Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and	)	ET Docket No. 14-165
	)	
Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap	)	
	)	
Promoting Spectrum Access for Wireless Microphone Operations	)	GN Docket No. 14-166
	)	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	)	GN Docket No. 12-268

COMMENTS OF CTIA – THE WIRELESS ASSOCIATION®

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February 4, 2015

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COMMENTS OF CTIA – THE WIRELESS ASSOCIATION®

CTIA – The Wireless Association® ("CTIA") hereby responds to the Commission's two Notices of Proposed Rulemaking seeking comment on issues related to unlicensed white space device and wireless microphone operations impacted by the Commission's upcoming broadcast television incentive auction.[1] In these comments, CTIA explains that, while there is room in the

[1] First, in a Notice of Proposed Rulemaking ("*Unlicensed NPRM*"), the Commission seeks comment on proposed rules for unlicensed operation of white space devices and wireless microphones in the reconstituted TV bands and the repurposed 600 MHz band after the incentive auction. *Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600MHz Duplex Gap,* Notice of Proposed Rulemaking, FCC 14-144, at ¶ 2 (Sept. 30, 2014) ("*Unlicensed NPRM*"). Second, in a concurrently-released Notice of Proposed Rulemaking ("*Wireless Microphones NPRM*"), the Commission examines wireless microphone users' needs and technologies that can address them, and seeks comment on a variety of existing and new spectrum bands that might accommodate

600 MHz band for both licensed wireless services and unlicensed operations, the Spectrum Act makes clear that unlicensed uses may only be permitted to the extent that they do not "cause interference to licensed operations."[2] To determine the interference potential of white space devices and wireless microphones operating in the duplex gap and guard band, CTIA and its members commissioned V-COMM to test interference from these sources to mobile broadband devices. The objective of this testing was to develop a framework for unlicensed operation in these bands that would ensure the protection of licensed services from interference.

Accordingly, CTIA urges the Commission to:

- Modify its proposed rules for unlicensed and wireless microphones operations to ensure compliance with the Spectrum Act's mandate that unlicensed operations adequately protect the substantial investments of 600 MHz licensees;
- Adopt out of band emissions requirements and buffers in the duplex gap and guard bands consistent with the findings of CTIA's test vendor V-COMM and CTIA's proposal included herein;
- Require unlicensed operations to cease use of licensed spectrum in areas where a 600 MHz licensee has commenced service;
- Explore additional spectrum bands for use by unlicensed and wireless microphone operations, consistent with the comments below; and
- Expedite the transition for wireless microphone operations in the 600 MHz band to reflect the rapid pace of mobile broadband growth and deployment.

CTIA submits that these changes will be necessary to create a 600 MHz spectrum ecosystem that maximizes the availability of licensed wireless services, protects those licensed services from

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those uses. *Promoting Spectrum Access for Wireless Microphone Operations*, Notice of Proposed Rulemaking, FCC 14-145, ¶ 4 (Sept. 30, 2014) ("*Wireless Microphones NPRM*"). Because the *Unlicensed NPRM* and *Wireless Microphones NPRM* implicate many of the same issues, and because there is significant overlap in CTIA's responses, CTIA is filing a single set of comments in response to both Notices.

[2] Middle Class Tax Relief and Job Creation Act of 2012, Pub. L. No. 112-96, § 6407(e) (codified at 47 USC §1452), 126 Stat. 156 (2012) ("Spectrum Act").

interference, and makes available spectrum for unlicensed uses, consistent with the Spectrum Act.

I. INTRODUCTION AND EXECUTIVE SUMMARY

CTIA strongly supports the efforts of Congress and the Commission to make available additional spectrum through the incentive auction provisions of the Middle Class Tax Relief and Job Creation Act of 2012 ("Spectrum Act"). That landmark legislation provides a path for repurposing television broadcast spectrum for licensed commercial mobile use through the mechanism of an incentive auction. When Congress passed the Spectrum Act, it recognized the complex relationship between new 600 MHz licensed mobile services and 600 MHz spectrum incumbents, including unlicensed white space devices and wireless microphones. The Spectrum Act allows unlicensed services to operate in the post-auction duplex gap and guard bands, provided that such unlicensed use "would not cause harmful interference to licensed services."[3]

CTIA supports rules that maximize the repurposing of spectrum for licensed exclusive use in the 600 MHz band and provide for unlicensed use of the 600 MHz guard band[4] and duplex gap, consistent with the Spectrum Act's requirements. In recent proceedings, CTIA has been a strong supporter of allocating additional spectrum for unlicensed operations.[5] In accordance with the Spectrum Act, however, unlicensed operations in the 600 MHz guard band and duplex

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[3] *Id.*

[4] In these comments, CTIA uses the term "guard band" to refer to the guard band at the lower end of the 600 MHz downlink spectrum that separates this spectrum from the TV band. As the Commission notes, there are three possibilities for the size of this guard band: 11 megahertz, 9 megahertz, and 7 megahertz. *Unlicensed NPRM* at ¶ 78.

[5] *See, e.g.*, Letter from Scott K. Bergmann, CTIA to Marlene H. Dortch, FCC, GN Docket No. 03-185 and WT Docket No. 13-49 (March 24, 2014) (supporting the Commission's efforts to make 100 megahertz of unlicensed spectrum in the 5 GHz U-NII band more useful for consumers and businesses).

gap can only be introduced under a regulatory framework that ensures that such operations do not raise interference concerns.

In light of the Spectrum Act's spectrum objectives, it is critical that the Commission proceed with a clear understanding of the interference environment in the 600 MHz band. For this reason CTIA and its members commissioned V-COMM to test mobile broadband devices to gauge the impact of unlicensed white spaces devices and wireless microphones in the 600 MHz duplex gap and guard bands. The objective of V-COMM's testing was to build a framework for unlicensed operation in these bands that would ensure the protection of licensed services from interference. As explained in these comments, the interference testing performed by V-COMM is based on reasonable, explicit technical assumptions required to protect future licensed spectrum from harmful interference and consistent with wireless industry standard practices.

As the Commission considers rules for the 600 MHz band, it should carefully consider V-COMM's findings and modify its proposed unlicensed technical rules to ensure compliance with the Spectrum Act's mandate that unlicensed operations adequately protect the considerable investments of future 600 MHz band licensees. In such regards, V-COMM found:

- **More Stringent OOBE Requirements Are Needed.** The V-COMM testing determined that the predominant interference effect from both wireless microphones and white space devices is out of band emissions ("OOBE"). The tests showed that OOBE interference, unless sufficiently attenuated, would limit the capabilities of affected licensed 600 MHz services. V-COMM found that to prevent harmful interference to licensed wireless services, OOBE from both white space devices and wireless microphones will need to be attenuated much more (32 dB more) than proposed in the *Unlicensed NPRM*. V-COMM's testing also showed that if white space devices or wireless microphones are permitted to operate at the proposed OOBE limit, LTE devices will suffer harmful interference as much as 20 meters away.

- **Assuming that the Commission Adopts Stricter OOBE Limits, the Proposed Five Megahertz Buffer is Sufficient to Protect Licensed Operations from Overload or Blocking Interference from White Space Devices in the Duplex Gap.** Assuming that the Commission adopts the much more stringent OOBE

limits discussed above, the V-COMM testing indicates that the FCC's proposed power limits (40 milliwatts or 16 dBm) would be sufficient to protect 600 MHz licensed operations from unlicensed white space devices operating in the duplex gap, as long as a five megahertz buffer is maintained between the white space device and licensed downlink spectrum.

- **A Five Megahertz Buffer is Also Required for Wireless Microphones in the Duplex Gap, in Addition to the More Stringent OOBE Limit.** V-COMM's testing demonstrates that, under the Commission's proposed band plan, wireless microphone operations in the duplex gap will present harmful interference to licensed systems unless the power levels are reduced substantially (*i.e*., below current power levels for wireless microphones). The V-COMM results indicate that wireless microphones require a five megahertz buffer from licensed downlink spectrum (like unlicensed white space devices) to operate in the duplex gap without harmful interference to licensed 600 MHz operations at the FCC proposed power levels (20 milliwatts or 13 dBm). As explained below, this will require alterations to the Commission's proposed band plan, and in particular to its framework for duplex gap operation.

- **In the Guard Band, In Addition to Stricter OOBE Limits, Buffers are Required to Protect Licensed 600 MHz Operations from Interference Caused by White Space Devices and Wireless Microphones.** The V-COMM results show that when wireless microphones are operating at the FCC's proposed power levels, even with the more stringent OOBE requirements listed herein, a buffer of nine megahertz is required on the guard band side of the licensed 600 MHz downlink band. The V-COMM testing further determined that white space devices in the guard band, even with the more stringent OOBE requirements listed herein and a lower power limit (5 milliwatts or 6.6 dBm), will need a five megahertz buffer to prevent harmful interference to licensed 600 MHz downlink operations.

V-COMM's tests were based on assumptions that are fully compliant with the interference protection requirements used by wireless industry standard practices for ensuring protection from harmful interference from other services outside licensed wireless bands. To that end, CTIA notes that several of the Commission's assumptions in modeling white space devices and wireless microphones – assumptions that, if applied, would likely result in harmful interference – require adjustment.

- First, CTIA notes that the *Unlicensed NPRM* provides an incomplete record of technical information needed to determine that the proposed rules would "fully protect" licensed 600 MHz operations from interference in accordance with the Spectrum Act.

- Second, CTIA believes that the propagation model used in the *Unlicensed NPRM* to determine separation distances is not well-suited to modeling the interference environment in the 600 MHz band, and the Commission has not properly applied a number of technical factors when calculating these required separation distances. CTIA believes that the FCC should instead use the Longley-Rice propagation model that it has employed in other similar circumstances.

- Third, CTIA notes that the Commission has been more cautious seeking to protect broadcast television stations from new 600 MHz wireless licensees than it has proposed to protect wireless licensees from white space devices and other unlicensed devices. CTIA submits that the Commission should be consistent in the level of interference protection it provides to primary licensed operations in the 600 MHz band.

In addition to providing a summary of V-COMM's testing, these comments provide input on several other issues raised by the Commission in the *Unlicensed NPRM* and *Wireless Microphones NPRM*. In particular:

- CTIA strongly opposes the proposal to permit unlicensed white space devices to use licensed 600 MHz spectrum after licensees have initiated operations in their licensed service areas.

- In light of the restrictions that must be placed on white space devices and wireless microphones in the 600 MHz spectrum to comply with the Spectrum Act, the Commission should focus on alternative spectrum bands for *both* wireless microphones and unlicensed devices. CTIA supports additional exploration in this area, but opposes the placement of these devices in certain bands identified in the *Wireless Microphones NPRM*, as they are more suitable for other purposes, including the provision of licensed mobile broadband services.

- CTIA believes that the proposed transition plans for wireless microphone operations should be expedited further to allow for use of the 600 MHz spectrum for licensed mobile broadband services in a more rapid fashion.

By taking the actions proposed by CTIA in these comments, CTIA believes that the Commission can foster a diverse 600 MHz spectrum ecosystem that complies with the Spectrum Act and places an appropriate priority on licensed wireless services.

II. CTIA AND ITS MEMBERS COMMISSIONED TESTING OF HARMFUL INTERFERENCE EFFECTS FROM UNLICENSED WHITE SPACE DEVICES AND WIRELESS MICROPHONES IN THE 600 MHZ BAND.

In light of the Commission's observation that "there is a lack of real world testing between white space transmitters and LTE receivers" and the Commission's invitation "to submit data and test results relevant to the record in this proceeding,"[6] CTIA and its members commissioned V-COMM to test LTE mobile device receivers and simulated interference from unlicensed white space devices and wireless microphones. As explained further below, the goal of this testing was to determine the appropriate power and emissions limits at which unlicensed white space devices and wireless microphones could operate without causing interference to licensed 600 MHz operators. By testing wireless devices that were the closest possible representation of 600 MHz receivers, and by simulating the technical parameters of white space devices and wireless microphones based on the Commission's technical parameters for those operations, V-COMM was able to conduct a variety of tests that emulate real world conditions.

About V-COMM. V-COMM, incorporated in 1995, is a leading provider of wireless engineering consulting services.[7] V-COMM has extensive experience in analyzing interference in various spectrum bands including Cellular, SMR, PCS, AWS, air-to-ground, public safety, 600 MHz, and 700 MHz.[8] V-COMM's engineers have considerable experience in all commercial wireless technologies, including LTE. V-COMM has studied interference issues for

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[6] *Unlicensed NPRM* at ¶ 82.

[7] V-COMM, "Company History," *at* http://www.vcomm-eng.com/company-history/; V-COMM Telecommunications Engineering, "Wireless Microphone and TVWS in 600 MHz Duplex Gap and Guard Band Test Results with LTE Devices" at 101 (Feb. 4, 2015) ("Test Report") (attached as Appendix B).

[8] Test Report at 101.

many spectrum licensees and other interested parties in numerous Commission proceedings.[9] By leveraging the experience of V-COMM's engineers, CTIA is able to provide a thorough overview of the potential interference environment between 600 MHz devices and unlicensed wireless microphones/white space devices.

Devices Tested. Because there are currently no existing 600 MHz LTE devices, the V-COMM testing used LTE devices operating in the 3GPP LTE Band 12 (699-716 MHz and 729-746 MHz). Band 12 was chosen to be representative of the 600 MHz spectrum, as it is the closest in operating frequency range, has a similar duplex gap (13 MHz as compared to 11 MHz), and has many devices that are commercially available for testing.[10] V-COMM tested a total of 10 commercial Band 12 LTE devices: eight smartphones and two tablets from four different device manufacturers.[11] Prior to commencing the interference testing, each LTE device was tested to ensure compliance with 3GPP receive sensitivity specifications.[12]

Interference Sources. The testing could not use actual white space devices or wireless microphones, as none exist that comply with the FCC's proposed technical parameters. Instead, the impact of white space devices and wireless microphones was simulated using the technical proposals by the Commission for their operations in the 600 MHz band. Wireless microphone interference was simulated by a two-tone FM modulated signal, using a frequency of 1 kHz at the rated deviation of 40 kHz, with the pilot frequency of 32.768 kHz at a 5 kHz deviation.[13] TV

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9 *Id.*

10 *Id.* at 3.

11 *Id.* at 4.

12 *Id.*

13 *Id.* at 5.

white space device interference was simulated by using an 802.11ac signal, using the sample rate parameter setting to achieve an occupied bandwidth of 4.875 MHz.[14] OOBE interference was simulated by additive white Gaussian noise ("AWGN") signals transmitted co-channel to the LTE device under test.[15]

Testing Scenarios. V-COMM conducted four types of tests. First, V-COMM tested all ten of the "devices under test" to ensure their compliance with 3GPP receive sensitivity specifications (all devices were compliant) and to determine a benchmark to be used to measure protections to LTE devices. Second, receiver blocking tests were performed with the LTE Band 12 devices to determine the rejection of the LTE devices to the interference sources (white space devices and wireless microphones). Third, tests were completed to determine the intermodulation rejection of the LTE devices from white space devices and wireless microphones. Fourth, and finally, OOBE receiver tests were used to determine the rejection of the LTE devices to emissions from adjacent band devices (in this case, white space devices and wireless microphones).

Interference Assumptions for Path Loss. In analysis of its testing, V-COMM used reasonable and conservative technical assumptions and parameters that are consistent with those used by wireless industry standard practices. In particular, V-COMM used the following assumptions for link/path losses:

- Device and user equipment antenna gain = 0 dBi
- Transmitter device antenna loss = 3 dB (held in hand)
- Receiver user equipment antenna loss = 3 dB (held in hand)

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14 *Id.*

15 *Id.*

- Antenna Polarization Mismatch and other losses = 3 dB
- Path loss at 665 MHz = 29 dB[16]

Summing these path losses, V-COMM applied a 38 dB (3 dB + 3 dB + 3 dB + 29 dB) coupling loss to model the interference environment where a licensed LTE device would be 1 meter away from a white space device or wireless microphone.[17] Assuming the FCC proposed power levels of 16 dBm for a white space device and 13 dBm for a wireless microphone therefore results in the following:

- The TV white space device interference level received at an LTE device one meter away is -22 dBm (16 dBm – 38 dB = -22 dBm) and
- The wireless microphone interference level received at an LTE device one meter away is -25 dBm (13 dBm – 38 dB = -25 dBm).[18]

Testing Interference Thresholds. The test results discussed in these comments capture the impact to the LTE devices under test at a 1 dB desensitization ("desense") interference threshold, which represents the increase in the noise floor of the LTE devices under test due to wireless microphone or white space device interference.[19] Increases in device noise floors degrade and negatively impact the device's forward link budget, which reduces the downlink system coverage and the performance of nearby LTE devices.[20] Using a 1 dB desense threshold will ensure that the forward link budget of affected LTE systems is maintained and performance

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16 *Id.* at 9-10.

17 *Id.*

18 *Id.*

19 *Id.* at 4. In addition to the 1 dB desense threshold testing, V-COMM also conducted testing at the 3 dB desense threshold. CTIA has also provided these test results to the Commission as additional data for consideration, but would note that the 1 dB desense threshold testing is the relevant benchmark for protecting licensed services from harmful interference.

20 *Id.*

of the licensed system is not degraded by white space devices or wireless microphones operating in the 600 MHz band.

Complete Test Plan and Test Results. The complete testing plan and parameters can be found at Appendix A to these comments, and contain additional details on the testing setup and methodology utilized. The results of the testing performed by V-COMM are provided at Appendix B. This test report provides the data on the actual results of real world devices and the interference effects from unlicensed white space devices and wireless microphones in the duplex gap and guard bands. In these comments, CTIA provides an overview of the V-COMM report's conclusions and discusses their impact on potential rules governing wireless microphone and white space device operation in the 600 MHz band. In particular, the OOBE and receiver blocking tests are discussed in more detail in Sections III and IV of these comments.[21]

III. DUPLEX GAP: V-COMM'S TESTING DEMONSTRATED THAT UNLESS THE COMMISSION'S TECHNICAL PROPOSALS ARE SUBSTANTIALLY MODIFIED, UNLICENSED WHITE SPACE DEVICES AND WIRELESS MICROPHONES IN THE DUPLEX GAP WILL CAUSE HARMFUL INTERFERENCE TO LICENSED LTE DEVICES.

The V-COMM test results demonstrate that without significant modifications to the Commission's technical proposals, unlicensed white space devices and wireless microphones operating in the 600 MHz duplex gap will cause harmful interference to LTE devices. For this reason, CTIA submits that the V-COMM testing requires that the Commission adopt more stringent OOBE limits, as well as a larger frequency buffer between licensed operations and

[21] These comments do not address in additional detail the intermodulation tests that were performed by V-COMM. As out of band emissions and receiver blocking were the predominant causes for the required frequency separation and power control, CTIA has focused on providing a detailed overview of those results in these comments. However, intermodulation interference was tested and found to contribute to the interference environment. Those testing results are therefore provided for the Commission to consider as part of its deliberations to protect licensed 600 MHz operations.

wireless microphones operating in the duplex gap, to comply with its mandate in the Spectrum Act.

In the *Unlicensed NPRM*, the Commission has proposed that unlicensed white space devices and wireless microphones be permitted to operate in the 600 MHz duplex gap.[22] The duplex gap is the guard band between the 600 MHz licensed downlinks (base station transmission) and uplinks (mobile station transmissions). While the precise location of the duplex gap is currently unknown and will be contingent on the outcome of the incentive auction, the Commission has adopted a requirement that the duplex gap be 11 megahertz wide.[23] As explained further below, the Commission's proposed use of the duplex gap, together with the proposed technical rules for unlicensed white space devices and wireless microphones, creates a significant interference problem that must be redressed by the Commission to comply with the Spectrum Act.

A. To Protect 600 MHz LTE User Equipment, Out of Band Emissions From Unlicensed White Space Devices and Wireless Microphones Need to be Significantly Attenuated.

The V-COMM test results indicated that OOBE from both unlicensed white space devices and wireless microphones will need to be attenuated significantly more than proposed in the *Unlicensed NPRM*. OOBE are a significant concern to licensed 600 MHz operators because OOBE interference is *co-channel.* Unlike receiver blocking or adjacent channel interference, 600 MHz licensees are unable to filter out OOBE because it is in the frequency range that they are intending to receive. As such, it is critical that such interference be mitigated by the

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22 *Unlicensed NPRM* at ¶¶ 91, 158.

23 *Id.* at ¶ 8.

Commission's technical rules to ensure that licensees are not faced with interference that cannot be alleviated by filtering or other technical means.

The V-COMM testing found that the proposed OOBE limit (-56.8 dBm/100 kHz) would cause 26 dB of desensitization to LTE devices within one meter of a white space device or wireless microphone.[24] This level of interference would significantly degrade LTE service and would impair coverage and performance for all LTE devices in the area.[25] All other analyses of the 600 MHz band interference environment in these comments are predicated on the Commission mandating these more stringent OOBE limits. Should the Commission reject the findings of the V-COMM testing and not adopt the OOBE protections assumed herein, the V-COMM testing would indicate that the buffers and other technical rules would require modification from the proposals recommended by CTIA in the following sections of these comments.

Measurement of Out of Band Emission Protection Requirement. V-COMM evaluated ten sample devices and determined that on average, the additive white Gaussian noise ("AWGN") interference level was at -127 dBm/100 kHz.[26] Based on the above-calculated coupling losses from white space devices/wireless microphones to LTE user equipment (38 dB),[27] an OOBE limit of -89 dBm/100 kHz into 600 MHz downlink spectrum is required.[28]

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[24] Test Report at 82.

[25] *Id.*

[26] Test Report at 75, 82. V-COMM evaluated the interference susceptibility of LTE devices at the tested devices' actual sensitivity level instead of at the standards set levels to better model real world effects of interference from adjacent white space devices and wireless microphones to actual LTE devices.

[27] *See* Section II, *supra.*

[28] Test Report at 82.

However, the Commission has proposed OOBE limits of -56.8 dBm/100 kHz for white space devices and wireless microphones operating in the duplex gap and guard band spectrum.[29] This OOBE limit would cause approximately 26 dB of desensitization to LTE devices at a separation distance of 1 meter.[30] This is a significant level of interference that substantially degrades LTE service and impairs coverage and performance for all LTE devices within the area.[31] Figure 1 below provides a representation of the additional attenuation needed to protect licensed services in the 600 MHz band from white space devices and wireless microphones.

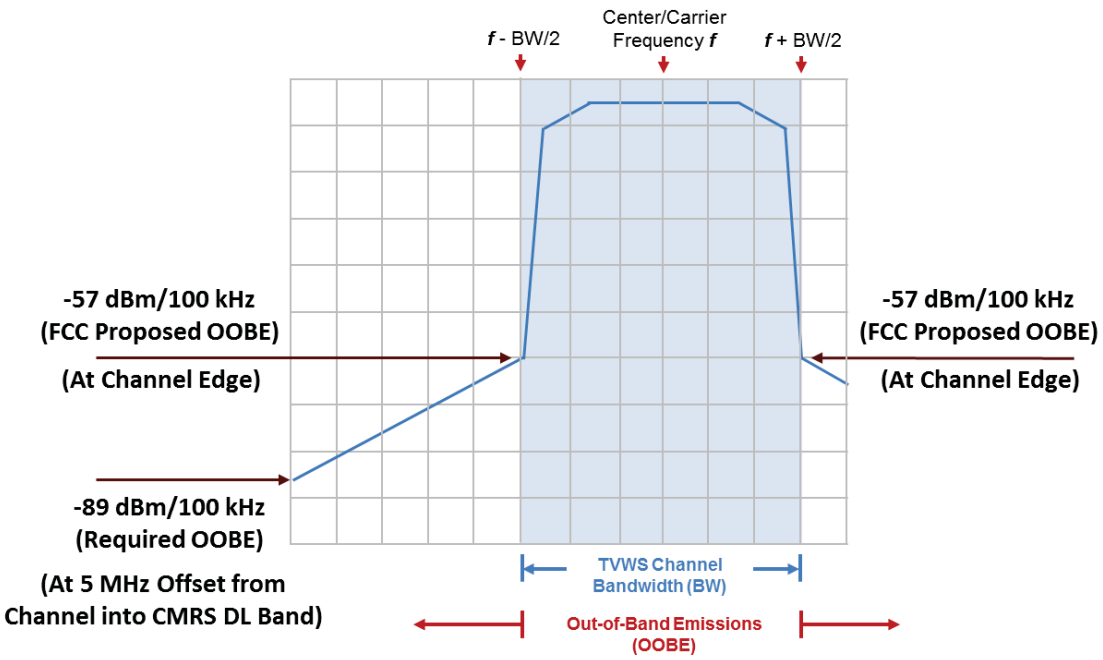

Figure 1: Required OOBE to Protect Licensed Operations

CTIA recognizes that this proposed OOBE limit is rigorous, but this standard is necessary and achievable for two reasons. First, the characteristics of 600 MHz spectrum dictate that OOBE limits be more stringent than in other spectrum bands. Propagation in 600 MHz spectrum

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29 *Unlicensed NPRM*, proposed 47 C.F.R. § 15.709(c)(ii).

30 Test Report at 82.

31 *Id.*

is approximately 9-10 dB better than propagation at the AWS and PCS mid-band frequencies.[32] As a result, more attenuation in this spectrum band is required than for higher band spectrum.[33] Second, the frequency buffer dictated by receiver blocking interference considerations (as discussed in detail below and shown in Figure 1 above) will help enable compliance with this limit. As explained below, receiver blocking issues dictate that there is at least a five megahertz frequency buffer between licensed 600 MHz downlink spectrum and unlicensed white space devices/wireless microphones. OOBE limits for these devices will be set at the band edge, which is more than five megahertz away from where white space devices and wireless microphones must reduce their emissions. At five megahertz away, the OOBE from white space devices and wireless microphones will likely be at lower levels (*i.e.*, approximately 12 dB lower due to the five megahertz separation between LTE receiver spectrum and white space device/wireless microphone transmission).[34] This will allow filtering of OOBE from white space devices and wireless microphones to more gracefully attenuate to meet these strict – and critically important – OOBE requirements.[35]

B. The Proposed Use of the Duplex Gap Would Result in Harmful Interference to Licensed Devices in the 600 MHz Band.

V-COMM's testing revealed that the proposed division of the duplex gap for wireless microphone and white space device use, combined with the proposed technical rules for these devices, will result in harmful interference to 600 MHz licensed downlink operations. To protect

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32 *Id.* at 97.

33 *Id.*

34 *Id.*

35 The additional 20 dB of attenuation needed to comply with the -89 dBm/100 kHz OOBE limit could be achieved using SAW filter technology. Test Report at 97.

600 MHz licensed downlink operations from interference, additional technical protections and frequency separation must be provided. Therefore, CTIA offers an alternative framework for the duplex gap that it believes will allow white space devices and wireless microphones to operate without causing harmful interference to licensed 600 MHz operation.

The Proposed Use of the Duplex Gap. The *Unlicensed NPRM* has proposed to divide the duplex gap into three segments. This proposal has been referred to as the "1-4-6 megahertz split"[36] and is depicted in Figure 2 below.

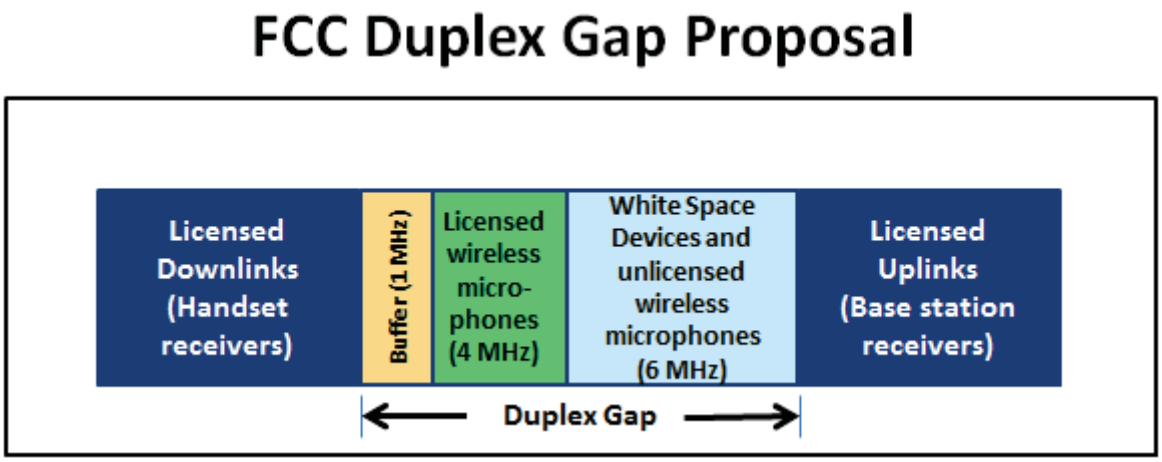

Figure 2: FCC Proposal for Operations in the Duplex Gap

Under the 1-4-6 megahertz split, a frequency separation of one megahertz would be provided immediately adjacent to the 600 MHz licensed downlink spectrum.[37] This buffer may not be used by any unlicensed white space devices or wireless microphones.[38] Immediately adjacent to the one megahertz frequency buffer would be a four megahertz segment for licensed wireless microphones only.[39] The six megahertz band segment at the upper end of the duplex

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36 *Unlicensed NPRM* at ¶ 94.

37 *Id.* at ¶ 92.

38 *Id.*

39 *Id.*

gap would then be made available for both unlicensed white space devices and unlicensed wireless microphones.[40]

V-COMM Analysis of the 1-4-6 Megahertz Split and Testing Parameters. V-COMM conducted receiver blocking interference tests in the duplex gap, based on the technical parameters proposed for the 1-4-6 megahertz split of the guard band. Receiver blocking interference occurs when an off-frequency signal causes the signal of interest – in this case, the licensed 600 MHz wireless receive signal – to be suppressed. As noted in Section II above, V-COMM determined that at 1 meter separation, harmful interference will occur from a white space device at the received interference levels below -22 dBm and from a wireless microphone at the received interference levels below -25 dBm.[41] These numbers are derived by subtracting the total device-to-LTE coupling losses (38 dB) from the transmit power level of the unlicensed device (16 and 13 dBm for white space devices and wireless microphones, respectively).[42] As explained above, the test results discussed below are based on a 1 dB desense interference threshold.[43]

V-COMM Results – Receiver Blocking in the Duplex Gap. As shown in Appendix B, none of the ten tested devices were able to meet the -25 dBm threshold for interference from a wireless microphone using only a one or three megahertz frequency buffer.[44] A summary of the

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40 *Id.*

41 Test Report at 9-10.

42 Test Report at 9.

43 *See* Section II, *supra.*

44 Test Report at 15-16.

overall test results from V-COMM for receiver blocking in the duplex gap at the 1 dB desense threshold is shown in Figure 3 below:

Average DUT Results, 1 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
Wireless Microphone @ 727.9 MHz	1	-51.5	21.4	-13.5
Wireless Microphone @ 725.9 MHz	3	-42.5	7.6	-4.5
Wireless Microphone @ 723.9 MHz	5	-26.0	1.1	12.0
Wireless Microphone @ 721.9 MHz	7	-8.9	0.2	29.1
Wireless Microphone @ 719.9 MHz	9	-0.4	0.1	37.6
TV White Space Device @ 721 MHz	5	-17.9	0.6	20.1

Figure 3: V-COMM Results for Receiver Blocking in the Duplex Gap

With a five megahertz buffer, the average interference level from a wireless microphone was -26 dBm, approximately meeting the protection criteria (would protect an LTE device that is 1.1 meter away from the wireless microphone).[45] As for white space devices, 7 of the 10 devices tested were able meet the -22 dBm threshold for interference with a five megahertz buffer, with an average interference level of -17.9 dBm (would protect an LTE device up to 0.6 meters away).[46] V-COMM's testing determined that any wireless microphone operating less than five megahertz away from the licensed downlink band would need to have extremely low transmitted power (less than 1 milliwatt) to protect 600 MHz handset receivers from receiver blocking.[47] Any wireless microphone operating at the Commission's proposed power levels less than five megahertz away from the licensed downlink band would cause interference to LTE devices within 21 meters.[48]

CTIA Alternative Proposal for the Duplex Gap. As noted above, a five megahertz buffer from licensed downlinks in the 600 MHz band to both wireless microphones and

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45 *Id.* at 17.

46 *Id.* at 20, 76.

47 *Id.* at 76.

48 *Id.*

unlicensed white space devices is needed to prevent harmful interference between these uses of the band. The Commission's proposal, however, only proposes a one megahertz frequency buffer between licensed downlink spectrum and licensed wireless microphones, which would not protect licensed 600 MHz operators from harmful interference. For this reason, CTIA submits that the Commission should divide the duplex gap into two portions: a five megahertz frequency buffer (a true guard band) and a six megahertz block where unlicensed white space devices and wireless microphones may operate subject to the additional OOBE limitations discussed above. CTIA's proposal is depicted in Figure 4 below.

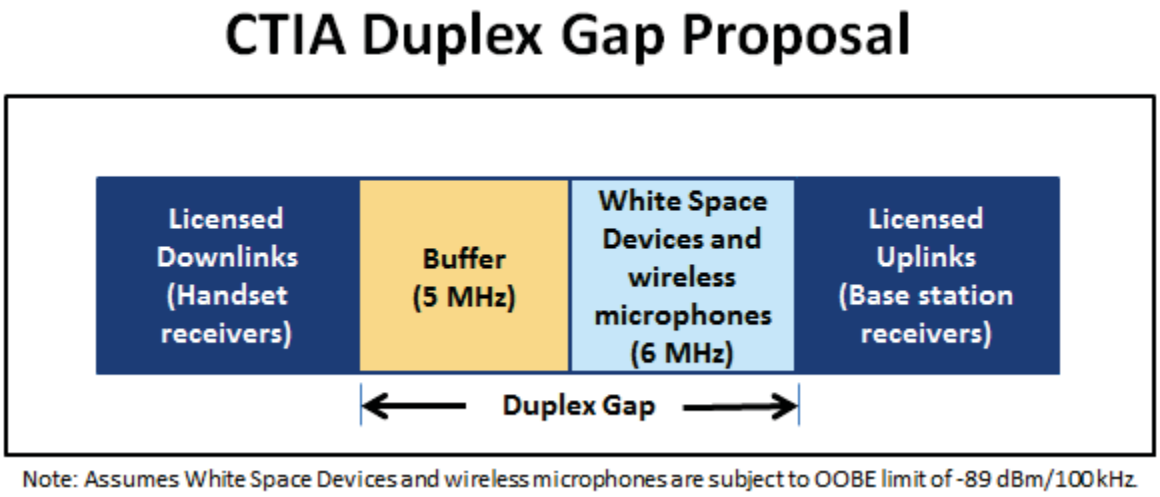

Figure 4: Proposed Alternative Division of the Duplex Gap

As the V-COMM testing data shows, the FCC proposal (if adopted) would allow harmful interference from licensed wireless microphones that are more than 21 meters away from licensed LTE devices. To put this into perspective, 21 meters is approximately 69 feet. A standard basketball court is 50 feet wide – so a wireless microphone on the opposite side of a basketball court could still cause harmful interference to a licensed LTE device under the 1-4-6 duplex gap proposal. CTIA therefore submits that in light of V-COMM's finding regarding harmful interference caused by wireless microphone and white space device operations in the

duplex gap, the modified duplex gap proposal submitted by CTIA is necessary to comply with the Spectrum Act's mandate that unlicensed 600 MHz operations not "cause interference to licensed services."[49]

IV. GUARD BAND: V-COMM'S TESTING DEMONSTRATED THAT USE OF THE GUARD BAND SPECTRUM MUST BE CAREFULLY-DESIGNED WITH TIGHTLY-PRESCRIBED PARAMETERS TO PREVENT HARMFUL INTERFERENCE TO LICENSEES OF THE 600 MHZ BAND.

The V-COMM test results also demonstrate that use of the guard band spectrum – the guard band between licensed 600 MHz downlinks and television broadcasters - by unlicensed white space devices and wireless microphones will need to be extremely limited to prevent harmful interference to licensed 600 MHz downlinks. CTIA therefore asks that the Commission, based on V-COMM's conclusions, take several steps to protect licensed 600 MHz downlinks from harmful interference from unlicensed devices in the guard band. First, just as in the duplex gap scenario outlined above, the Commission should adopt the more stringent -89 dBm/100 kHz OOBE limit for unlicensed white space devices and wireless microphones to protect 600 MHz mobile downlink spectrum. Second, the Commission should require a frequency buffer of nine megahertz between wireless microphones operating at the FCC's proposed power levels and licensed LTE downlink spectrum. Finally, the Commission should require a five megahertz frequency buffer between white space devices operating at 6.6 dBm (5 milliwatts) and licensed LTE downlink spectrum.

In the *Unlicensed NPRM*, the Commission has proposed that unlicensed white space devices and wireless microphones be permitted to operate in at least a portion of the 600 MHz

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[49] Spectrum Act § 6407.

guard band.[50] The guard band will be immediately adjacent to the 600 MHz downlink band, as well as the upper end of the broadcast television spectrum.[51] Depending on the amount of spectrum reclaimed in the incentive auction, the bandwidth of the guard band will be either 7, 9, or 11 MHz.[52] With respect to the guard band, the licensed band edge does not have the duplex filtering that is present within the duplex gap. As a result, performance and/or interference rejection at the licensed band edge of the guard band-adjacent spectrum will not be as strong as that at the edge of the duplex gap.[53] Due to the fundamental technical differences between the duplex gap and guard band, V-COMM separately tested interference in the guard band and duplex gap. As explained further below, V-COMM's testing indicates that the frequency buffers necessary for the guard band to protected licensed 600 MHz operations are generally larger than those required in the duplex gap.

A. As in the Duplex Gap, a More Stringent OOBE Limit Will Be Needed to Protect Licensed Operations from Unlicensed Use of the Guard Band.

Through its testing, V-COMM found that to protect licensed devices from interference, the same stringent OOBE limits (-89 dBm/100 kHz) would be needed in both the guard band and

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50 The *Unlicensed NPRM* specifies that for white space devices a one, three, or five megahertz buffer would be required (depending on the size of the guard band). *Unlicensed NPRM* at ¶¶ 87-89 (outlining the proposed buffer under the 7, 9, or 11 MHz guard band scenario). As for unlicensed wireless microphones, the Commission proposes that a one megahertz buffer be employed regardless of the guard band size. *Unlicensed NPRM* at ¶159.

51 *Unlicensed NPRM* at ¶ 8.

52 *Id.*

53 This measured difference by V-COMM in filtering between the duplex gap band edges and the guard band edges is not surprising. Indeed, Broadcom noted that "… LTE filtering will be weaker in the guard band than the duplex gap." *See Ex Parte Presentation* of Broadcom Corporation, GN Docket No. 12-268, filed April 23, 2014 at 5.

the duplex gap.[54] OOBE cannot be removed at the victim device and must be mitigated at the interfering source – in this case, the wireless microphone or white space device. As explained above, the Commission's proposed OOBE limit is 32 dB higher than the level required to protect LTE devices to a 1 dB desense interference threshold, which V-COMM determined would significantly degrade and impair LTE service, performance, and coverage.[55] V-COMM's testing indicates that an OOBE limit of -89 dBm/100 kHz is required, and will require greater filtering for wireless microphones and white space devices as compared to the Commission's proposed out of band emissions mask when operating in 600 MHz spectrum.[56]

B. Without Adoption of Appropriate Frequency Buffers, Unlicensed Operations in the Guard Band Will Cause Harmful Interference to Licensed 600 MHz Downlinks.

V-COMM's testing revealed that the Commission's proposed use of the guard band, combined with the Commission's proposed technical rules for unlicensed white space device and wireless microphone operation, will result in harmful interference to 600 MHz licensed downlink operations. To protect 600 MHz licensed downlink operations from interference, not only will stronger OOBE protections be required (see above), but the Commission will also need to adopt additional technical protections and frequency buffers for the guard band.

The Commission's Proposed Division of the Guard Band. The *Unlicensed NPRM* notes that the size of the guard band could be 7, 9, or 11 megahertz, depending on the amount of spectrum reclaimed from broadcast television licensees.[57] With respect to white space device

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54 Test Report at 82.

55 *Id.*

56 *Id.*

57 *Unlicensed NPRM* at ¶ 8.

operations, the *Unlicensed NPRM* proposed frequency buffers of one, three, or five megahertz between unlicensed white space device operation and 600 MHz downlinks, depending on the size of the guard band.[58] The Commission proposed a one megahertz frequency buffer between unlicensed wireless microphones and 600 MHz downlinks, regardless of the size of the guard band.[59]

V-COMM Analysis and Testing Parameters. V-COMM conducted receiver blocking interference tests in the guard band based on the Commission's proposed technical parameters. Because the size of the guard band is currently unknown, V-COMM conducted a number of compatibility tests to determine the appropriate technical protections needed within the various guard bands to protect licensed 600 MHz systems. The interference levels for white space devices (-22 dBm at 1 meter) and wireless microphones (-25 dBm at 1 meter) received at LTE mobile receivers are the same in the guard band as compared to the duplex gap since the propagation factors and losses are the same for both cases.[60] Because the size of the guard band has yet to be determined, V-COMM conducted interference tests for wireless microphones using buffers ranging from one to five megahertz for white space devices and one to nine megahertz for wireless microphones.[61]

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[58] *Id.* at ¶¶ 87-89.

[59] *Id.* at ¶159.

[60] Test Report at 9-10. As is true for all testing done by V-COMM, the results based upon the 1 dB desense threshold are used to define the interference protection criteria for licensed services.

[61] *Id.* at 78. The V-COMM testing did not extend past a five megahertz frequency buffer for unlicensed white space devices as it is believed that these devices would require six megahertz for operations. As the largest guard band would be 11 megahertz – V-COMM did not test past 11 MHz for white space devices (five megahertz frequency buffer plus six megahertz for the white space device).

V-COMM Results – Receiver Blocking in the Guard Band. As shown in Appendix B, none of the ten tested devices were able to meet the -25 dBm threshold for interference from a wireless microphone when the buffer was only one, three, or five megahertz.[62] While a couple of the tested devices were able to meet the -25 dBm threshold when a seven megahertz buffer was used, the majority did not, and, on average, frequency buffers of this size were insufficient to provide the needed protection to licensed services.[63] Only when a nine megahertz buffer was used did the average device performance approach the -25 dBm threshold.[64] As for white space devices, none of the ten devices were able to meet the -22 dBm threshold using a one, three, or five megahertz buffer when the white space device was operated at the FCC's proposed power levels (16 dBm or 40 milliwatts).[65] Figure 5 below summarizes the V-COMM findings (providing an average of the ten devices tested and their ability to protect licensed systems).

Average DUT Results, 1 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
Wireless Microphone @ 747.1 MHz	1	-51.6	21.6	-13.6
Wireless Microphone @ 749.1 MHz	3	-45.4	10.6	-7.4
Wireless Microphone @ 751.1 MHz	5	-36.6	3.8	1.4
Wireless Microphone @ 753.1 MHz	7	-30.9	2.0	7.1
Wireless Microphone @ 755.1 MHz	9	-25.7	1.1	12.3
TV White Space Device @ 750 MHz	1	-44.2	13.0	-6.2
TV White Space Device @ 752 MHz	3	-38.3	6.6	-0.3
TV White Space Device @ 754 MHz	5	-31.4	3.0	6.6

Figure 5: V-COMM Test Results for Receiver Blocking in the Guard Band

V-COMM's testing determined that white space devices require a five megahertz buffer *and* a reduced power limit of 6.6 dBm (5 milliwatts) in the guard band to prevent interference to

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62 *Id.* at 21-22.

63 *Id.* at 23-24.

64 *Id.* at 25.

65 *Id.* at 26-28.

