Docket No. 12-296, DA 12-2051 December 20, 2012).

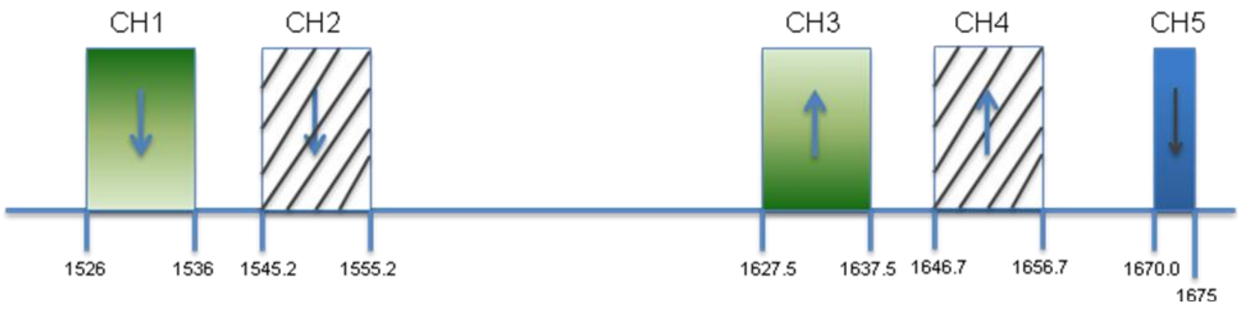

Figure 4.1: LightSquared Spectrum Holding

In addition, LightSquared has contractual and regulatory authority to use the 5 MHz of spectrum associated with the FCC's nationwide license for 1670-1675 MHz (CH5 in Figure 4.1). FCC Rules allow 2000 Watts peak EIRP from base station, and 4 Watts EIRP from mobile terminals (CFR Title 47 §27.50(f) [3]).

LightSquared has requested to expand the downlink band to 10 MHz bandwidth, i.e. 1670-1680 MHz and has identified options for pairing this band with uplink spectrum at 1627.5-1637.5 or 1646.7-1656.7 MHz (see Figure 4.2). The FCC recently issued public notices for LightSquared's requests to operate its terrestrial network using the downlink frequencies at 1670-1675 MHz and 1675-1680 MHz, and the comment cycle was completed in early January 2013 without serious objections.

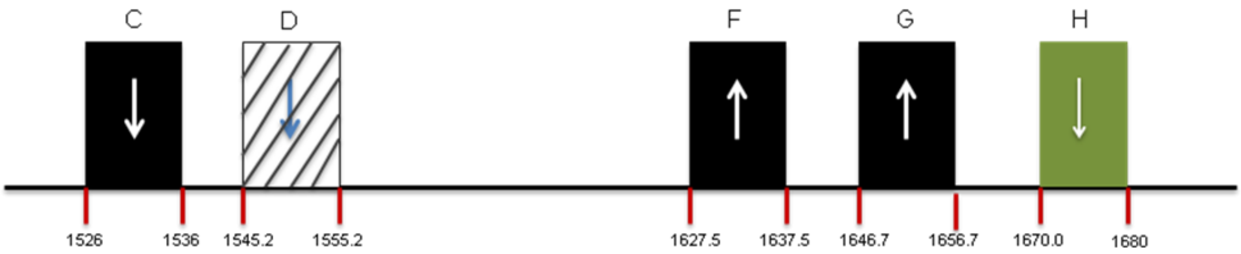

Figure 4.1: Potential LightSquared Spectrum Holding

5 Band allocation plan and regulatory background

This Section provides the frequency band arrangements and regulatory backgrounds for the proposed band.

5.1 Existing Rules for 1670-1675 MHz.

FCC rules allow 2000 Watts peak EIRP from base stations, and 4 Watts EIRP from mobile terminals (47 CFR §27.50(f)) in the 1670-1675 MHz band.

FCC has not mandated the radio propagation direction for the 1670 – 1675 MHz band (forward or reverse link), and leaves that to the operator's discretion. Acceptable access techniques include both FDD and TDD technologies, provided the relevant FCC transmitter emissions and other regulatory and requirements are met. LightSquared aims to use the spectrum as the downlink component of an FDD LTE system, with band 24 UL as its uplink spectrum.

This band was licensed to Crown Castle for the broadcast of a nationwide DVB-H mobile video service, called Modeo, with at least 10 video channels and 24 audio channels. Crown Castle sought and received approval from the FCC to operate at higher power under certain conditions for the provision of its Modeo services (identified in FCC 07-16). For economic reasons, Modeo service was abandoned by Crown Castle and the spectrum was leased to LightSquared.

The LTE deployment in this band will adhere to all 3GPP terrestrial out-of-band requirements for spurious emissions including those for UE, eNB, and UE-to-UE emissions as will be defined in 3GPP TS 36.101, TS 36.104, 3GPP TS 25.101, and other relevant documents. Spurious emission requirements from the addition of this new band are expected to be the same as those required from the addition of other new US bands in 3GPP.

5.1.1 Base Station and Mobile Station Power Limits for 1670-1675 MHz

Pursuant to Section 27.50(f) of the Commission's rules, fixed and base station operations in the 1670-1675 MHz band are limited to 2000 watts EIRP peak power. This power level includes transmit antenna gains.

As mentioned above, Crown Castle International Corporation sought and received in FCC Order FCC 07-16 waiver of Section 27.50(f) of the Commission's rules, which specifies a peak 2 kW EIRP limit for fixed and base station operations in the 1670-1675 MHz band.. Under this waiver, the fixed and base station macrocells are allowed to transmit up to 4 kW/MHz (which is equivalent to 36 dBW/MHz or 66 dBm/MHz) peak EIRP density in non-rural, and 8 kW/MHz (which is equivalent to 39 dBW/MHz or 69 dBm/MHz) peak EIRP density in rural areas only in 30

Cellular Market Areas (CMAs) specified in Crown Castle's Initial Market Deployment Plan (identified in FCC 07-16). In all other CMAs, the lower 2 kW or 33 dBW peak base station EIRP limit applies. All these power limits include the transmit antenna gains. Note that, based on FCC 07-16, any power level above 2 kW is defined as high power transmission. This approach would have enabled Crown Castle to operate its proposed 5 MHz bandwidth DVB-H technology at up to 20 kW and 40 kW peak EIRP, for a 5 MHz channel, in non-rural and rural areas, respectively.

Mobile terminals are limited to 4 watts EIRP peak power or 6 dBW (36 dBm) EIRP, including the terminal's antenna gain.

5.1.2 Out of Band Emission (OOBE) Limits

In addition to all co-ordination and power limit requirements, operation in 1670-1675 MHz band is required to meet the following Out-Of-Band Emission (OOBE) limits:

Per 47 CFR §27.53(k), the power of any emission outside the licensee's frequency band of operation, shall be attenuated below the transmitter power (P) by at least 43 + 10 log (P) dB. Compliance with this provision is based on the resolution bandwidth of 1 MHz or less, but at least one percent of the fundamental emission bandwidth of the transmitter, provided the measured energy is integrated over a 1 MHz bandwidth.

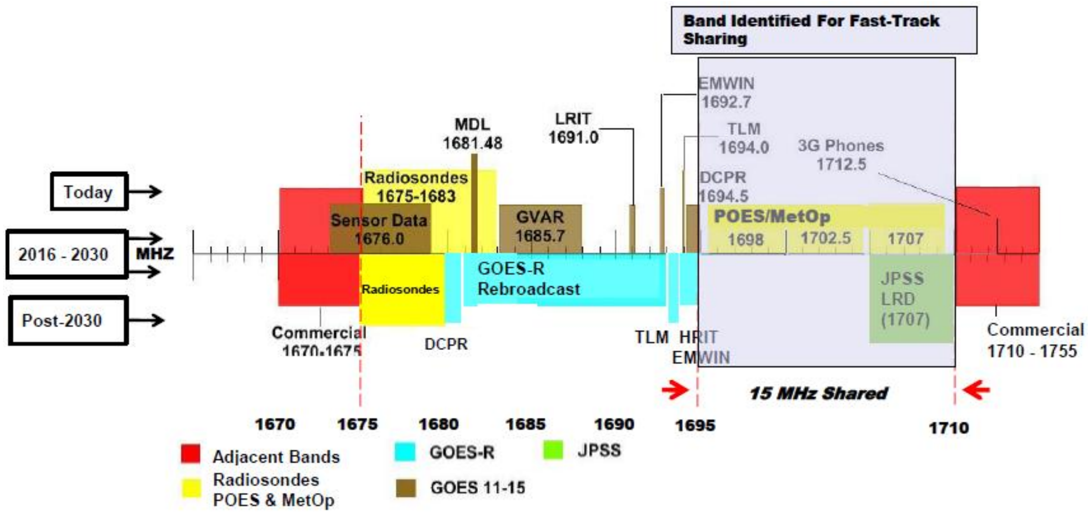

Figure 5.1: NOAA Services in 1600MHz band [Courtesy to NOAA]

5.1.3 Coordination

Figure 5.1 depicts the services in the 1600 MHz band that might require coordination from any commercial services deployed in 1670-1680 MHz band. The figure shows the current and future plans for this band.

5.1.3.1 Meteorological Satellite Earth Stations

Although the 1670-1675 MHz band has been generally unencumbered, there are three vital federal Geostationary Operational Environmental Satellite System (GOES) earth stations adjacent to this band (centred at 1676 MHz). 47 C.F.R §1.924(g) (1) establishes coordination zones around downlinks for these earth stations, which are located at Wallops Island, Virginia; Fairbanks, Alaska; and Greenbelt, Maryland. More earth stations are located in Suitland MD, Fairmont WV, and Omaha NE. However, there is no explicit FCC requirement establishing a coordination zone for these additional earth stations. The coordination zone for Wallops Island and Fairbanks are specified locations bounded by circles with a radius of 100 km (62.1 miles), respectively, while the Greenbelt zone is a specified location bounded by a circle with a radius of 65 km (40.4 miles). For the 30 CMAs defined in FCC 07-16, where the transmission power could be greater than 2 kW (i.e., high power), the radius of the circle for the coordination zone surrounding Fairbanks increases to 180 km and the radius of the circle for the coordination zone for Greenbelt increases to 100 km. Even considering the larger coordination zones in Fairbanks and Greenbelt, only 4% of USA PoPs would be impacted around these six locations.

Regardless of power levels, Section 1.924(g) (2) requires licensees to protect Wallops Island and Fairbanks at all times, and to protect Greenbelt, which is a back-up for Wallops Island, when it is active. 47 C.F.R. §27.903(b) (3) requires licensees to file a separate station application with the FCC and obtain an individual station license, prior to construction or operation of any station in a coordination zone. Licensees are required to notify the National Oceanic and Atmospheric Administration (NOAA) Office Frequency Management, either before or simultaneously with the filing of such an application

5.1.3.2 Radio Astronomy Services (RAS)

Radio Astronomy Service (RAS) also operates at two of the four hydroxyl line frequencies, namely 1665 and 1667 MHz. To protect RAS, any operator with a high power station (i.e. more than 2 kW EIRP) within 185 km radius of RAS facilities (listed in 47 CFR §2.106, footnote US385) is obligated to co-ordinate with the National Science Foundation (NSF) by initiating consultations in writing at least 30 days before undertaking any such operations. No coordination is required if the transmission power is no more than 2 kW EIRP, as per FCC rules for the 1670 – 1675 MHz band.

In the FCC rulemaking establishing technical requirements for the 1670-1675 MHz band, the National Research Council’s Committee on Radio Frequencies (CORF) requested the FCC to establish exclusion and coordination zones for the protection of RAS. However, the FCC rejected the request, and rather considered the OOBE for the 1670-1675 MHz licensee sufficient to protect RAS operations.

Footnote US74 of 47 C.F.R. §2.106, stating that “RAS operation will be protected from extra-band radiation only to the extent that such radiation exceeds the limits for a station operating in compliance with all applicable Commission rules,” applies to the 1670-1675 MHz band. Footnote US385 of 47 C.F.R §2.106 lists the location of RAS sites that are considered under this provision.

5.1.3.1 Meteorological Aids

National Weather Service Radiosondes (NWS) operates radiosondes in 1675-1683 MHz to obtain upper-air data that are essential for weather forecasts and research. Radiosondes use an approximate 250 mW transmitter power and operate out to a range of 250 kilometers from NWS Upper Air Sites. To address the potential interference from high power operations (i.e., more than 2 kW EIRP), any operator deploying stations in 1670-1675 MHz within 1.3 km of any NWS Upper Air Site is required to coordinate with NWS. No coordination is required if the transmission power is no more than 2 kW EIRP.

5.2 Current Rules for 1675-1680 MHz

On November 2, 2012, LightSquared asked for FCC authority to use the 1675-1680 MHz band to provide a commercially-useable terrestrial wireless broadband service as part of a contiguous 10 MHz downlink channel. The 5 MHz band at 1675–1680 MHz will be shared with existing federal government users. LightSquared’s proposal is uniquely suited to protecting the integrity of essential government operations in the 1675-1680 MHz band. The FCC has accepted public comment on the proposal, and the comment cycle has been closed.

The 1675-1680 MHz band currently is allocated on a primary basis for both non-Federal and Federal use by the Meteorological Aids (MetAids) and Meteorological-Satellite (MetSat) Services; it is not allocated for terrestrial mobile service. LightSquared’s FCC filings recognize that its proposed use of 1675-1680 MHz may require modification of the Commission’s rules in order to facilitate the prompt processing and grant of its applications.

There are two downlink MetSat services deployed in 1675-1680 MHz band that must be protected from any terrestrial operation in the same band: 1) Sensor Data Link (SD) on current GOES-NOP (centred at 1676 MHz) , and 2) Data Collection Platform Report (DCPR) on future GOES-R satellite (centred at 1679.9 MHz and 1680.2 MHz). While locations for both SD and DCPR are known based on NTIA's report, currently there are no rules specifying protection zones around these sites.

The 1675 – 1680 MHz band also overlaps with NOAA Channel 1 (1676 MHz) and Channel 2 (1678 MHz) used for MetAids (Radiosonde) operations in the Continental United States (CONUS). Currently, there are 71 government operated Radiosonde receive stations in the CONUS. The International Table of Allocations contains primary allocations for MetAids (Radiosondes) at both 400.15-406 MHz and 1668.4-1700 MHz.