LTE devices one meter away.[66] In fact, V-COMM found that any white space device operating at the Commission's proposed power levels (16 dBm or 40 milliwatts) with a five megahertz frequency buffer would cause interference to LTE devices within three meters (or three times the acceptable separation distance).[67] Meanwhile, V-COMM determined that wireless microphones operating at the Commission's proposed power levels (13 dBm or 20 milliwatts) would require a nine megahertz buffer in the guard band to prevent interference to LTE devices at 1 meter.[68]

CTIA Proposal for White Space Devices in the Guard Band. The V-COMM test results show that – assuming the adoption of the -89 dBm/100 kHz OOBE limit – white space devices could operate at reduced power levels (6.6 dBm or 5 milliwatts) with a five megahertz frequency separation in the guard band.[69] This would permit a six megahertz block for the operation of unlicensed white space devices in the 11 MHz guard band case.[70] Figure 6 below describes the findings from the V-COMM test report and corresponding use of the 11 MHz guard band that may occur by white space devices without harmful interference to licensed services:

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66 *Id.* at 78.

67 *Id.*

68 *Id.*

69 *Id.*

70 V-COMM did not test white space devices with bandwidths of less than six megahertz as the operating parameters for a narrowband white space device (a device using less than six megahertz) have not been provided in the record by white space proponents. There is a possibility that white space use may be possible with narrowband white space devices in the 9 MHz and 7 MHz guard band cases. However, CTIA would require the technical parameters for such equipment to allow testing to determine the compatibility between these types of white space devices and LTE receivers.

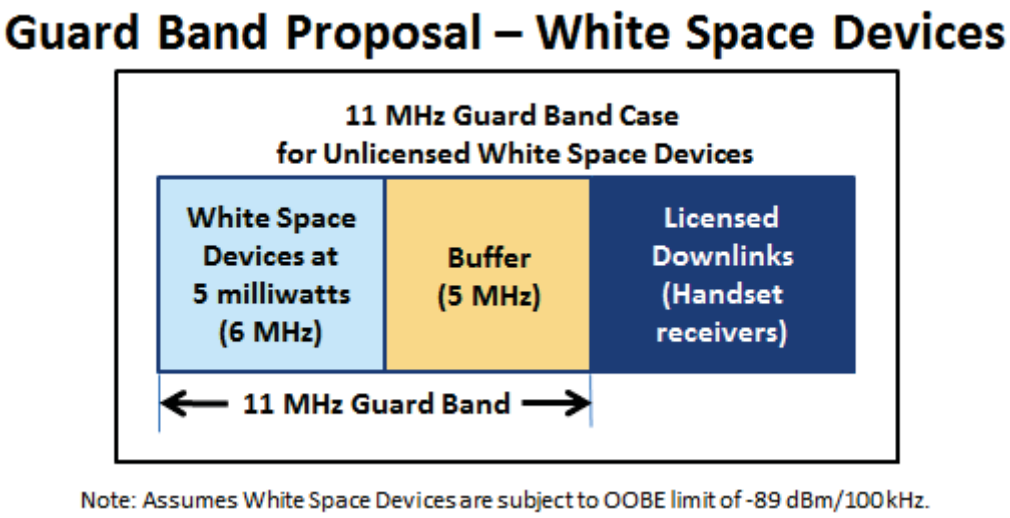

Figure 6: Guard Band Proposal for White Space Devices

CTIA Proposal for Wireless Microphones in the Guard Bands. As for wireless microphones, because the V-COMM testing determined that a nine megahertz buffer is required for wireless microphones to operate at the FCC's proposed power levels without causing harmful interference, the potential 600 MHz band plans with 7 MHz or 9 MHz guard bands would not be able to support wireless microphones. The V-COMM report finds that with less than or equal to a 7 MHz buffer in the guard band, wireless microphones would need to operate at very low power levels to protect LTE devices at a 1 dB desense threshold.[71] Additionally, the V-COMM testing indicates that at the FCC's proposed power levels and with a buffer of 7 MHz or less, wireless microphone operations would cause interference to LTE devices up to 21 meters away – a distance greater than the width of a regulation-sized basketball court.[72] A band plan with an 11 MHz guard band – assuming the adoption of the suggested -89 dBm/100 kHz OOBE limit – could support wireless microphone operations at the lower end of the guard band. Figure 7

[71] Test Report at 91.

[72] *Id.*

below describes the findings from the V-COMM test report and corresponding use of the guard bands that may occur by wireless microphones without harmful interference to licensed services:

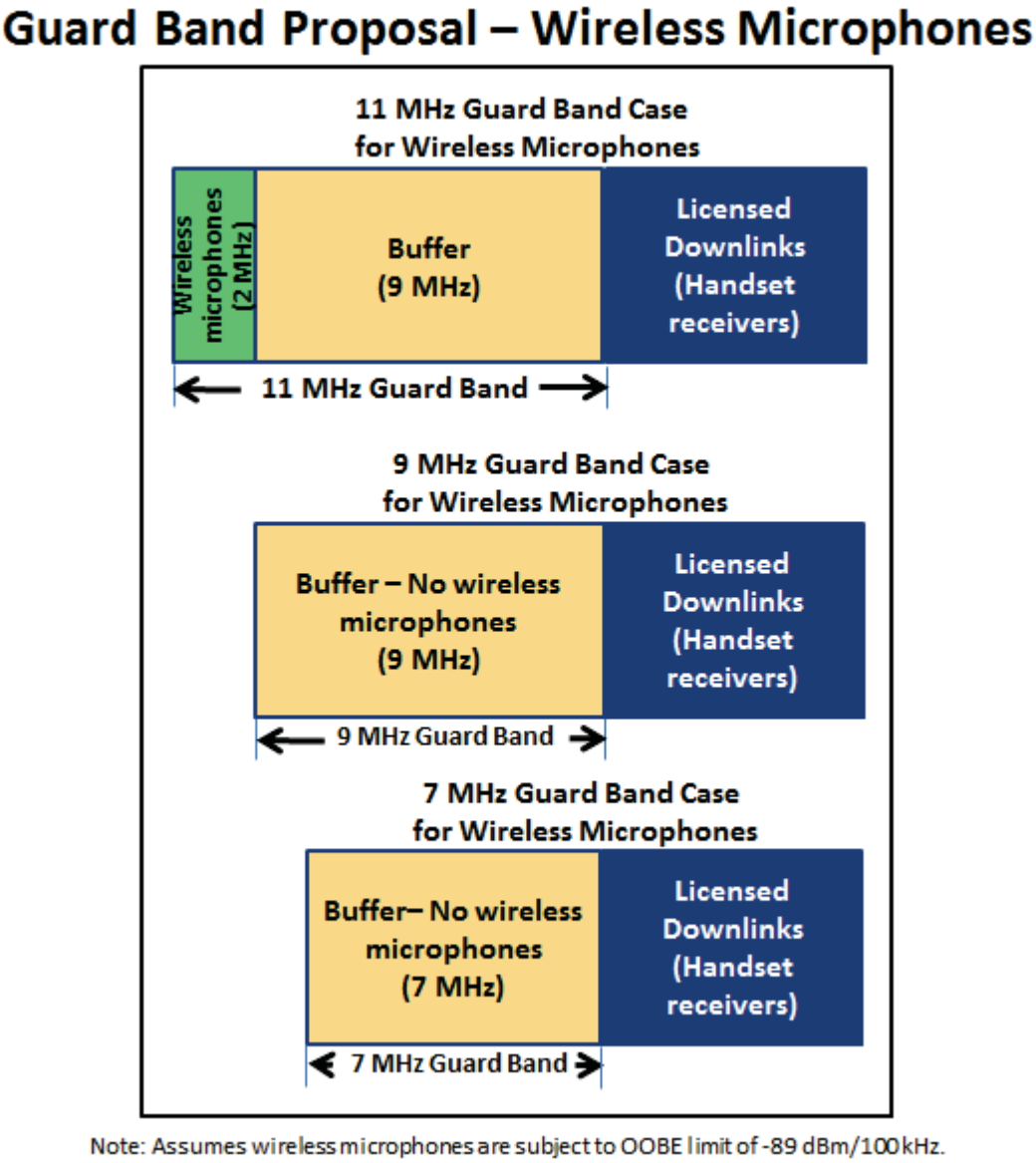

Figure 7: Guard Band Proposal for Wireless Microphones

V. THE ASSUMPTIONS USED BY THE COMMISSION TO MODEL INTERFERENCE BETWEEN WHITE SPACE DEVICES, WIRELESS MICROPHONES, AND LICENSED 600 MHZ OPERATIONS ARE INCOMPLETE AND INCONSISTENT WITH INDUSTRY STANDARD PRACTICES FOR PROTECTION FROM HARMFUL INTERFERENCE.

When modeling interference between white space devices, wireless microphones, and licensed 600 MHz operations, technical assumptions must be used that accurately reflect the 600 MHz radio environment and consensus by industry experts. The *Unlicensed NPRM* provides link budget information and certain other assumptions used to develop proposed rules, but this information is incomplete and/or contradicts industry standard practices. In some cases, these assumptions even contravene the Spectrum Act. CTIA believes that the technical assumptions made in the V-COMM report better reflect reasonable engineering practice, and should serve as the basis for the Commission's rules.

A. The Commission's Link Budget Information is Incomplete.

In the *Unlicensed NPRM*, the Commission has provided only a brief and incomplete view of its link budget assumptions for modeling interference between white space devices, wireless microphones, and 600 MHz licensed operations. In particular, the Commission has assumed at least 25 dB of loss in addition to path loss – 10 dB for adjacent channel selectivity plus 15 dB of other losses.[73] As the Commission itself notes, this is inconsistent with the 3GPP standard.[74] The Commission further argues that a worst case interference distance of seven meters would be acceptable to protect licensed 600 MHz operations.[75] The Commission argues that this "worst

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[73] *Unlicensed NPRM* at ¶ 84.

[74] *Id.* at n. 127.

[75] *Id.* at ¶ 84.

case" scenario would be improbable, and that LTE systems are capable of handling these levels of interference.[76]

CTIA submits that the approach in the *Unlicensed NPRM* is utterly inconsistent with the global wireless standards and practices that have been developed by industry organizations to ensure protection from harmful interference. Initially, the *Unlicensed NPRM* fails to indicate what separation distance between LTE mobile devices and white space devices/wireless microphones it is attempting to protect. Wireless industry standards have consistently applied one meter separation criteria when modeling compatibility between mobile devices.[77]

Next, the Commission applies an additional 10 dB for adjacent channel selectivity based upon what appears to be a single filing by Broadcom in the incentive auction proceeding.[78] This value, however, is inconsistent with the sensitivity values used by 3GPP, the global industry standards body. Moreover, the Commission has failed to acknowledge the existing record arguing against use of 10 dB adjacent channel selectivity – that Broadcom's small sample of devices is not indicative of the over 1500 devices in the marketplace.[79] CTIA believes that the FCC made this proposal without available information on LTE device rejection. To remedy this issue, the V-COMM testing did use actual LTE devices. Therefore, V-COMM's testing of ten separate devices did take into account the actual rejection levels for the devices tested, making the addition of 10 dB in losses unnecessary.

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[76] *Id.* at ¶ 85.

[77] *See e.g.*, 3GPP TR 25.942 v. 12.0.0 at 4.2.1(d), *at* http://www.3gpp.org/ftp/Specs/archive/25_series/25.942/25942-c00.zip.

[78] *Unlicensed NPRM* at ¶ 84.

[79] *See e.g.*, *Ex Parte Presentation* of Qualcomm Incorporated, GN Docket No. 12-268, filed August 5, 2014 at 6 (noting that the Commission cannot rely upon an unscientific sampling of device sensitivity to override industry standards).

The *Unlicensed NPRM* also has failed to adequately explain the other 15 dB of losses it introduces – it simply cites to an October 2008 analysis without describing how the 15 dB is divided among antenna losses, polarization mismatch or other categories.[80] The *Unlicensed NPRM* has provided no basis or rationale for the additional 6 dB in losses it assumes above and beyond what V-COMM has presented in its testing. Most critically, even including all these extraneous losses, the *Unlicensed NPRM* finds that there would be interference between LTE and white space devices/wireless microphones that are seven meters apart.[81] As noted above, industry standards modeling compatibility between mobile devices use one meter separation as the requirement for protection – the *Unlicensed NPRM* inexplicably asserts a distance *7 times* the well-accepted separation distance would be sufficient. CTIA does not believe that the promulgation of technical rules that would allow a device more than 20 feet away from a licensed LTE mobile to cause harmful interference is acceptable.

CTIA believes the *Unlicensed NPRM* assumptions are arbitrary and capricious and not in accordance with the Spectrum Act. At a minimum, the Commission must:

- Provide a full accounting of all the losses the FCC is assuming and the rationale for each assumption, and

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[80] *Unlicensed NPRM* at ¶ 84. CTIA reviewed the Office of Engineering and Technology report of October 10, 2008 and could not determine how the Commission arrived at 15 dB of losses from this report. *See Advanced Wireless Service Interference Tests Results and Analysis*, DA 08-2245, Office of Engineering and Technology, WT Docket Nos. 07-195 and 04-356, released October 10, 2008. At page 13 of the report, OET provides a full accounting of the assumptions in modeling TDD interference into the AWS-1 spectrum but, at best, 8 dB of losses applicable to the 600 MHz band are apparent.

[81] *Unlicensed NPRM* at ¶ 84.

- Provide a complete description of the basis for determining that interference from devices over 20 feet away from licensed LTE mobiles is an acceptable benchmark for protection from harmful interference.[82]

B. Several of the Commission's Assumptions Regarding Separation Distances Between White Space Devices and Wireless Base Stations Do Not Reflect the 600 MHz Radio Environment.

When making calculations regarding separation distances and other technical matters in the 600 MHz band, CTIA submits that the Commission should make assumptions and employ parameters that accurately reflect the operating environment the Commission seeks to regulate. Just as the Commission's link budget assumptions are not in line with 3GPP specifications, CTIA is concerned that certain of the Commission's assumptions concerning the proposed separation distances between co-channel and adjacent-channel white space devices and wireless base stations do not reflect the 600 MHz radio environment.

The Commission's Chosen Propagation Model Does Not Reflect the 600 MHz Radio Environment. As an initial matter, to determine the necessary separation distance to protect 600 MHz base stations from interference from white space devices, the Commission has proposed to use the TM 91-1 propagation model.[83] As the authors of this model make clear, TM 91-1 is valid only for short distances (less than 10 miles) and relatively low height antennas (300 feet).[84] Yet, as the *Unlicensed NPRM* itself notes, this model is used even with antennas that are as high

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82 *Am Radio Relay League, Inc. v. FCC*, 524 F.3d 227 (D.C. Cir. 2008) (finding that the Commission failed to provide a reasoned justification for the technical model being used to protect Amateur Radio licensees from interference from broadband over power lines).

83 *Unlicensed NPRM* at ¶ 135.

84 William Daniel and Harry Wong, "Propagation in Suburban Areas at Distances Less Than Ten Miles at 1, 6 (Jan. 25, 1991), *available at* http://transition.fcc.gov/oet/info/documents/technical/tm91-1.pdf ("TM 91-1").

as 250 meters above ground and to distances as great as 60 kilometers (37 miles).[85] CTIA submits that use of the TM 91-1 propagation model is an incorrect choice as the interference environment being modeled does not comport with the parameters of the model.

CTIA provides, as Appendix C, a series of graphs that show the signal levels that would be produced by a 4 watt EIRP (2.44 watt ERP) white space signal from various transmit antenna heights to a 30 meter high wireless base station.[86] Plotted on these graphs are Longley-Rice propagation curves at F(50,50) and F(50,10) along with TM 91-1. For very short distances (less than 15 kilometers) and tall towers (250 meters), the propagation curves are almost perfectly aligned. TM 91-1, however, shows much less propagation at 600 MHz (as much as 20 dB) than Longley-Rice predicts for shorter towers (less than 250 meters) and short distances (less than 15 kilometers). For medium distances (15-65 kilometers), TM 91-1 also predicts much less propagation than Longley-Rice regardless of tower height.

Therefore, CTIA believes that TM 91-1 understates the level of interference that would occur to licensed 600 MHz wireless operations. As the FCC's proposed separation distance tables relied upon medium distances to derive the separation distances, CTIA believes that Longley-Rice is a better predictor of interference from white space devices and wireless microphones. CTIA would note that the FCC uses Longley-Rice for the prediction of interference between DTV stations and also has proposed to use it for protections between 600 MHz wireless operations and DTV stations in the *ISIX NPRM*.[87] Implementation of this change

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85 *Unlicensed NPRM* at ¶¶ 135-136.

86 The first four graphs cover white space transmission heights of 250 meters, 75 meters, 10 meters and 3 meters for ranges out to 150 km. The second four graphs cover the same white space transmission heights but show more detail for the range of 1-15 km.

87 *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, Office of Engineering and Technology Releases and Seeks Comment on Updated OET-*

in the propagation model would modify the separation tables proposed in the *Unlicensed NPRM*, for both co-channel and adjacent channel protections to licensed 600 MHz wireless operations. CTIA urges the Commission to make these changes to ensure that the separation distances between white space devices/wireless microphones and licensed 600 MHz services adequately protected the licensed services.

The Commission's Consideration of Clutter Inexplicably Doubles its Effects and is Inconsistent With its Actions in Related Proceedings. The FCC, in utilizing the TM 91-1 propagation model, has inadvertently added clutter effects twice to the modeling of interference from wireless space devices/wireless microphones and licensed 600 MHz systems. In addition, the Commission's assumptions regarding clutter represent a marked departure from its findings in other proceedings.

A review of the TM 91-1 model indicates that it relies upon empirical data that *already* includes clutter losses for suburban areas. Further, it states the model "assumes average conditions for a typical U.S. suburban area," so it represents average clutter losses for a typical suburban environment.[88] If the Commission adds an additional clutter factor, then it would effectively be adding the clutter losses twice, which is unsupported and invalid. As a result, use of a clutter factor, in addition to the effects of clutter that is already built into the TM 91-1 model, would greatly understate the interference effects from unlicensed white space devices and wireless microphones to licensed 600 MHz operations.

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69 Software, Office of Engineering and Technology Seeks to Supplement the Incentive Auction Proceeding Record Regarding Potential Interference Between Broadcast Television and Wireless Services, Second Report and Order and Further Notice of Proposed Rulemaking, FCC 14-157, at ¶¶ 36, 48 (Oct. 16, 2014) ("*ISIX Order and FNPRM*").

[88] TM 91-1 at 1.

In the *Unlicensed NPRM*, the Commission declines to adopt greater separation distances on the basis that clutter will limit the propagation of white space device transmissions.[89] This finding by the Commission is in direct contrast to its statements in its concurrent proceeding addressing inter-service interference between wireless and broadcast television services. In that proceeding, the Commission has declined to consider clutter loss – over the objections of the wireless industry – when calculating separation distances necessary to protect wireless user equipment from interference from broadcast television transmissions, and to protect broadcast receivers from interference caused by co- or adjacent-channel wireless base station operation.[90] The Commission has offered no explanation for why clutter is irrelevant in the inter-service interference context but is relevant in this related proceeding as the physical characteristics of the interference environment are the same in each instance. CTIA believes that the FCC should have a consistent approach for the use of clutter. Further, clutter should not be a factor in white space device propagation if white space device antennas are more than 10 meters above ground (which the Commission has clearly considered as a likely possibility).[91] As TM 91-1 itself notes, clutter should be ignored and free space path loss considered instead, when antenna heights are greater than 10 meters and a line-of-sight path is available.[92]

Other Assumptions Regarding White Space Device Propagation Are Unlikely to be Borne Out by the Radio Environment. The Commission makes other assumptions about the operations of 600 MHz white space devices that are unlikely to be borne out in practice. Most

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89 *Unlicensed NPRM* at ¶ 136.

90 *ISIX Order and FNPRM* at ¶¶ 36, 48.

91 *Unlicensed NPRM* at ¶ 136.

92 TM 91-1 at 2.

problematically, the Commission assumes that any white space device's line-of-sight signal will stop at 60 kilometers (37 miles), which is not the case.[93] And the Commission also assumes that a white space device's transmission will never propagate beyond the line-of-sight radio horizon (87 kilometers) even though the 600 MHz band's propagation characteristics make propagation beyond the radio horizon a distinct possibility.[94]

C. More Accurate and Conservative Assumptions Are Warranted In Light of the Spectrum Act's Requirements.

In light of the Spectrum Act's mandates regarding interference to licensed operations, it is critical that the Commission's technical assumptions be accurate or err on the side of conservative. As stated above, there are several technical realities of the 600 MHz band that cast significant doubt on many of the technical assumptions used in this proceeding. Indeed, by framing the problem as one of "how much interference can licensed services be made to tolerate," the Commission's approach is inconsistent with the requirements of the Spectrum Act. The Spectrum Act makes clear that the Commission is forbidden from allowing *any* guard band use that would cause harmful interference to licensed services.[95] It is therefore incumbent upon the Commission to provide licensed 600 MHz operations full protection from harmful interference, consistent with past actions by the Commission and the wireless industry's thoughtfully-developed standards for interference protection.[96]

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[93] *Unlicensed NPRM* at ¶ 136.

[94] *Id.* Propagation at 600 MHz (in the UHF frequency range) can have tropospheric effects such as refraction and ducting that allows propagation much further than the radio horizon.

[95] Spectrum Act § 6407.

[96] *See, e.g., Revisions to Rules Authorizing the Operation of Low Power Auxiliary Stations in the 698-806 MHz Band*, Report and Order and Further Notice of Proposed Rulemaking, 25 FCC Rcd 643 (2010) (requiring that the 700 MHz band be cleared of wireless microphone operations to ensure that licensed services may operate free from interference).

CTIA therefore urges the Commission to take a cautious approach when predicting interference to licensed 600 MHz operations, just as it has when considering potential interference to broadcasters.[97] In the concurrent inter-service interference proceeding, the Commission strenuously advocated in favor of a cautious approach for protecting broadcast television stations from interference caused by nearby wireless operations.[98] The Commission should adopt a similar approach in this proceeding. Particularly in light of the Spectrum Act's mandate that the Commission not adopt an unlicensed regime that would interfere with licensed wireless operations, there is no basis for the Commission to be less conservative in protecting wireless operations than in protecting broadcasters. Indeed, failing to accord similar treatment is arbitrary and capricious, especially when the incomplete nature of the Commission's technical assumptions is considered. And in this case, the approach taken by V-COMM in its testing is the correct, cautious approach, and is the only method that will ensure the Commission's compliance with the intent of Congress to not permit any use of the guard bands that "would cause harmful interference to licensed services."

VI. CTIA STRONGLY OPPOSES USE OF LICENSED 600 MHZ SPECTRUM BY UNLICENSED WHITE SPACE DEVICES FOLLOWING THE INITIATION OF COMMERCIAL SERVICE IN A MARKET.

To comply with the Spectrum Act and serve the public interest, the Commission should require white space devices operating in the 600 MHz band to cease operation in a market once a commercial licensee has initiated service in that market. In the *Unlicensed NPRM*, the Commission has proposed that 600 MHz licensed service providers be required to provide

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[97] For example, the interference protection afforded to DTV service at cell edge is equivalent to an I/N ratio of -7 dB (i.e. S/N of 16 dB minus D/U=23 dB), or a 0.8 dB increase in interference plus noise levels. This is more stringent than the 1 dB interference threshold used in the V-COMM analysis from unlicensed devices to LTE devices.

[98] *ISIX Order and FNPRM* at ¶ 66.

detailed information to TV bands database administrators so that white space devices can coordinate their usage around licensed operations without causing interference.[99] CTIA strongly opposes this proposal, as it conflicts with the exclusive rights purchased by wireless operators through auction and imposes impermissible burdens on 600 MHz licensees that are inconsistent with the dictates of the Spectrum Act.[100]

The Commission should decline to permit white space device operation in a licensed 600 MHz market area contemporaneous with licensed wireless operation; such an action would undermine the rights of wireless licensees and place undue burdens on these licensees. The Commission has proposed that white space devices be permitted to operate in Partial Economic Areas ("PEAs") where wireless licensees have commenced service, so long as white space devices do not interfere with the licensee's "polygon" of operations.[101] To enable this framework, licensed wireless carriers would be impermissibly burdened with obligations inconsistent with the spectrum rights they have purchased at great cost.

In the *Unlicensed NPRM*, the Commission proposes that wireless licensees be required to specify the coordinates of at least eight points representing the corners of a polygon of the minimum size necessary to encompass all base stations within the area where a licensee is

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[99] *Unlicensed NPRM* at ¶¶ 177-181.

[100] In a similar vein, the Commission should reject calls by the New America Foundation's Open Technology Institute and Public Knowledge ("OTI/PK") in a related proceeding for the Commission to permit white space devices to access spectrum licensed to non-operational LPTV or TV translator stations. Comments of Open Technology Institute at New America Foundation and Public Knowledge, MB Docket No. 03-185, at 9-10 (Jan. 12, 2015). Just as white space devices should be required to discontinue service once a 600 MHz licensee commences operation in a PEA, white space devices should not be permitted to operate in "fallow" licensed LPTV and/or TV translator spectrum as soon as licensed service is initiated in a market. *Id.*

[101] *Unlicensed NPRM* at ¶¶ 177-181.

commencing operations.[102] The wireless licensee must also provide information regarding the frequencies being used and the date the licensee plans to commence operations.[103] Wireless licensees would submit this data to white space database administrators and would be responsible for ensuring the ongoing accuracy of this information.[104] The Commission envisions that unlicensed white space devices would then be permitted to operate in licensed spectrum in markets where a licensee has commenced operations, so long as the white space device maintains an appropriate (and as yet undefined) distance from the operational 600 MHz system.[105]

CTIA strongly opposes the ongoing use of white space devices in licensed spectrum within PEAs where a commercial licensee has initiated service, and believes that white space device operations should cease in a PEA as soon as the commercial licensee has initiated service anywhere in the market. These wireless operators will have purchased rights to use all spectrum in their licensed area without impingement from ongoing unlicensed operations. Licensees should be able to use all spectrum licensed to them in a PEA free of the regulatory burdens proposed by the Commission. Because commercial wireless licensees are constantly modifying their base stations – including the frequencies used – to meet consumer demands, a wireless licensee would need to constantly update the TV bands databases to ensure that unlicensed devices would not harmfully interfere with their operations. As explained further below, this

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102 *Id.* at ¶ 178.

103 *Id.*

104 *Id.*

105 *Id.* at ¶¶ 177-181.

action is wholly inconsistent with the "exclusive license" provided to bidders in the incentive auction and impermissibly elevates the rights of unlicensed services.

CTIA proposes that to comply with the Spectrum Act and the principle of exclusive licensing, the Commission should require white space device operations to cease on licensed spectrum throughout any PEA where a commercial licensee has initiated service. There is no language in the Spectrum Act that envisions or compels access to licensed 600 MHz spectrum by unlicensed white space devices. With respect to unlicensed operations, the Spectrum Act simply stated that the Commission "may permit the use of . . . guard bands for unlicensed use" and that "[t]he Commission may not permit any use of a guard band that the Commission determines would cause harmful interference to licensed services."[106] When considered against the backdrop of the general principles of exclusive licensing, Congress' actions with respect to unlicensed make clear that it would be impermissible for the Commission to elevate the rights of unlicensed services through the framework proposed in the *Unlicensed NPRM.*

Instead, CTIA urges the Commission to allow white space devices to utilize licensed spectrum in a PEA until such time as a 600 MHz wireless licensee initiates service in that PEA. A licensee should simply have to notify the TV bands database administrators that it has commenced service in a particular PEA on its licensed spectrum. At that point, no further use of the licensed spectrum by secondary white space devices should occur. Importantly, this approach would obviate the need for 600 MHz licensees to create and notify TV bands database administrators of polygons, as well as the need for other complicated notification requirements. Instead, the database administrator will simply be able to update the database to note that the particular frequencies and PEA are now in commercial, licensed operation and no longer

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[106] Spectrum Act § 6407(c), (e).

available for unlicensed white space devices. Should a party desire use of licensed spectrum in a market where a commercial licensee has initiated service, the Commission's existing secondary market licensing regime would allow the parties to negotiate an equitable agreement to govern that spectrum usage.[107] Under this framework, the unlicensed operator seeking spectrum access would have the consent and agreement of the spectrum licensee, and the parties would negotiate terms that would protect the interests of all parties involved, with clearly designed rights and responsibilities. This is a significantly more reasonable outcome than requiring the licensed party to bear the burden of staking a claim to its own assets.

VII. CTIA AGREES THAT OTHER SPECTRUM BANDS SHOULD BE INVESTIGATED FOR UNLICENSED WHITE SPACE DEVICES AND WIRELESS MICROPHONES BUT OPPOSES SOME BANDS SUGGESTED BY THE COMMISSION FOR THESE USES.

CTIA is supportive of the Commission's efforts to identify additional spectrum bands for both white space devices and wireless microphones. However, the *Wireless Microphones NPRM* seeks comment on two spectrum bands for wireless microphones that would be problematic if

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[107] 47 C.F.R. § 1.9080. The Commission's private commons option provides a cooperative mechanism for licensees or lessees to make licensed spectrum available to users employing advanced technologies in a manner similar to that by which unlicensed users gain access to spectrum to suit their particular needs. A private commons arrangement is an arrangement, distinct from a spectrum leasing arrangement but permitted in the same services for which spectrum leasing arrangements are allowed, in which a licensee or spectrum lessee makes certain spectrum usage rights under a particular license authorization available to a class of third-party users employing advanced communications technologies that involve peer-to-peer (device-to-device) communications and that do not involve use of the licensee's or spectrum lessee's end-to-end physical network infrastructure (e.g., base stations, mobile stations, or other related elements). A private commons arrangement differs from a spectrum leasing arrangement in that, unlike spectrum leasing arrangements, a private commons arrangement does not involve individually negotiated spectrum access rights with entities that seek to provide network-based services to end-users. This framework eliminates the need to enter into individual spectrum leasing arrangements under the Commission's rules. *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, Second Report and Order, Order on Reconsideration, and Second Further Notice of Proposed Rulemaking, 19 FCC Rcd 17503, ¶ 92 (2004).

repurposed for such uses. CTIA believes that the 1920-1930 MHz and 1427-1535 MHz bands proposed by the Commission likely are better served for other purposes, including as protective guard bands for existing commercial mobile services.

There Are Additional Spectrum Bands Under FCC Consideration That Can Accommodate Unlicensed Uses. The Commission's actions in this proceeding are consistent with its ongoing efforts to identify new spectrum for unlicensed services, and the Commission has taken action in other bands that could enable future white space device and wireless microphone use of these bands. For example, the Commission notes that the rules for unlicensed operation in the 5 GHz band permit operation of a variety of unlicensed devices.[108] Earlier this year, the Commission adopted an Order designed to increase the utility of the 5 GHz band for unlicensed devices.[109] CTIA supports this effort, and believes that the 5 GHz band should be closely examined as a potential home for wireless microphones and white space devices. Similarly, the Commission has pending before it a proposed three-tiered authorization plan that would allow diverse uses of spectrum in the 3550-3650 MHz band.[110] In that proceeding, CTIA highlighted the potential benefits of such a framework and noted that by adopting a transitional approach to the 3.5 GHz band, the Commission will allow interested parties to develop and demonstrate the viability of a multi-tiered spectrum access framework.[111] CTIA has also

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[108] *Id.* at ¶ 168.

[109] *Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, First Report and Order, 29 FCC Rcd 4127 (2014).

[110] *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3350-3650 MHz Band*, Further Notice of Proposed Rulemaking, 29 FCC Rcd 4273 (2014).

[111] Comments of CTIA – The Wireless Association®, GN Docket No. 12-354, at 3 (July 14, 2014).

supported technical flexibility in the 3.5 GHz band, such that a variety of innovative services can be deployed.[112] CTIA welcomes a discussion of potential accommodation of wireless microphones and/or white space devices in the 3.5 GHz band, and supports a thorough examination of existing and proposed unlicensed bands for such operation.

Certain Bands Proposed by the Commission Are Better Suited for Other Uses. The 1920-1930 MHz and 1435-1525 MHz bands proposed by the Commission are better suited for uses other than wireless microphone operation, and CTIA does not believe these bands should be considered for unlicensed services. The Commission has invited comment on current and potential uses of the 1920-1930 unlicensed PCS band for wireless microphone applications.[113] In addition to hosting unlicensed services, this band currently serves as the duplex gap of the Broadband PCS band. In light of the adjacency of this band to licensed wireless services in the Broadband PCS band, CTIA notes that this spectrum will present many of the same interference challenges for wireless microphones as the 600 MHz spectrum does – something the Commission is well aware of due to the concerns raised in the H Block proceedings that addressed the spectrum adjacent to this band.[114] To the extent the Commission seeks to allow additional uses in the unlicensed PCS band, it should focus on uses that would not interfere with existing wireless applications in adjacent bands.

The Commission has also asked whether the 1435-1525 MHz band, currently used for aeronautical mobile telemetry operations, could be made available for wireless microphone

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112 *Id.* at 9.

113 *Wireless Microphones NPRM* at ¶ 174.

114 *See, e.g., Service Rules for Advanced Wireless Services H Block,* Report and Order, 28 FCC Rcd 09483, at ¶¶ 81-153 (2013).

use.[115] This spectrum is under consideration in international fora for potential use by mobile broadband services[116] and, more critically, is in the prime spectrum location between 500 MHz and 3 GHz that is ideally suited for mobile broadband services. Because spectrum appropriate for licensed wireless services is becoming increasingly scarce, CTIA believes that the Commission should not take action with respect to this spectrum until it has been fully examined for its suitability to host licensed wireless services.

VIII. THE COMMISSION SHOULD EXPEDITE THE TRANSITION PROCESS FOR WIRELESS MICROPHONES FROM THE 600 MHZ BAND.

The Commission should further expedite its proposed transition timeline for wireless microphones in the 600 MHz band, as this will facilitate the rapid use of this spectrum for licensed mobile broadband services. In the *Unlicensed NPRM,* the Commission noted the need to establish cutoff dates for the certification, manufacturing, and marketing of wireless microphones in the guard bands and repurposed 600 MHz band spectrum to ensure that manufacturers cease making and marketing equipment that cannot be legally used after a certain date.[117] CTIA agrees with the Commission's finding that "[c]utoff dates will encourage manufacturers to concentrate on developing wireless microphones that operate in compliance with new Part 74 and Part 15 rules."[118] While CTIA is pleased that the Commission is focusing on these transition issues now, it submits that the transition timetable proposed by the

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115 *Wireless Microphones NPRM* at ¶¶ 175, 177.

116 *See, e.g.,* "Revisions to Sharing Study Between LTE Systems and Aeronautical Mobile Telemetry Systems in the Band 1 435- 1 525 MHz" (Feb. 2014), *available at* http://wwwa.itu.int/md/choice_md.asp?id=R12-JTG4567.AR-C-0402!!MSW-E&lang=en&type=sitems (account required).

117 *Unlicensed NPRM* at ¶ 204.

118 *Id.*

Commission is unnecessarily long and could delay the deployment of 600 MHz wireless services.

In the *Unlicensed NPRM*, the Commission has proposed that parties may no longer submit applications for Part 15 certification of 600 MHz band wireless microphones beginning nine months after the release of the Commission's *Channel Reassignment PN*.[119] The Commission also proposed a manufacturing and marketing cutoff on noncompliant wireless microphones 18 months after the release of the *Channel Reassignment PN*.[120] However, the timetable proposed by the Commission does not reflect the potential rapid post-auction evolution in the 600 MHz band. In some markets, broadcasters who elect to cease operations will go off the air within six months after the incentive auction's conclusion. Allowing continued equipment certification for nine months with manufacturing and marketing of noncompliant wireless microphone devices continuing for 18 months could frustrate the rapid use of the 600 MHz spectrum for licensed mobile broadband services.

Instead, CTIA suggests a more rapid timetable that reflects the urgency of 600 MHz band access for the wireless community and reflects the pace of evolution in this spectrum. CTIA submits that no new wireless microphones be certified that are inconsistent with the 600 MHz band plan as of the date of issuance of the *Channel Reassignment PN*. Further, CTIA suggests that no new noncompliant devices be manufactured or marketed six months after the release of the *Channel Reassignment PN*. This will ultimately benefit all interested parties by providing clarity to key stakeholders and preventing further growth of the embedded base of wireless microphone equipment operating in this section of the 600 MHz band. By following this

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119 *Id.* at ¶ 207.

120 *Id.*

expedited timetable, the Commission will facilitate rapid clearing of the 600 MHz wireless spectrum by wireless microphone uses, which will enable that spectrum to be more rapidly and effectively used to provide mobile services to the public.

IX. CONCLUSION

While there is room in the 600 MHz band for both primary wireless licensees and unlicensed wireless operations, the Spectrum Act makes clear that unlicensed uses, such as white space devices and wireless microphones, may only be permitted to the extent they do not "cause interference to licensed operations." V-COMM's testing demonstrates the interference potential of these devices, and provides a path forward toward a framework that protects primary licensed services from harmful interference. CTIA urges the Commission to closely consider the V-COMM test results, as well as the other submissions in these comments regarding unlicensed operation and transition of the 600 MHz band to new uses. CTIA also observes that in making its proposals regarding wireless microphone and white space device operation, the Commission has made assumptions in modeling the radio frequency environment that are incomplete, improperly applied, and/or inconsistent with the Commission's treatment of similar situations. For these reasons, CTIA submits that V-COMM's assumptions more accurately model the potential interference environment in this spectrum.

The Commission should take several other actions in this proceeding that will protect primary licensed operations and are consistent with the principles and clear language of the Spectrum Act. Specifically, the Commission should prohibit unlicensed white space device operation in licensed spectrum in those markets where the licensee has commenced operation, identify appropriate spectrum bands as long-term homes for wireless microphones, and take action to expedite the transition of wireless microphones out of the 600 MHz band.

By taking all of these steps, the Commission will ensure proper protection of primary licensed services while maintaining a diverse unlicensed ecosystem in the 600 MHz and other spectrum bands, thus fulfilling the objectives of the Spectrum Act.

Respectfully submitted,

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Dated: February 4, 2015

APPENDIX A: CTIA 600 MHz TESTING PLAN

CTIA 600MHz Testing Plan

February 4, 2015

Overview of Testing

The objective of the testing plan is to determine appropriate Power and Emissions limits for the operation of wireless microphones and unlicensed TV white space devices in the duplex gap and guard band of the planned 600 MHz spectrum band plan, which will protect CMRS devices operating in 600MHz spectrum from harmful interference.

The testing will utilize LTE devices operating in the 3GPP Band 12 in the Lower 700MHz spectrum band, and simulate the operation of wireless microphones and unlicensed TV white space devices, with the corresponding frequency offsets planned for operation in the guard band and duplex gap per the FCC NPRM 14-144 (NPRM). The LTE Band 12 is selected for this testing as it is the closest representation of the operating frequency band and duplex gap planned for 600MHz commercial operations. Per 3GPP standards, LTE Band 12 is defined as 699-716 MHz for uplink operations and 729-746 MHz for downlink operations.

These lab tests will be performed as RF conduction tests with LTE devices, with connection to base station emulators and interference sources as required per the testing plan, in the lab within shielded rooms or isolation chambers.

As per the NPRM, the 600MHz band plan proposes the following operation for wireless microphones and unlicensed TV white space devices in the guard band and duplex gap.

Guard Band:

- This will be located directly below the wireless downlink (DL) band, and be between wireless downlink and broadcast TV spectrum.
- Depending on the number of channels cleared, the guard band will consist of 7, 9 or 11 MHz of spectrum.
- 7 MHz Guard Band Option:
    - 1 MHz buffer to CMRS DL, with 6 MHz for white space devices [1]
    - 1 MHz buffer to CMRS DL, with 6 MHz for wireless microphones
- 9 MHz Guard Band Option (This includes CH37 with 3 MHz case, as well):
    - 3 MHz buffer to CMRS DL, with 6 MHz for white space devices
    - 1 MHz buffer to CMRS DL, with 8 MHz for wireless microphones
- 11 MHz Guard Band Option:
    - 5 MHz buffer to CMRS DL, with 6 MHz for white space devices
    - 1 MHz buffer to CMRS DL, with 10 MHz for wireless microphones

[1] Unlicensed TV white space operation is not proposed in the 7 MHz guard band option, however the FCC requests comment on this option, so it is included in the test plan.

Duplex Gap:

- The duplex gap will be 11 MHz wide, and will be located between wireless uplink and downlink spectrum blocks. The duplex gap will remain the same size in all spectrum clearing scenarios.
- Per the NPRM, there will be a 1 MHz buffer to CMRS DL, then 4 MHz for licensed wireless microphones, then 6 MHz for white space devices and unlicensed wireless microphones.
- The 11 MHz Duplex Gap will consist of the following operations.
    - 5 MHz buffer to CMRS DL, with 6 MHz for white space devices
    - 1 MHz buffer to CMRS DL, with 10 MHz for wireless microphones

The testing plans, operating parameters, interference sources, general testing guidelines, and the test setup diagram are provided in the sections below. Spectrum charts of the test case scenarios are provided in the Appendix.

1. LTE Device Receive Sensitivity Tests

The receive sensitivity power level will be measured for the LTE Band 12 devices under test. The receive sensitivity power level will be measured on three LTE channel numbers in Band 12, as specified in the receiver blocking, intermodulation and AWGN tests below.

Per 3GPP (36.101, Section 7.3.1), the reference sensitivity power level is the minimum power applied to both the UE antenna ports at which the throughput shall be greater than or equal to 95% of the maximum throughput of the channel. The block error rate (BLER) must not exceed 5%. Tests will operate LTE devices in QPSK 1/3 mode using all resource blocks (RB) specified for the channel. All test devices must meet the minimum requirements for 3GPP receive sensitivity,[2] which is -97 dBm for LTE 5 MHz devices operating in Band 12.

The test results of the receive sensitivity tests will be used as a reference point for LTE UE power levels used in the receiver blocking, intermodulation and AWGN tests below.

2. Receiver Blocking Tests

Receiver blocking tests will be performed on the LTE Band 12 devices to determine the rejection of the LTE devices to the interference sources (wireless microphones and unlicensed TV white space devices) operating at the frequency offsets from the CMRS DL band, which correspond to the 600MHz band plan options provided above.

Filtering will be required in these tests (to be used in line with the interference signal generators) to isolate and measure the rejection of the LTE devices under test to the interference sources operating adjacent to the CMRS DL band.

[2] The LTE device receive sensitivity power level specification is provided in Table 7.3.1-1 of 3GPP 36.101.

Receiver blocking tests include the following test scenarios for wireless microphones and unlicensed TV white space devices operating in the duplex gap and guard band.

Duplex Gap Test Scenarios:

- The LTE devices will be operating in the 5 MHz channel closest to duplex gap (LTE Channel # 5035 at center frequency 731.5 MHz, which is the 5 MHz channel within Band 12 at DL 729-734 MHz)
- The wireless microphone interference signal will operate at the highest channel in the duplex gap, with a 1 MHz buffer below Band 12 DL, at the center frequency of 727.9 MHz. (Wireless microphones operate with an authorized bandwidth of 200 kHz, which places the top of the channel at 728 MHz.)
    - In additional tests, wireless microphone interference signals will be simulated throughout the duplex gap (i.e. at every 2 MHz). LTE devices are expected to have greater rejection at these frequency offsets.
- The unlicensed TV white space interference signal will operate within a 6 MHz channel, with a 5 MHz buffer below Band 12 DL, at the center frequency of 721 MHz.
- In addition, supplemental testing will be performed with several LTE devices using 2 interfering signal sources simultaneously. Both interfering signals will be operating at the same output level. These tests will be performed with wireless microphone and TV white space interference signals in the duplex gap as follows:
    - With a 1 and 2 MHz buffer below Band 12 DL, at the center frequencies 727.9 MHz and 726.9 MHz for two wireless microphones signals.
    - With a 5 MHz buffer below Band 12 DL, at the center frequencies 723.9 MHz and 721 MHz for the wireless microphone and TV white space signals, respectively.