If coordination with these services requires LightSquared to limit its deployment within an exclusion zone, a 5 MHz deployment (from 1670-1675 MHz) could be considered.

5.3 Technical Rules for UEs

The following information outlines the UE emissions masks for 1626-1660 MHz UL, in EIRP metrics, consistent with FCC's rules.

- Maximum Power: 0 dBW or 30 dBm [6; (g)(1)] & [7].
- Out-of-Band Emissions for Mobile Terminals
    - OOCE/OOBE Emission [8]:
        - Limit of -58 dBW/4kHz (-28 dBm/4kHz) per terminal at a 1 MHz offset and beyond from the edge of the spectrum used for terrestrial deployment.
    - Specific Emissions Requirement to protect RNSS (GPS) band [9]:
        - Wideband Emissions - (averaged over any 2 millisecond active transmission interval):
            - 1559 – 1605 MHz: -60 dBm/MHz; After 5 years: -65 dBm/MHz
            - 1605 – 1610 MHz: Linear interpolation from -60 dBm/MHz to -36 dBm/MHz; After 5 years: linear interpolation from -65 dBm/MHz to -41 dBm/MHz
        - Narrowband Emissions - (EIRP of discrete emissions of less than 700 Hz bandwidth, averaged over any 2 millisecond active transmission interval):
            - 1559 – 1605 MHz: -70 dBm; -75 dBm after 5 years
            - 1605 – 1610 MHz: Linear interpolation from -70 dBm to -46 dBm; After 5 years: linear interpolation from -75 dBm to -51 dBm

6 List of band specific issues for LTE FDD in 1670-1680MHz and band 24 UL

- General issues
    - Co-existence with nearby 3GPP bands

   - Co-existence with band 24

- E-UTRA issues
   - UE Duplexer
      - Potential receiver desensitization due to UL TX noise
      - Potential device receiver overload due to its UL TX power
   - UE REFSENS

- MSR issues

7 General Issues

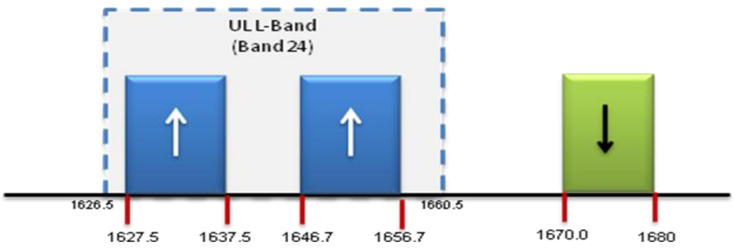

Figure 7.1: Proposed Band including B24 UL

The LTE deployment in this band will adhere to all 3GPP terrestrial out-of-band requirements for spurious emissions including those for UE, eNB, and UE-to-UE emissions as will be defined in 3GPP TS 36.101, TS 36.104, 3GPP TS 25.101, and other relevant documents.

The downlink spectrum covered by this study item is 1670 to 1680 MHz, and the corresponding paired 10 MHz uplink band is included within band 24 UL, 1626.5 to 1660.5 MHz (Figure 7.1). In particular the proposed UL band is either 1627.5 to 1637.5 MHz, or 1646.7 to 1656.7 MHz. These configurations are depicted in Figure 7.2.

As depicted in Figure 7.2, the band would consider both 5 MHz and 10 MHz channel bandwidths. The 5 MHz deployment is considered for the markets with exclusion zone requirements to coordinate with weather services in 1675-1680 MHz. Tables 7.1. and 7.2. depict the proposed operating band configurations

Table 7.1: LTE proposed operating band configuration; option 1

E-UTRA operating Band	Uplink (UL) band				Downlink (DL) band				TRX separation
	UE transmit / BS receive F_{UL_low} (MHz) – F_{UL_high} (MHz)			Channel BW [MHz]	UE receive / BS transmit F_{DL_low} (MHz) – F_{DL_high} (MHz)			Channel BW [MHz]	
XX	1627.5	-	1637.5	[5]/[10]	1670	–	1680	[5]/[10]	42.5 MHz

Table 7.2: LTE proposed operating band configuration; option 2

E-UTRA operating Band	Uplink (UL) band				Downlink (DL) band				TRX separation
	UE transmit / BS receive F_{UL_low} (MHz) – F_{UL_high} (MHz)			Channel BW [MHz]	UE receive / BS transmit F_{DL_low} (MHz) – F_{DL_high} (MHz)			Channel BW [MHz]	
XX	1646.7	-	1656.7	[5]/[10]	1670	–	1680	[5]/[10]	23.3 MHz

The choices under study for 10 MHz pairing are H and F, H and G as depicted in Figure 7.2. The distance between the UL and DL edges of the proposed band for 10 MHz carrier is as small as 13.3 MHz (1670-1656.7=13.3 MHz). The pass-band is 10 MHz, with a UL-DL distance of either 23.3 MHz or 42.5 MHz, depending on selected pairing option. These requirements may be challenging, but are not without precedence in 3GPP RAN4. For example, bands 8, 26, and 28 have duplexing gap of 10 MHz, band 12 has the duplexing gap of 13 MHz, and 15 MHz for band 25. The corresponding gaps for 5 MHz pass-band are 18.3 MHz (1670 - 1651.7=18.3 MHz) or 37.5 MHz (1670 – 1632.5=37.5 MHz).

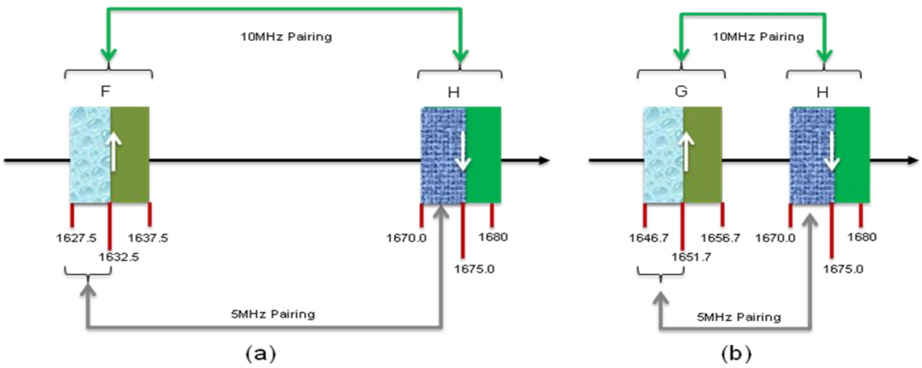

Figure 7.2: Proposed UL & DL Pairings (a) Pairing Lower UL Carrier (b) Pairing Upper UL Carrier

7.1 Co-existence with band 24

Due to the proximity of this proposed downlink spectrum with band 24 uplink (1626.5-1660.5), the co-existence issues between these two bands have to be studied. In order to manage the interference from band 24 UEs to the UEs receiving DL signal at 1670-1680 MHz, the OOBE from B24 into this downlink band needs to be reduced. If a new OOBE limit is needed for band 24 UEs to protect the receivers at this band, new Network Signaling (NS) could also be devised, potentially.