Guard Band Test Scenarios:

- The LTE devices will be operating in the 5 MHz channel closest to guard band (LTE Channel # 5155 at center frequency 743.5 MHz, which is the 5 MHz channel within Band 12 at DL 741-746 MHz)
- The wireless microphone interference signal will operate at the lowest channel in the guard band, with a 1 MHz buffer above Band 12 DL, at the center frequency of 747.1 MHz. (Wireless microphones operate with an authorized bandwidth of 200 kHz, which places the bottom of the channel at 747 MHz.)
    - In additional tests, wireless microphone interference signals will be simulated throughout an 11 MHz guard band (i.e. at every 2 MHz). LTE devices are expected to have greater rejection at these frequency offsets.
- The unlicensed TV white space interference signal will operate within a 6 MHz channel, with 1, 3 and 5 MHz buffers above Band 12 DL, at the center frequencies of 750, 752 and 754 MHz, respectively, in 3 separate test cases to represent the 7, 9 and 11 MHz guard band cases.
- In addition, supplemental testing will be performed with several LTE devices using 2 interfering signal sources simultaneously. Both interfering signals will be

operating at the same output level. These tests will be performed with wireless microphone and TV white space interference signals in the guard band as follows:

- With a 1 and 2 MHz buffer above Band 12 DL, at the center frequencies 747.1 MHz and 748.1 MHz for two wireless microphones signals.
- With a 5 MHz buffer above Band 12 DL, at the center frequencies 751.1 MHz and 754 MHz for the wireless microphone and TV white space signals, respectively.

All tests will be performed at the 1 and 3 dB desensitization levels for the LTE devices under test, with the interference signal power levels recorded for each test.

The results of these tests will be used to determine the Power limits for wireless microphones and unlicensed TV white space devices operating in the 600MHz duplex gap and guard band.

3. Intermodulation Tests

Intermodulation tests will be performed on the LTE Band 12 devices to determine the rejection of the LTE devices to intermodulation interference from wireless microphones and unlicensed TV white space devices operating at the frequency offsets from the CMRS DL band, which correspond to the 600MHz band plan options provided above.

Filtering will be required in these tests (to be used in line with the interference signal generators) to isolate and measure the rejection of the LTE devices under test to the interference sources operating adjacent to the CMRS DL band in the duplex gap.

Intermodulation tests include the following test scenarios for wireless microphones and unlicensed TV white space devices operating in the duplex gap.

Duplex Gap Test Scenarios:

- The LTE devices will be operating on a 5 MHz channel within Band 12 that corresponds to the 3rd order intermodulation product from the interference source in the duplex gap. (LTE Channel # 5080 at center frequency 736 MHz, which is the 5 MHz channel within Band 12 at DL 733.5-738.5 MHz)
- The frequency offset of the interfering signals corresponds to the 600 MHz band plan that result in a 3rd order intermodulation product between the device's transmitter and receiver's operating frequency.
- The wireless microphone interference signal will operate in the duplex gap with a 8 MHz buffer below Band 12 DL, at the center frequency of 721 MHz.
- The unlicensed TV white space interference signal will operate within a 6 MHz channel, with a 5 MHz buffer below Band 12 DL, at the center frequency of 721 MHz.

All tests will be performed at the 1 and 3 dB desensitization levels for the LTE devices under test, with the interference signal power levels recorded for each test.

The results of these intermodulation tests, along with the results of the receiver blocking tests, will be used to determine the Power limits for wireless microphones and unlicensed TV white space devices operating in the 600MHz duplex gap.

4. OOBE Receiver Testing

OOBE receiver tests will be performed on the LTE Band 12 devices to determine the rejection of the LTE devices to emissions from adjacent band devices (i.e. wireless microphones and white space devices). The emissions will be simulated by using an AWGN interference signal that is operating co-channel with the LTE device under test, and on operates on the same channel bandwidth of the LTE device under test. No filtering is required for this test (filter is removed for this test).

OOBE Receiver Test Scenarios:

- The LTE devices will be operating in the 5 MHz channel closest to duplex gap (LTE Channel # 5035 at center frequency 731.5 MHz, which is the 5 MHz channel within Band 12 at DL 729-734 MHz)

All tests will be performed at the 1 and 3 dB desensitization levels for the LTE devices under test, with the interference signal power levels recorded for each test.

The results of these tests will be used to determine the OOBE limits for wireless microphones and unlicensed TV white space devices operating in the 600MHz duplex gap and guard band. OOBE limits will be specified in units of dBm/100kHz.

Interference Signal Sources

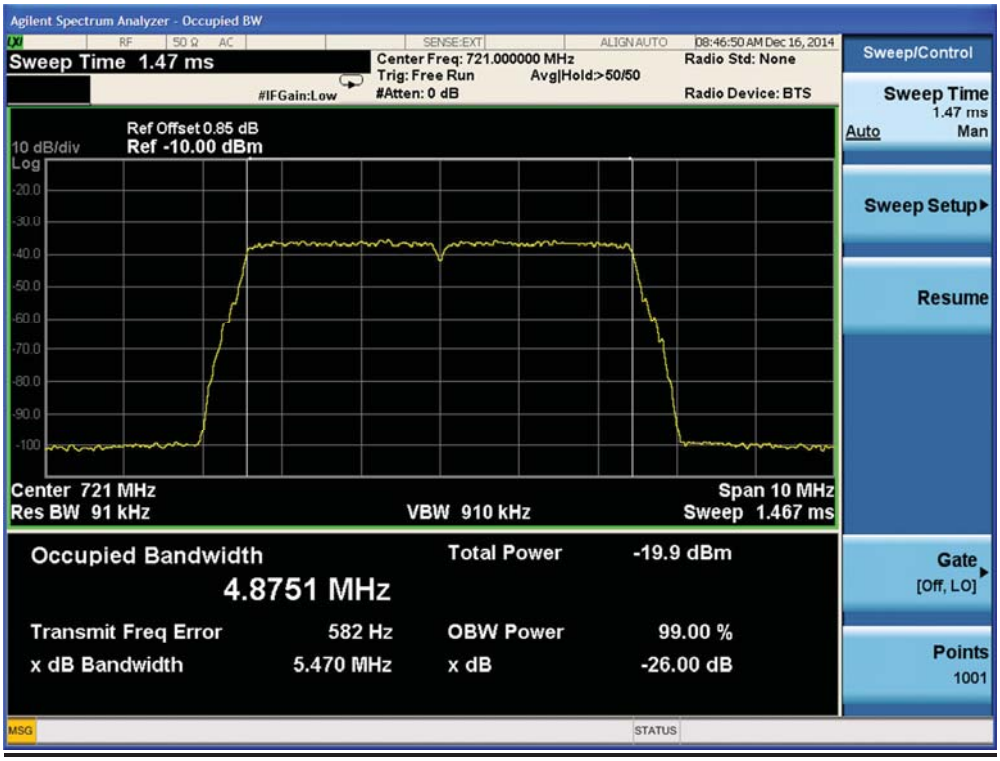
1.) In receiver OOBE tests, Additive White Gaussian Noise (AWGN) interference signals will be used to represent the emissions received in the CMRS mobile receive band from the interference sources operating in the guard band and duplex gap. In these tests, the AWGN interference signal will be co-channel and operate on the same bandwidth of the LTE channel used by the LTE devices under test.

2.) In receiver blocking and intermodulation tests, wireless microphone interference signals will be generated as a frequency modulated (FM) signal that represents wireless microphones operating in UHF TV bands. This will use a frequency modulated tone of 1 kHz at the rated deviation of 40 kHz, and a pilot frequency of 32.768 kHz at a 5 kHz deviation.

3.) In receiver blocking and intermodulation tests, unlicensed TV white space (TVWS) device interference signals will be generated using an 802.11ac interference signal, with adjustment of the sample rate variation parameter to achieve an occupied bandwidth of 4.875 MHz. This signal source represents unlicensed TV white space signals that use

802.11af modulation, which has an occupied bandwidth of 4.875 MHz. Both signal types use OFDM modulation, and have similar operating parameters and occupied bandwidths. The spectrum trace of the signal source used for the TVWS interference testing is provided below.

TV White Space Signal (802.11ac, 4.875 MHz Bandwidth)

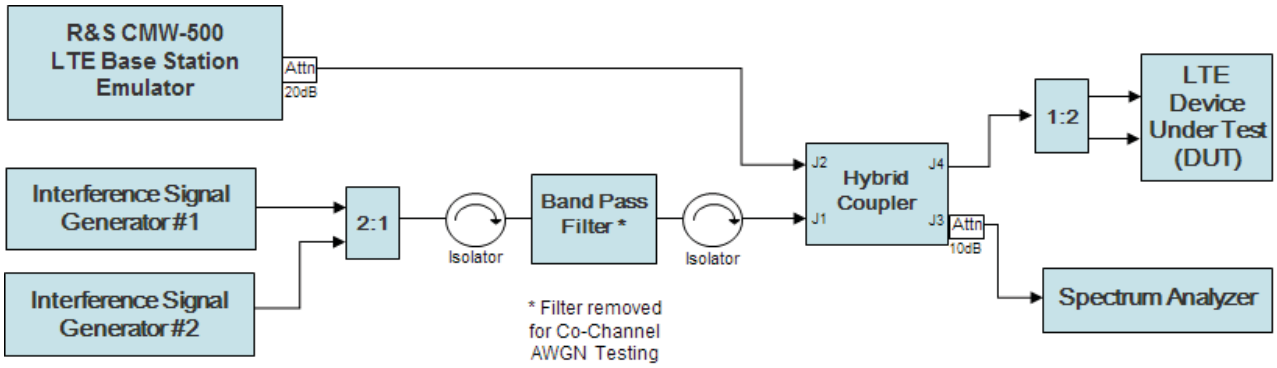


General Testing Guidelines

- Tests are to be performed on a variety of LTE band 12 devices to show range of impacts that can be expected for the test cases outlined above. LTE devices will be representative of the embedded base of LTE devices operating within CMRS networks today.
- Tests are to be performed with a cabled connection to the device's RF antenna connector. The insertion loss of the device's antenna adaptor cable must be specified. The testing will use both antenna diversity ports of the LTE devices under test.
- The R&S CMW500 LTE base station emulator will be used for the LTE device testing, and signal generator(s) will be used for the interference sources.
- All cable offsets will be measured, and signal levels will be reported referenced to the LTE device's RF antenna connector.
- Testing will be performed within shielded rooms or isolation chambers in the test lab, at room temperature.

- In receiver blocking and intermodulation tests, custom filtering is required for these tests, and is used in line with the interference signal generator to reduce its broadband noise and emissions, to isolate and measure the rejection of the LTE devices under test to the adjacent band interference sources.
- LTE devices will be transmitting at nominal power levels (i.e. 0 dBm) during testing on channels used for receiver blocking tests, and at maximum power levels (i.e. 23 dBm) during testing on channels used for intermodulation tests.
- LTE devices will be tested in receive sensitivity tests, then measured in receiver blocking, intermodulation and OOBE receiver tests, with interference sources simulated with the interference signal generator(s).
- Receiver blocking, intermodulation and OOBE receiver tests will be performed with the LTE devices under test at the 1 and 3 dB desensitization (desense) levels, increased above their receive sensitivity operating levels, while recording the level of the interference signals for each test. The interference level will start at a low level and increased until the LTE device under test reaches the 5% BLER threshold (95% of the measurement channel). At these interference levels, the LTE devices under test has been degraded with their receive performance by 1 and 3 dB, respectively.
- The results of these tests will be used to determine appropriate Power and OOBE limits for wireless microphones and white space devices operating in the 600MHz duplex gap and guard band, which provides interference protection to CMRS devices operating in 600MHz spectrum.

Test Setup Diagram



Appendix – Spectrum Charts of Test Cases

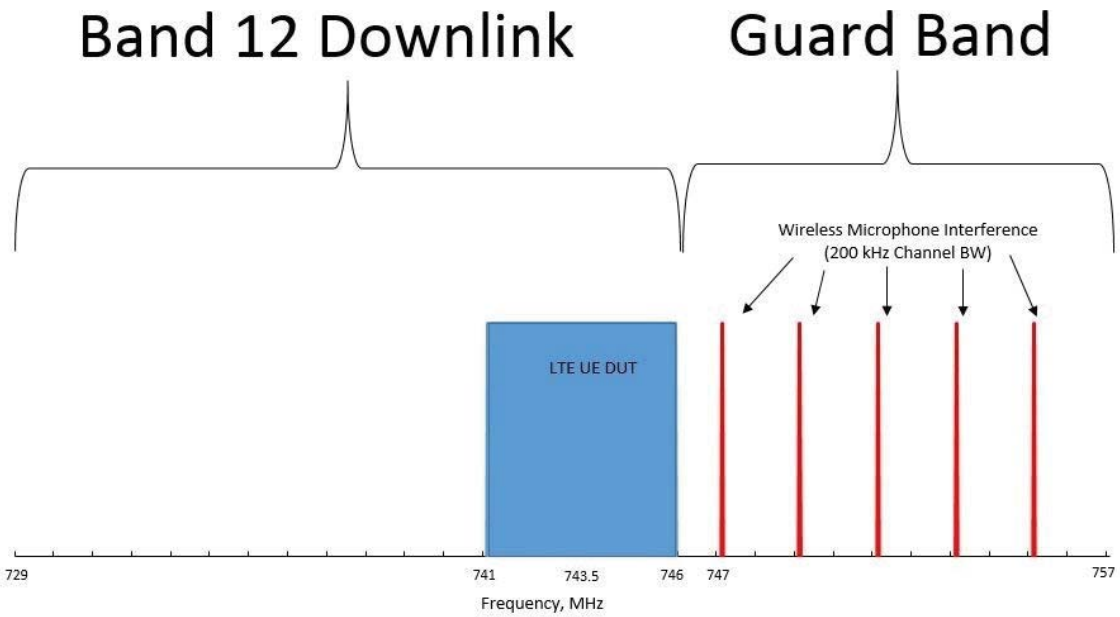


Figure 1 – Wireless Microphone Guard Band Interference Test Case Scenario

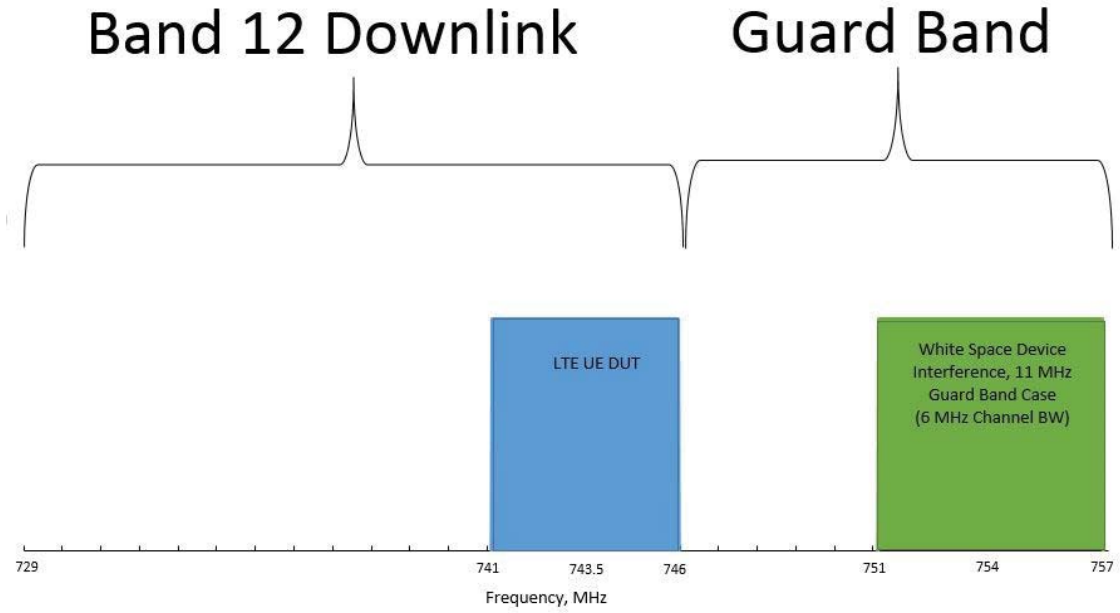


Figure 2 – White Space Device Interference, 11 MHz Guard Band Test Case Scenario

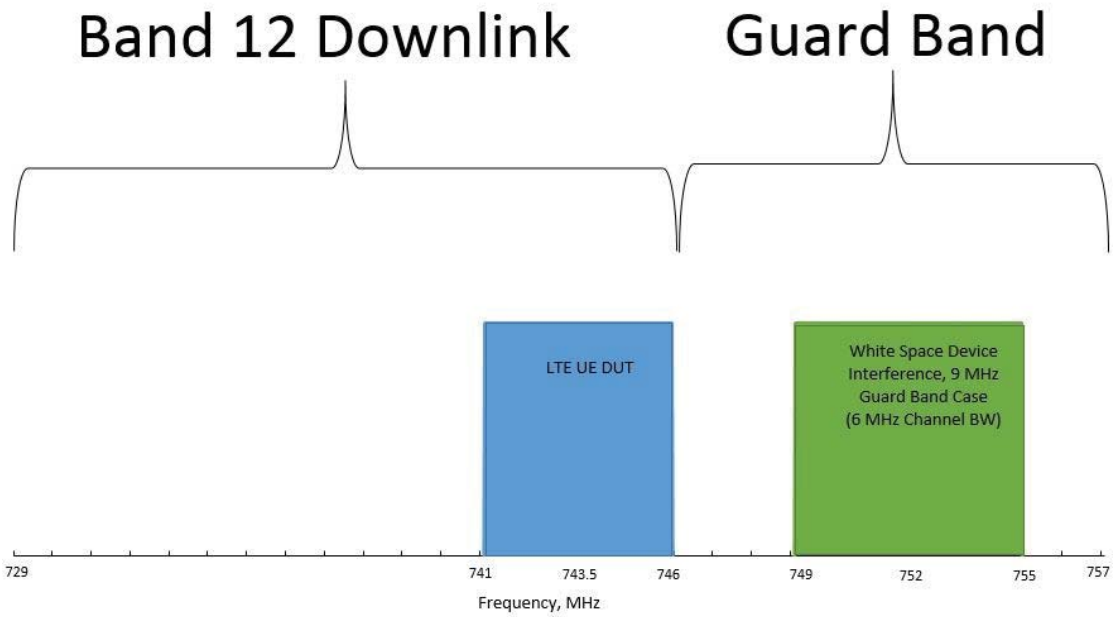


Figure 3 – White Space Device Interference, 9 MHz Guard Band Test Case Scenario

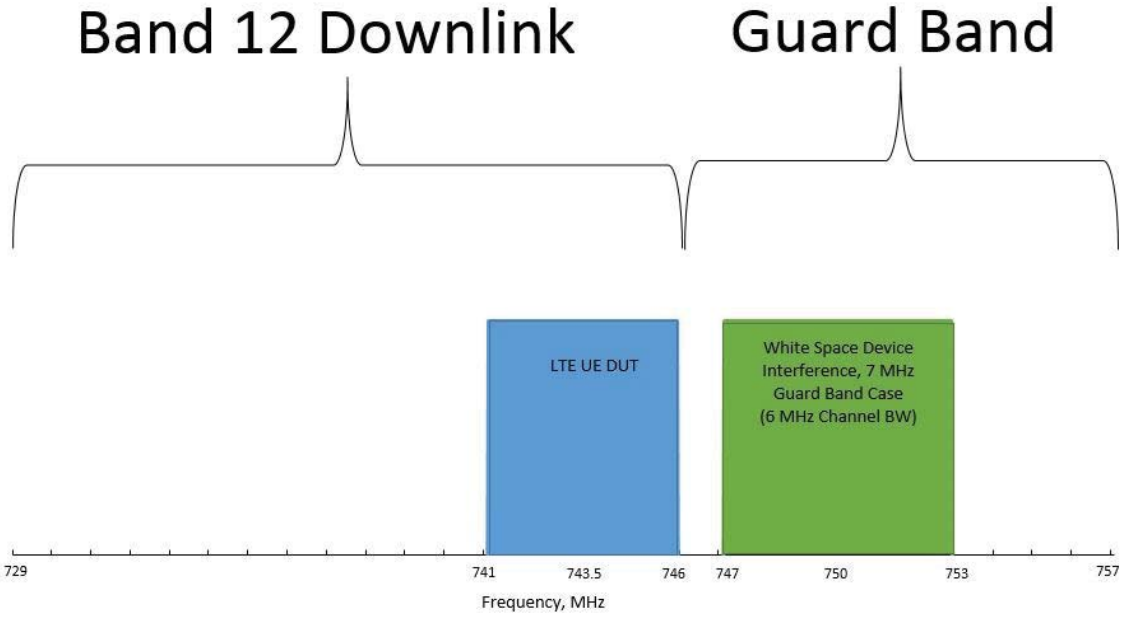


Figure 4 – White Space Device Interference, 7 MHz Guard Band Test Case Scenario

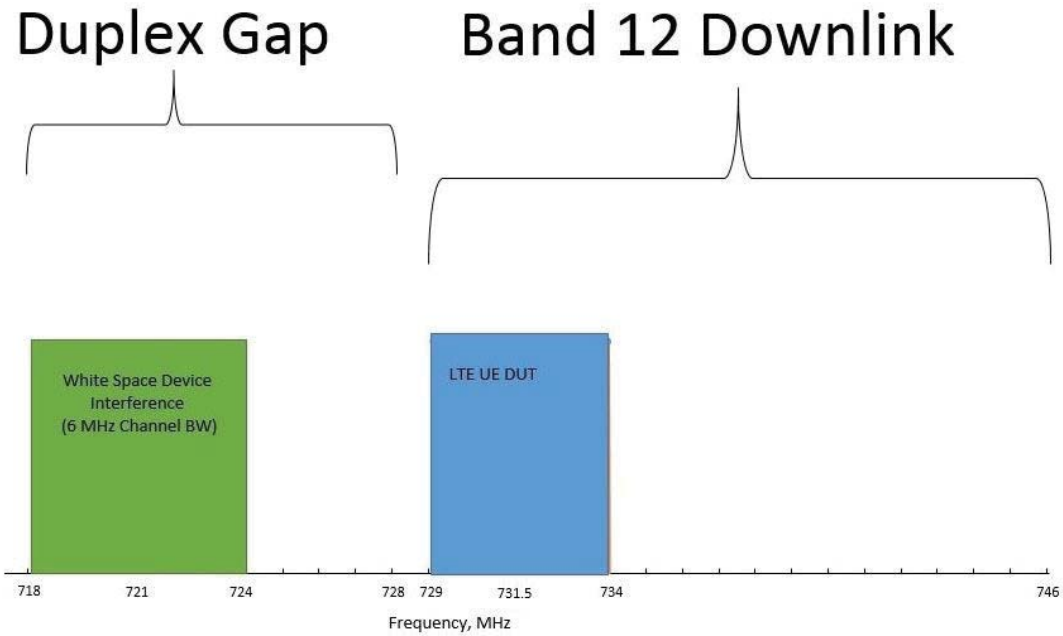


Figure 5 – White Space Device Interference, Duplex Gap Test Case Scenario

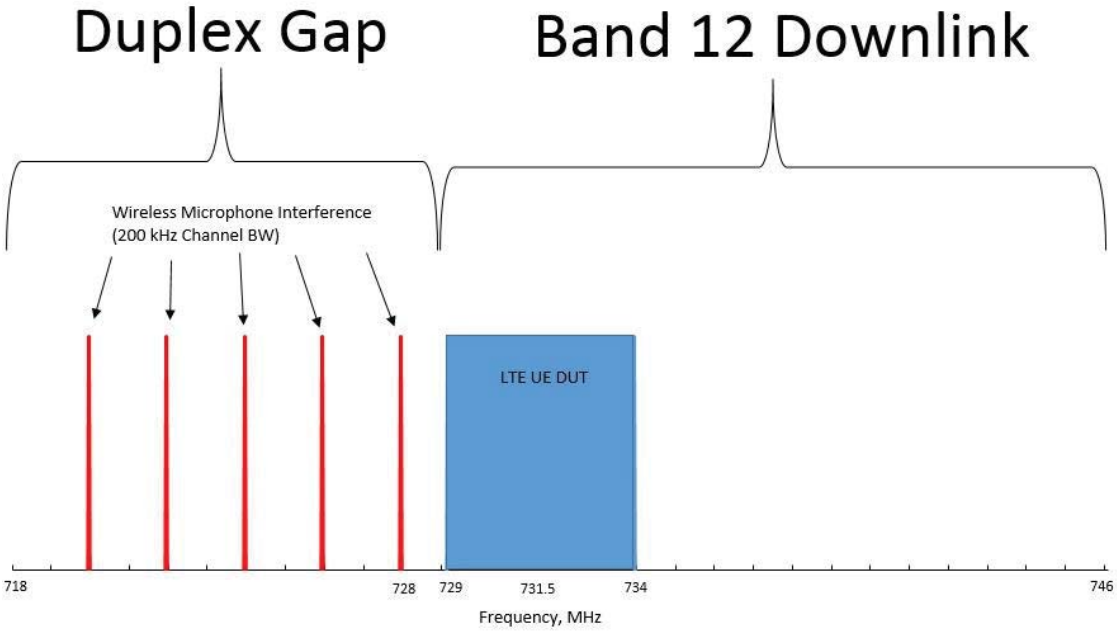


Figure 6 – Wireless Microphone Duplex Gap Interference Test Case Scenario

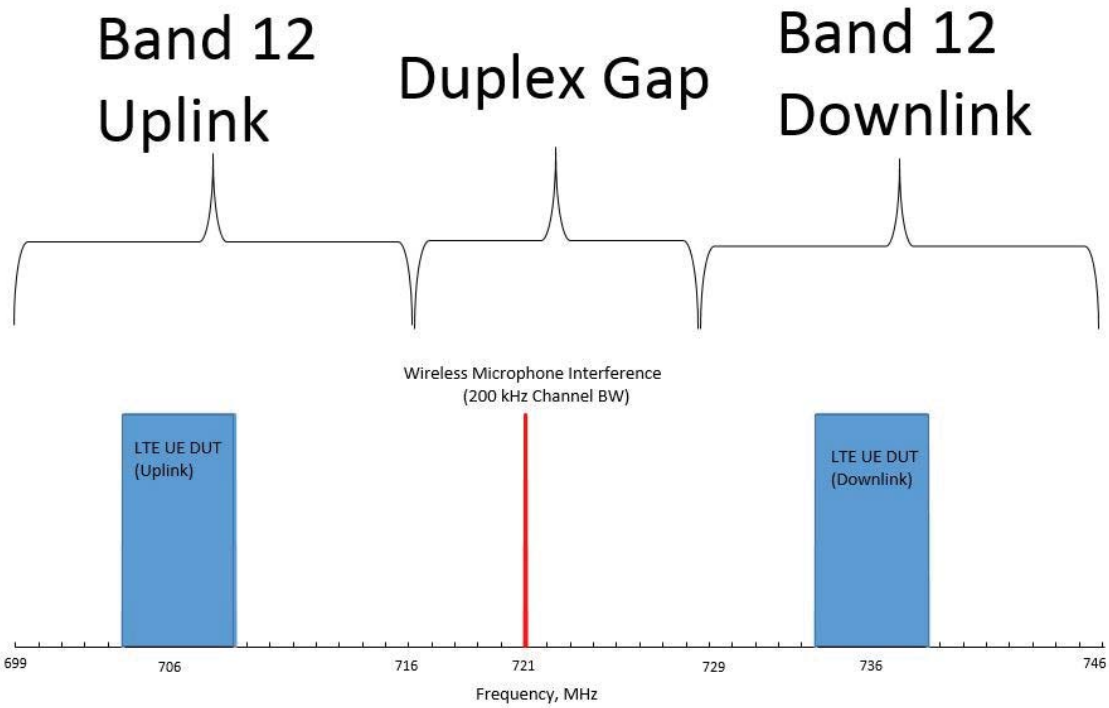


Figure 7 – Wireless Microphone Intermodulation Interference Test Case Scenario

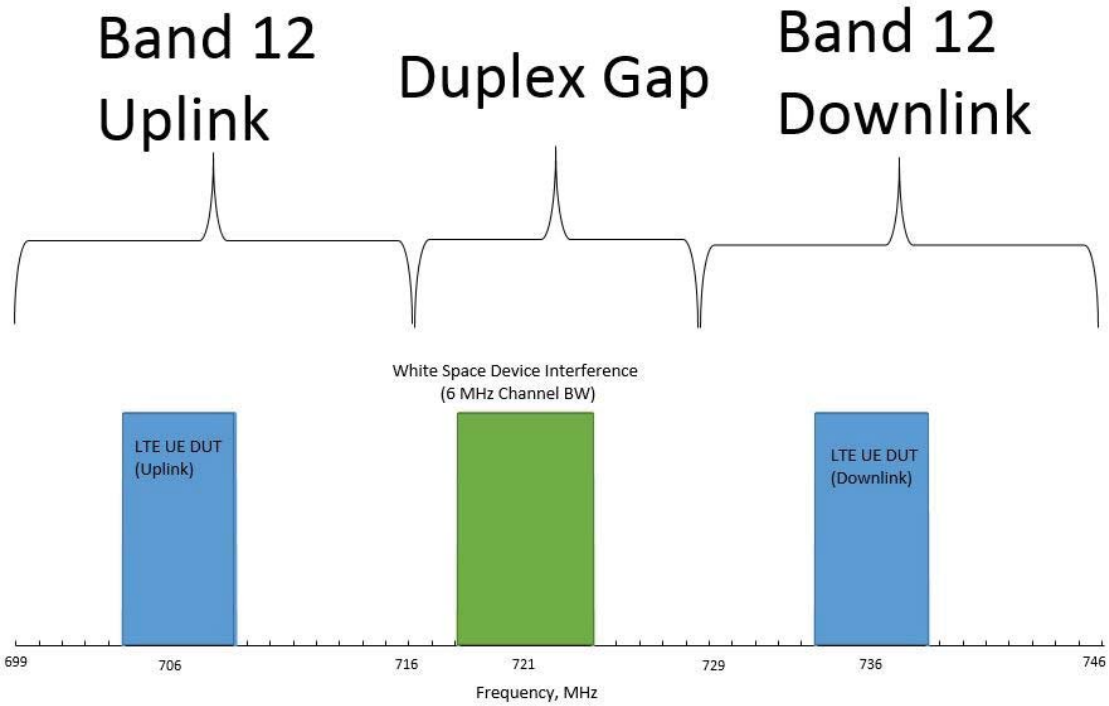


Figure 8 – White Space Device Intermodulation Interference Test Case Scenario

APPENDIX B: WIRELESS MICROPHONE AND TVWS IN 600 MHz DUPLEX GAP AND GUARD BAND—TEST RESULTS WITH LTE DEVICES

Wireless Microphone and TVWS in 600MHz Duplex Gap and Guard Band Test Results with LTE Devices

Sean Haynberg – Director RF Technologies
Justin Day – Staff RF Engineer
David Lacross – Staff RF Engineer

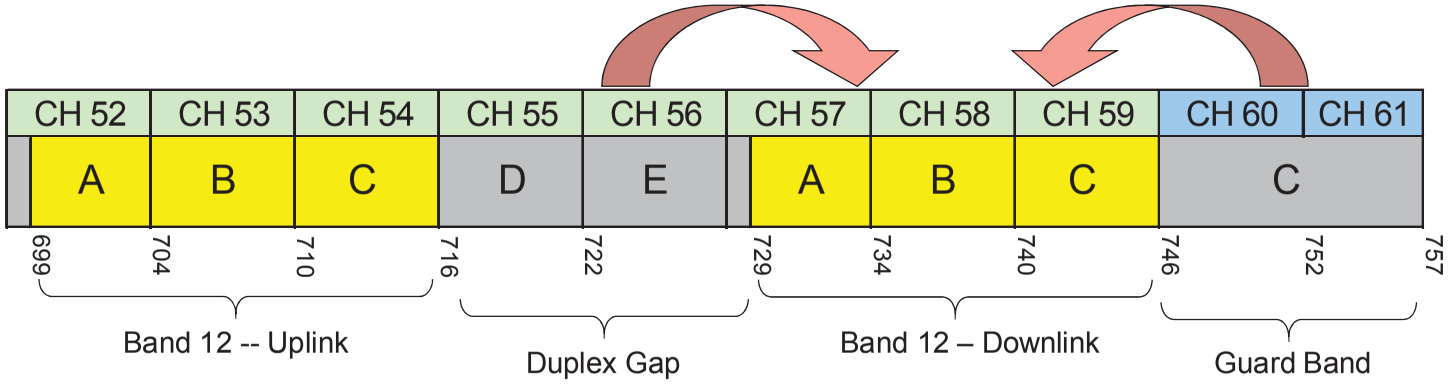
February 4, 2015

Overview

- Introduction
- Testing Overview
- Test Equipment, Setup, and Diagram
- UE Separation Distance vs. Interference levels
- LTE Band 12 Interference Test Results
- Summary of Test Results
- Supplemental Test Results
- Summary of Supplemental Test Results
- Conclusions
- Appendix

Introduction

- Pursuant to the FCC's 600MHz NPRM (14-144), V-COMM performed testing with interference sources in the duplex gap and guard band to study the impact on LTE devices operating in Lower 700 MHz spectrum. See spectrum chart below.
  - Testing was performed to simulate the use of Wireless Microphones and TV White Space (TVWS) devices, with the corresponding frequency offsets planned for operation in the duplex gap and guard band of 600 MHz spectrum.
  - This type of interference is device to device, which impacts CMRS downlink spectrum.
  - Band 12 was chosen to be representative of the 600 MHz spectrum, as it is the closest in operating frequency range, has a similar duplex gap (13 MHz as compared to 11 MHz), and has many devices that are commercially available for testing.
- Testing includes Receiver Blocking and Intermodulation tests with Wireless Microphone and TV White Space device signals, and co-channel AWGN tests, to study the impact to commercial Band 12 LTE devices. Analysis of test results will determine appropriate Wireless Microphone and TV White Space device Power and Emissions limits required to protect 600 MHz CMRS licensees.



Lower 700 MHz Spectrum Chart

Testing Overview

- Testing includes a variety of commercial Band 12 LTE devices (10 in total)
  - Represents typical devices from embedded base of LTE devices. Includes a total of 10 LTE devices (8 smartphones, 2 tablets) from 4 different manufacturers.
  - All LTE devices were tested to meet 3GPP receive sensitivity specifications.
- Receiver Blocking tests with Wireless Microphone and TV White Space device signals located within the Duplex Gap were performed on LTE devices operating in Band 12 on channel 5035 at 731.5 MHz.
- Receiver Blocking tests with Wireless Microphone and TV White Space device signals located within the Guard Band were performed on LTE devices operating in Band 12 on channel 5155 at 743.5 MHz.
- Intermodulation tests with Wireless Microphone and TV White Space device signals located within the Duplex Gap were performed on LTE devices operating in Band 12 on channel 5080 at 736 MHz, for the 3rd order intermodulation impacts.
- Co-channel AWGN interference tests was performed on LTE devices operating in Band 12 on channel 5035 at 731.5 MHz, for OOBE receiver impacts.
- All tests capture the impact to the LTE devices under test (DUT) at the 1 dB and 3 dB desensitization (desense) interference thresholds, which represents the increase in the noise floor of the LTE devices under test due to Wireless Microphone/TV White Space device interference.
  - Increases in device noise floors degrade and negatively impacts the forward link budget, which reduces the downlink (DL) system coverage and performance of nearby LTE devices.
  - Receiver Blocking and AWGN tests were performed with LTE DUT operating at 0 dBm power level, and Intermodulation tests were performed with the LTE DUT operating at 23 dBm power level, and according to 3GPP receive sensitivity standards specification at 5% BLER (Block Error Rate) for 95% throughput of the specified channel.
- All signal levels in this report are referenced to the LTE DUT's RF antenna ports.

Testing Overview

- Wireless Microphone interference was simulated by a two-tone FM modulated signal, using a frequency of 1 kHz at the rated deviation of 40 kHz, with the pilot frequency of 32.768 kHz at a 5 kHz deviation.
  - The Wireless Microphone interference was tested with 1, 3, 5, 7 and 9 MHz buffers* in the Duplex Gap, at the center frequency 727.9 MHz, 725.9 MHz, 723.9 MHz, 721.9 MHz, and 719.9 MHz, respectively.
  - The Wireless Microphone interference was tested with 1, 3, 5, 7, and 9 MHz buffers in the Guard Band, at the center frequency 747.1 MHz, 749.1 MHz, 751.1 MHz, 753.1 MHz, and 755.1 MHz, respectively.
  - The Wireless Microphone interference was tested with a 8 MHz buffer at 721 MHz in the Duplex Gap for the Intermodulation tests.
- TV White Space device interference was simulated by using an 802.11ac signal, using the sample rate parameter setting to achieve an occupied bandwidth of 4.875 MHz.
  - The TV White Space device interference was tested with a 5 MHz buffer in the Duplex Gap at 721 MHz, in receiver blocking and intermodulation tests.
  - The TV White Space device interference was tested with 1, 3 and 5 MHz buffers in the Guard Band, at 750 MHz, 752 MHz, and 754 MHz, respectively.
- OOBE interference was simulated by AWGN interference signals operating co-channel to the LTE device under test.
- For additional testing details, see the CTIA 600 MHz Testing Plan (dated Feb. 4, 2015).
- See spectrum charts below of the guard band and duplex gap test cases.

* Note: The buffer represents the frequency separation from CMRS DL band to the interfering signal's channel edge.

Spectrum Charts of Guard Band Test Cases

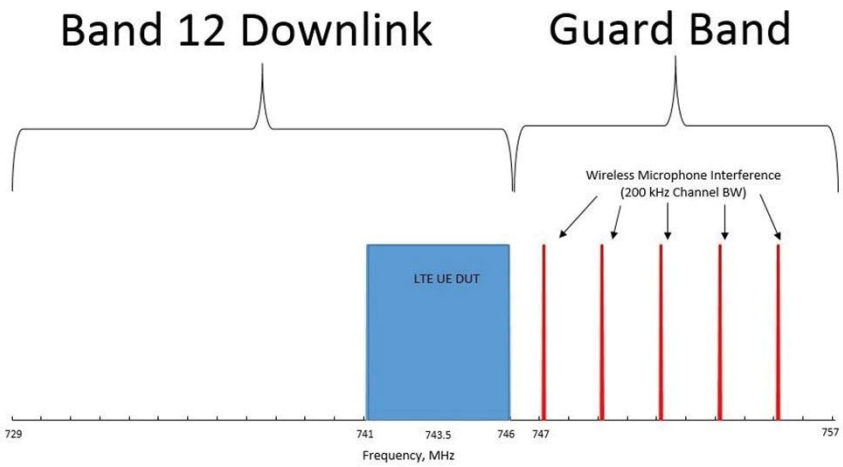


Figure 1 – Wireless Microphone Guard Band Interference Test Case Scenario

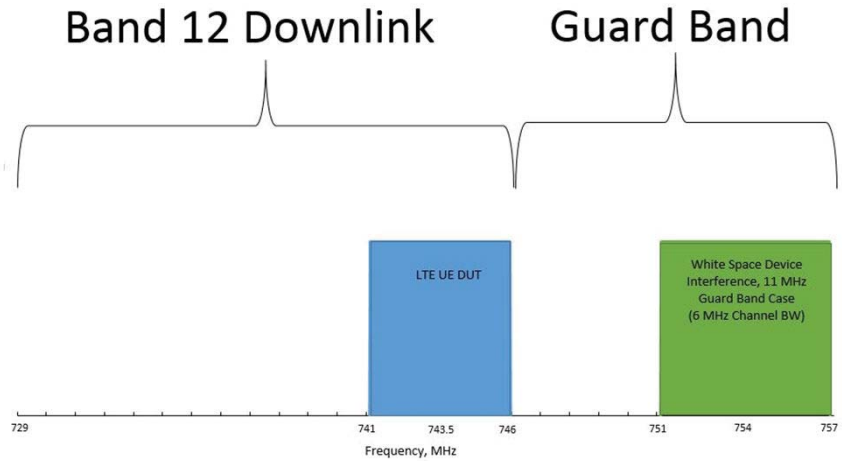


Figure *2* – White Space Device Interference, 11 MHz Guard Band Test Case Scenario

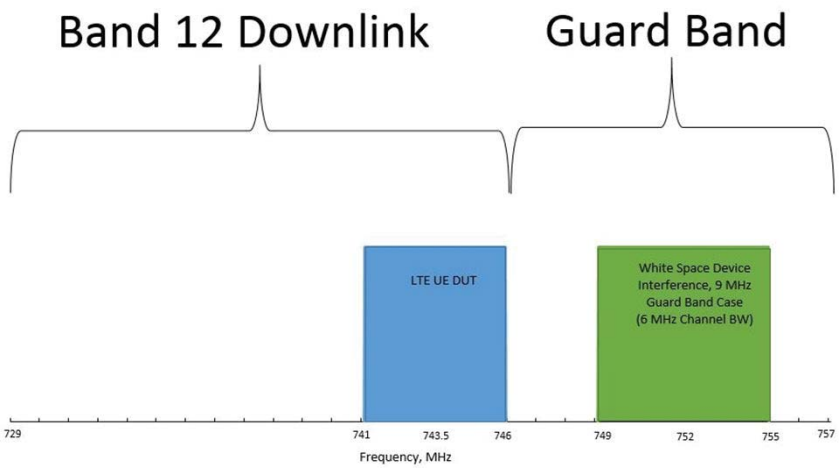


Figure 3 – White Space Device Interference, 9 MHz Guard Band Test Case Scenario

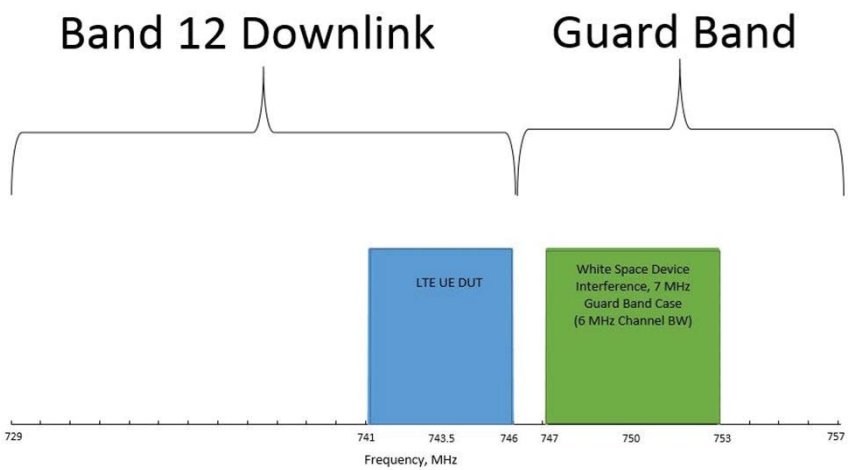


Figure *4* – White Space Device Interference, 7 MHz Guard Band Test Case Scenario

Note: The above spectrum charts are also provided in the CTIA Testing Plan with more detail.