8 Study of E-UTRA specific issues

8.1 UE Special Issues for Pairing Upper UL Carrier

If the upper UL carrier is paired with the DL carrier, the UE Rx filter in the duplexer (pass-band of 1670 – 1680 MHz) has to sufficiently attenuate uplink transmissions from 1646.7-1656.7 MHz at a separation of 13.3 MHz from the downlink. The UE TX filter in the duplexer must sufficiently suppress adjacent channel emissions into the downlink band, from an emission 13.3 MHz away. This demanding rejection requirement of the duplexer might impact the insertion loss of both TX and RX filters.

To this end, some issues have to be addressed, including the followings:

1. Potential receiver desensitization (at 1670-1680 MHz) due to UL TX noise.
2. Potential device receiver overload due to its UL TX power
3. OOBE and 3rd order Intermodulation products from UL aggressor band into victim DL band (M2M case).

The same issue applies to two devices using this band in proximity (say 1- 5m separation), one receiving downlink signal in 1670-1680MHz, and another one transmitting uplink signal in 1646.7-1656.7MHz.

As a result, overload, receiver desensitization, OOBE, and duplexer design have to be studied for this band.

8.1.1 Potential receiver desensitization due to UL TX noise

Currently, the UE band 24 duplexer supports band 24 UL in the range 1626-1660 MHz. This duplexer provides a sharp edge at the left side (to protect GPS), but the isolation at 1670-1680 MHz is not significant. As a result, assuming that re-designing band 24 duplexer to be sharp at both sides is costly and complex, a new duplexer has to be designed for this proposed band. The duplexer has to support high isolation, as a practical measure, 50 dB at the Rx band 1670-1680 MHz. The feasibility of supporting 50 dB isolation is provided with low risk using simulation by credible duplexer/filter vendors using BAW/FBAR technology. Assuming this isolation value, Table 8.1.1-1 calculates the receiver desensitization, and the additional attenuation required to achieve 1 dB and 3 dB receiver desensitization, using 9 dB UE NF (Noise Figure). The UE PA OOBE attenuation is verified by evaluating the characteristics of existing band 24 PA, using 23 dBm transmit power, and 50 RBs for UL transmission.

Table 8.1.1-1: 10 MHz Receiver Desensitation for in-device isolation Pairing upper UL carrier

Parameter	Value	Unit
Max UE PA OOBE (50 PRBs), 13.3 MHz from carrier edge	-92	dBm/Hz
Duplexer isolation at 13.3 MHz from carrier edge	50	dB
Tx noise at 1670-1680 MHz	-142	dBm/Hz
Acceptable noise at the Rx carrier for 1 dB Rx desensitization	-170.9	dBm/Hz
Acceptable noise at the Rx carrier for 3 dB Rx desensitization	-165	dBm/Hz
Minimum Additional Required Isolation for 1 dB Desense.	28.9	dB
Minimum Additional Required Isolation for 3 dB Desense.	23	dB

Simulations performed at 25°C, using Film Bulk Acoustic Resonator (FBAR) filter technology process proves that the 50 dB isolation at 1670-1680 MHz is feasible, with duplexer Tx and Rx insertion loss of 1dB.

The additional isolation must be achieved either by improving the OOBE of the Tx band-pass filter, or by inserting an additional Rx band-rejection filter after the PA in the transmit chain. The former is not feasible for UEs, and the later requires dealing with potential insertion loss of this additional filters.

Table 8.1.1-2, provides the same analysis for 5 MHz UL Tx channel at 1646.7-1651.7 and DL carrier at 1670-1675 MHz. Note that the PA OOBE at 18.3 MHz away from carrier edge is obtained assuming 25.8 maximum UL Tx power.

Table 8.1.1-2: 5 MHz Receiver Desensitation for in-device isolation Pairing upper UL carrier

Parameter	Value	Unit
Max UE PA OOBE (25 PRBs), 18.3 MHz from carrier edge	-125	dBm/Hz
Duplexer isolation at 18.3 MHz from carrier edge	50	dB
Tx noise at 1670-1675 MHz	-175	dBm/Hz
Acceptable noise at the Rx carrier for 1 dB Rx desensitization	-170.9	dBm/Hz

Acceptable noise at the Rx carrier for 3 dB Rx desensitization	-165	dBm/Hz
Additional Margin for 1 dB Desense.	4.1	dB
Additional Margin for 3 dB Desense.	10	dB

As seen above, for 5 MHz channel, no additional isolation is needed, and we have 4.1 and 10 dB additional margin for 1 dB and 3 dB Rx accepted desensitization, respectively.

8.1.2 Potential device receiver overload due to its UL TX power

8.1.3 Mobile to Mobile OOBE Effect

Assuming two 10 MHz UEs using this band, one transmitting in UL (aggressor), and one receiving in the DL (victim) are in 1 meter proximity of each other, Table 8.1.3-1 provides the OOB noise from aggressor-UE transmitter at the receiver of the victim-UE. In this analysis, it is assumed that antenna and body loss is 8 dB at each UE, with maximum 23 dBm Tx power. It is assumed that the duplexer (Tx and Rx duplexer filters) provide a sum of 30 dB isolation from Tx band into Rx band.

Table 8.1.3-1: Same band 10 MHz M2M Noise, assumiung upper UL band pairing

Parameter	Value	Unit
Max UE PA OOBE (50 PRBs), 13.3 MHz from carrier edge	-92	dBm/Hz
Duplexer Tx filter attenuation at 1670-1680 MHz (worst case)	30	dB
Path Loss at 1m	36.6	dB
Minimum Coupling Loss (MCL)	52.6	dB
Tx noise at 1670-1680 MHz	-174.6	dBm/Hz
Acceptable noise at the Rx carrier for 1 dB Rx desensitization	-170.9	dBm/Hz
Acceptable noise at the Rx carrier for 3 dB Rx desensitization	-165	dBm/Hz
Additional Margin for 1 dB Desense.	3.7	dB
Additional Margin for 3 dB Desense.	9.6	dB

As seen above, for 10 MHz channel, we have 3.7 and 9.6 dB additional margin for 1 dB and 3 dB Rx accepted desensitization, respectively.

Table 8.13-2 provides the same analysis for 5 MHz UEs, where the additional margins are changed to 36.7 and 42.6 dB for 1dB and 3dB Rx accepted desensitization, respectively.

Table 8.1.3-2: Same band 5 MHz M2M Noise, assumiung upper UL band pairing

Parameter	Value	Unit
Max UE PA OOBE (25PRBs), 18.3MHz from carrier edge	-125	dBm/Hz
Duplexer Tx filter attenuation at 1670-1675 MHz (worst case)	30	dB

Path Loss at 1m	36.6	dB
Minimum Coupling Loss (MCL)	52.6	dB
Tx noise at 1670-1675 MHz	-207.6	dBm/Hz
Acceptable noise at the Rx carrier for 1 dB Rx desensitization	-170.9	dBm/Hz
Acceptable noise at the Rx carrier for 3 dB Rx desensitization	-165	dBm/Hz
Additional Margin for 1 dB Desense	36.7	dB
Additional Margin for 3 dB Desense	42.6	dB

8.2 UE Special Issues for Pairing Lower UL Carrier

If the lower UL carrier is paired with the DL carrier, the UL-DL gap is 32.5 MHz (1670 – 1637.5=32.5 MHz) for the 10 MHz carrier, and 37.5 MHz (1670 – 1632.5=37.5 MHz) for 5 MHz carrier. Consequently the duplexer design is not as critical as the case where the upper UL carrier is used. A typical 50dB TX-RX isolation would be enough to achieve the nominal expected performance. However, in this case the mobile to mobile OOBE form an aggressor UL TX UE in 1646.7-1656.7 MHz into a victim DL RX UE in 1670-1680 MHz could be problematic, and must be studied.