Spectrum Charts of Duplex Gap Test Cases

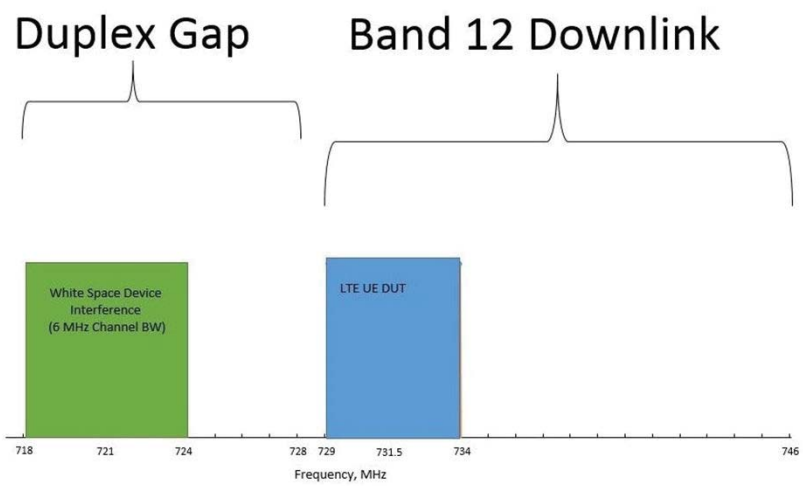


Figure 5 – White Space Device Interference, Duplex Gap Test Case Scenario

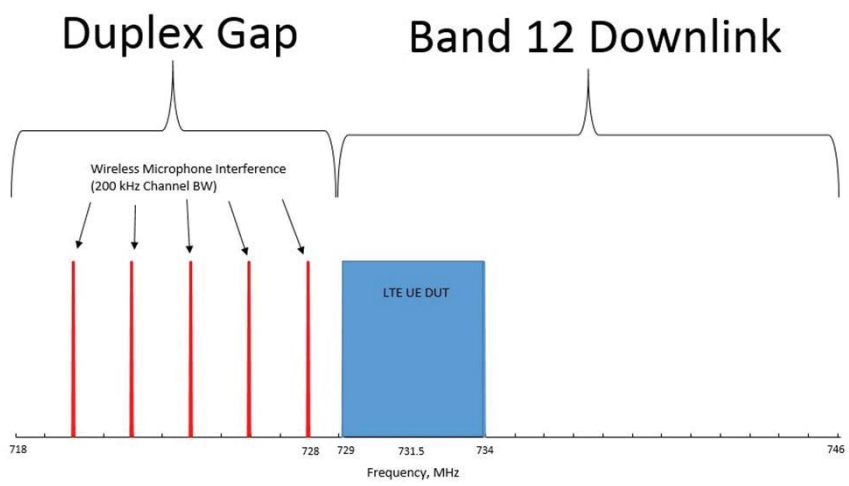


Figure 6 – Wireless Microphone Duplex Gap Interference Test Case Scenario

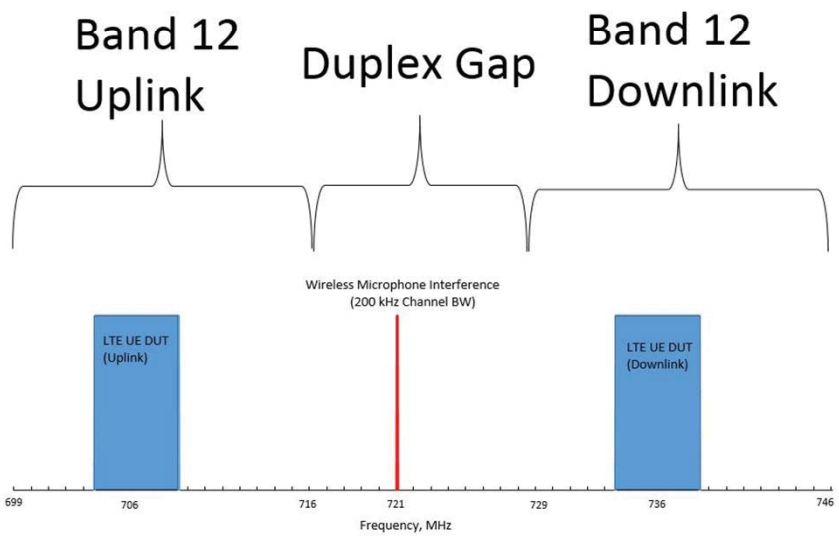


Figure 7 – Wireless Microphone Intermodulation Interference Test Case Scenario

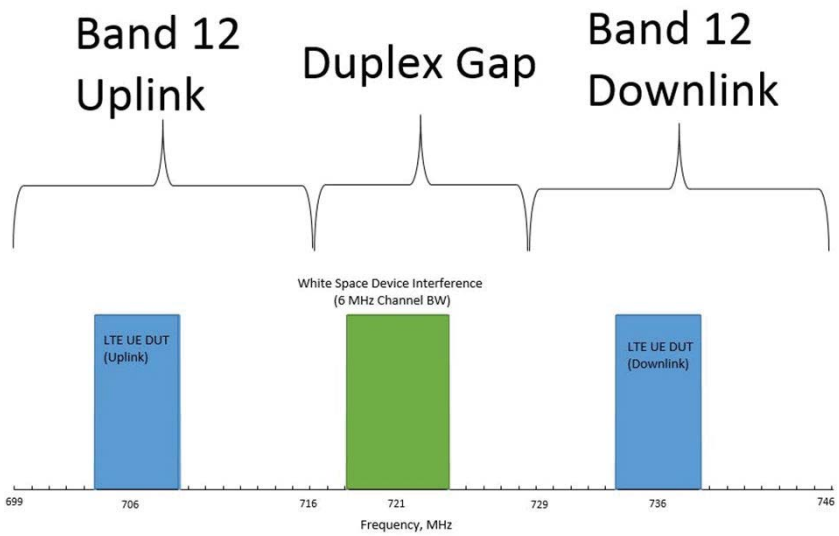


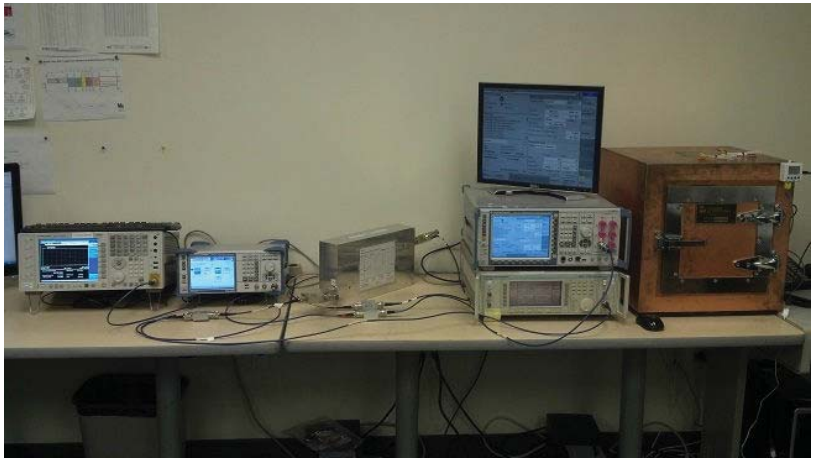
Figure 8 – White Space Device Intermodulation Interference Test Case Scenario

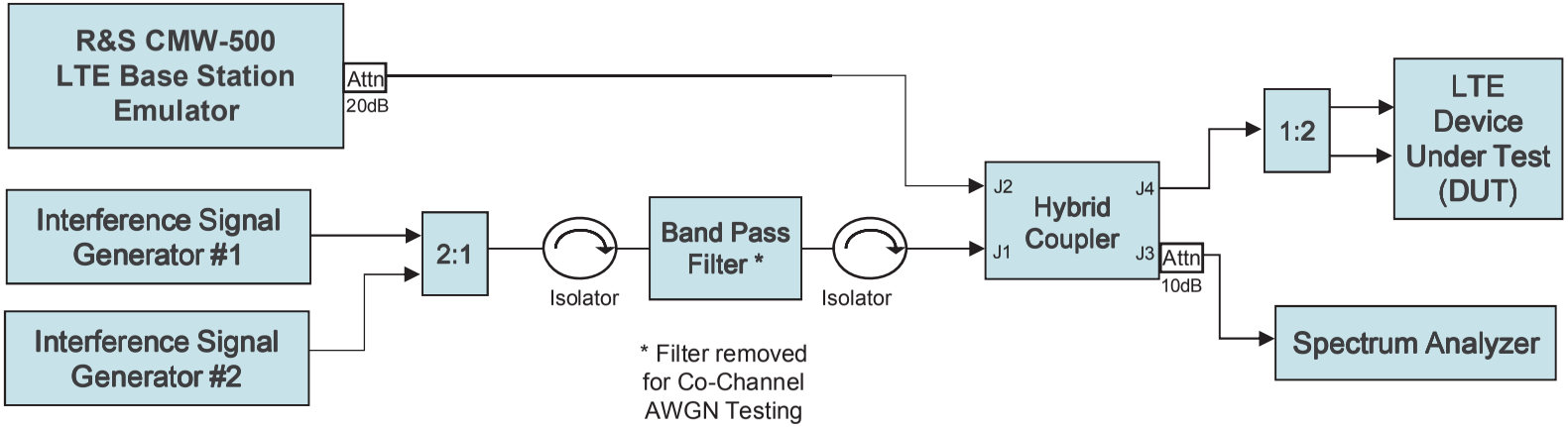
Note: The above spectrum charts are also provided in the CTIA Testing Plan with more detail.

Test Equipment, Setup, and Diagram

Test Equipment & Devices Under Test (DUT):

- R&S CMW500 LTE Base Station Emulator
- R&S SMBV100A Vector Signal Generator (TVWS/802.11ac, AWGN, FM sources)
- Aeroflex/Marconi 2031 FM Signal Generator
- Agilent MXA Spectrum Analyzer
- Duplex Gap/Guard Band filters, to reduce interference generator spurious emissions
- Coupler/power dividers, isolators, attenuators
- LTE devices tested in RF Enclosure/Chamber, connected to both antenna ports
- 10 LTE Devices Tested – representative of embedded base of CMRS devices





UE Separation Distances vs. Interference levels

TV White Space Devices to LTE UE

Device to LTE UE Link/Path Losses:

- TV White Space device TX Power = +16 dBm (at proposed 40 milliwatts per NPRM)
- Device and UE Antenna Gain = 0 dBi
- TX Device Antenna Loss = 3 dB (held in hand)
- RX UE Antenna Loss = 3 dB (held in hand)
- Antenna Polarization Mismatch, and Misc. Losses = 3 dB
- Path Loss at 665 MHz
- See Interference Received Levels at UE vs. UE separation distances to the right.

For example, at 1 meter device separation:

- Free-space Path Loss at 665 MHz is 29 dB
- Total Device to UE coupling losses is 38 dB
  (3 + 3 + 3 + 29 = 38 dB)
- TV White Space Device interference level received at LTE UE is -22 dBm at 1 m device separation.* (+16 dBm - 38 dB = -22 dBm)
- TV White Space device interference received above -22 dBm level occurs at distances less than 1 meter.

Interference Rx Level @ UE (dBm)	Separation Distance (m)
-15	0.5
-16	0.5
-17	0.6
-18	0.6
-19	0.7
-20	0.8
-21	0.9
-22	1.0
-23	1.1
-24	1.3
-25	1.4
-26	1.6
-27	1.8
-28	2.0
-29	2.3
-30	2.5
-31	2.8
-32	3.2
-33	3.6
-34	4.0
-35	4.5
-36	5.1
-37	5.7

Interference Rx Level @ UE (dBm)	Separation Distance (m)
-38	6.4
-39	7.2
-40	8.0
-41	9.0
-42	10.1
-43	11.3
-44	12.7
-45	14.3
-46	16.0
-47	18.0
-48	20.2
-49	22.6
-50	25.4
-51	28.5
-52	32.0
-53	35.9
-54	40.2
-55	45.2
-56	50.7
-57	56.8
-58	63.8
-59	71.6
-60	80.3

* Note: The charts for TVWS test results include a display line at -22 dBm to show this received level at 1 meter. TVWS devices are used in similar applications as CMRS devices and are used in close proximity, thus 1 meter separation is used for interference analysis and is referenced in industry standards.

UE Separation Distances vs. Interference levels

Wireless Microphones to LTE UE

Device to LTE UE Link/Path Losses:

- Wireless Microphone TX Power = +13 dBm (at proposed 20 milliwatts per NPRM)
- Device and UE Antenna Gain = 0 dBi
- TX Device Antenna Loss = 3 dB (held in hand)
- RX UE Antenna Loss = 3 dB (held in hand)
- Antenna Polarization Mismatch, and Misc. Losses = 3 dB
- Path Loss at 665 MHz
- See Interference Received Levels at UE vs. UE separation distances to the right.

For example, at 1 meter device separation:

- Free-space Path Loss at 665 MHz is 29 dB
- Total Device to UE coupling losses is 38 dB
  (3 + 3 + 3 + 29 = 38 dB)
- Wireless Microphone interference level received at LTE UE is -25 dBm at 1 m device separation.* (+13 dBm - 38 dB = -25 dBm)
- Wireless Microphone interference received above -25 dBm level occurs at distances less than 1 meter.

Interference Rx Level @ UE (dBm)	Separation Distance (m)
-15	0.3
-16	0.4
-17	0.4
-18	0.5
-19	0.5
-20	0.6
-21	0.6
-22	0.7
-23	0.8
-24	0.9
-25	1.0
-26	1.1
-27	1.3
-28	1.4
-29	1.6
-30	1.8
-31	2.0
-32	2.3
-33	2.5
-34	2.8
-35	3.2
-36	3.6
-37	4.0

Interference Rx Level @ UE (dBm)	Separation Distance (m)
-38	4.5
-39	5.1
-40	5.7
-41	6.4
-42	7.2
-43	8.0
-44	9.0
-45	10.1
-46	11.3
-47	12.7
-48	14.3
-49	16.0
-50	18.0
-51	20.2
-52	22.6
-53	25.4
-54	28.5
-55	32.0
-56	35.9
-57	40.2
-58	45.2
-59	50.7
-60	56.8

* Note: The charts for wireless microphones include a display line at -25 dBm to show this received level at 1 meter. These devices may be used in close proximity to CMRS devices, and consistent with interference analysis of TVWS devices, 1 meter separation is used for interference analysis of wireless microphones to nearby CMRS devices.

LTE Band 12 Interference Test Results

Test Results Overview

- Sensitivity of LTE Devices Tested
- Receiver Blocking Test Results into LTE Band 12 Duplex Gap *
    - Wireless Microphone @ 727.9 MHz, 1 MHz Buffer
    - Wireless Microphone @ 725.9 MHz, 3 MHz Buffer
    - Wireless Microphone @ 723.9 MHz, 5 MHz Buffer
    - Wireless Microphone @ 721.9 MHz, 7 MHz Buffer
    - Wireless Microphone @ 719.9 MHz, 9 MHz Buffer
    - TV White Space Device @ 721 MHz, 5 MHz Buffer
- Receiver Blocking Test Results into LTE Band 12 Guard Band *
    - Wireless Microphone @ 747.1 MHz, 1 MHz Buffer
    - Wireless Microphone @ 749.1 MHz, 3 MHz Buffer
    - Wireless Microphone @ 751.1 MHz, 5 MHz Buffer
    - Wireless Microphone @ 753.1 MHz, 7 MHz Buffer
    - Wireless Microphone @ 755.1 MHz, 9 MHz Buffer
    - TV White Space Device @ 750 MHz, 1 MHz Buffer
    - TV White Space Device @ 752 MHz, 3 MHz Buffer
    - TV White Space Device @ 754 MHz, 5 MHz Buffer
- Intermodulation Test Results into LTE Band 12 Duplex Gap
    - Wireless Microphone @ 721 MHz, 8 MHz Buffer
    - TV White Space Device @ 721 MHz, 5 MHz Buffer

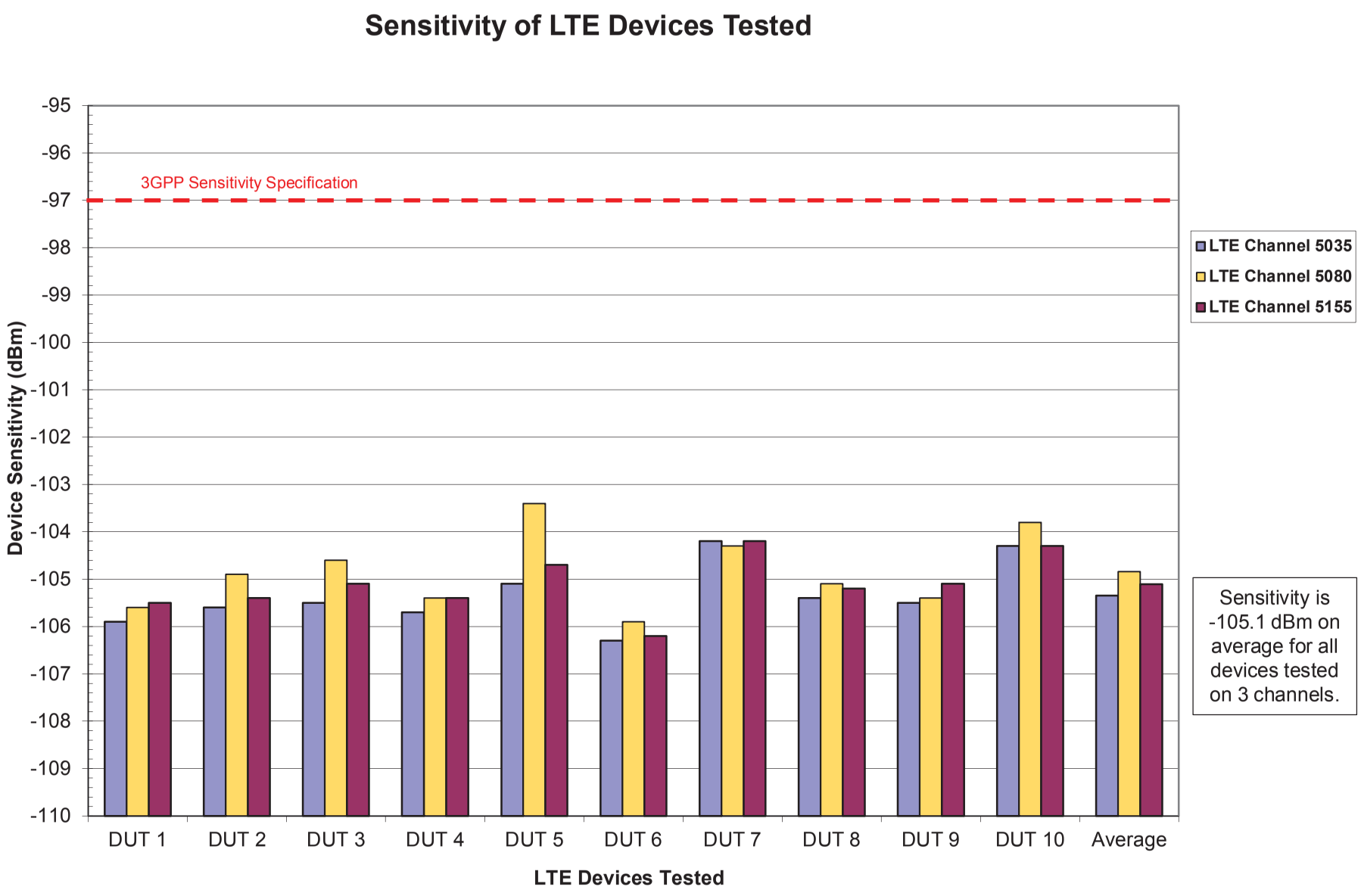
* Note: These results are also shown graphically on pages 31 to 74 in the Individual Device Test Results section.

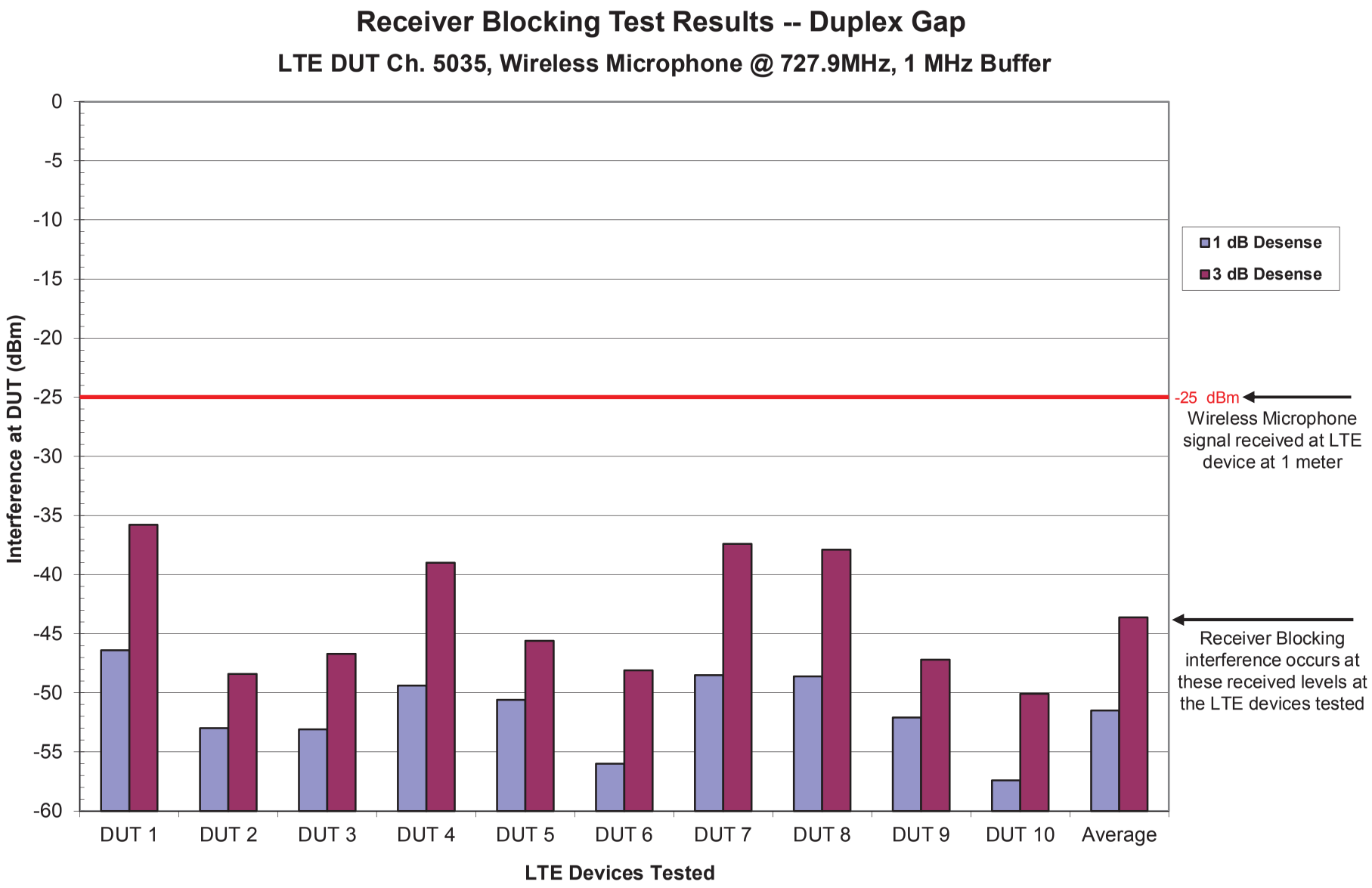
Note: The Buffer represents the frequency separation from CMRS DL band to the interfering signal's channel edge.

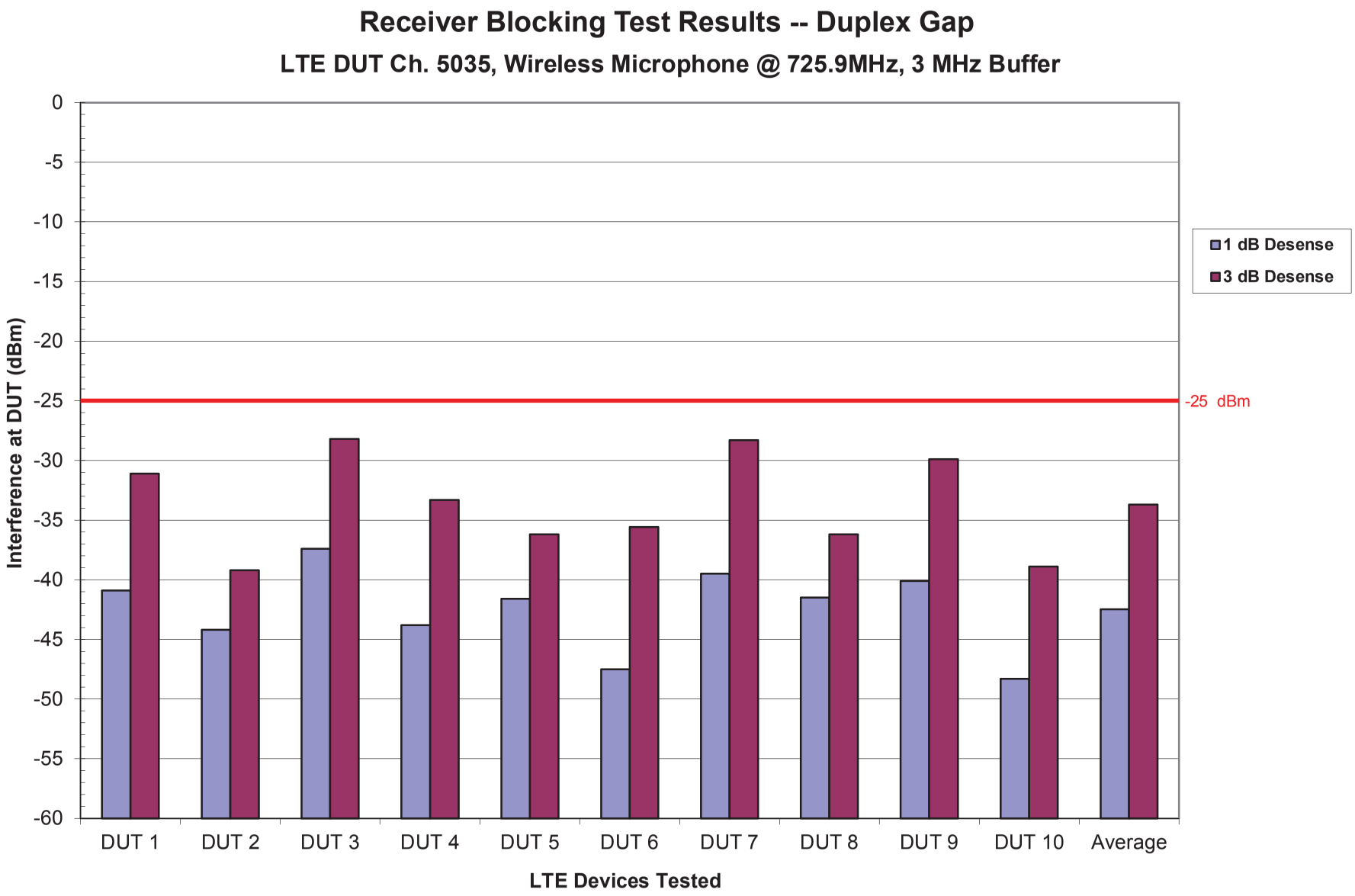
Test Results Overview

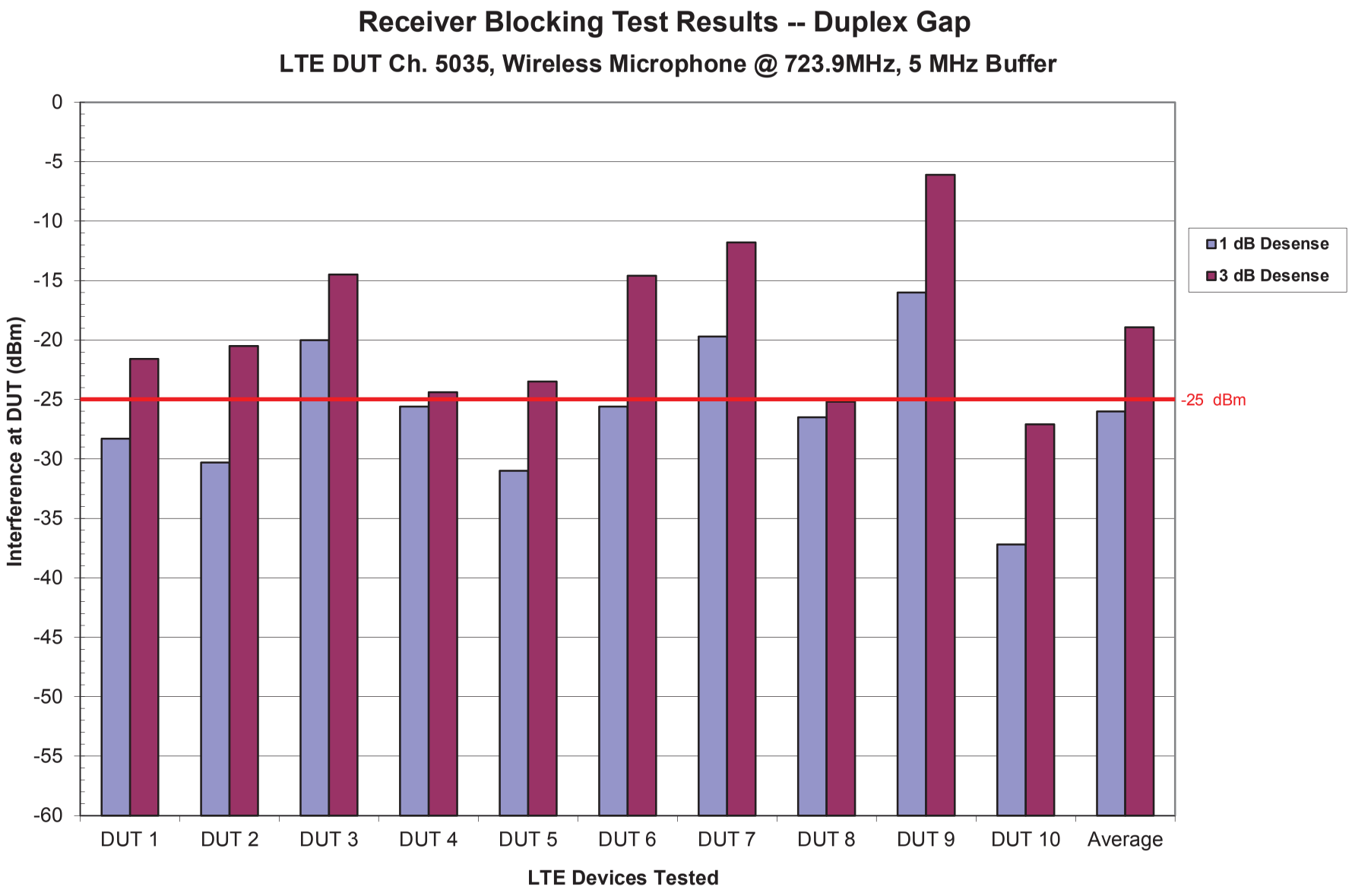
- Individual Device Receiver Blocking Test Results into LTE Band 12 Duplex Gap *
    - DUT 1 @ 1 dB and 3 dB Desense
    - DUT 2 @ 1 dB and 3 dB Desense
    - DUT 3 @ 1 dB and 3 dB Desense
    - DUT 4 @ 1 dB and 3 dB Desense
    - …..
    - DUT 10 @ 1 dB and 3 dB Desense
    - Average of 10 LTE Devices @ 1 dB and 3 dB Desense
- Individual Device Receiver Blocking Test Results LTE Band 12 Guard Band *
    - DUT 1 @ 1 dB and 3 dB Desense
    - DUT 2 @ 1 dB and 3 dB Desense
    - DUT 3 @ 1 dB and 3 dB Desense
    - DUT 4 @ 1 dB and 3 dB Desense
    - …..
    - DUT 10 @ 1 dB and 3 dB Desense
    - Average of 10 LTE Devices @ 1 dB and 3 dB Desense
- Co Channel AWGN Test Results

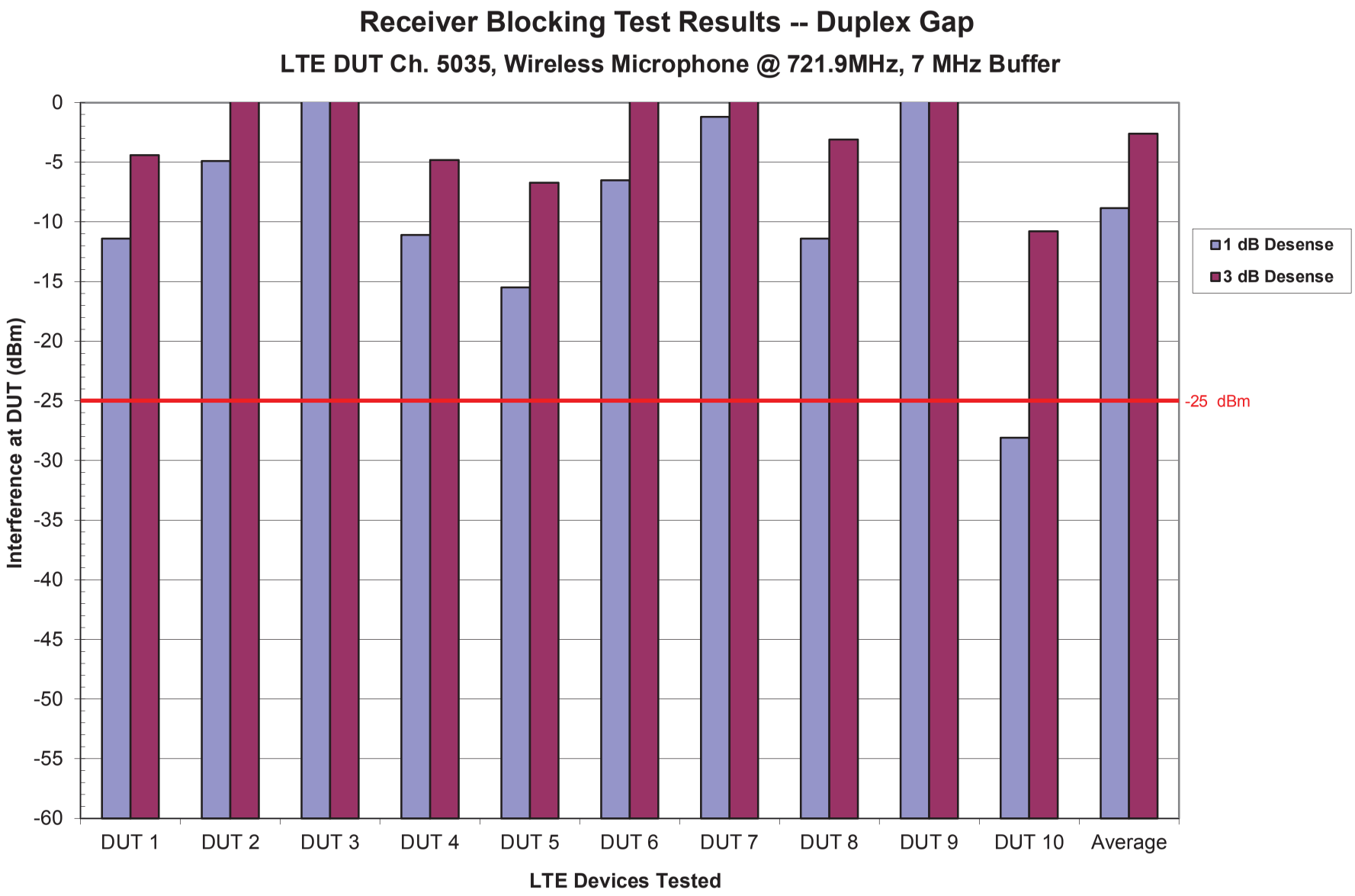
Note: * The Individual Device Test Results are provided for all 10 DUT, and the average, at 1 dB and 3 dB desense thresholds. The interference power levels are referenced to the total channel power of the interfering signal.

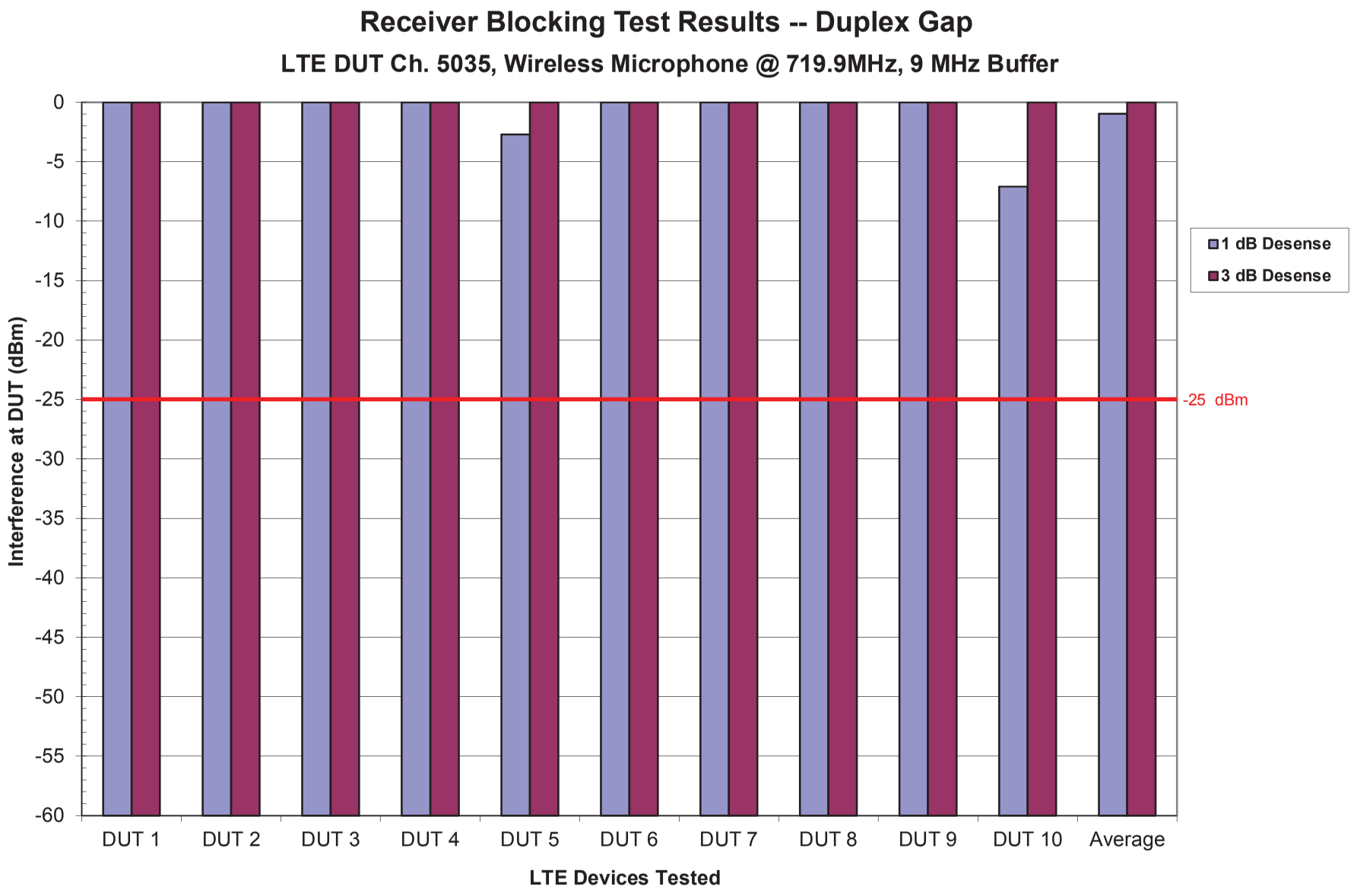

Sensitivity of LTE Devices Tested
3GPP Sensitivity Specification
Device Sensitivity (dBm)
-95
-96
-97
-98
-99
-100
-101
-102
-103
-104
-105
-106
-107
-108
-109
-110
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested
LTE Channel 5035
LTE Channel 5080
LTE Channel 5155
Sensitivity is -105.1 dBm on average for all devices tested on 3 channels.