The rejection at 32.5 MHz away from the channel edge is -130 dBm/Hz. Considering the analysis in Table 8.1.1-1, even with 50-[-92-(-124)-28.9]=44.9 dB Tx-Rx isolation, we can achieve maximum 1dB desensitization.

For 5 MHz channel BW, the separation is 37.5 MHz. Considering the analysis in Table 8.1.1-2, even with 50-[-125-(-1323)-4.1] = 46.1 dB Tx-Rx isolation, we can achieve maximum 1dB desensitization.

8.2.1 Mobile to Mobile OOBE Effect

Assuming two 10 MHz UEs, one transmitting in UL (aggressor) at 1646.7-1656.7 MHz, and one receiving in the DL (victim) at 1670-1680 MHz, are in 1 meter proximity of each other, Table 8.2.2-1 provides the OOB noise from aggressor UE transmitter at the receiver of the victim UE. In this analysis, it is assumed that antenna and body loss is 8 dB at each UE, with maximum 23 dBm Tx power. Current band 24 duplexer does not provide any attenuation at 1670-1680 MHz. Once again, a 9dB NF is assumed at UE receiver.

Table 8.2.1-1: 10MHz M2M Noise

Parameter	Value	Unit
Max UE PA OOBE (50 PRBs), 13.3 MHz from carrier edge	-92	dBm/Hz
Duplexer Tx filter attenuation at 1670-1680 MHz (worst case)	0	dB
Path Loss at 1m	36.6	dB
Minimum Coupling Loss (MCL)	52.6	dB
Tx noise at 1670-1680 MHz	-144.6	dBm/Hz
Acceptable noise at the Rx carrier for 1 dB Rx desensitization	-170.9	dBm/Hz
Acceptable noise at the Rx carrier for 3 dB Rx desensitization	-165	dBm/Hz
Minimum Additional Required Isolation for 1 dB Desense.	26.3	dB

Minimum Additional Required Isolation for 3 dB Desense.	20.4	dB

As seen above, for 10 MHz channel, we need at least an extra 26.3 and 20.4 dB additional isolations for 1 dB and 3 dB Rx accepted desensitization, respectively. These extra isolations could be provided either by re-designing the band 24 duplexer, or adding a band rejection filter at the transmitter.

8.3 UE REFSENS

The potential impact of small duplexing gap and duplex filter design, if the upper UL carrier is paired, and the M2M OOBE if the lower carrier is paired, on UE DL Receive Sensitivity (PREFSENS) need to be analyzed.

8.4 BS TX RF filtering

The frequency separations between the uplink and downlink of the proposed pairing options are given in Table 8.4.1 below.

Table 8.4.1: Calculation of BS ACS requirement

Pairing option	Uplink (MHz)	Downlink (MHz)	Frequency separation between the uplink and downlink (MHz)
1	1627.5 - 1637.5	1670 - 1680	32.5
2	1646.7 - 1656.7	1670 - 1680	13.3

It can be seen that pairing option 2 is the more challenging BS to BS coexistence scenario where the frequency separation between the BS uplink and downlink is 13.3 MHz. To protect the BS receiver from own or different BS transmitter, the operators should ensure the following:

- The BS transmitter unwanted emissions received by the BS receiver do not cause unacceptable BS receiver desensitization.
- The total carrier power of the BS transmitter attenuated by the BS receiver RF, IF and baseband filters do not result in BS receiver blocking.

Currently, the BS spurious emissions limits for protection of the BS receiver of own or different BS is specified in 3GPP as -96 dBm/100 kHz (-86 dBm/MHz) in the UL frequency range of the BS receiver for Wide Area BS [10]. This requirement value is obtained assuming a 5 dB BS noise figure, a 30 dB BS to BS minimum coupling loss (MCL) and a 0.8 dB victim BS receiver desensitization [11]. The calculation for 5 MHz and 10 MHz channel bandwidths is shown in Table 8.4.2 below.

Table 8.4.2: Calculation of spurious emission limits for BS receiver protection

Thermal Noise power spectral density	dBm/Hz	-174	
BS noise figure	dB	5	
Channel bandwidth	MHz	5	10
Noise bandwidth	MHz	4.5	9
Receiver noise floor	dBm	-102.47	-99.46
BS Spurious emissions limits	dBm/MHz	-86	
BS-BS MCL	dB	30	

Receiver interference	dBm	-109.47	-106.46
Receiver interference + noise floor	dBm	-101.68	-98.67
Receiver sensitivity degradation	dB	0.79	0.79

Note that for BS with common transmit and receive antenna port, there may not be any considerable coupling loss between the BS transmitter and receiver, hence the 30 MCL cannot be used and the BS spurious emission limits shall be (-86 – 30 =) -116 dBm/MHz. Now if we assume the out-of-band (OOB) emission from the power amplifier (PA) is designed to meet the -13 dBm/MHz specified in 3GPP [10], then the required rejection by the BS RF transmit (TX) filter to meet the -116 dBm/MHz emission limit will be (116 – 13 =) 103 dB.

The RF filter simulation results for pairing option 1 with five metal resonators are shown in Figure 8.4.1 below. It can be seen that the required minimum rejection of 103 dB over the receive frequencies (1627.5 - 1637.5 MHz) can be achieved (with likely drift of ~100 kHz due to manufacturing and environmental variations), with an acceptable transmit passband (1670 - 1680 MHz) insertion loss of <1.0 dB (including an additional ~0.2 dB for connectors and internal transmission lines). Note that temperature-compensation and implementation margin were not included in the simulation, thus the simulation results should only be used as an approximation but not the expectation of actual products performance.