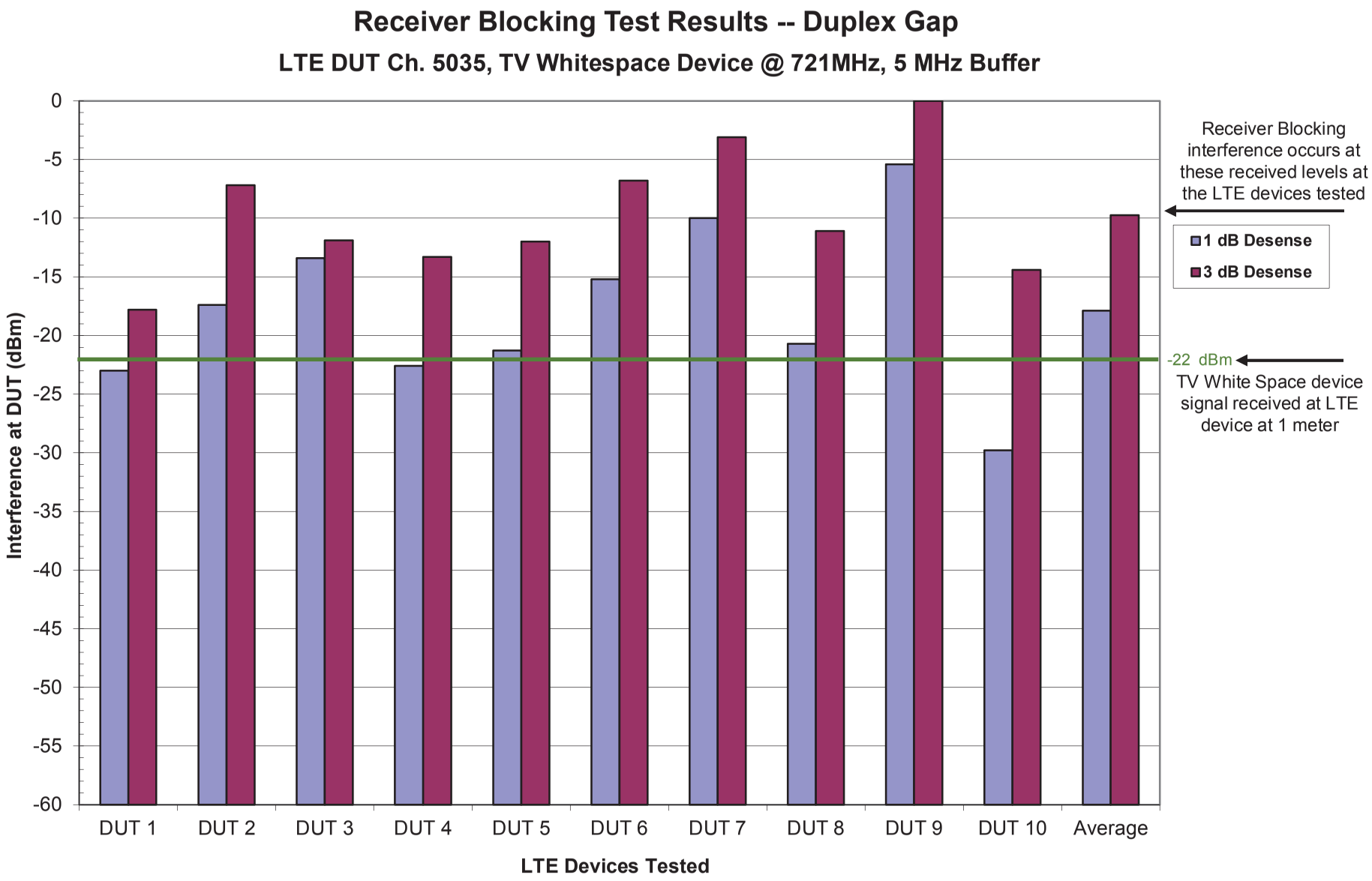

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, Wireless Microphone @ 727.9MHz, 1 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested
1 dB Desense
3 dB Desense
-25 dBm
Wireless Microphone signal received at LTE device at 1 meter
Receiver Blocking interference occurs at these received levels at the LTE devices tested

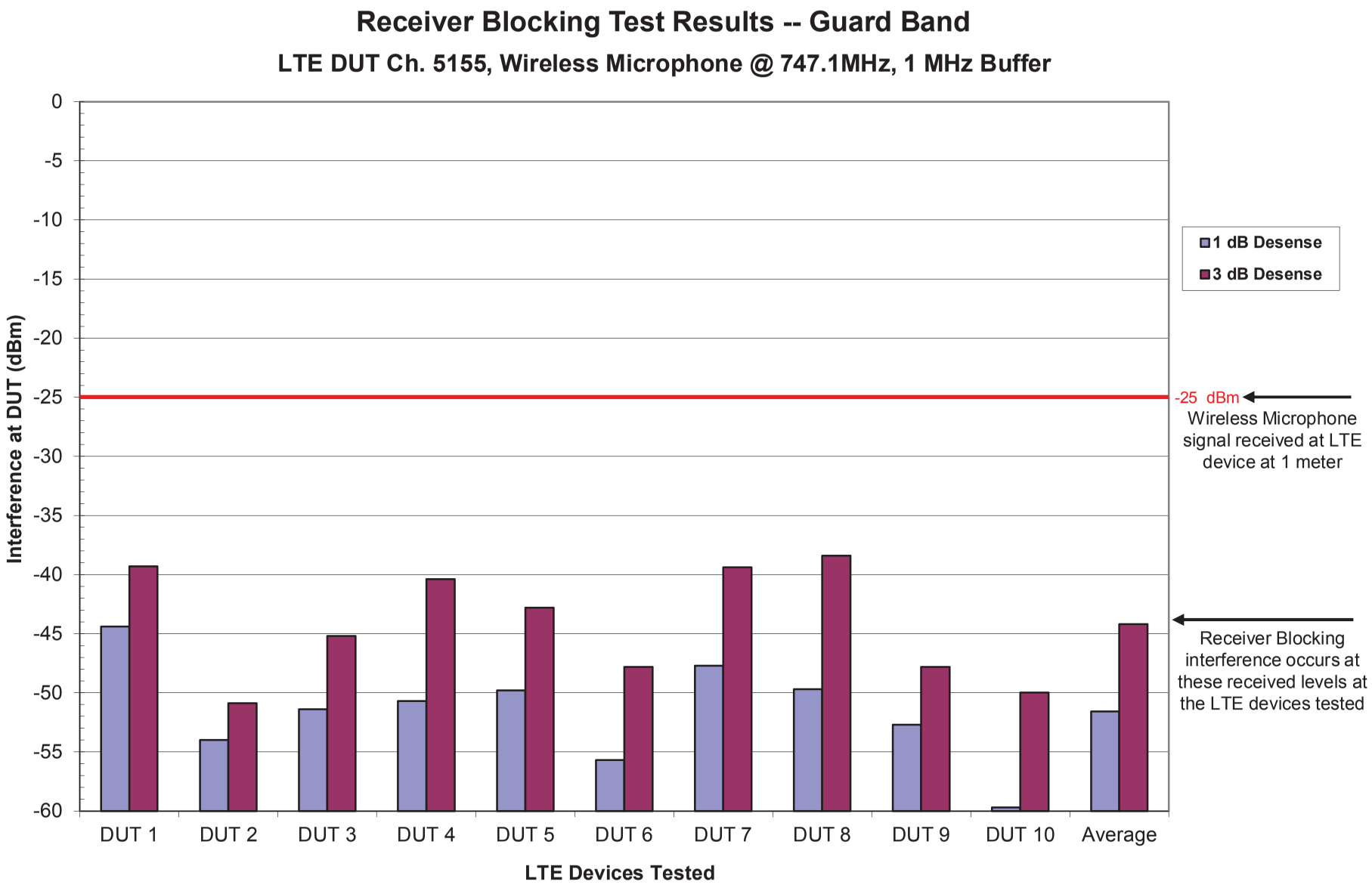

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, Wireless Microphone @ 725.9MHz, 3 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-25 dBm
1 dB Desense
3 dB Desense
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested

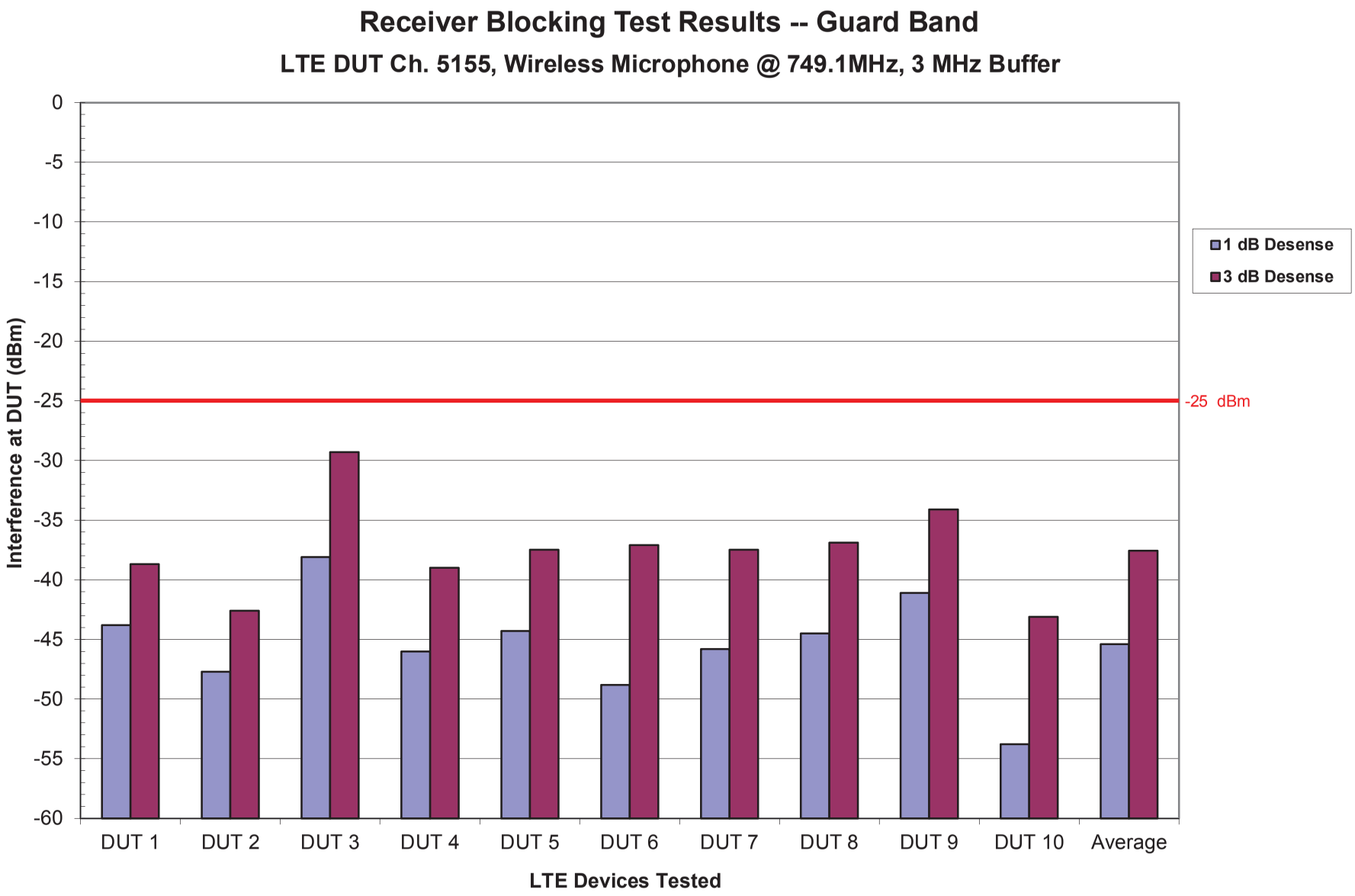

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, Wireless Microphone @ 723.9MHz, 5 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-25 dBm
1 dB Desense
3 dB Desense
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested

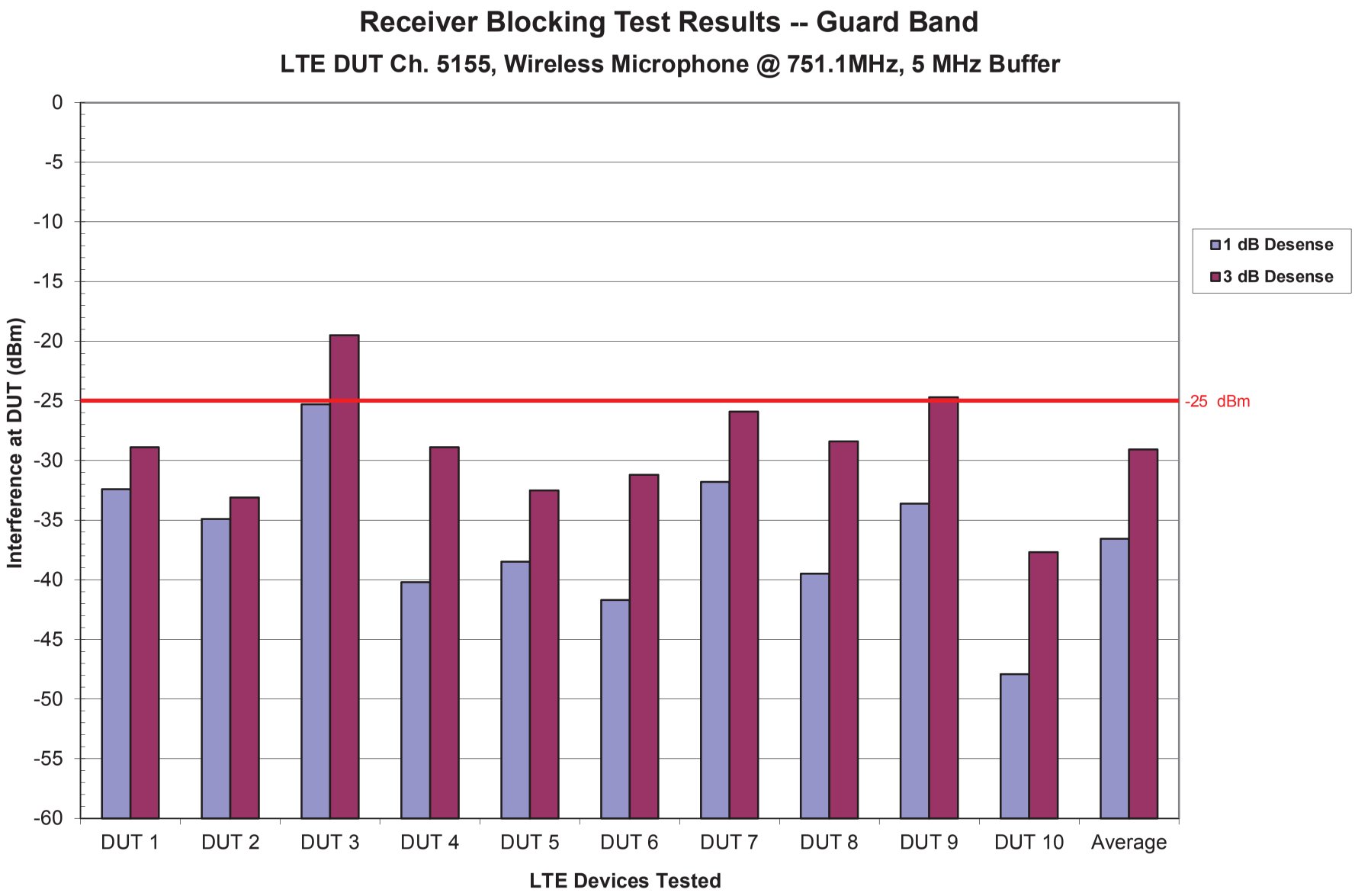

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, Wireless Microphone @ 721.9MHz, 7 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-25 dBm
1 dB Desense
3 dB Desense
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested

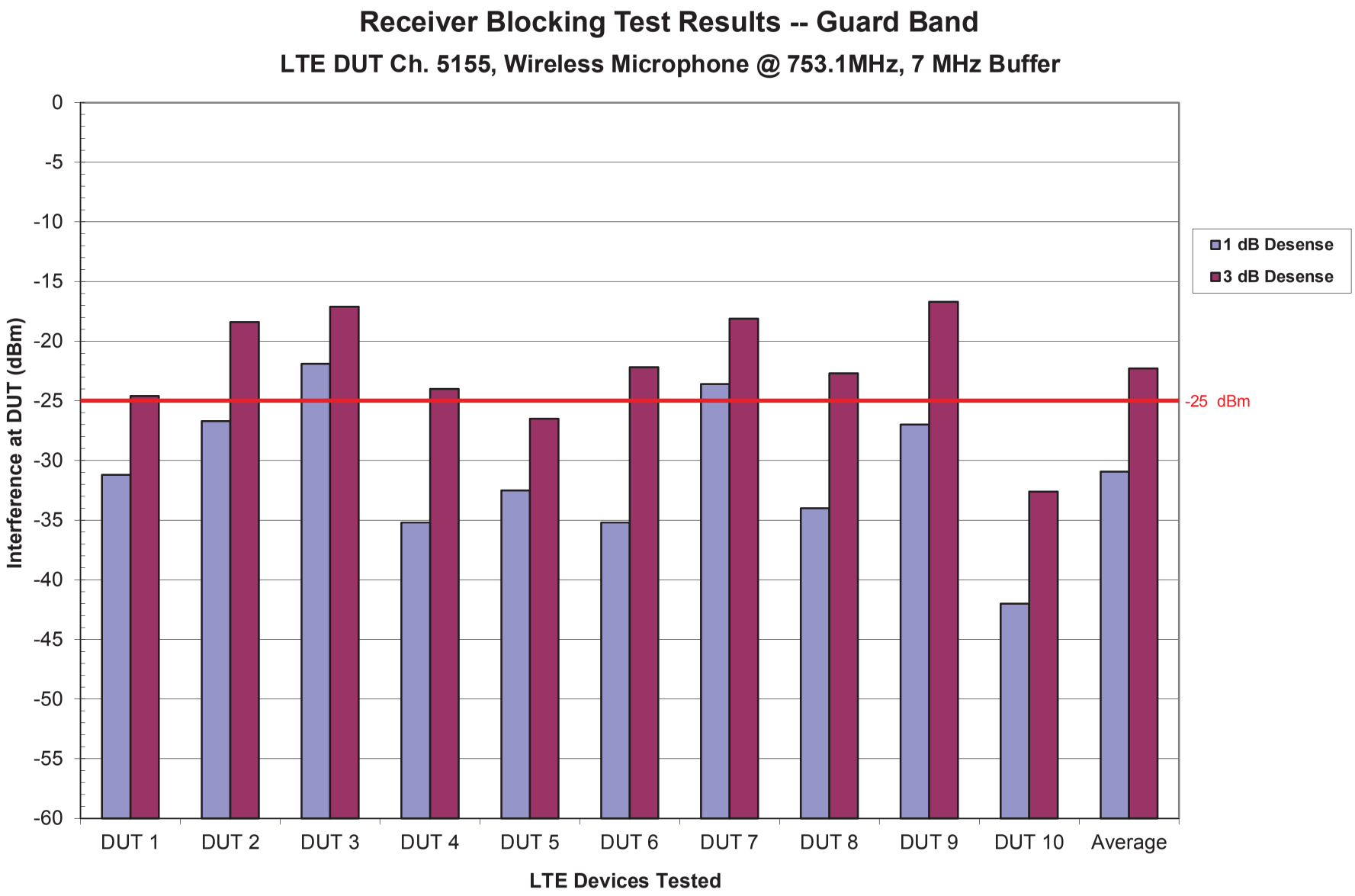

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, Wireless Microphone @ 719.9MHz, 9 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-25 dBm
1 dB Desense
3 dB Desense
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested

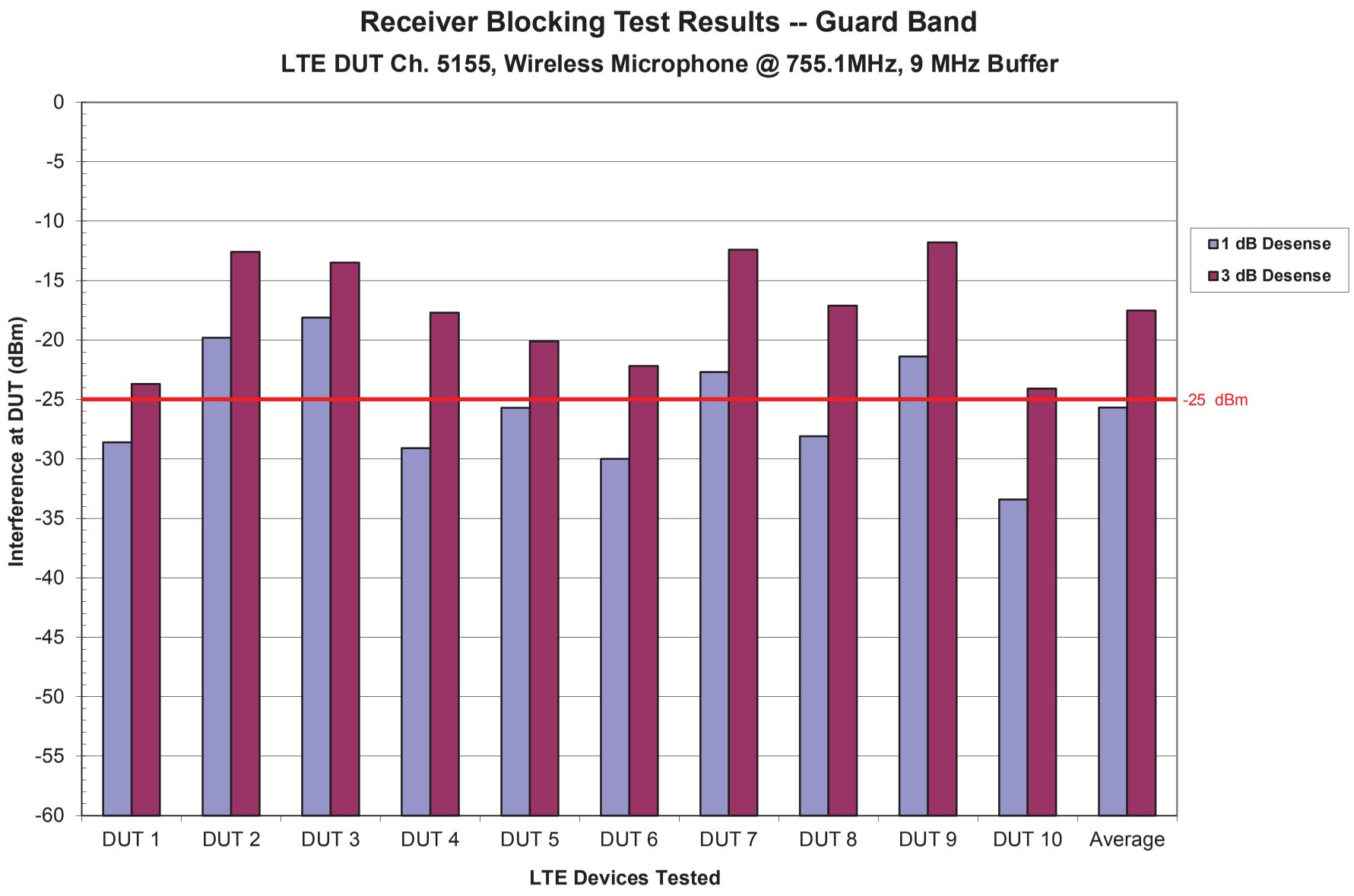

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, TV Whitespace Device @ 721MHz, 5 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested
Receiver Blocking interference occurs at these received levels at the LTE devices tested
1 dB Desense
3 dB Desense
-22 dBm
TV White Space device signal received at LTE device at 1 meter

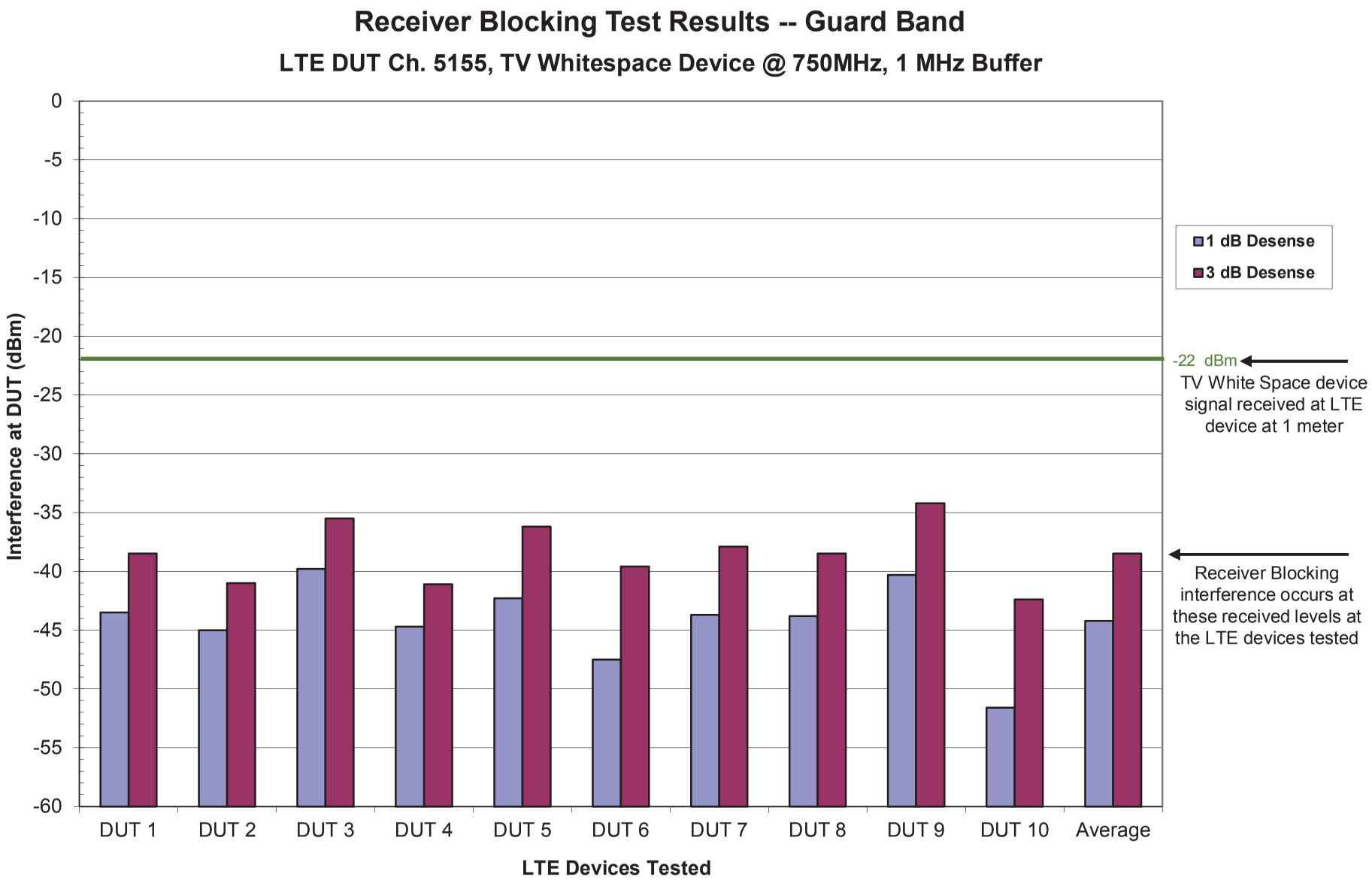

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, Wireless Microphone @ 747.1MHz, 1 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested
1 dB Desense
3 dB Desense
-25 dBm
Wireless Microphone signal received at LTE device at 1 meter
Receiver Blocking interference occurs at these received levels at the LTE devices tested

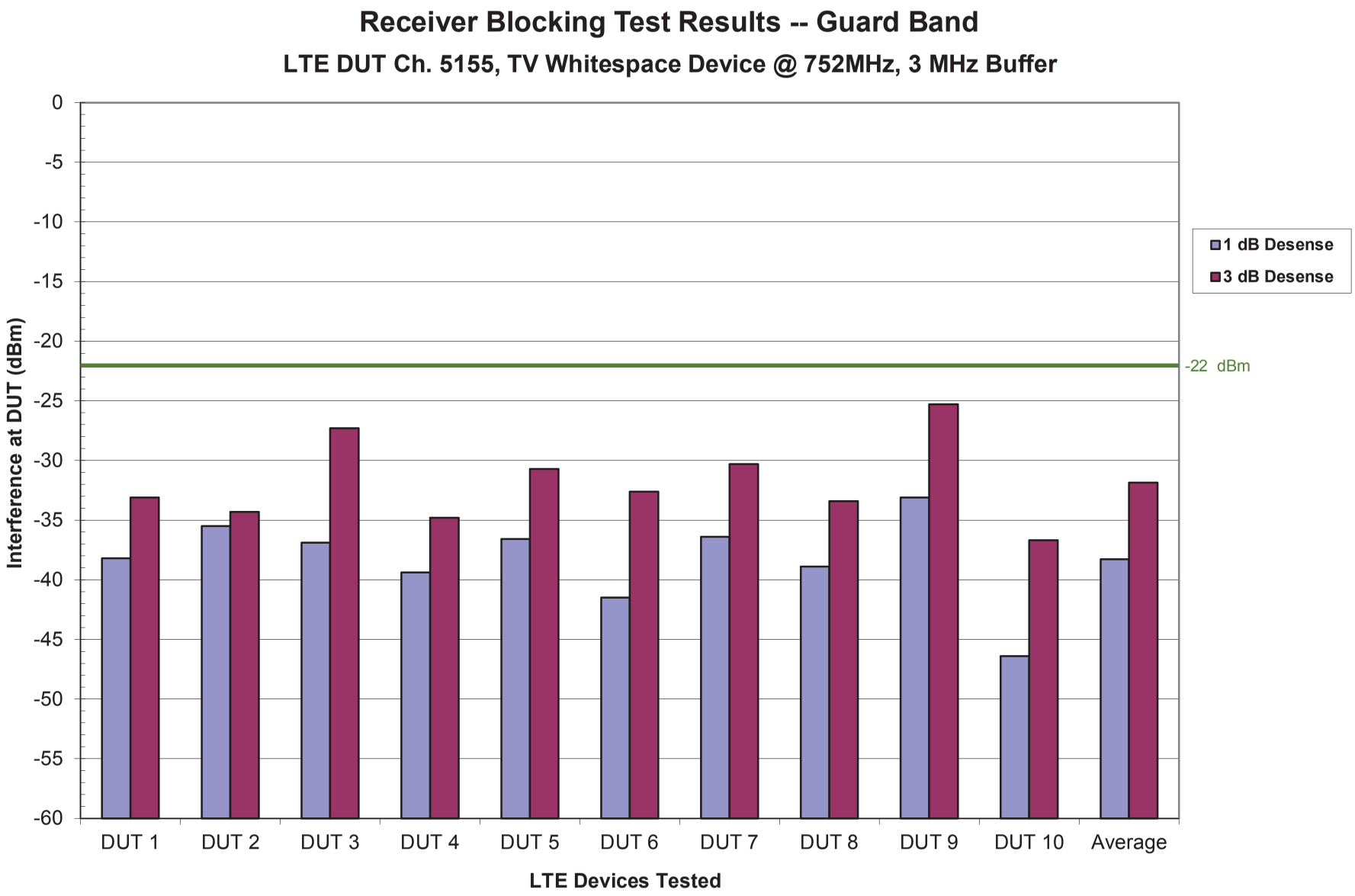

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, Wireless Microphone @ 749.1MHz, 3 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-25 dBm
1 dB Desense
3 dB Desense
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested

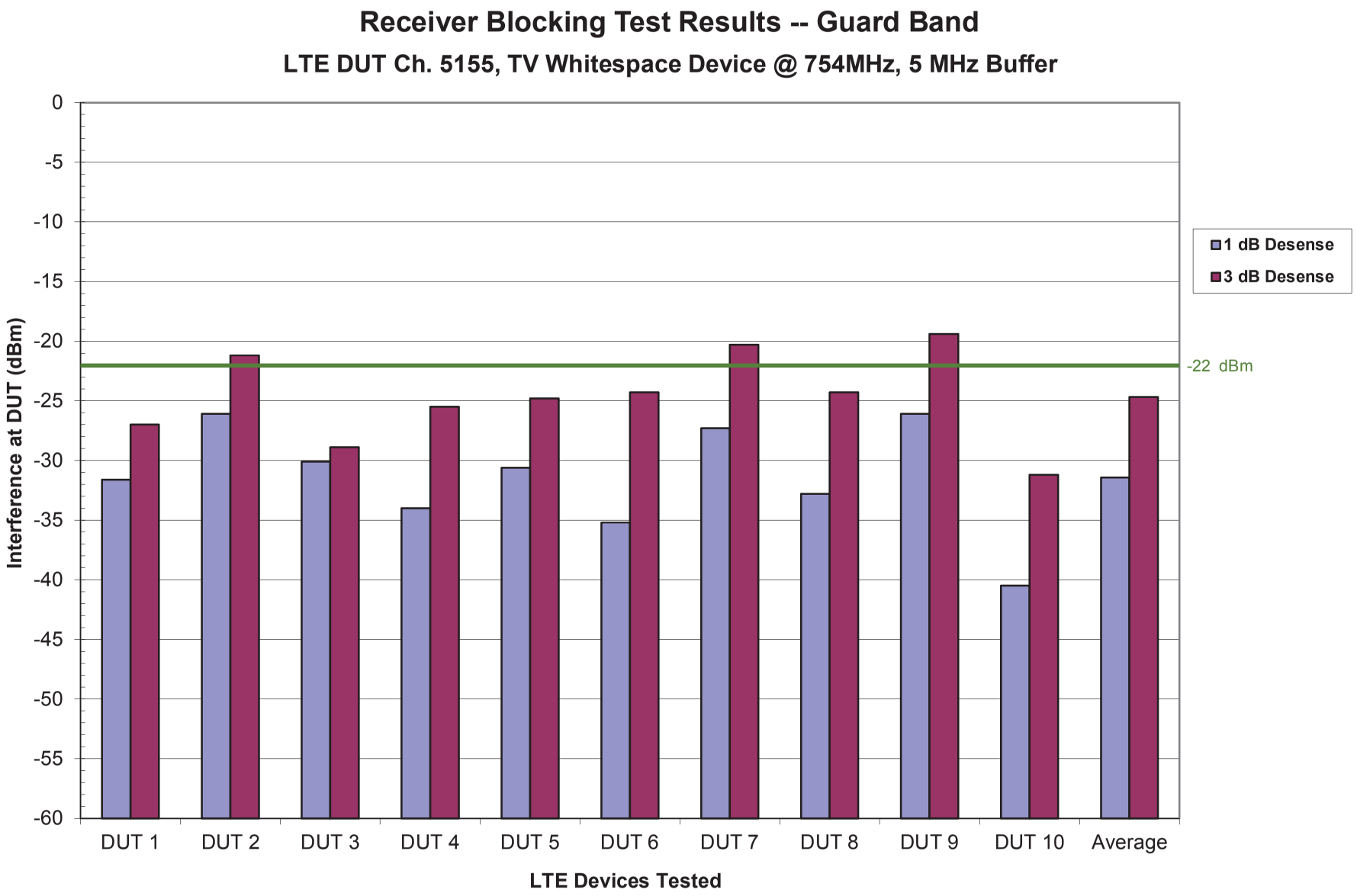

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, Wireless Microphone @ 751.1MHz, 5 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-25 dBm
1 dB Desense
3 dB Desense
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested

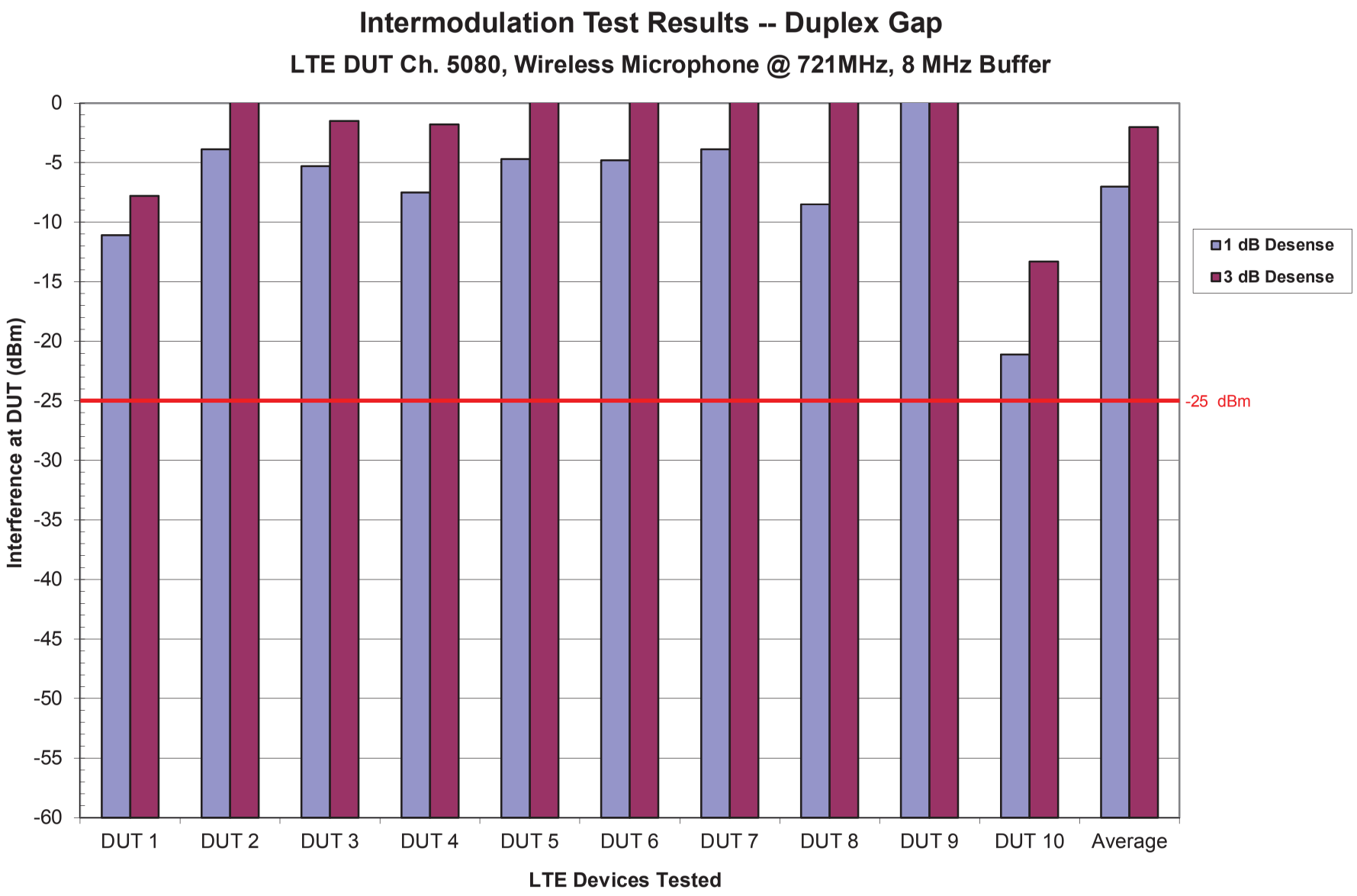

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, Wireless Microphone @ 753.1MHz, 7 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
1 dB Desense
3 dB Desense
-25 dBm
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested

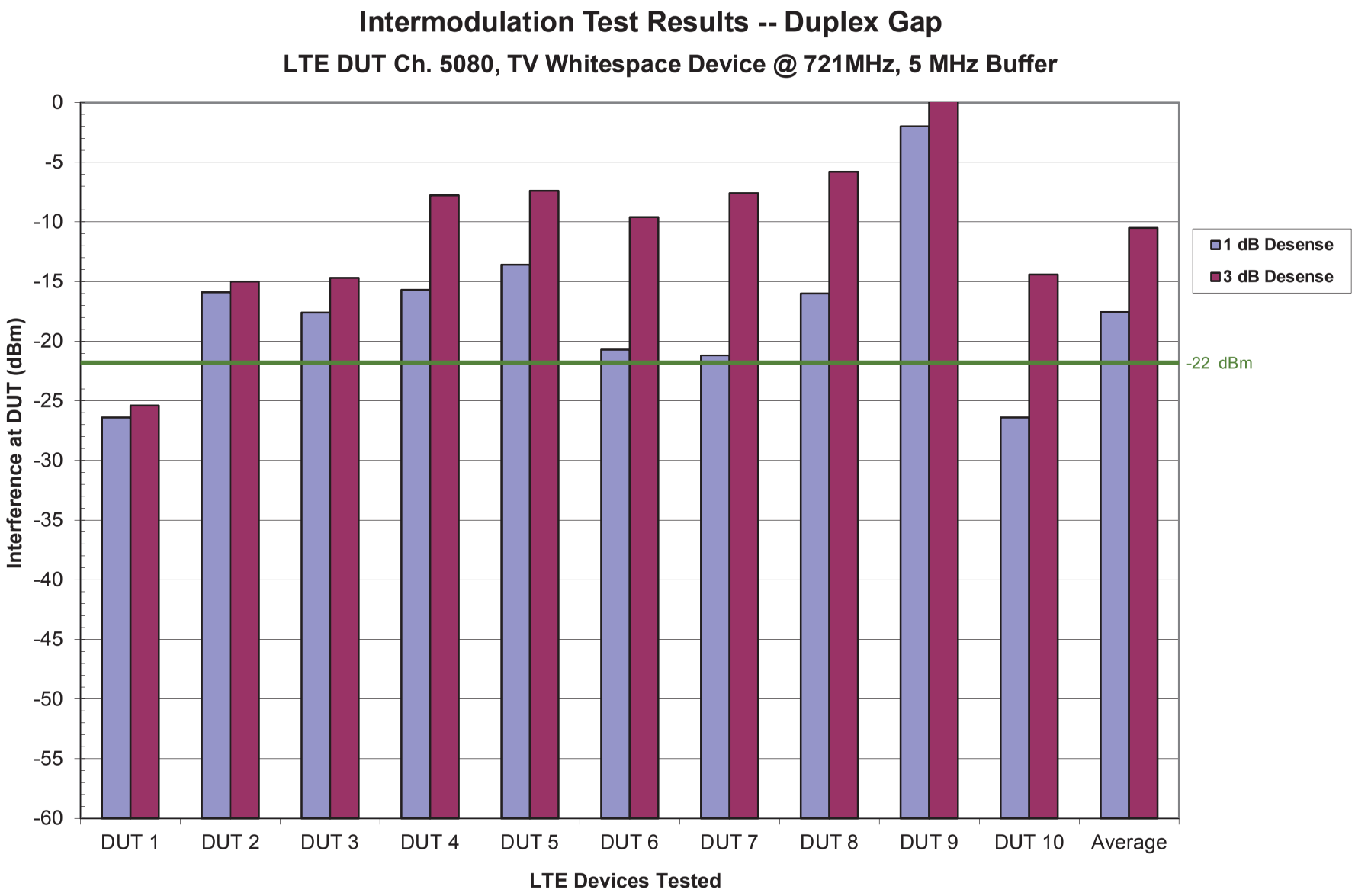

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, Wireless Microphone @ 755.1MHz, 9 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
1 dB Desense
3 dB Desense
-25 dBm
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested


Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, TV Whitespace Device @ 750MHz, 1 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested
1 dB Desense
3 dB Desense
-22 dBm
TV White Space device signal received at LTE device at 1 meter
Receiver Blocking interference occurs at these received levels at the LTE devices tested


Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, TV Whitespace Device @ 752MHz, 3 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-22 dBm
1 dB Desense
3 dB Desense
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested

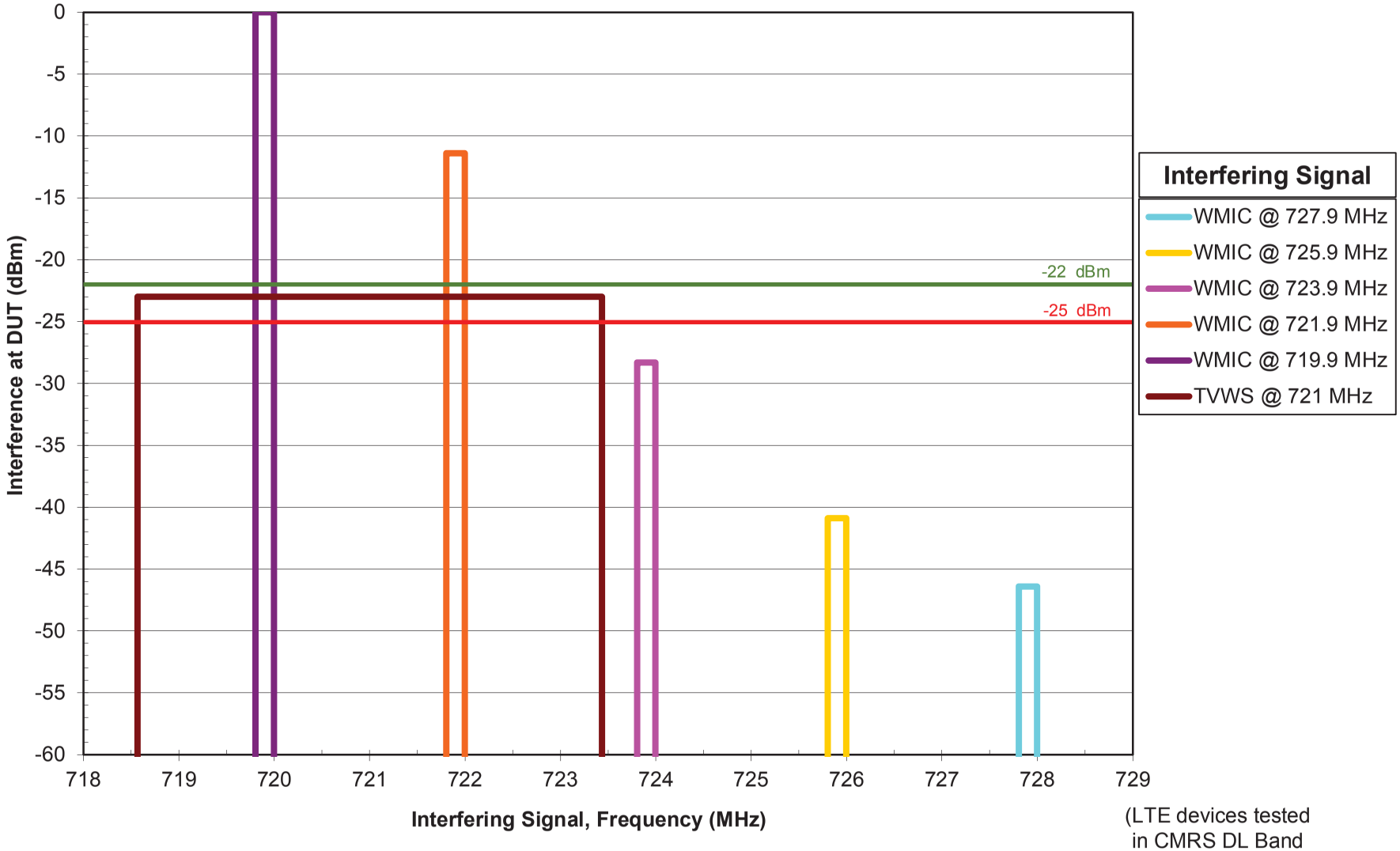

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, TV Whitespace Device @ 754MHz, 5 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
1 dB Desense
3 dB Desense
-22 dBm
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested


Intermodulation Test Results -- Duplex Gap
LTE DUT Ch. 5080, Wireless Microphone @ 721MHz, 8 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-25 dBm
1 dB Desense
3 dB Desense
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested


Intermodulation Test Results -- Duplex Gap
LTE DUT Ch. 5080, TV Whitespace Device @ 721MHz, 5 MHz Buffer
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested
1 dB Desense
3 dB Desense
-22 dBm