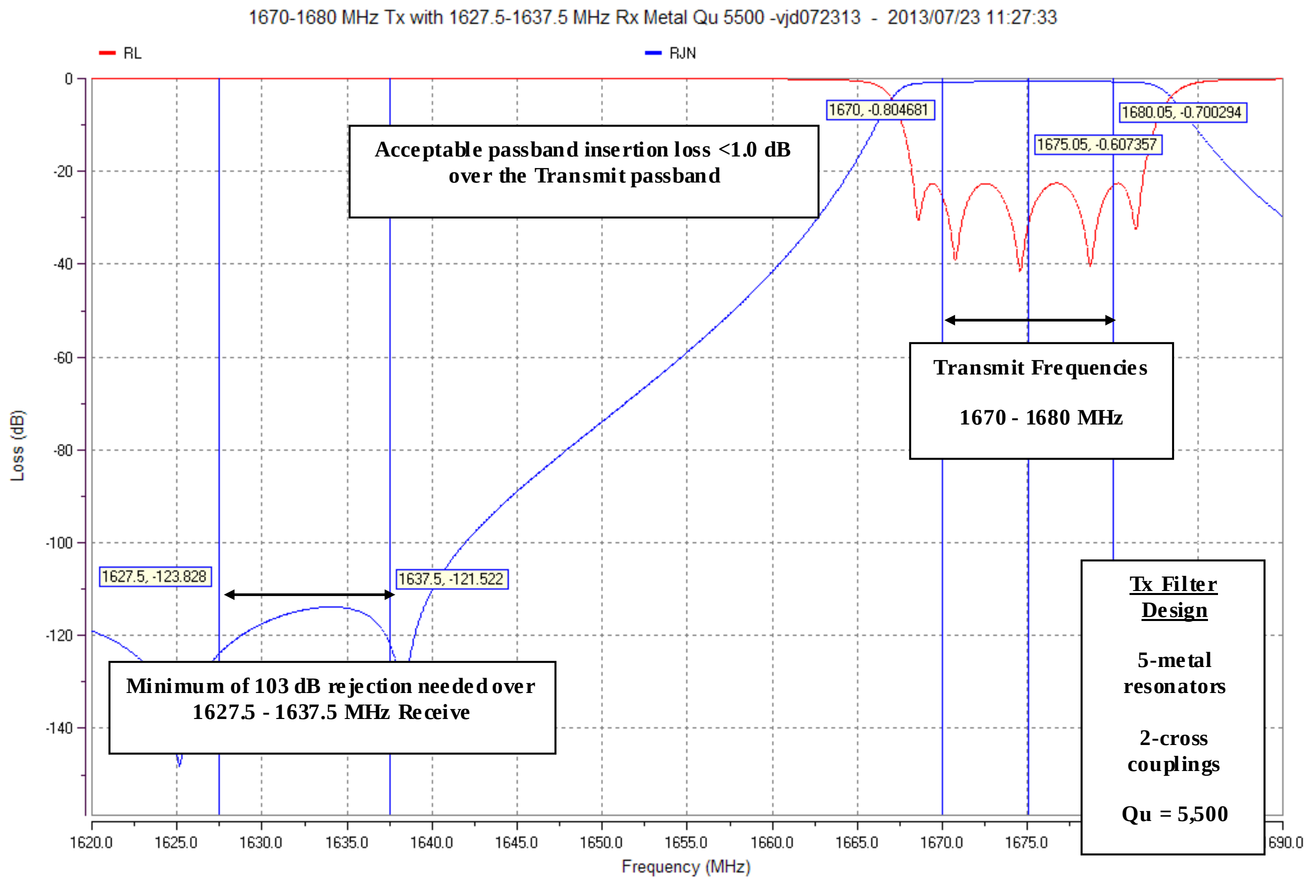

Figure 8.4.1: Simulated BS RF TX Filter Characteristics – 5 Metal Resonators

The RF filter simulation results for pairing option 2 with five metal resonators are shown in Figure 8.4.2 below. It can be seen that in order to maintain an acceptable insertion loss of ~1.0 dB over the transmit frequencies (1670 - 1680 MHz), the required minimum rejection of 103 dB over the receive frequencies (1646.7 - 1656.7 MHz) cannot be met with five metal resonators. But it can be seen that ~93 dB of rejection can be achieved (with likely drift of ~100 kHz due to manufacturing and environmental variations), and the remaining rejection can be obtained by using separate transmit and receive antenna ports to provide enough coupling loss between the transmitter and receiver. Otherwise, with 93 dB of rejection, the receiver interference will be (-13 – 93 =) -106 dBm/MHz, leading to ~5 dB receiver sensitivity degradation. Note that temperature-compensation and implementation margin were not included in the simulation, thus the simulation results should only be used as an approximation but not the expectation of actual products performance.

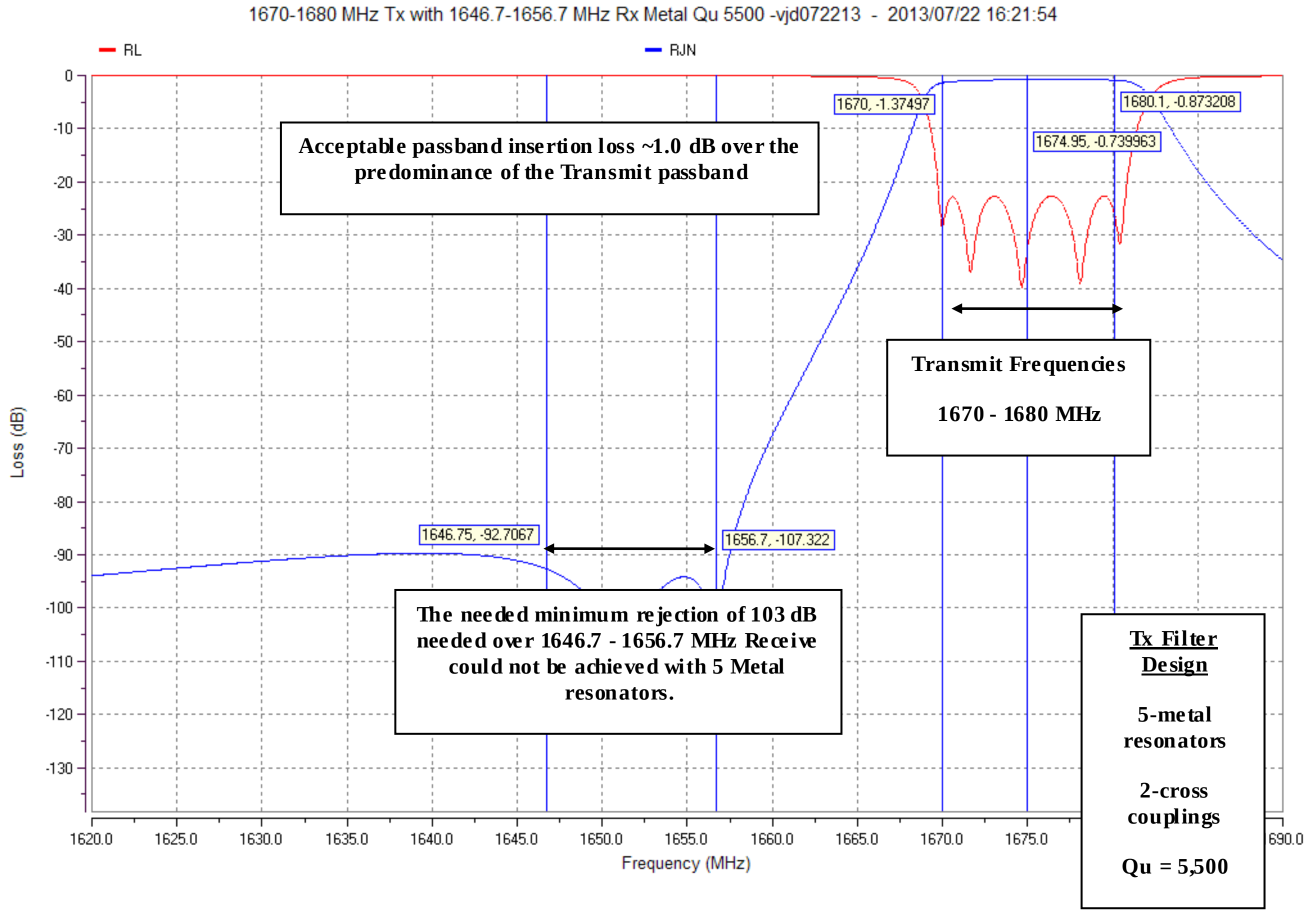

Figure 8.4.2: Simulated BS RF TX Filter Characteristics – 5 Metal Resonators

The RF filter simulation results for pairing option 2 with ceramic resonators are shown in Figure 8.4.3 below. It can be seen that using ceramic resonators, the required minimum rejection of 103 dB over the 1646.7 - 1656.7 MHz receive frequencies can be achieved (with likely drift of ~100 kHz due to manufacturing and environmental variations) with <1.0 dB insertion loss over the 1670-1680 MHz transmit frequencies (including an additional ~0.2 dB for connectors and internal transmission lines). However, it should be noted that ceramic resonators will increase the weight and cost of the RF filter. Note that temperature-compensation and implementation margin were not included in the simulation, thus the simulation results should only be used as an approximation but not the expectation of actual products performance.

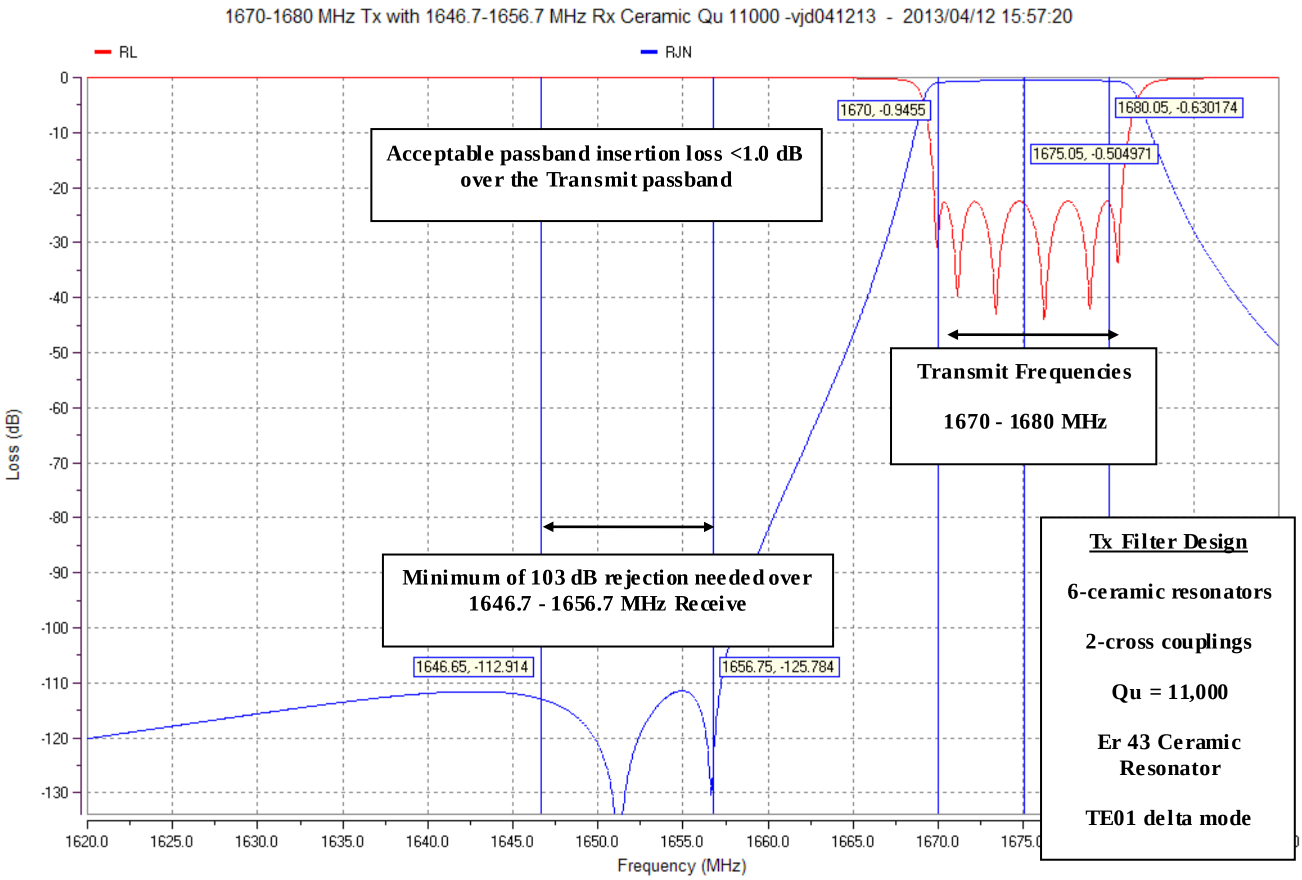

Figure 8.4.3: Simulated BS RF TX Filter Characteristics – Ceramic Resonators

To summarize, the simulation results in Figures 8.4.1 – 8.4.3 show that it could be feasible for the BS RF TX filter to provide the required rejections for pairing the 1670 - 1680 MHz downlink with either 1627.5 - 1637.5 MHz uplink or 1646.7 - 1656.7 MHz uplink. However, pairing 1670 - 1680 MHz downlink with 1646.7 - 1656.7 MHz uplink will require the use of separate transmit and receive antenna ports or ceramic resonators, with which the increase in cost, size, weight, and complexity of the filter still need to be considered.

8.5 UE Tx RF Requirements

8.5.1 UE Tx RF harmonic and IMD analysis

In Tables 8.5.1.1 and 8.5.1.2 the IMD and harmonic products for the two UL options for this proposed band are presented, respectively. These harmonics and IMD products are caused by the nonlinearities at the output of the UE transmit PA, and could potentially appear at the receiver antenna connector as spurious emission. These products will not be attenuated by the receiver filter, and could potentially pass into the receive path and desensitize the receiver

Table 8.5.1.1: UE IMD products for the two pairing options for the proposed bands

UL Pairing Options	Option 1		Option 2	
f1_low	**f1_low**	**f1_high**	**f1_low**	**f1_high**
UL frequency (MHz)	1627.5	1637.5	1646.7	1656.7
Two-tone 3rd order IMD products	|2*f1_low – f1_high|	|2*f1_high – f1_low|	|2*f1_low – f1_high|	|2*f1_high – f1_low|
IMD frequency range (MHz)	1617.5 to 1647.5		1636.7 to 1666.7	
Two-tone 3rd order IMD products	(2*f1_low + f1_high)	(2*f1_high + f1_low)	(2*f1_low + f1_high)	(2*f1_high + f1_low)
IMD frequency range (MHz)	4892.5 to 4902.5		4950.1 to 4960.1	
Two-tone 5th order IMD products	(3*f1_low – 2*f1_high)	(3*f1_high – 2*f1_low)	(3*f1_low – 2*f1_high)	(3*f1_high – 2*f1_low)
IMD frequency range (MHz)	1607.5 to 1657.5		1626.7 to 1676.7	
Two-tone 7th order IMD products	(4*f1_low – 3*f1_high)	(4*f1_high -3*f1_low)	(4*f1_low – 3*f1_high)	(4*f1_high -3*f1_low)
IMD frequency range (MHz)	1597.5 to 1667.7		1616.7 to 1686.7	