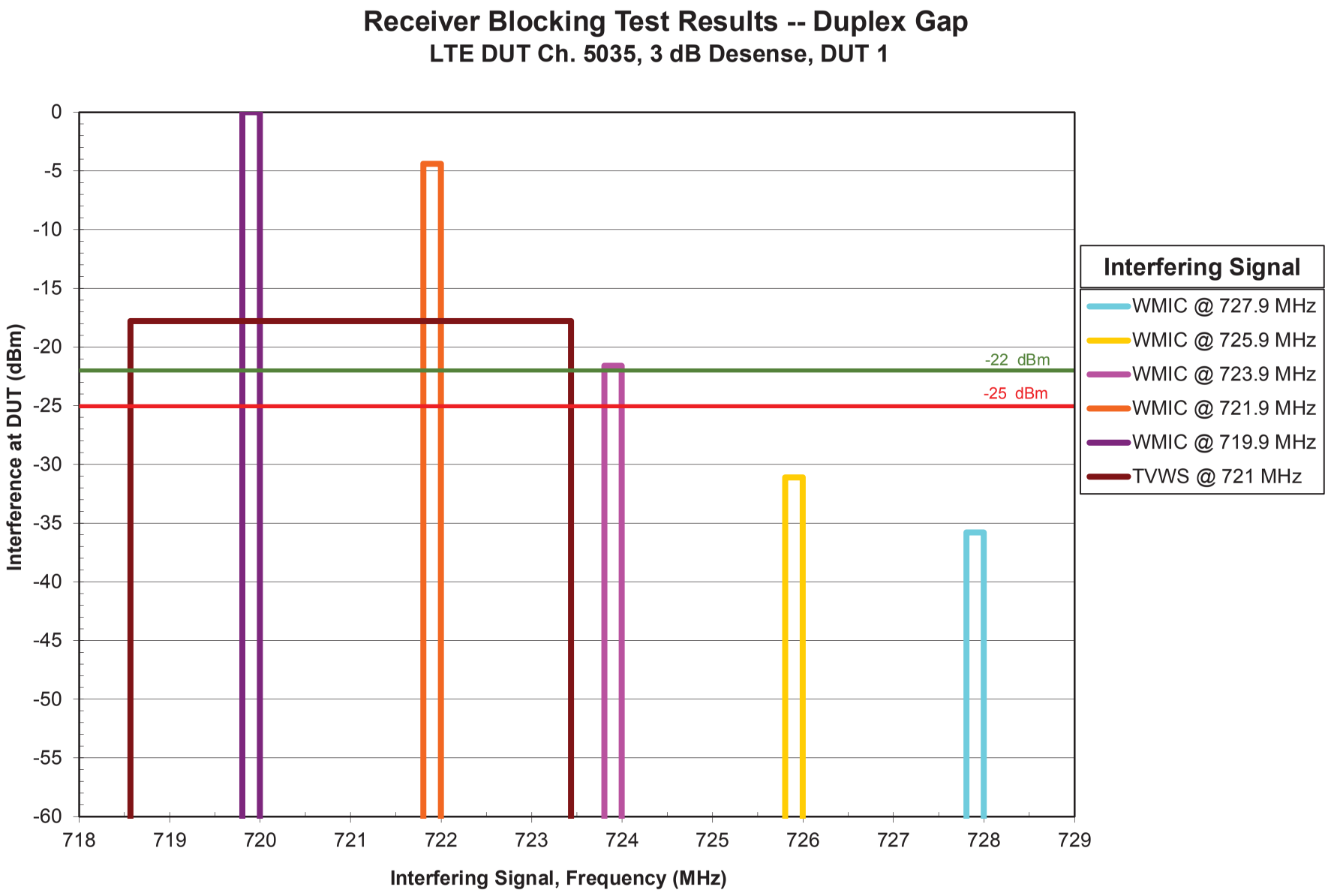
Receiver Blocking Test Results -- Duplex Gap

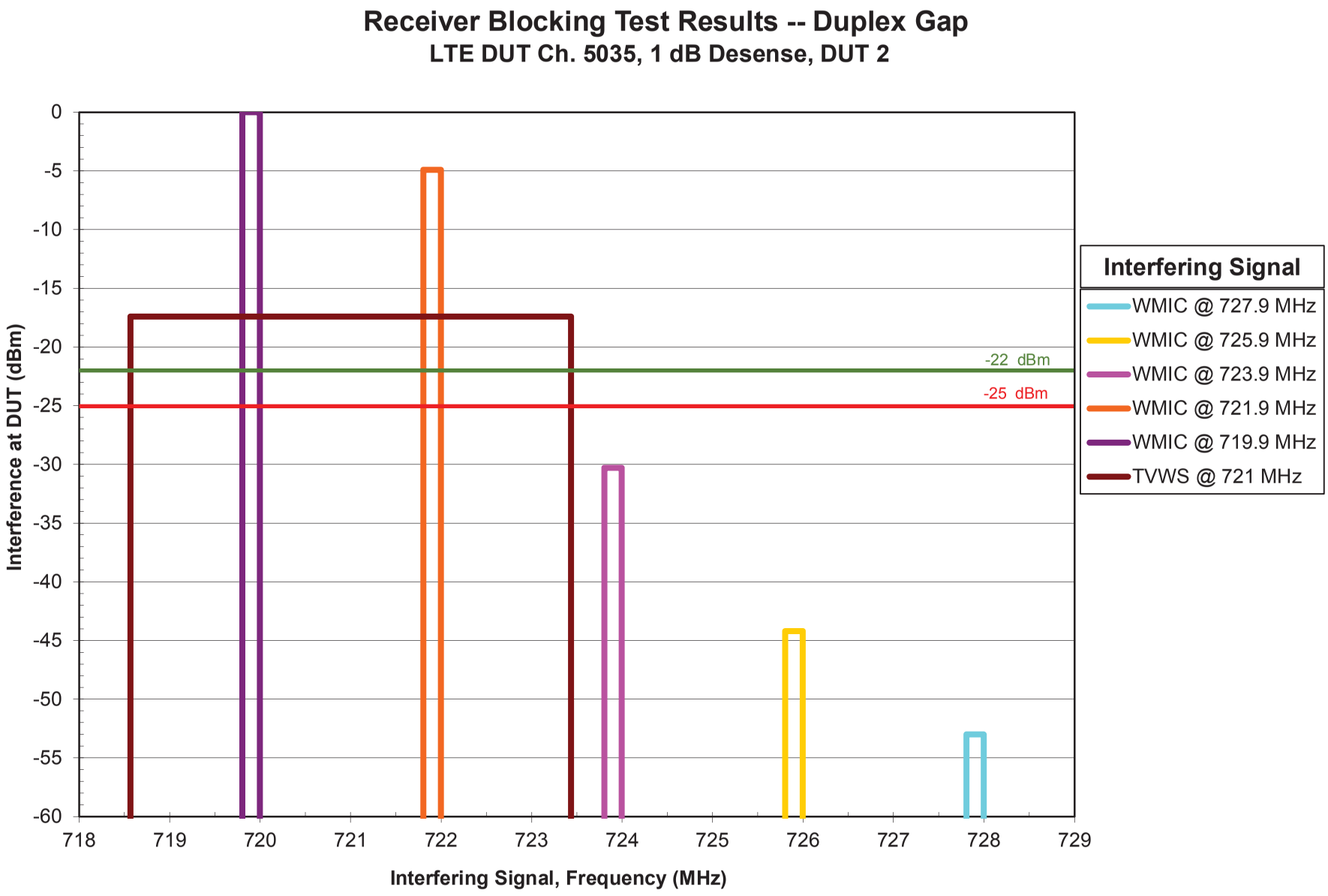
LTE DUT Ch. 5035, 1 dB Desense, DUT 1

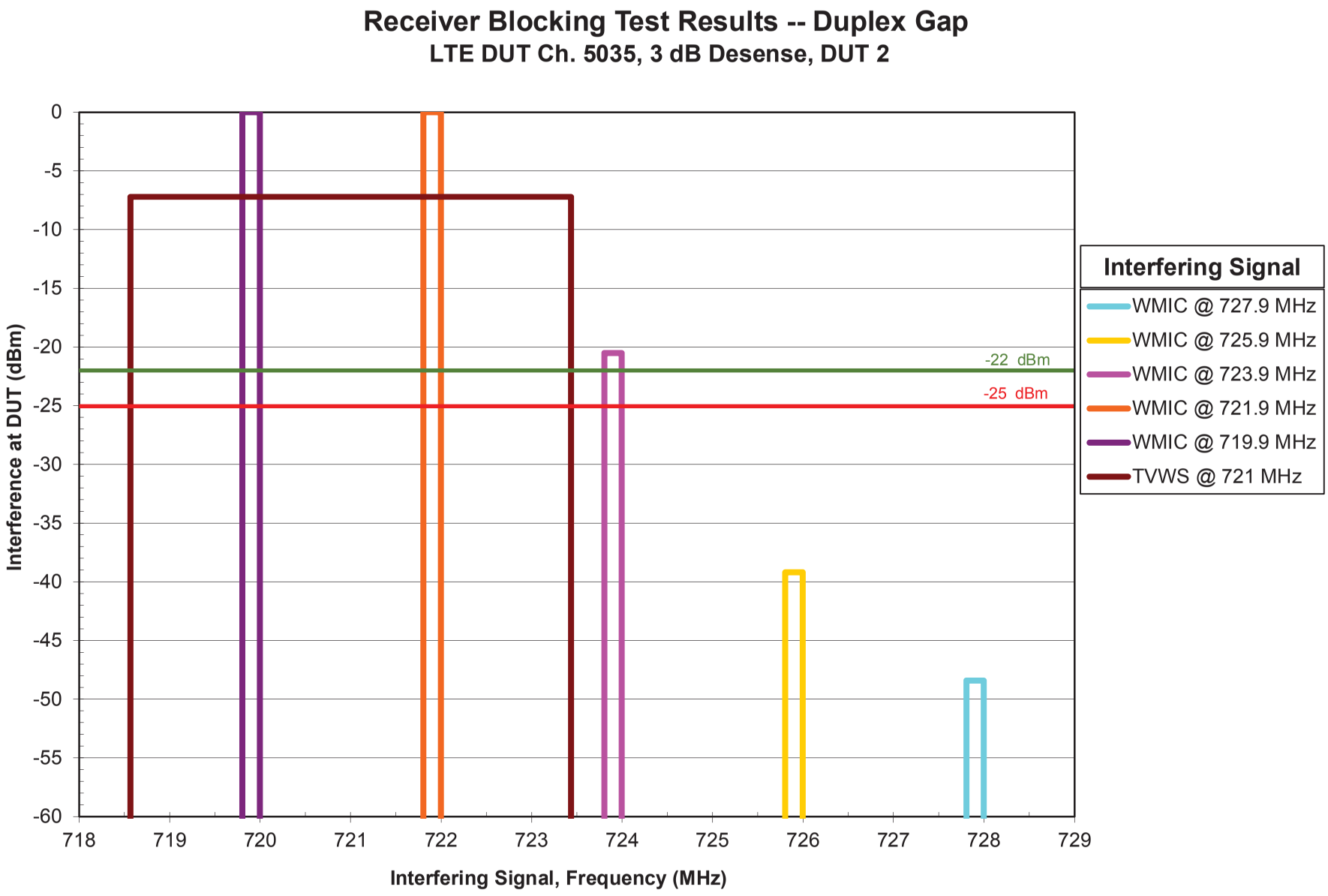


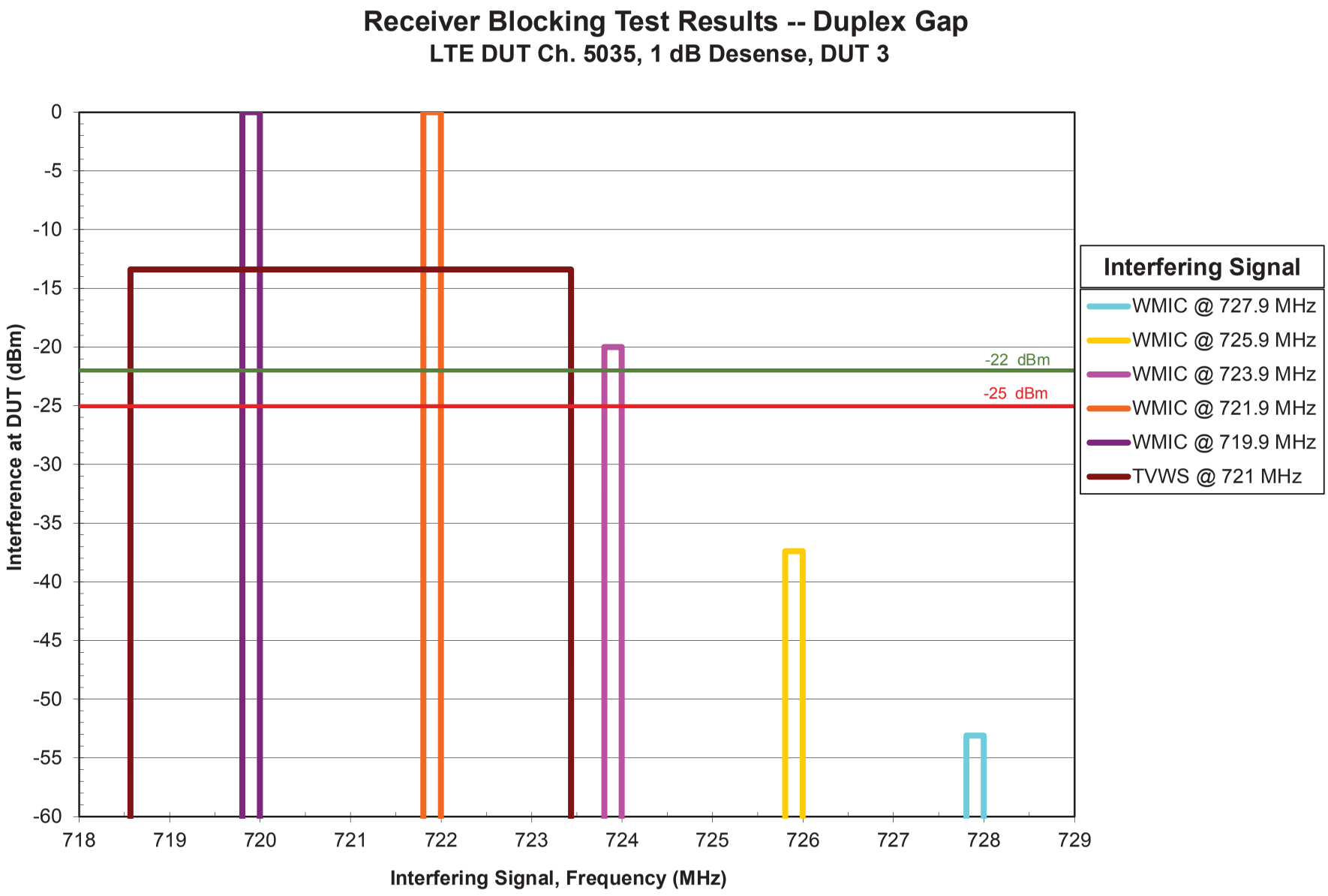
(Interfering Signal levels received in Duplex Gap 718-729 MHz)

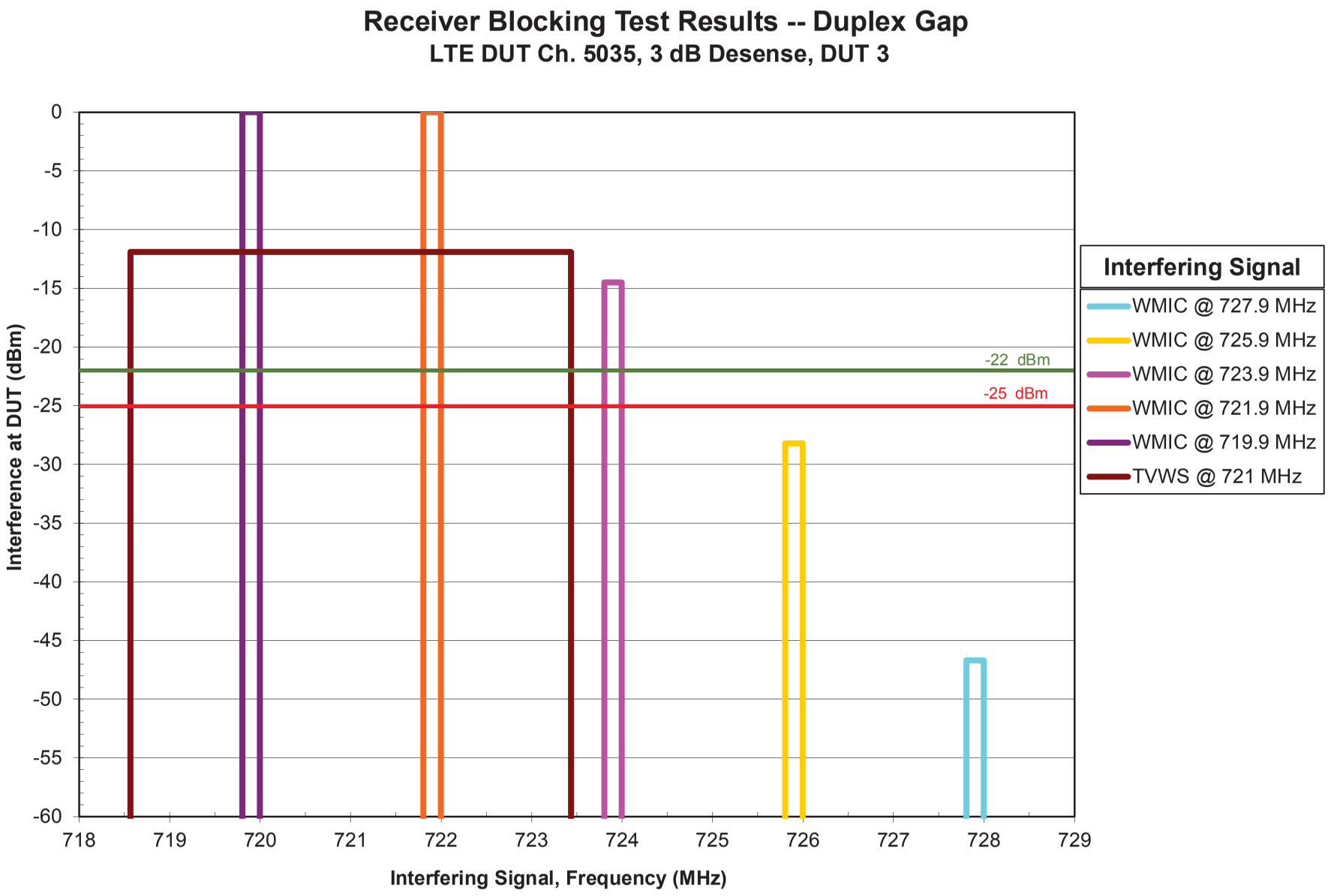
(LTE devices tested in CMRS DL Band 729-746 MHz)

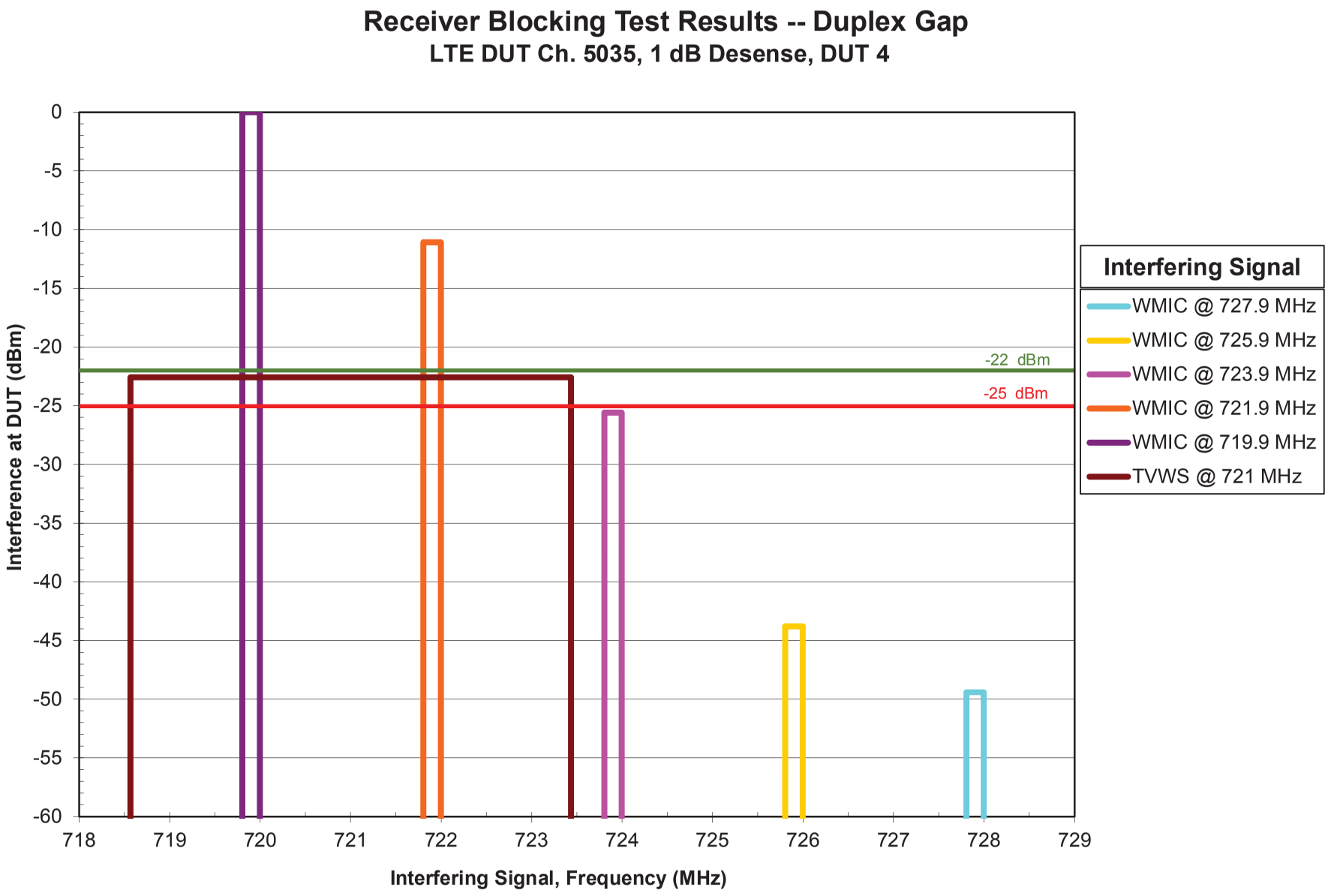

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, DUT 1
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

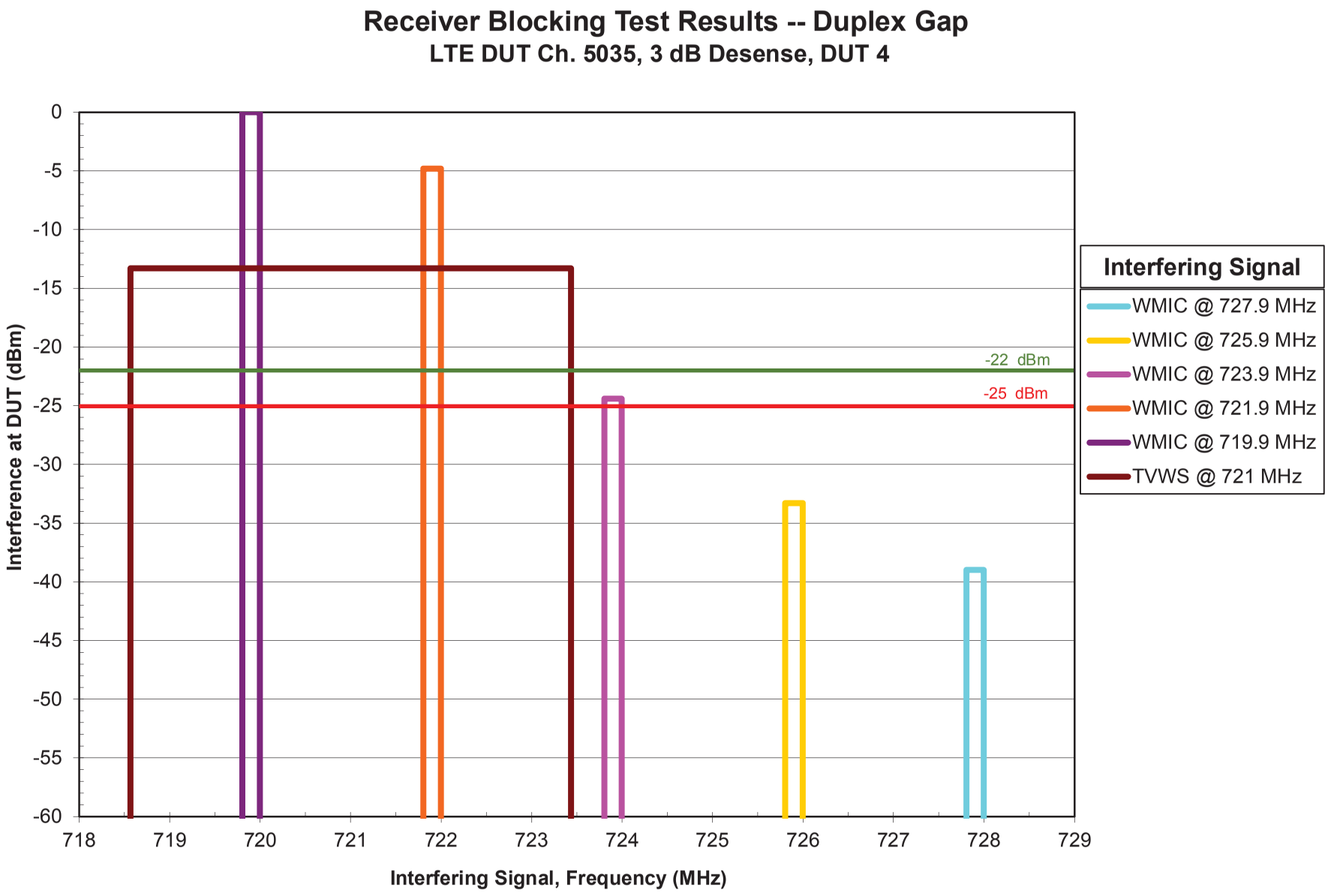

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 1 dB Desense, DUT 2
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

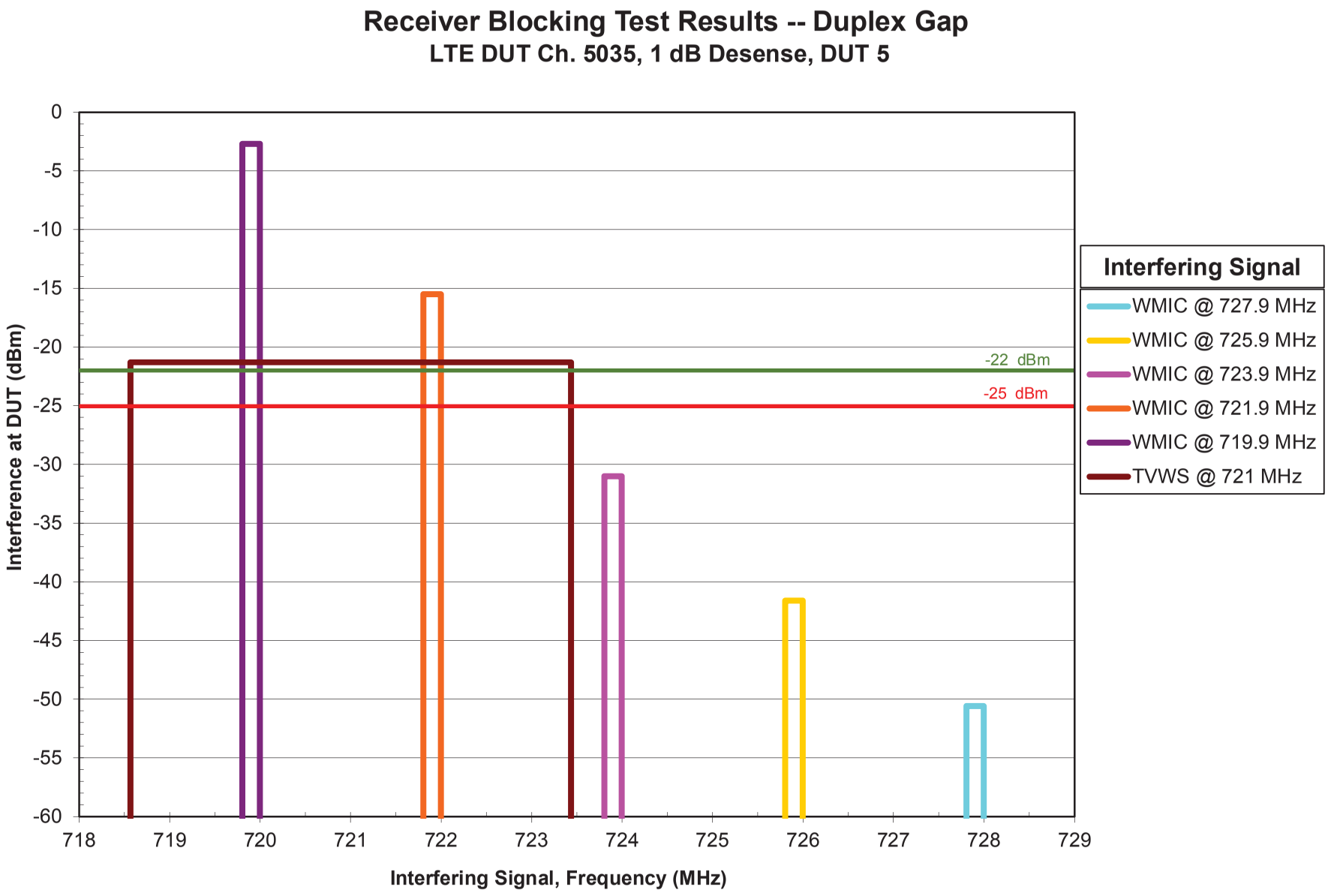

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, DUT 2
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

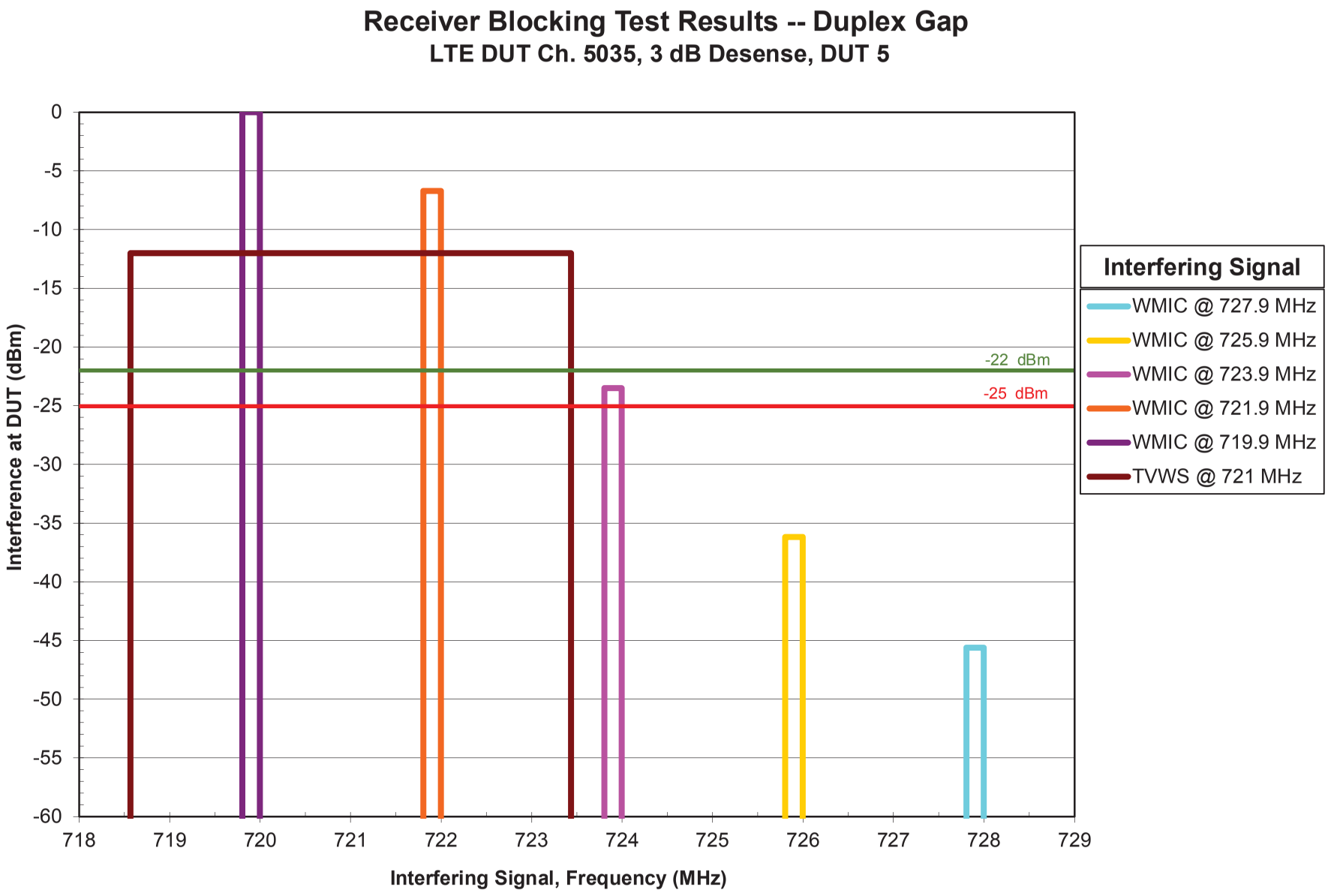

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 1 dB Desense, DUT 3
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

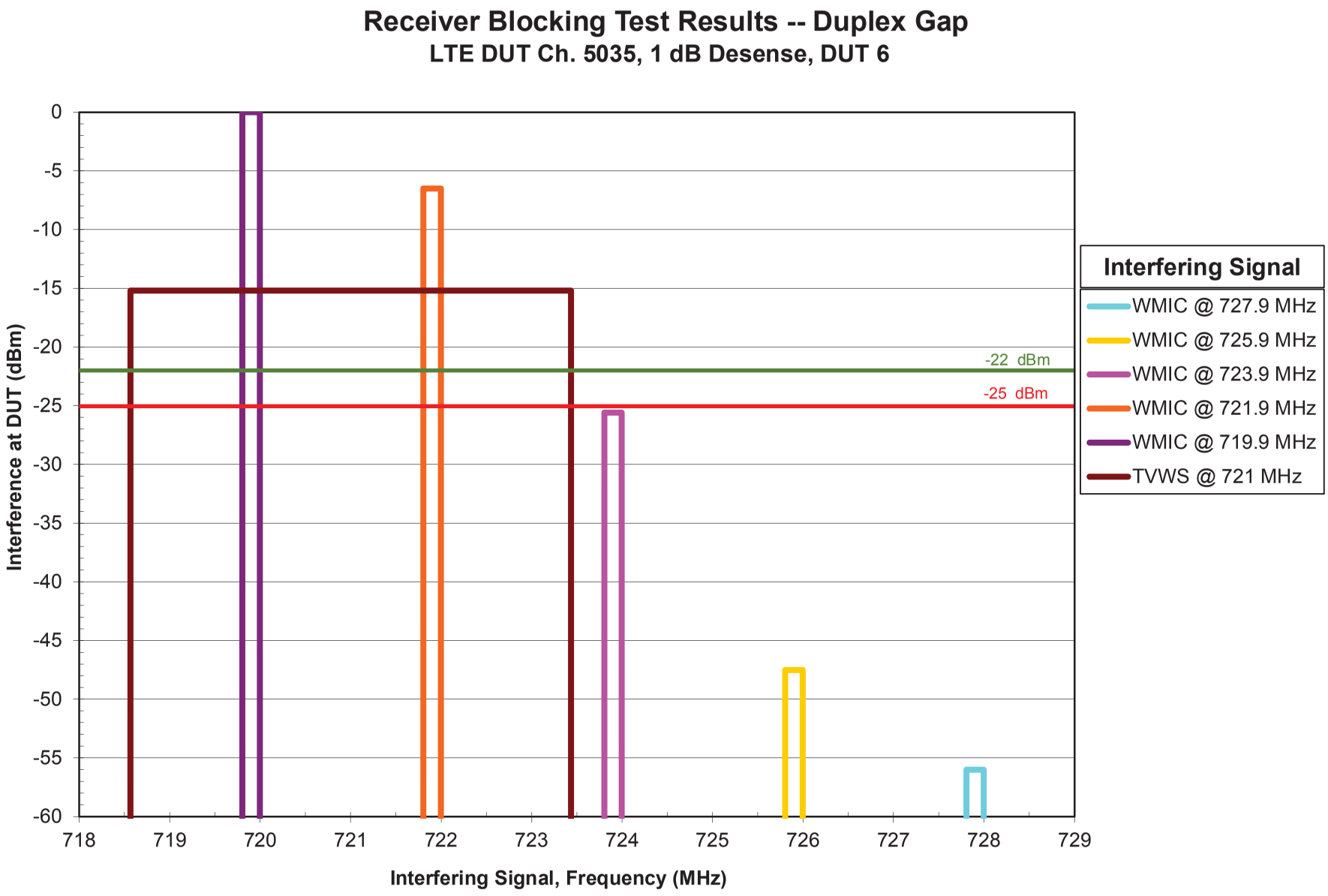

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, DUT 3
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

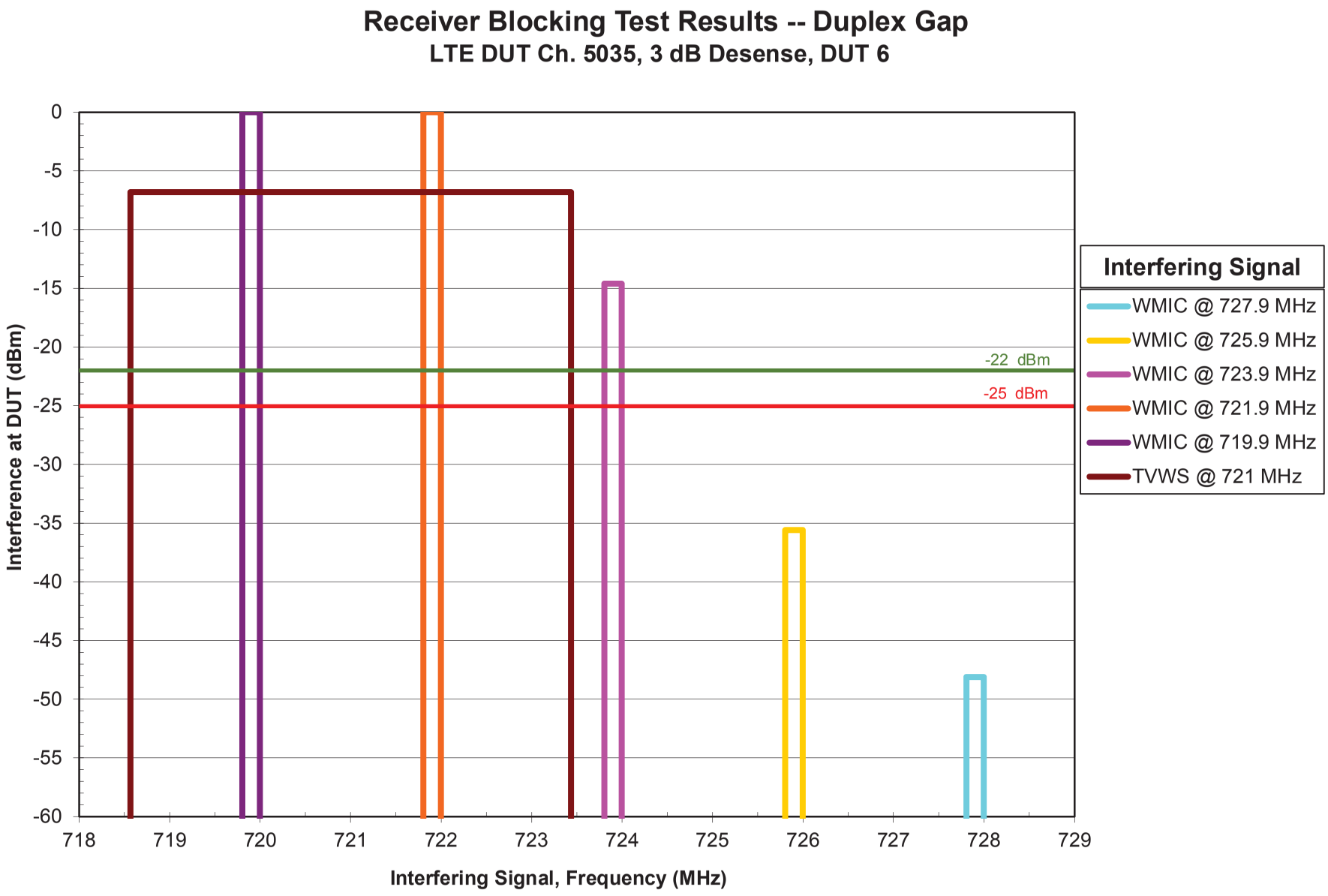

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 1 dB Desense, DUT 4
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

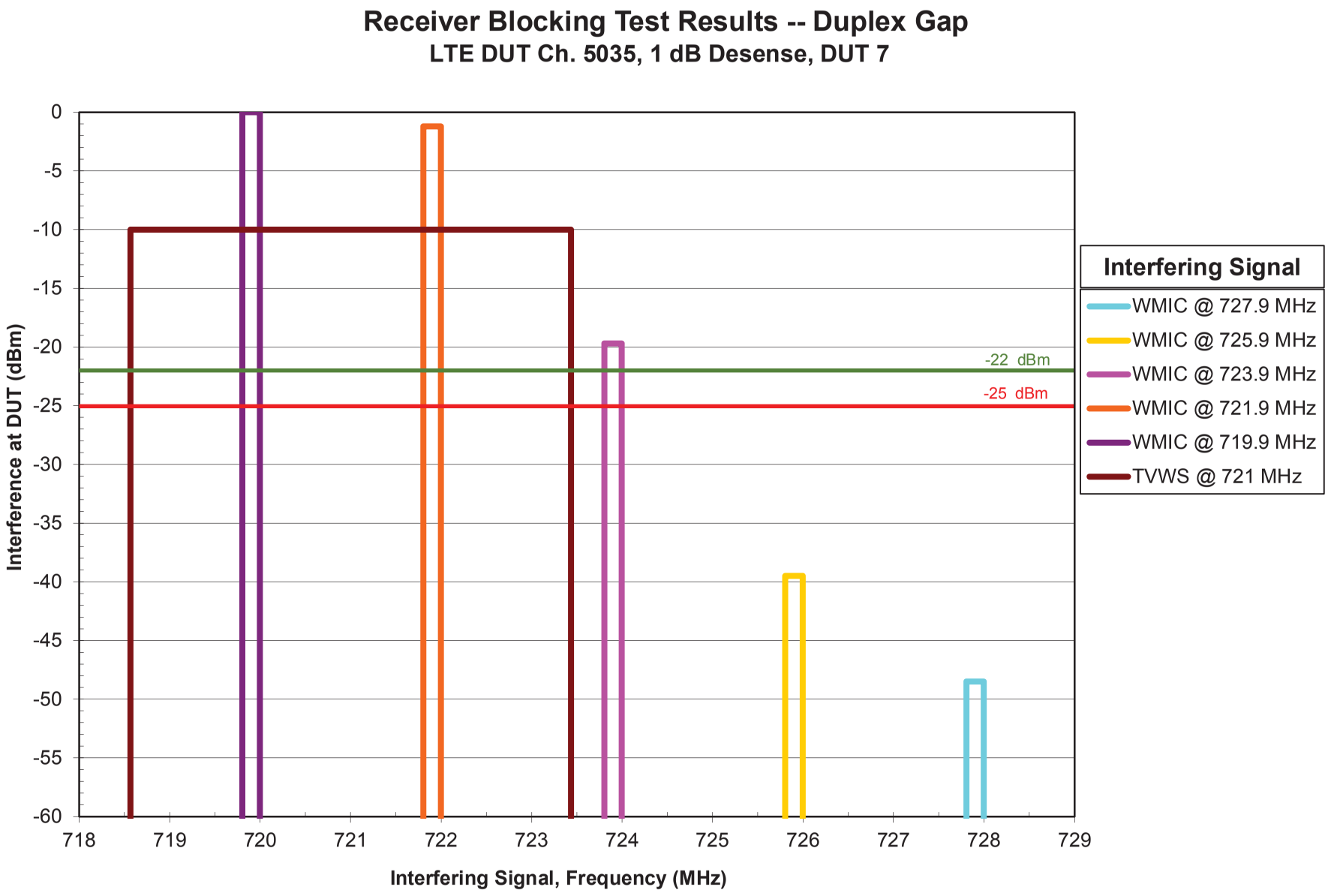

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, DUT 4
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

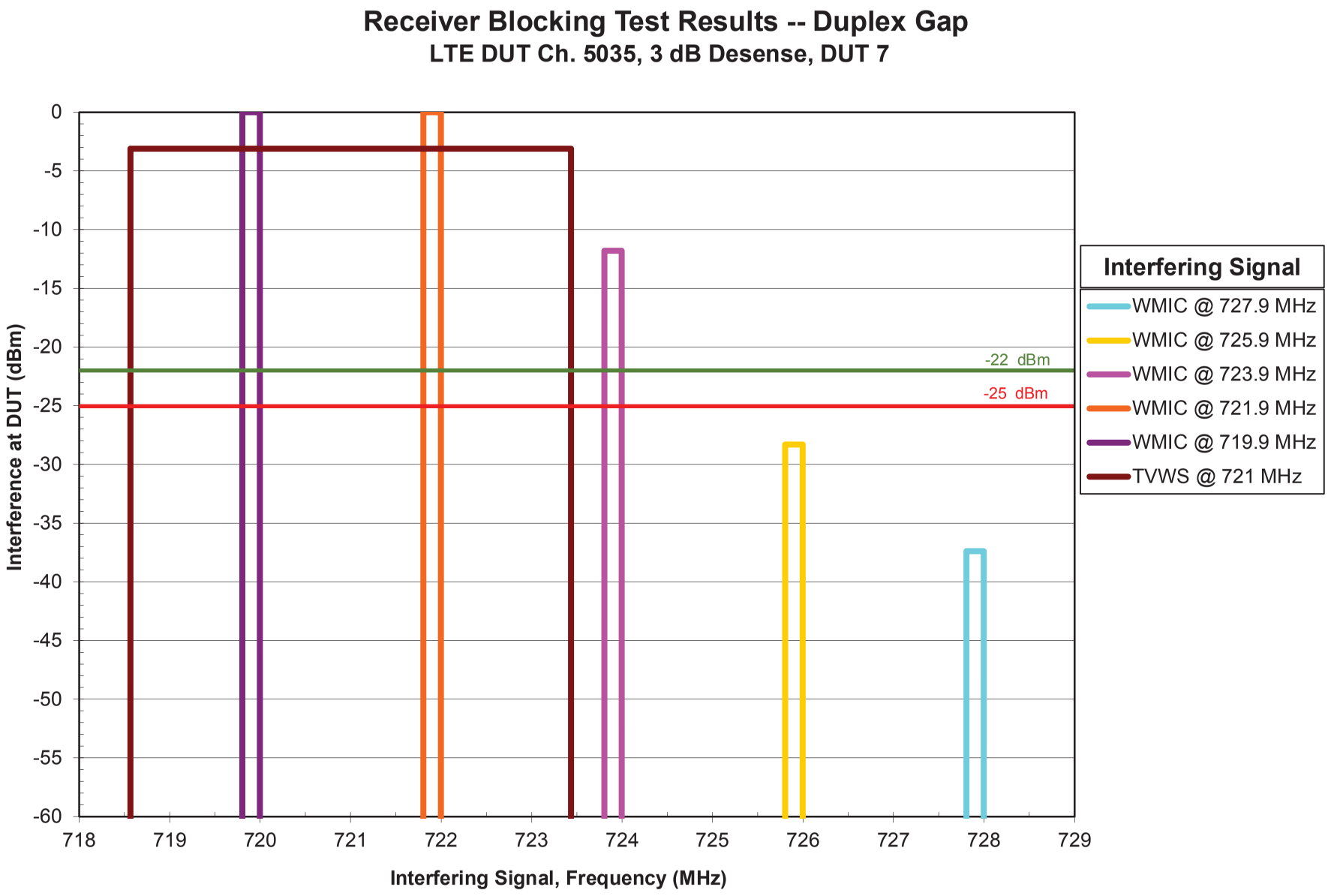

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 1 dB Desense, DUT 5
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

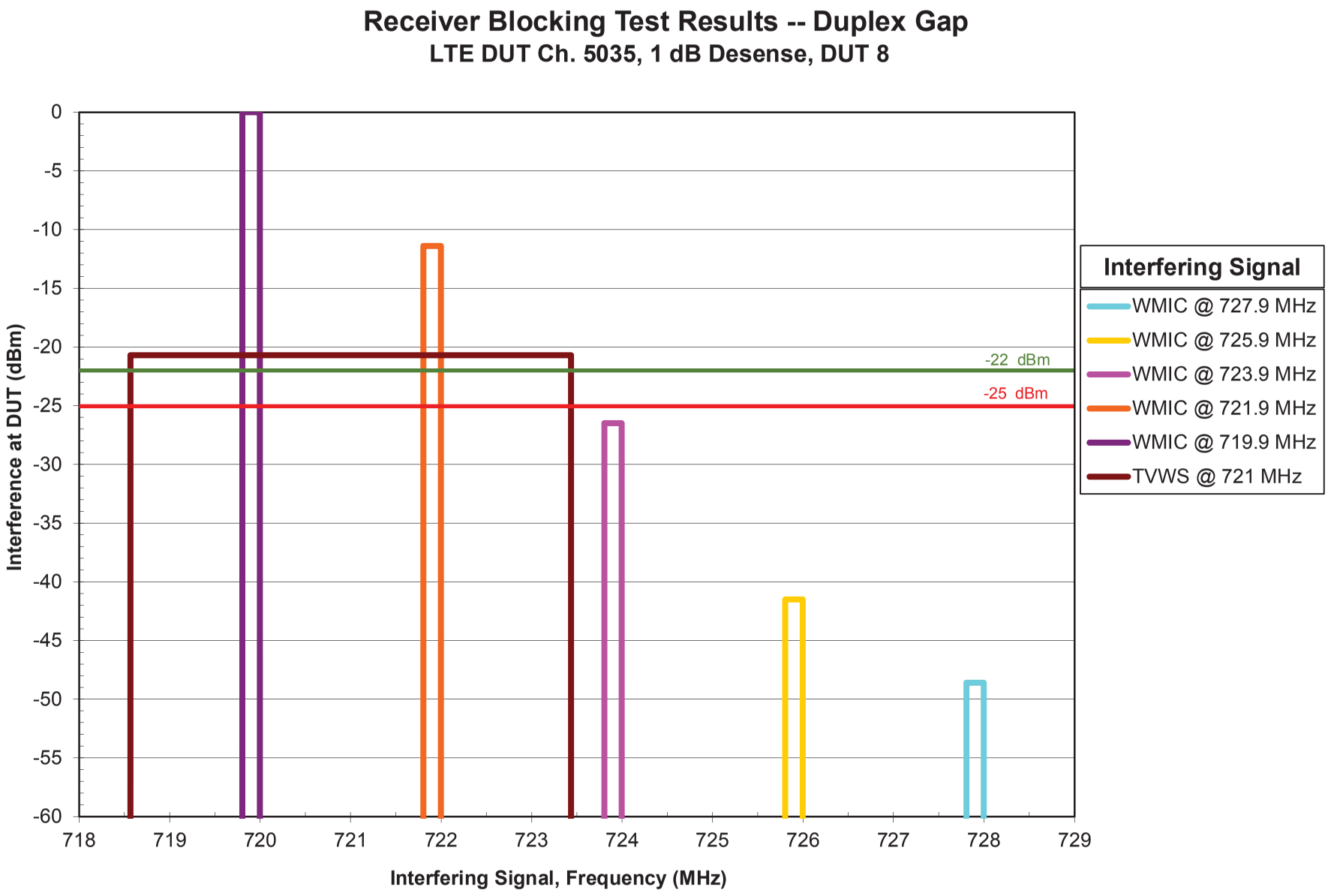

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, DUT 5
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

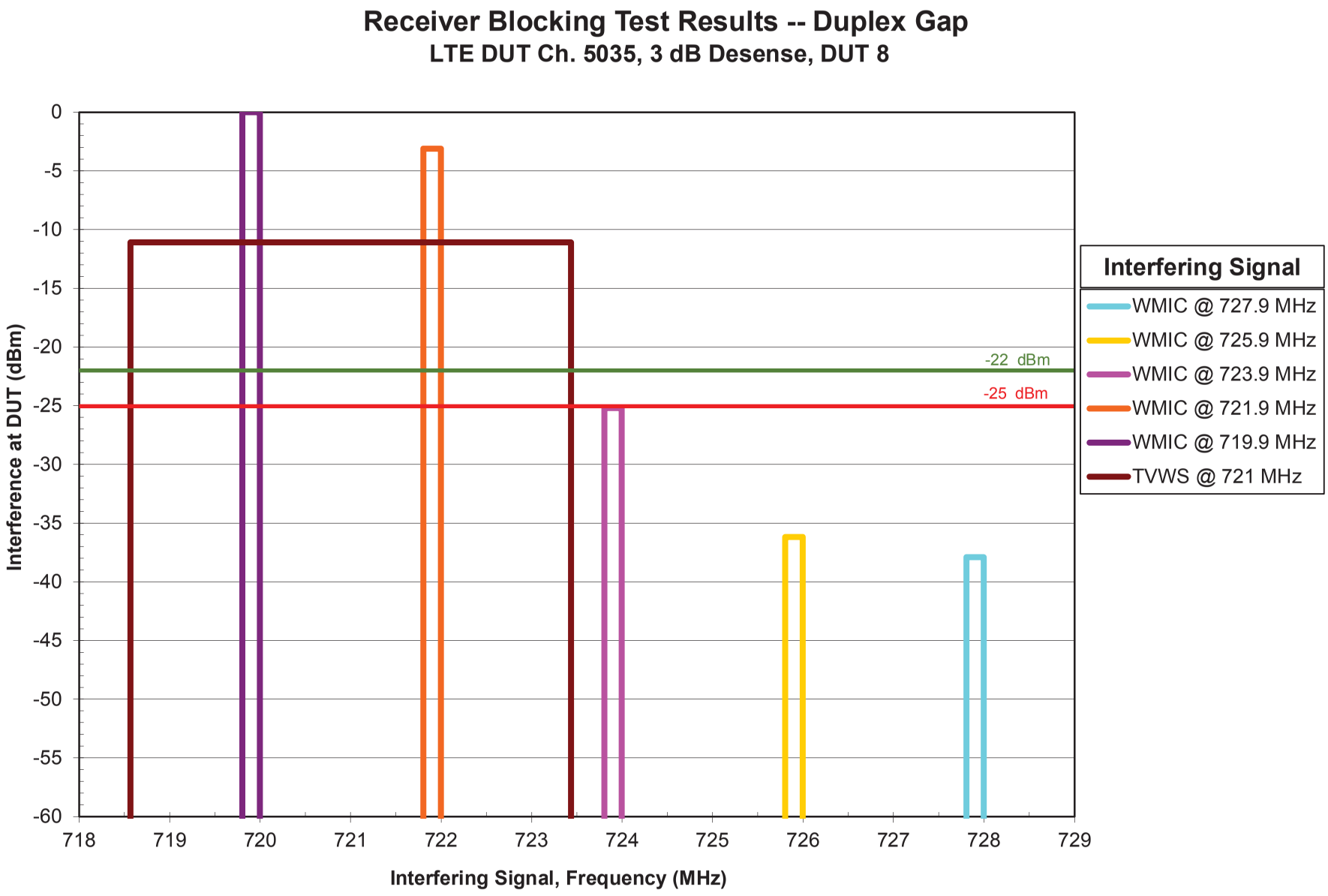

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 1 dB Desense, DUT 6
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

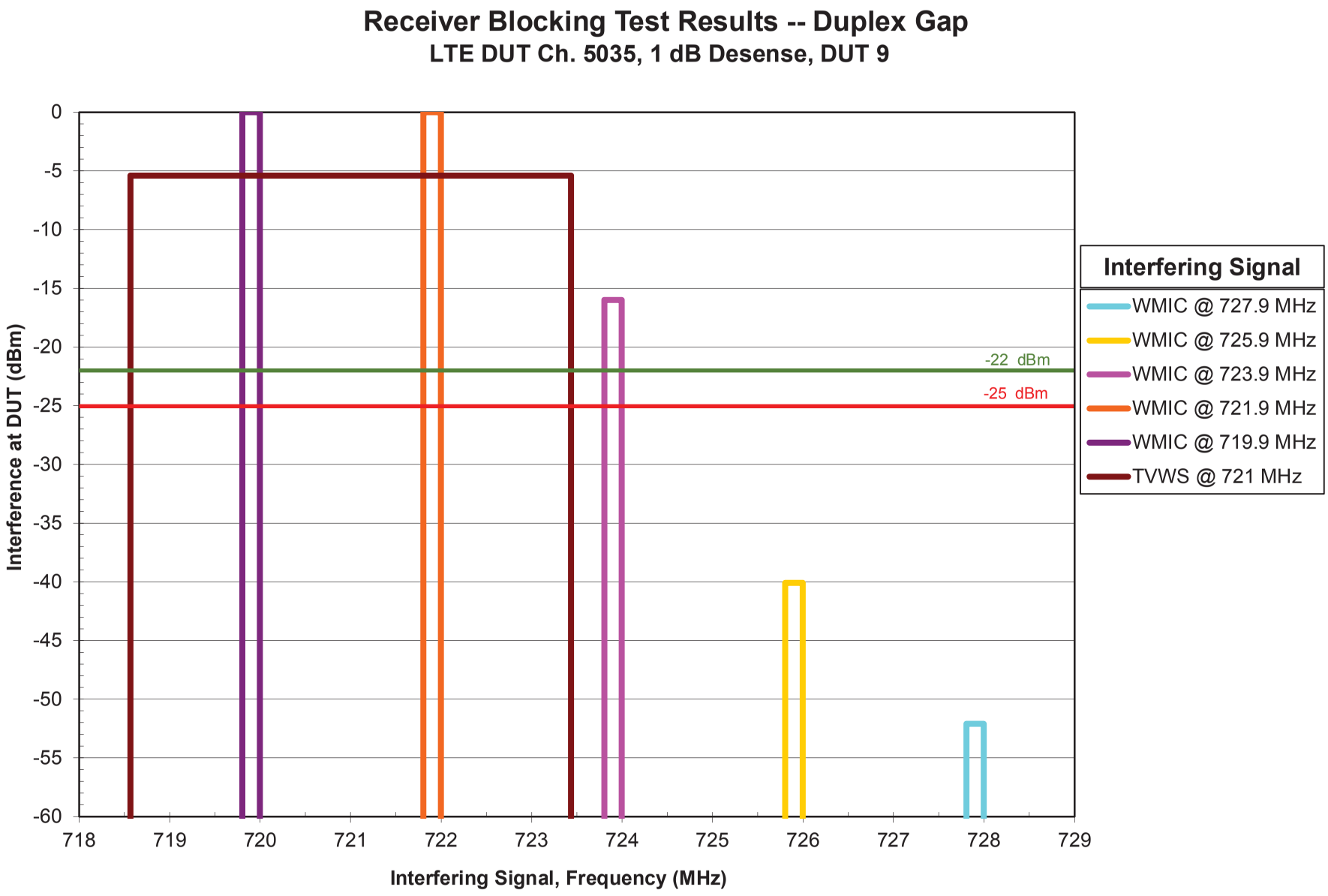

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, DUT 6
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

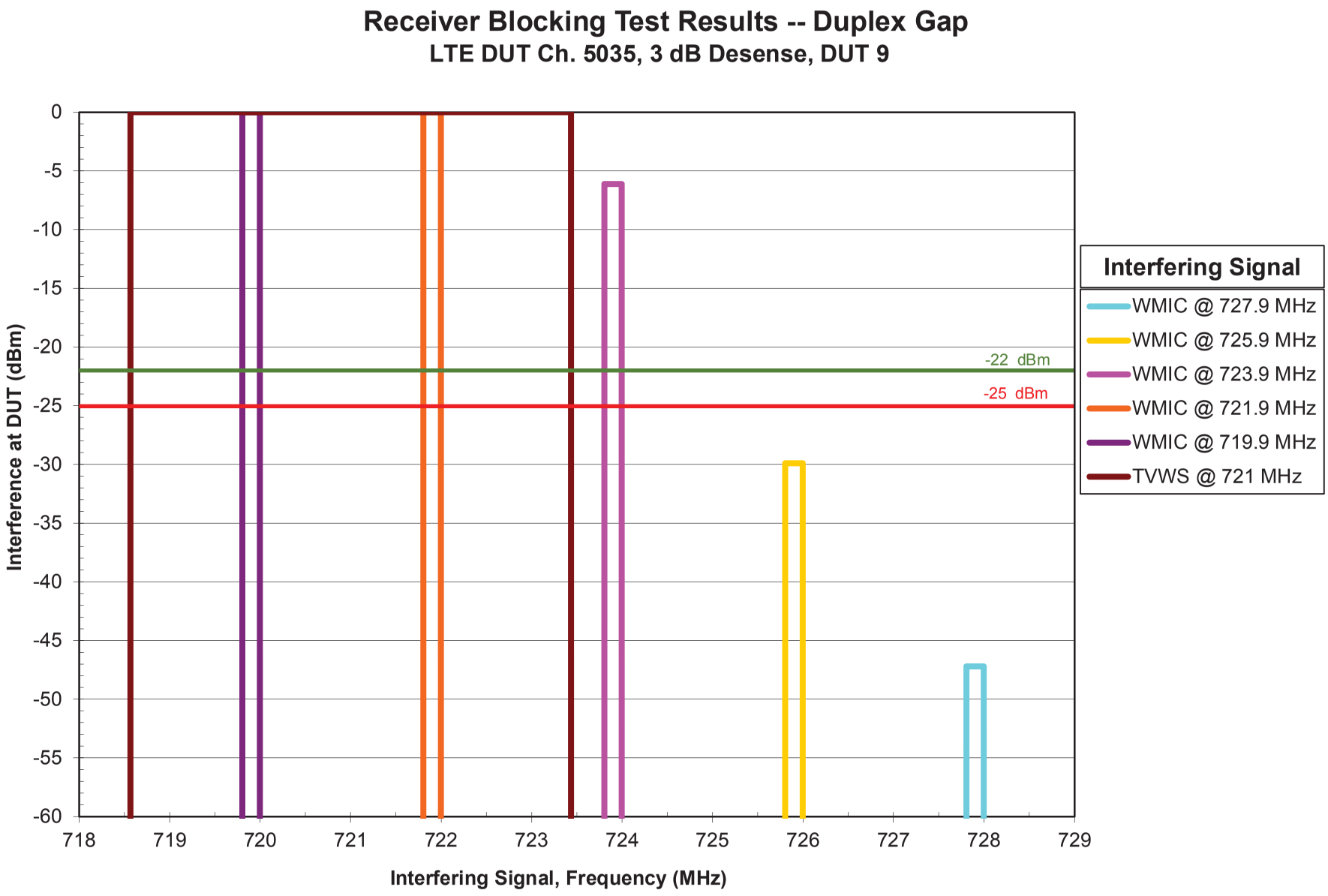

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 1 dB Desense, DUT 7
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

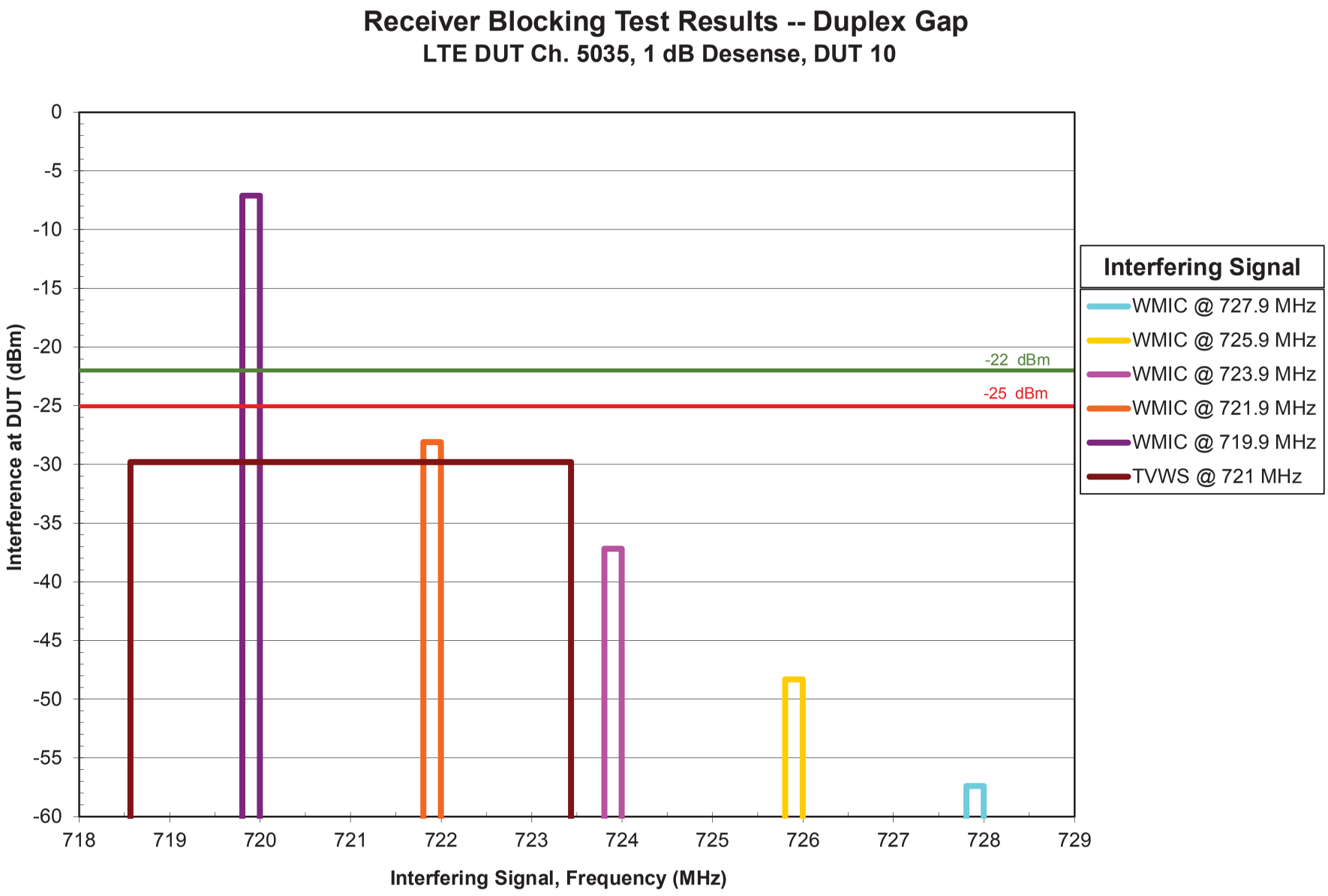

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, DUT 7
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

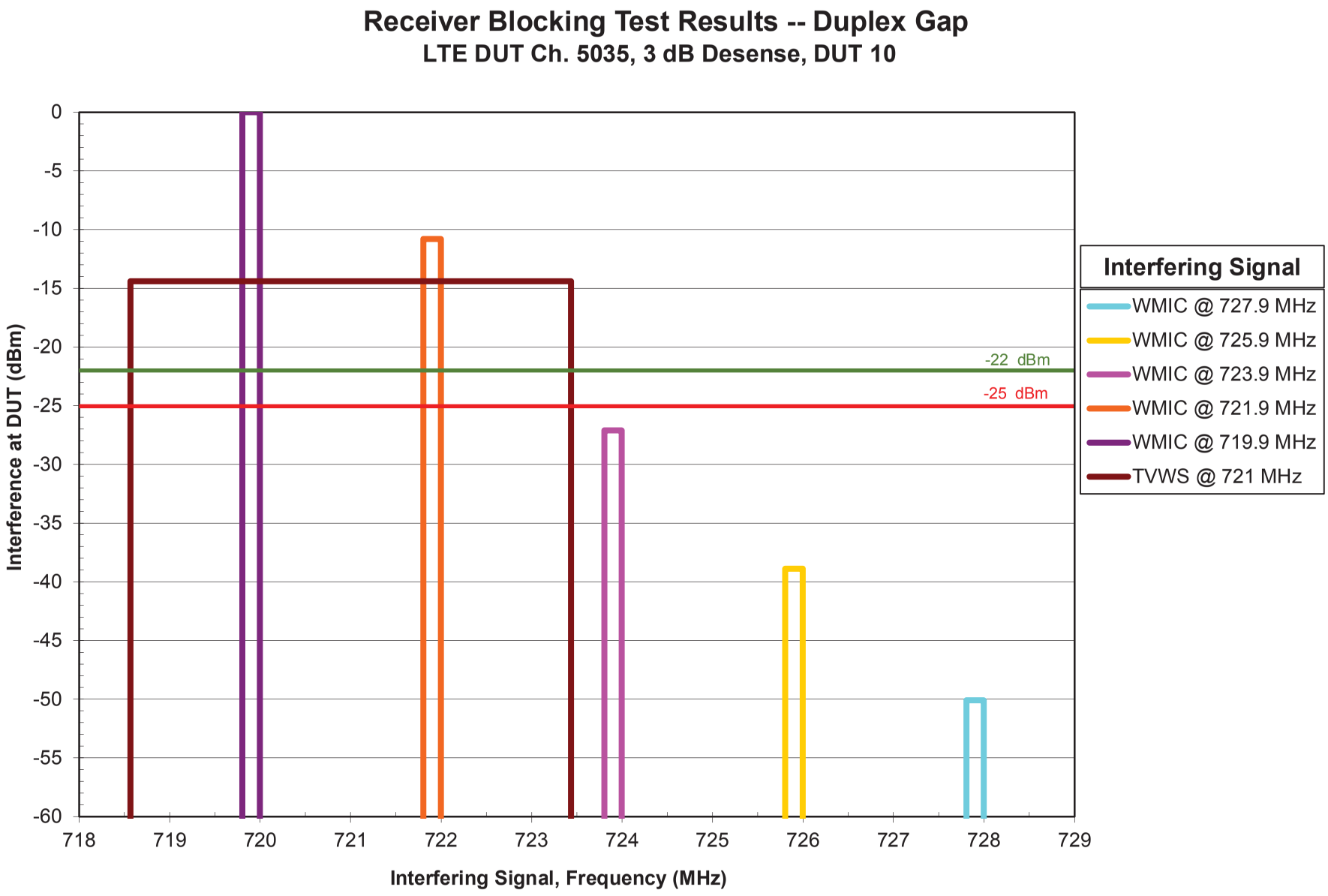

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 1 dB Desense, DUT 8
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

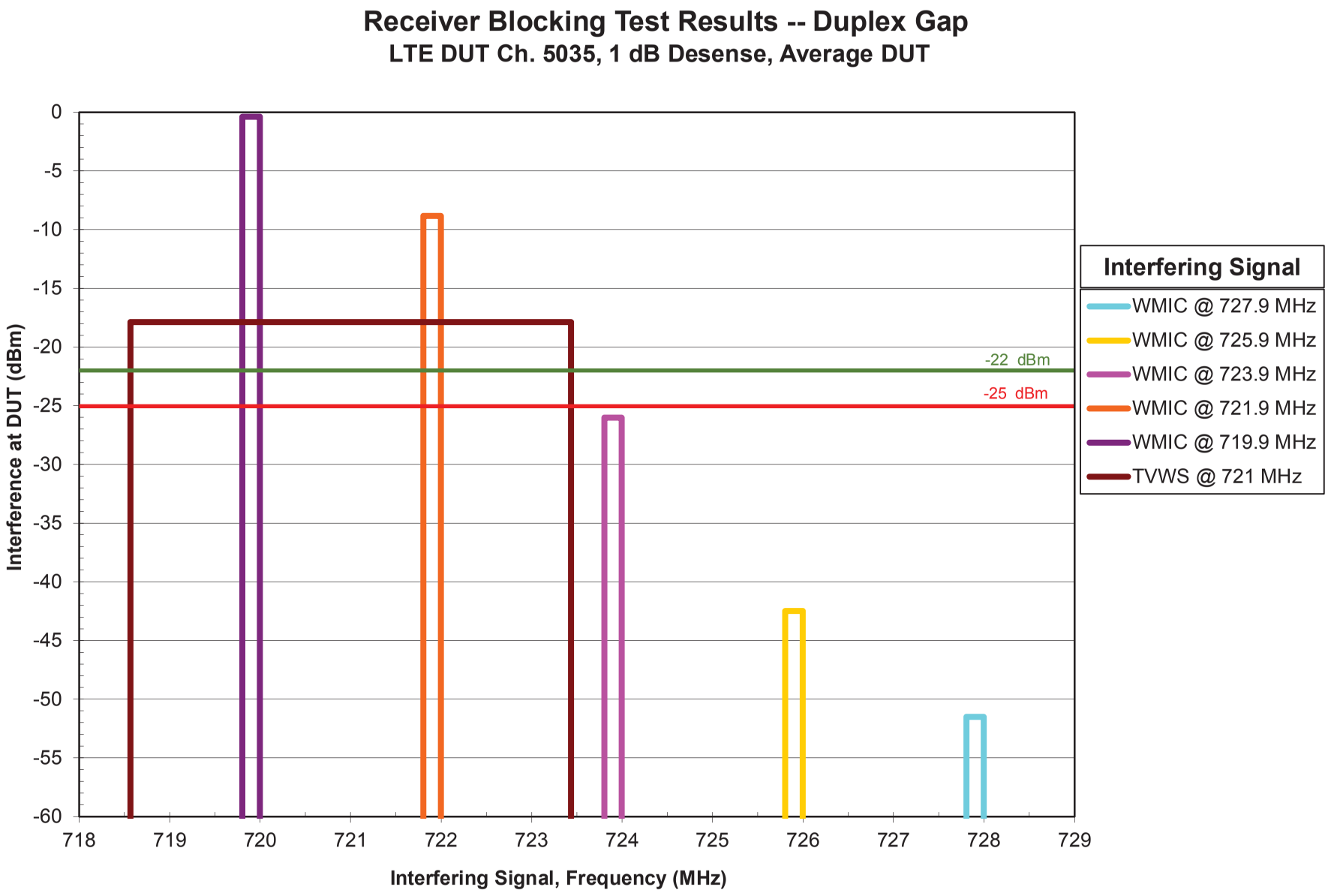

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, DUT 8
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

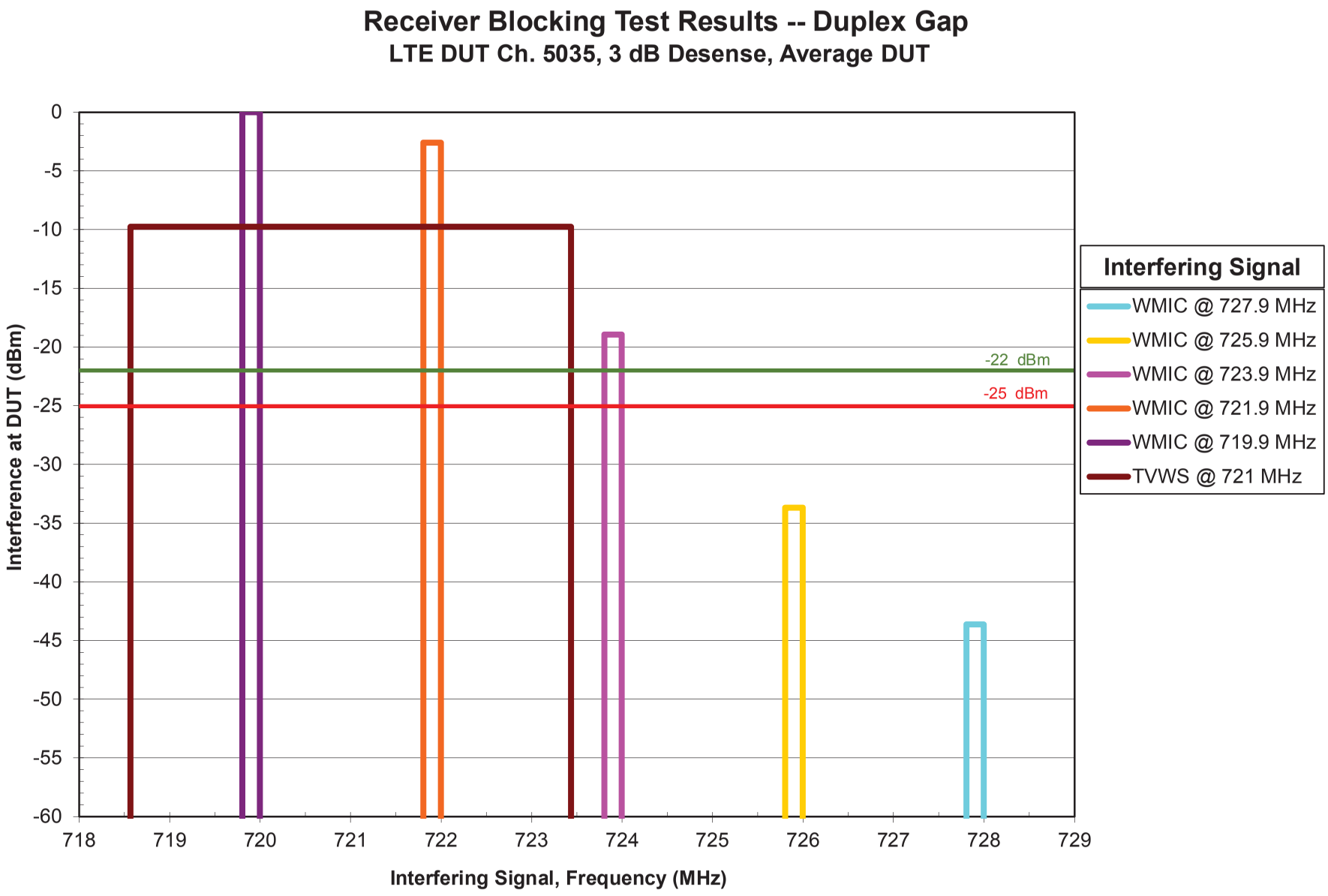

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 1 dB Desense, DUT 9
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz


Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, DUT 9
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz


Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 1 dB Desense, DUT 10
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-22 dBm
-25 dBm
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

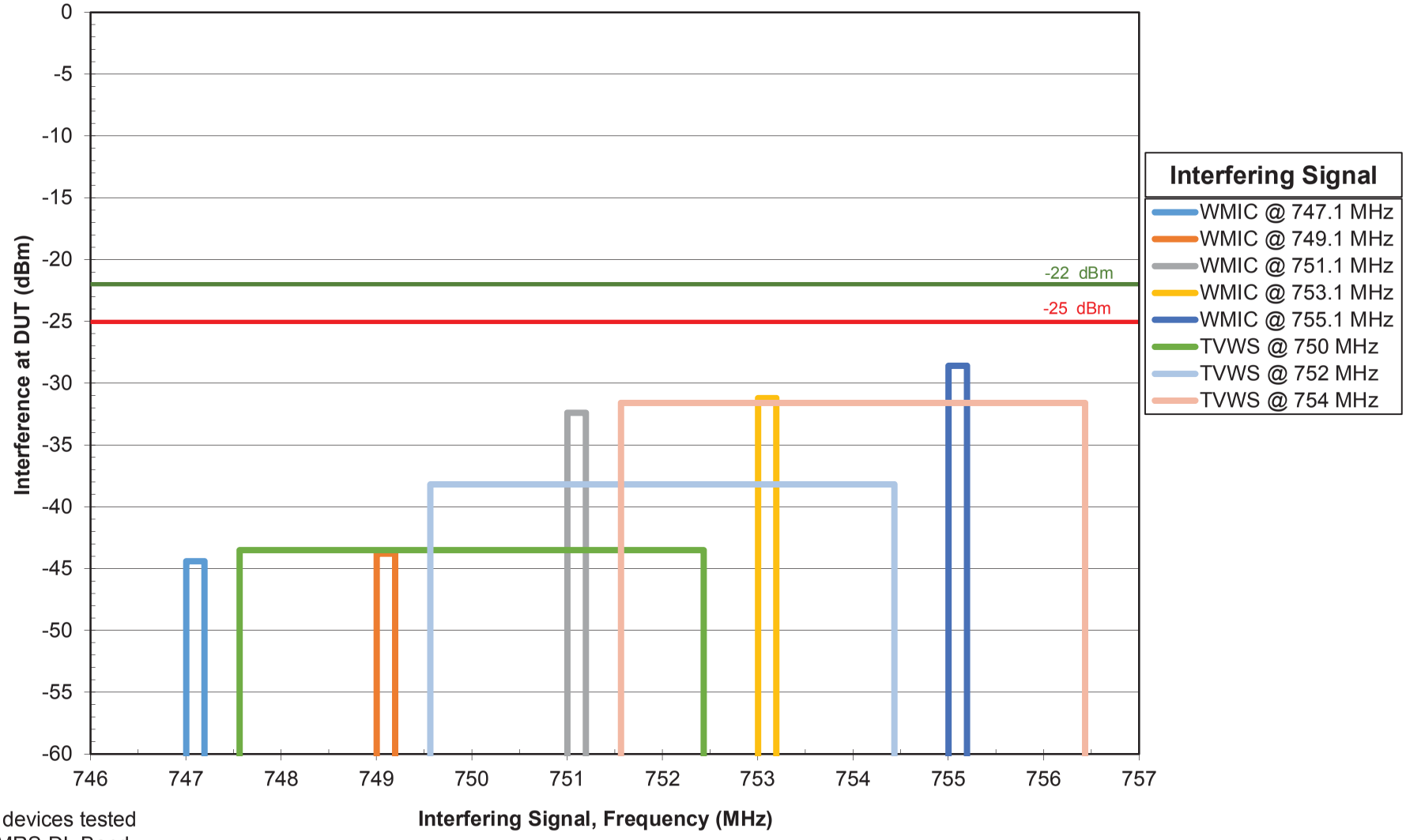

Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, DUT 10
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz


Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 1 dB Desense, Average DUT
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz


Receiver Blocking Test Results -- Duplex Gap
LTE DUT Ch. 5035, 3 dB Desense, Average DUT
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
718
719
720
721
722
723
724
725
726
727
728
729
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 727.9 MHz
WMIC @ 725.9 MHz
WMIC @ 723.9 MHz
WMIC @ 721.9 MHz
WMIC @ 719.9 MHz
TVWS @ 721 MHz

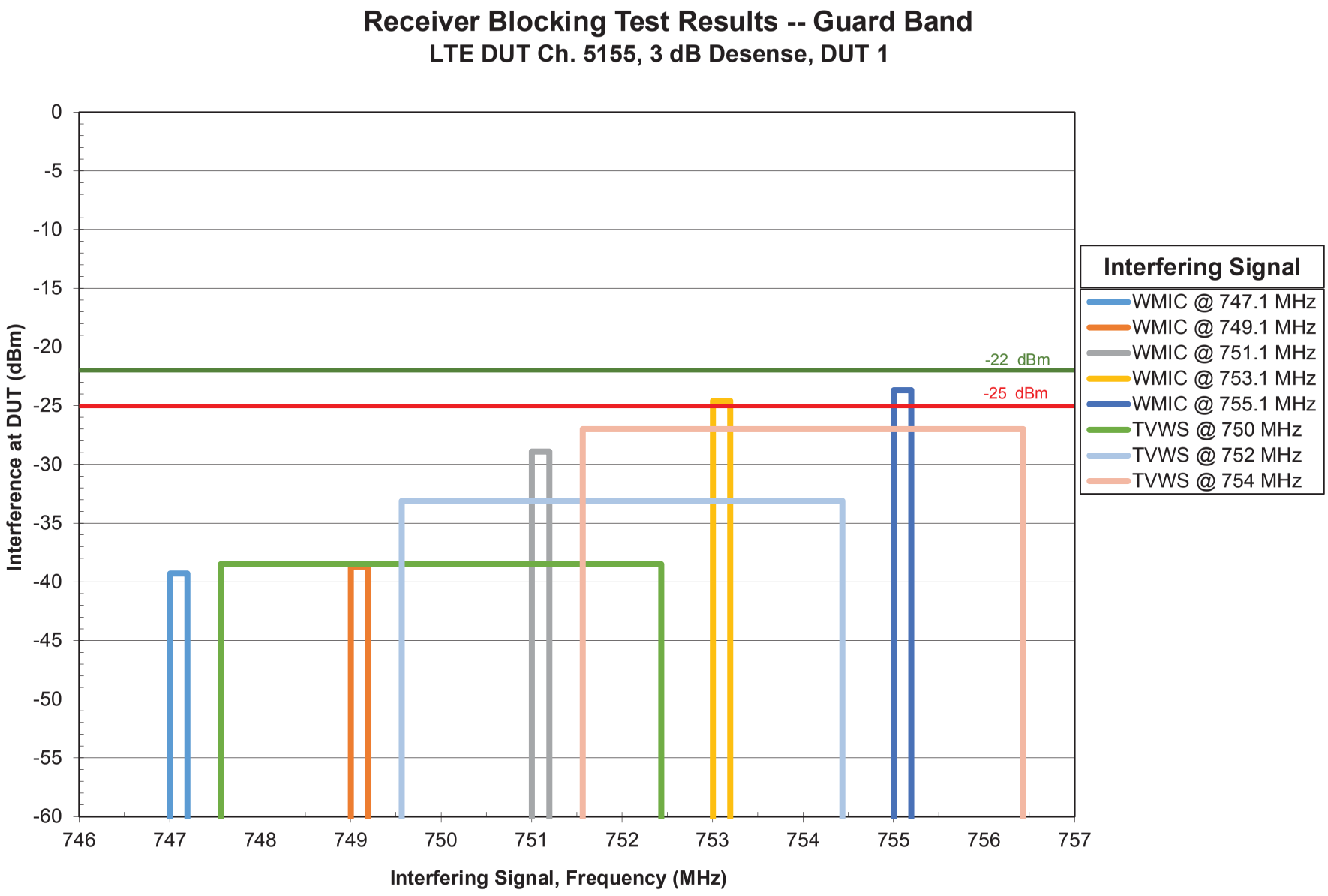
Receiver Blocking Test Results -- Guard Band