Table 8.5.1.2: UE harmonic products for the two pairing options for the proposed bands

UE UL carriers	f1_low	f1_high	f1_low	f1_high
UL frequency (MHz)	1627.5	1637.5	1646.7	1656.7
2nd order harmonics frequency range (MHz)	3255 to 3275		3293.4 to 3313.4	
3rd order harmonics frequency range (MHz)	4882.5 to 4912.5		4940.1 to 4970.1	

From Tables 8.5.1.1 and 8.5.1.2 the following impacts from IMD and harmonics from each of the two alternatives can be observed:

1. Option 1:

   a. None of the harmonics fall into either own DL or any other LTE band, which means there is no harmonic problem from this proposed band.

   b. None of the IMD products fall into own DL.

   c. The 3rd order IMD product falls into band 24 UL.

   d. The 5th order IMD product falls into the upper edge of GNSS band, with considerably low power.

   e. The 5th order IMD product falls into band 24 UL, with considerably low power.

   f. The 7th order IMD falls into GNSS band, with considerably low power.

   g. The 7th order IMD product falls into band 24 UL, with considerably low power.

2. Option 2:

   a. None of the harmonic products fall into either own DL or any other LTE band, which means there is no harmonic problem from this proposed band.

   b. The 3rd order IMD product falls into band 24 UL.

   c. The 5th order IMD product falls into own DL band, with considerably low power.

   d. The 5th order IMD falls into band 24 UL, with considerably low power.

   e. The 7th order IMD product falls into own DL band, with considerably low power.

f. The 7th order IMD falls into band 24 UL, with considerably low power.

8.5.2 Spurious emission for UE co-existence

From the UE-to-UE coexistence analysis and harmonic/IMD product analysis in this paper, Tables 8.5.2.1 and 8.5.2.2 provide the spurious emission requirements for UE-to-UE coexistence of this proposed band for the two alternative UL pairings, respectively.

Table 8.5.2.1: Spurious emission band UE co-existence of this proposed band for option 1 UL pairing

E-UTRA Band	Spurious emission						
	Protected band	**Frequency range (MHz)**			**Level (dBm)**	**Bandwidth (MHz)**	**Comment**
XX	E-UTRA Band 2, 4, 5, 10, 12, 13, 14, 17, 23, 24, 25, 26, 29, 41	F_{DL_low}	-	F_{DL_high}	-50	1	

Table 8.5.2.2: Spurious emission band UE co-existence of this proposed band for option 2 UL pairing

E-UTRA Band	Spurious emission						
	Protected band	**Frequency range (MHz)**			**Level (dBm)**	**Bandwidth (MHz)**	**Comment**
XX	E-UTRA Band 2, 4, 5, 10, 12, 13, 14, 17, 23, 24, 25, 26, 29, 41	F_{DL_low}	-	F_{DL_high}	-50	1	

8.5.3 Other expected UE Tx/Rx RF requirements

In Table 8.5.3.1, detailed descriptions on UE RF requirements are provided to predict any potential requirements changes for two pairing alternatives of this proposed band.

Table 8.5.3.1: Considering UE RF requirements for the proposed band

Clause	Description	Requirement for option 1	Requirement for option 2
6.2.2	UE Maximum Output Power	No changes are needed for power class 3.	FFS, due to the small duplex gap and Tx-Rx separation.
6.2.4	UE Maximum Output Power with additional requirements (A-MPR)	No changes are expected.	FFS. Co-existence with band 24 DL to be studied
6.6.2.2	Additional Spectrum Emission Mask	No changes are needed to protect adjacent coexistence bands, due to no IMD and harmonic with other DL bands.	No changes are needed to protect adjacent coexistence bands, due to no IMD and harmonic with other DL bands
6.6.3.2	Spurious emission band UE co-existence	Defines SE requirements as -50dBm/MHz to protect UE coexistence bands. FFS for co-existence with	Defines SE requirements as -50dBm/MHz to protect UE coexistence bands.
7.3.1	Reference sensitivity requirement	No changes are expected.	FFS, due to the small duplex gap and Tx-Rx separation
7.5, 7.6, 7.7, and 7.8	ACS, blocking, spurious, and intermod	FFS, due to proximity with band 24 UE transmitting from 1646.7-1656.7 MHz.	FFS. due to the small duplex gap and Tx-Rx separation, as well as UE-UE co-existence.

9 Study of MSR specific issues

10 Channel numbering for E-UTRA and MSR

11 Required changes to E-UTRA and MSR specifications

The required changes to the 3GPP specifications for the new band are summarised in a Table 11-1.

Table 11-1: Overview of 3GPP specifications with required changes3GPP specification	Clause in TR 30.007 where the required changes are given	Clause in the present document identifying additional changes
TS 36.101	8.2.1.1	
TS 36.104	8.2.1.2	
TS 36.106	8.2.1.3	
TS 36.113	8.2.1.4	
TS 36.124	8.2.1.5	
TS 36.133	8.2.1.6	
TS 36.141	8.2.1.7	
TS 36.143	8.2.1.8	
TS 36.307	8.2.1.9	
TS 25.101	8.2.2.1	
TS 25.102	8.2.2.2	
TS 25.104	8.2.2.3	
TS 25.105	8.2.2.4	
TS 25.106	8.2.2.5	
TS 25.113	8.2.2.6	
TS 25.123	8.2.2.7	
TS 34.124	8.2.2.8	
TS 25.133	8.2.2.9	
TS 25.141	8.2.2.10	
TS 25.142	8.2.2.11	
TS 25.143	8.2.2.12	
TS 25.307	8.2.2.13	
TS 25.331	8.2.2.14	
TS 25.461	8.2.2.15	
TS 25.466	8.2.2.16	
TS 37.104	8.2.3.1	
TS 37.113	8.2.2.2	
TS 37.141	8.2.2.3	

Annex A: Change history

Change history

Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
2013-4	RAN4#66bis	R4-131688			TR skeleton created from 3GPP TS template TR30.007.		0.0.1
2013-4	RAN4#66bis	R4-131979			Extension_LTE_FDD_1670_US_SI Regulatory requirements		0.0.1
2013-5	RAN4#67	R4-132680			TR 36.844 for FS_LTE_FDD_1670_US		0.1.1
2013-5	RAN4#67	R4-133095			FS_LTE_FDD_1670_US Specific Issues		
2013-5	RAN4#67	R4-132709			FS_LTE_FDD_1670_US UL Pairing Comparison		
2013-8	RAN4#68	R4-134087			TR 36.844 for FS_LTE_FDD_1670_US		0.2.0
2013-8	RAN4#68	R4-133375			Analysis and simulation results on BS TX RF filtering for 1670-1680MHz Band		
2013-8	RAN4#68	R4-134098			Evaluation of UE RF requirements using IMD and harmonic analysis for FS_LTE_FDD_1670_US		
2013-8	RAN4#68	R4-134xxx			TR 36.844 for FS_LTE_FDD_1670_US		0.3.0