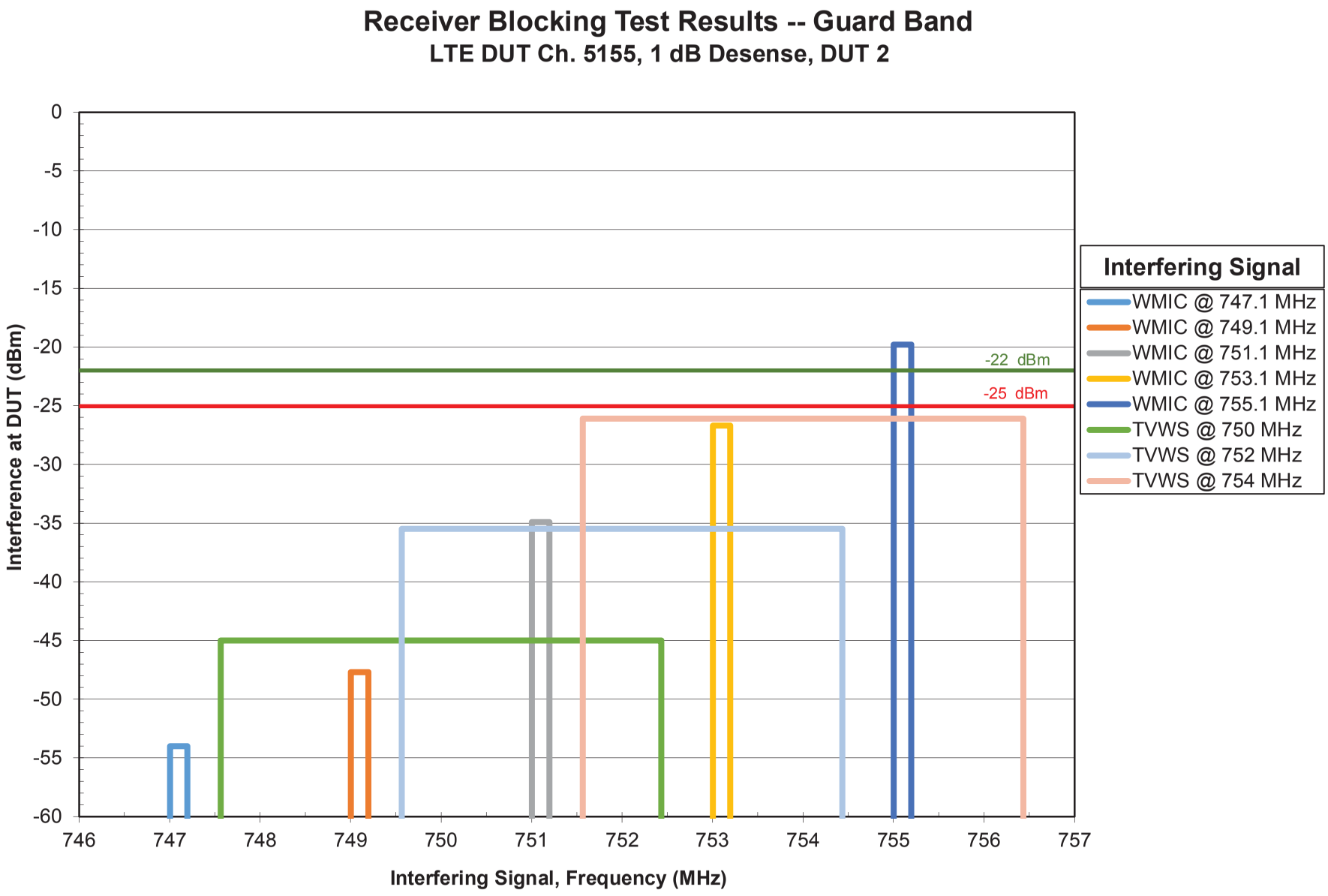
LTE DUT Ch. 5155, 1 dB Desense, DUT 1

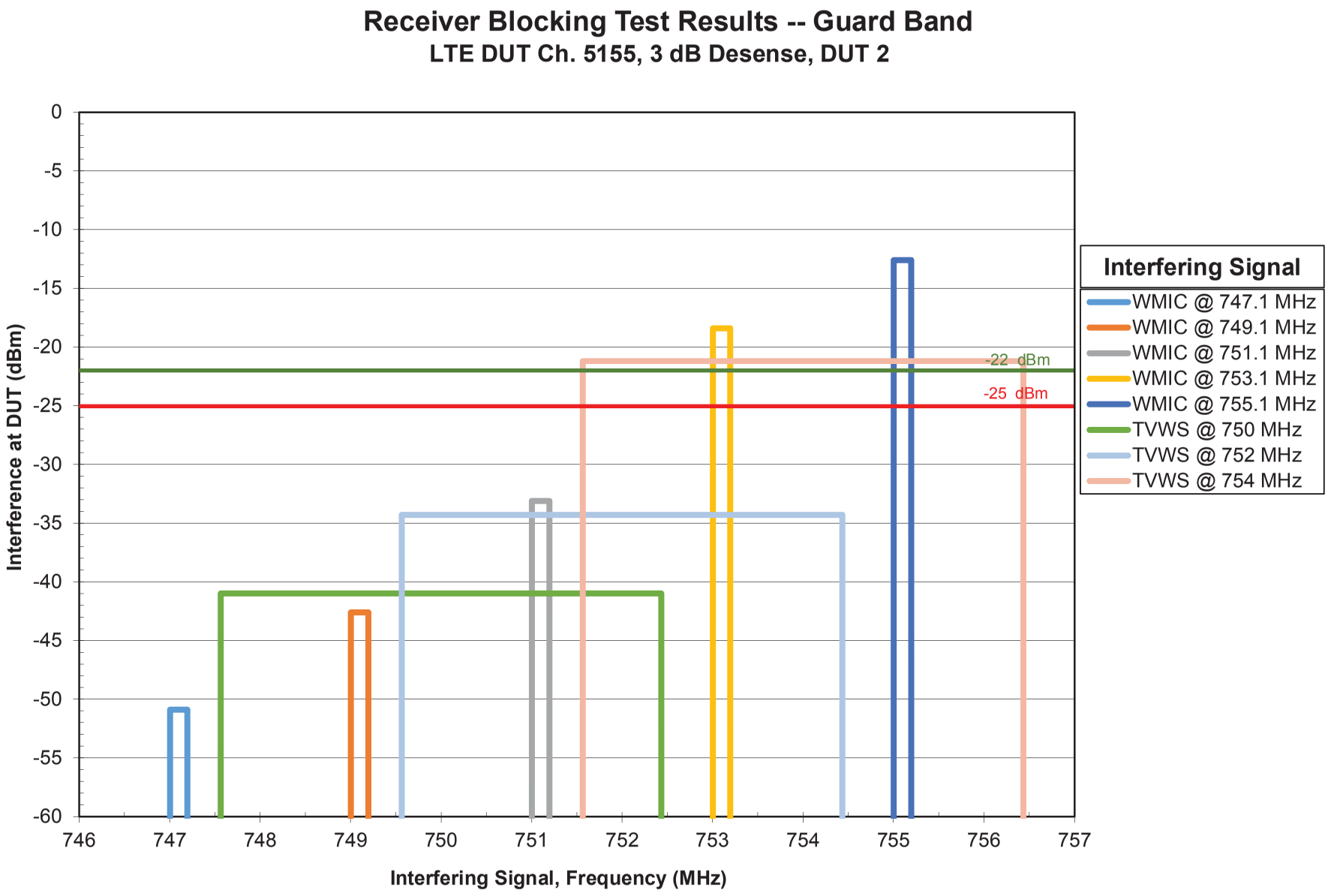


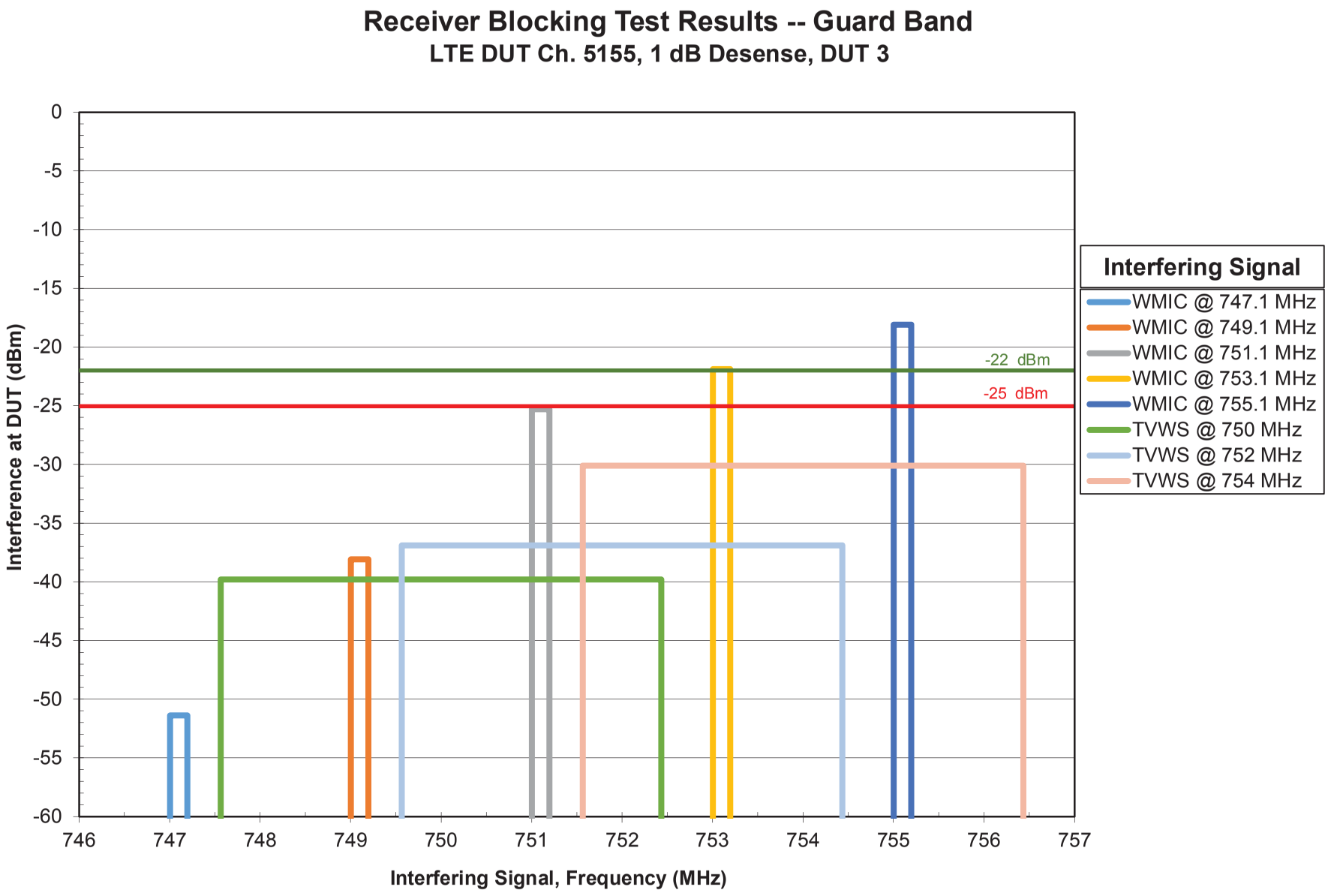
(LTE devices tested in CMRS DL Band 729-746 MHz)

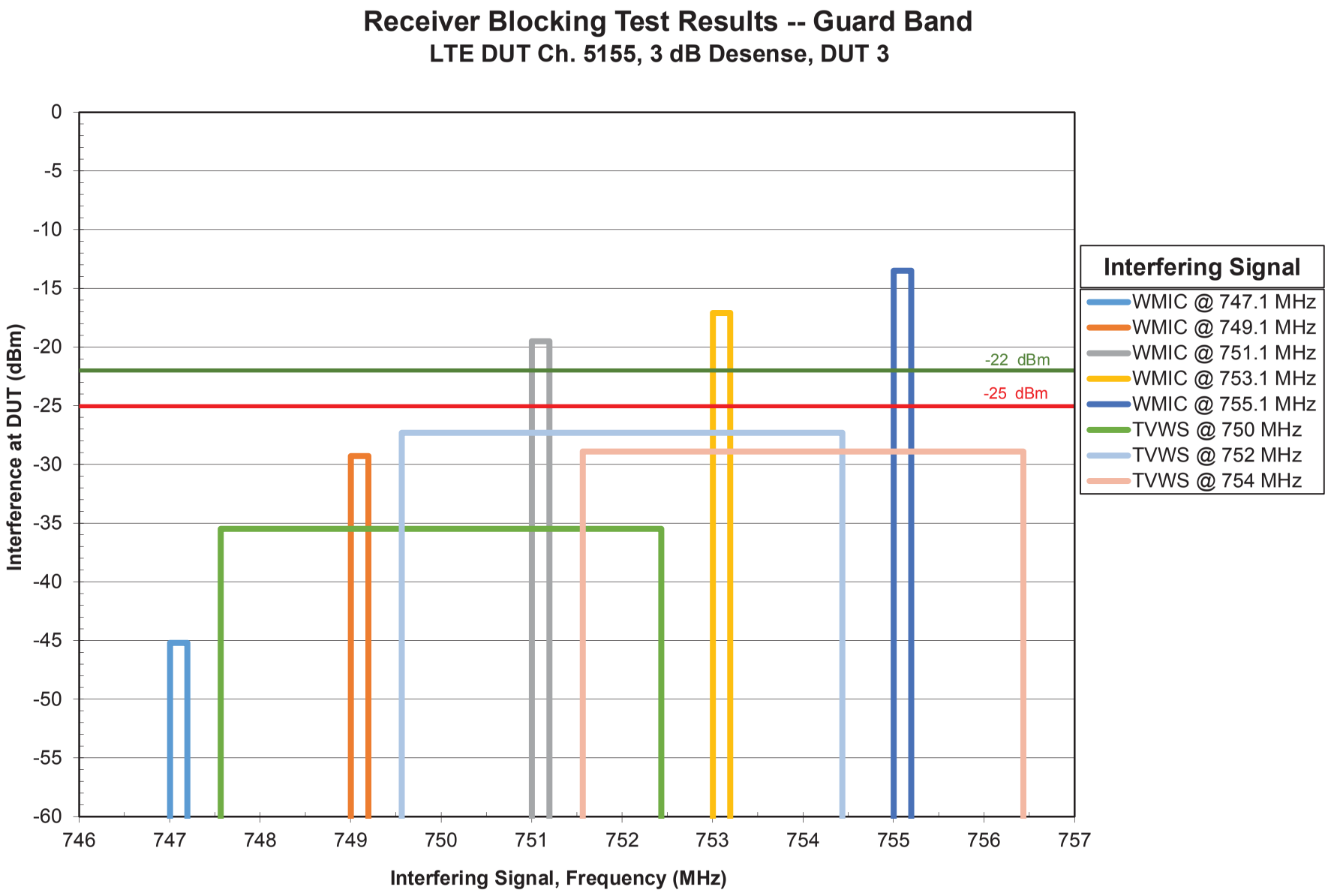
(Interfering Signal levels received in Guard Band 746-757 MHz)

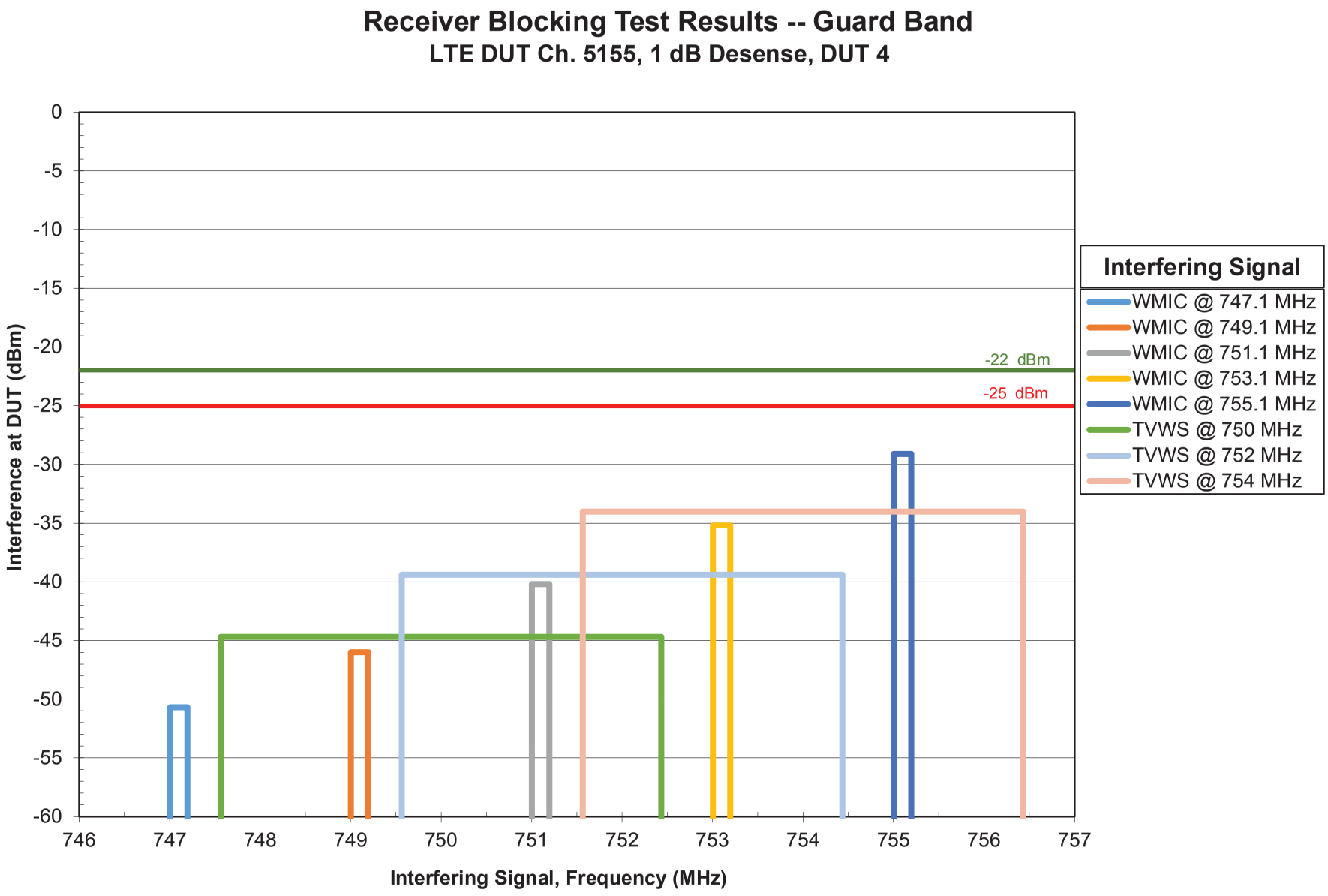

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, DUT 1
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

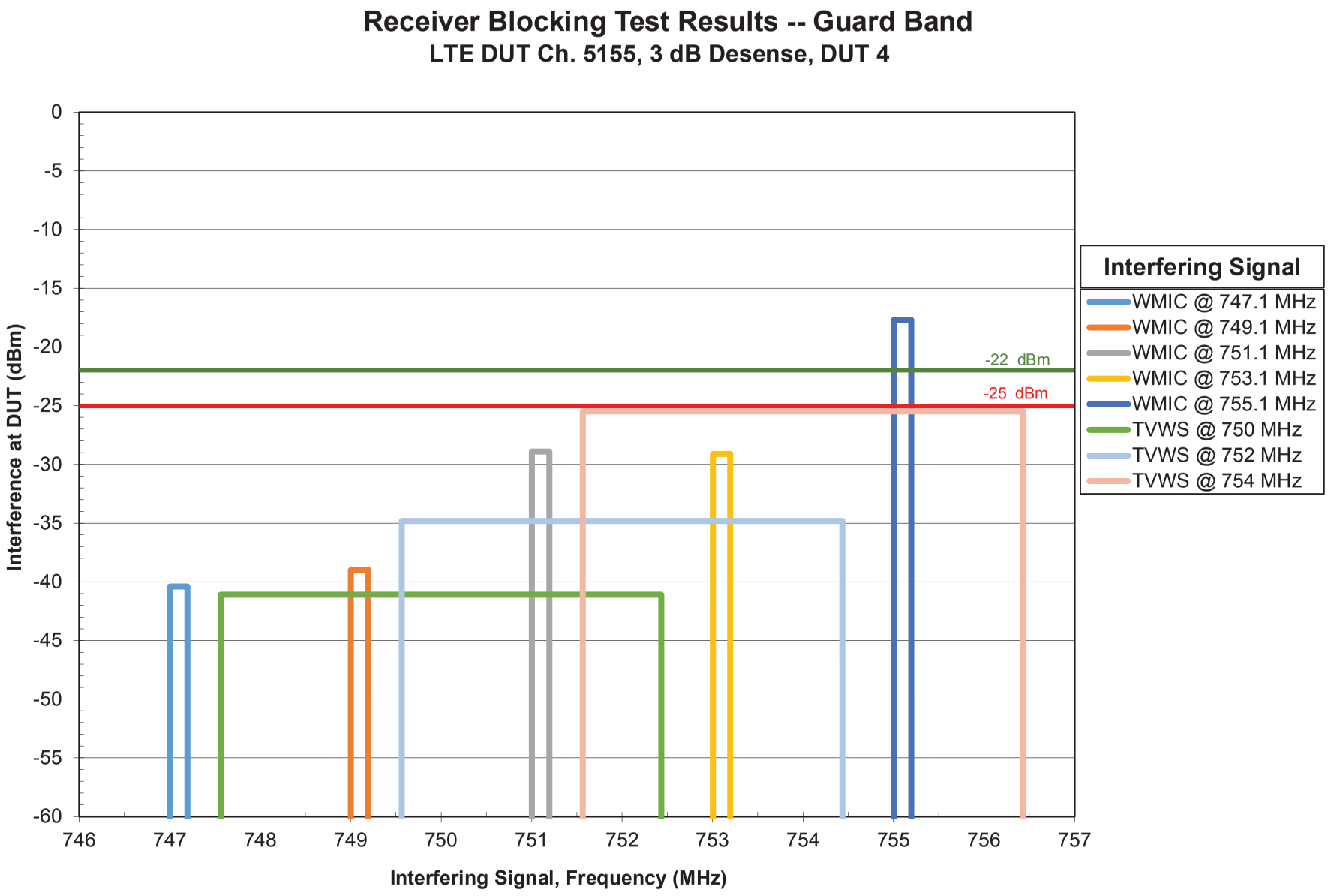

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 1 dB Desense, DUT 2
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

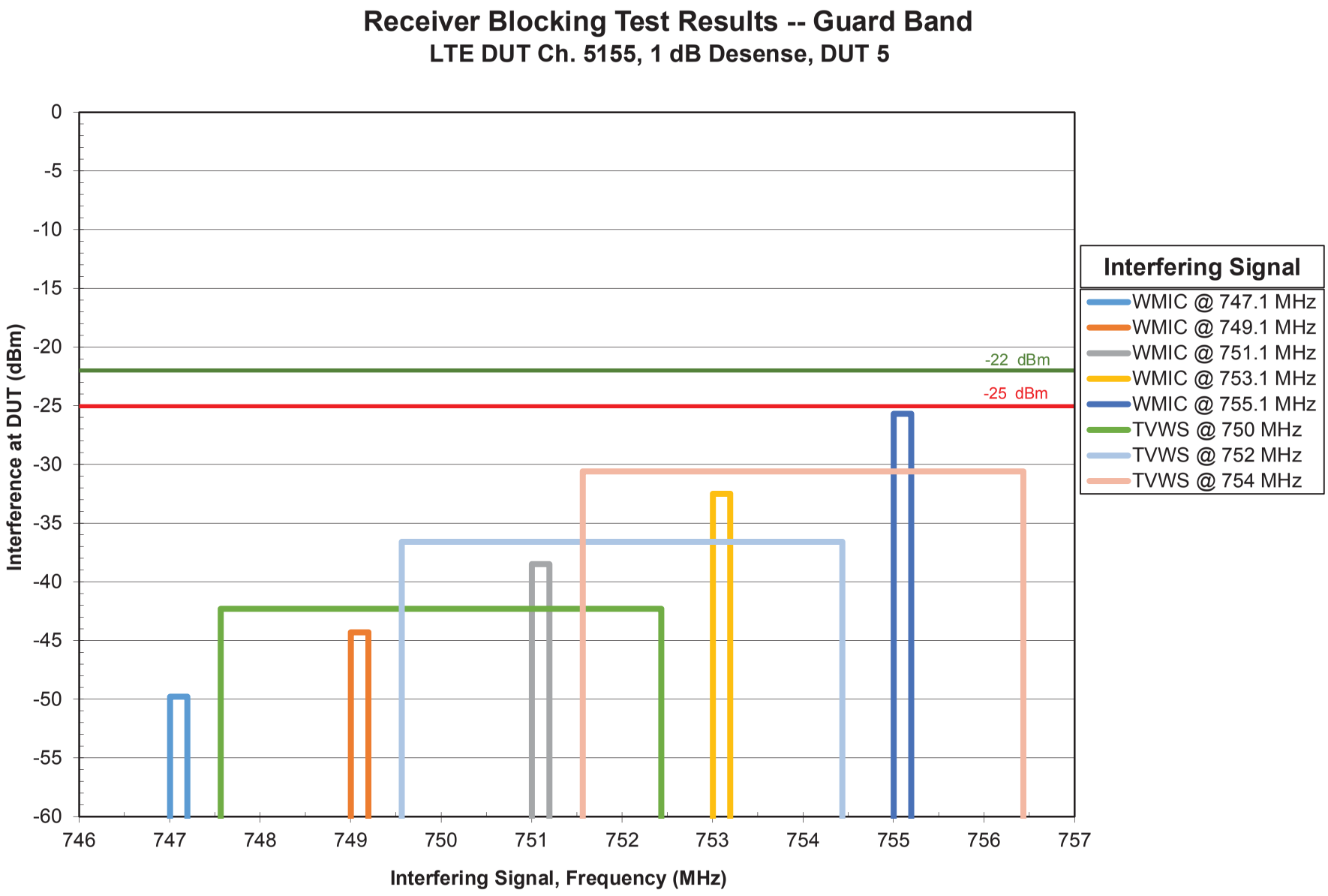

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, DUT 2
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

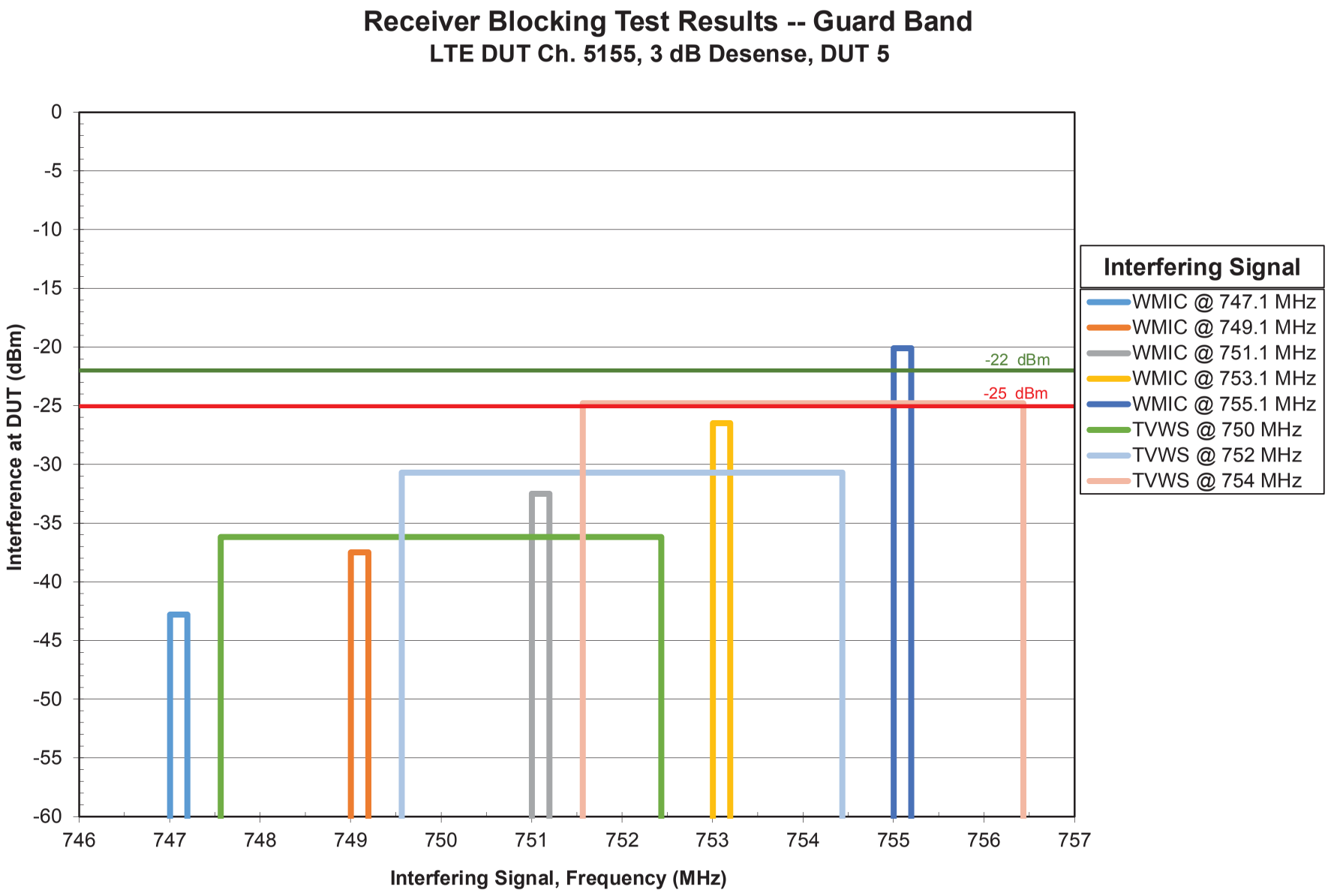

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 1 dB Desense, DUT 3
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

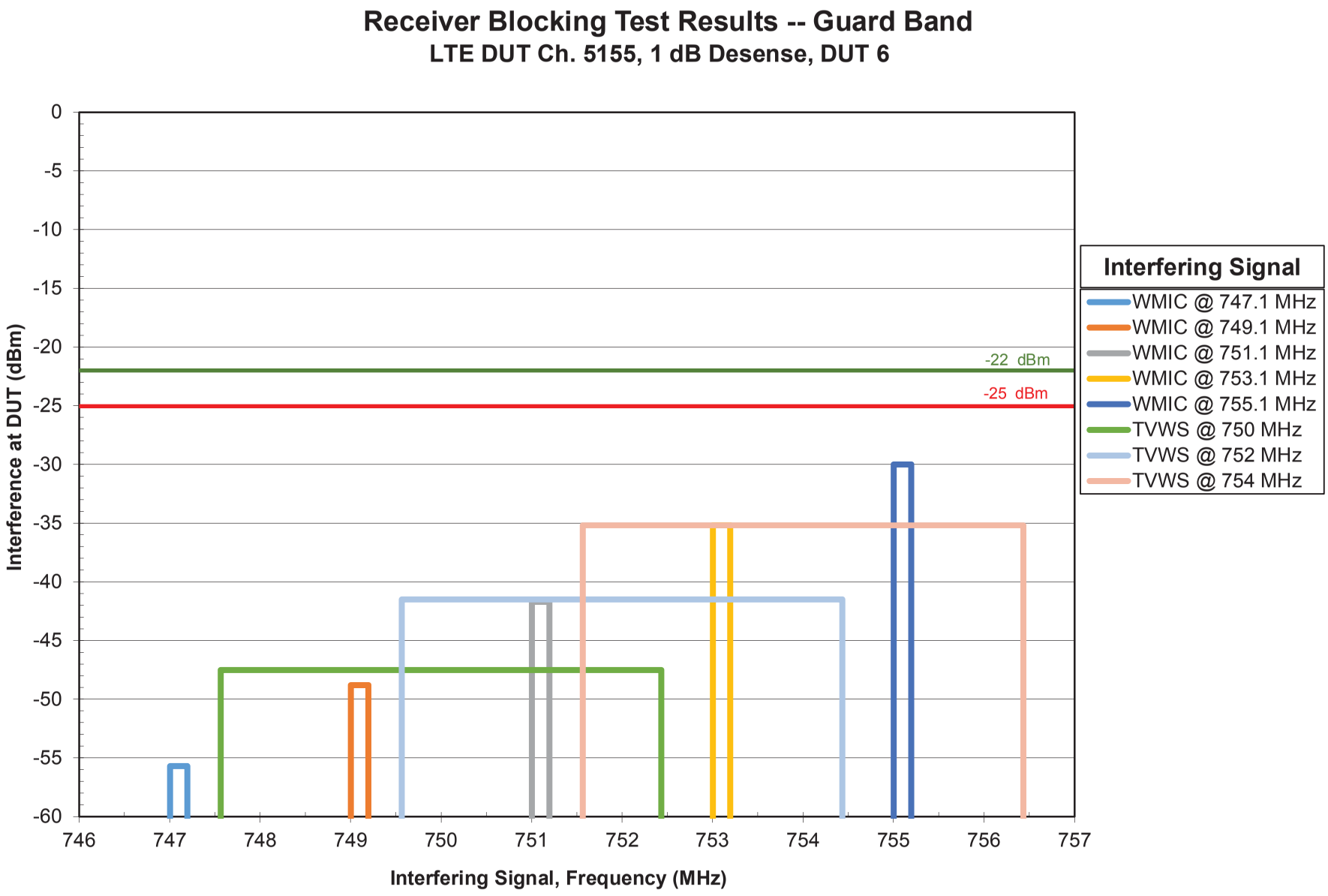

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, DUT 3
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

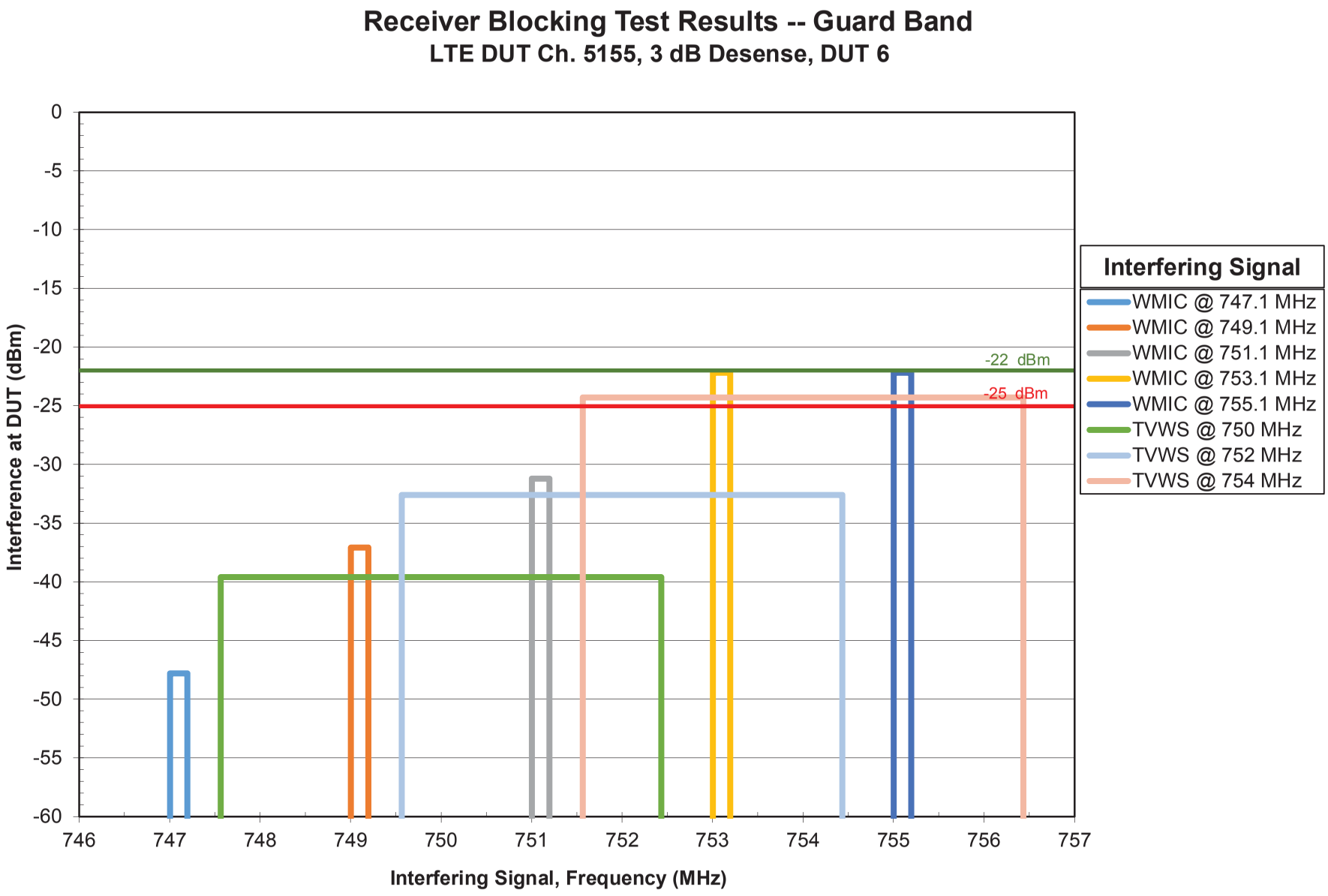

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 1 dB Desense, DUT 4
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-22 dBm
-25 dBm
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

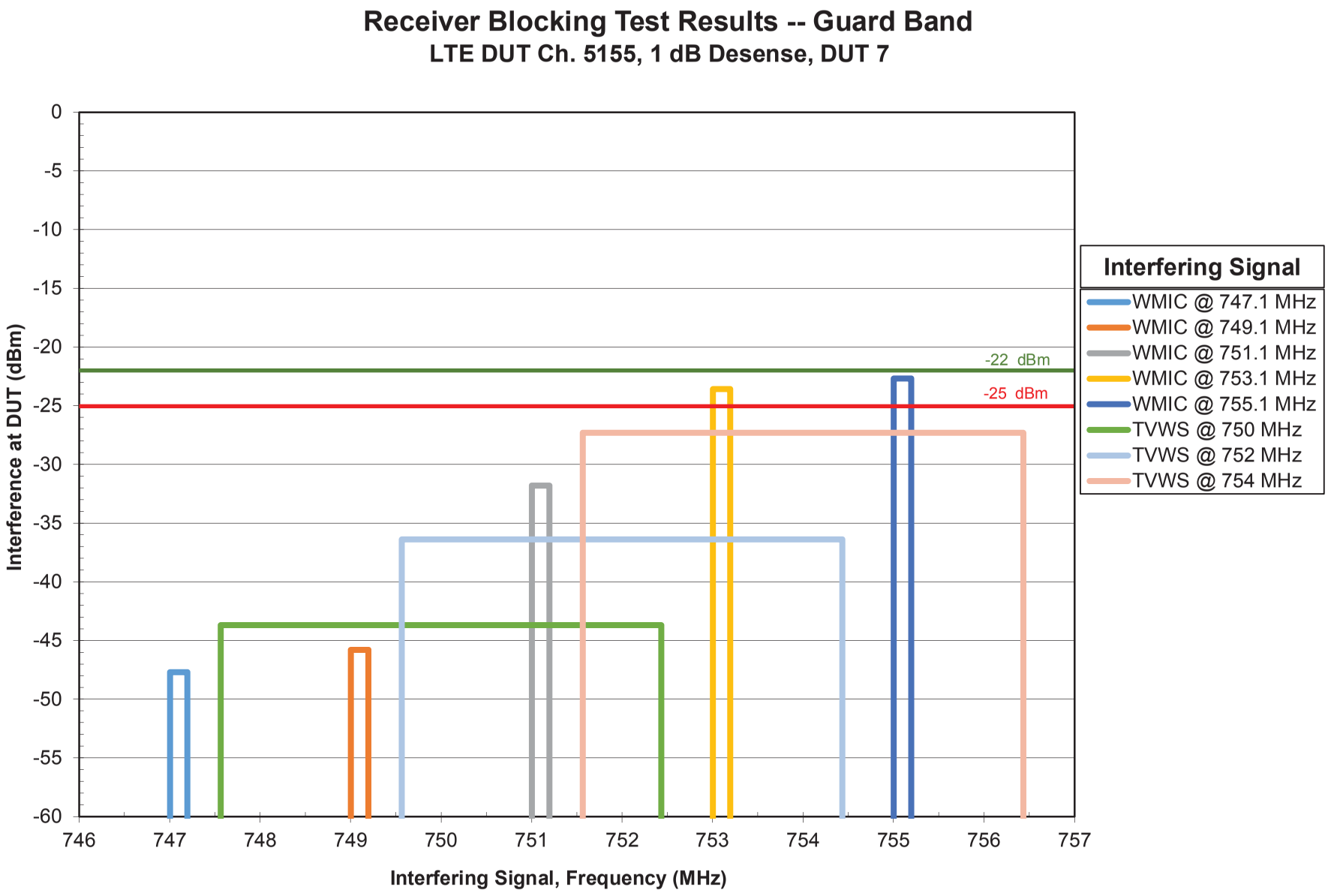

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, DUT 4
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

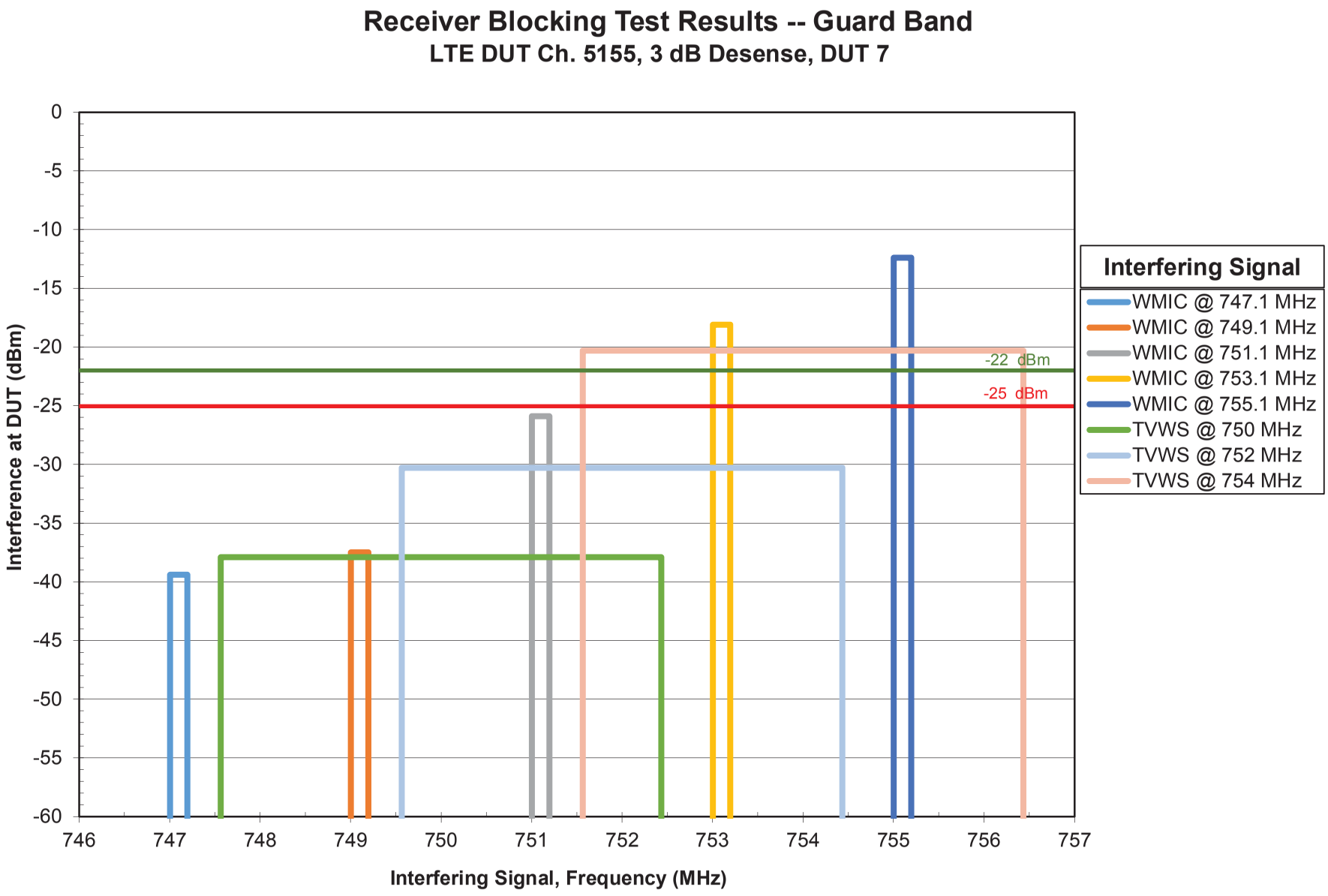

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 1 dB Desense, DUT 5
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-22 dBm
-25 dBm
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

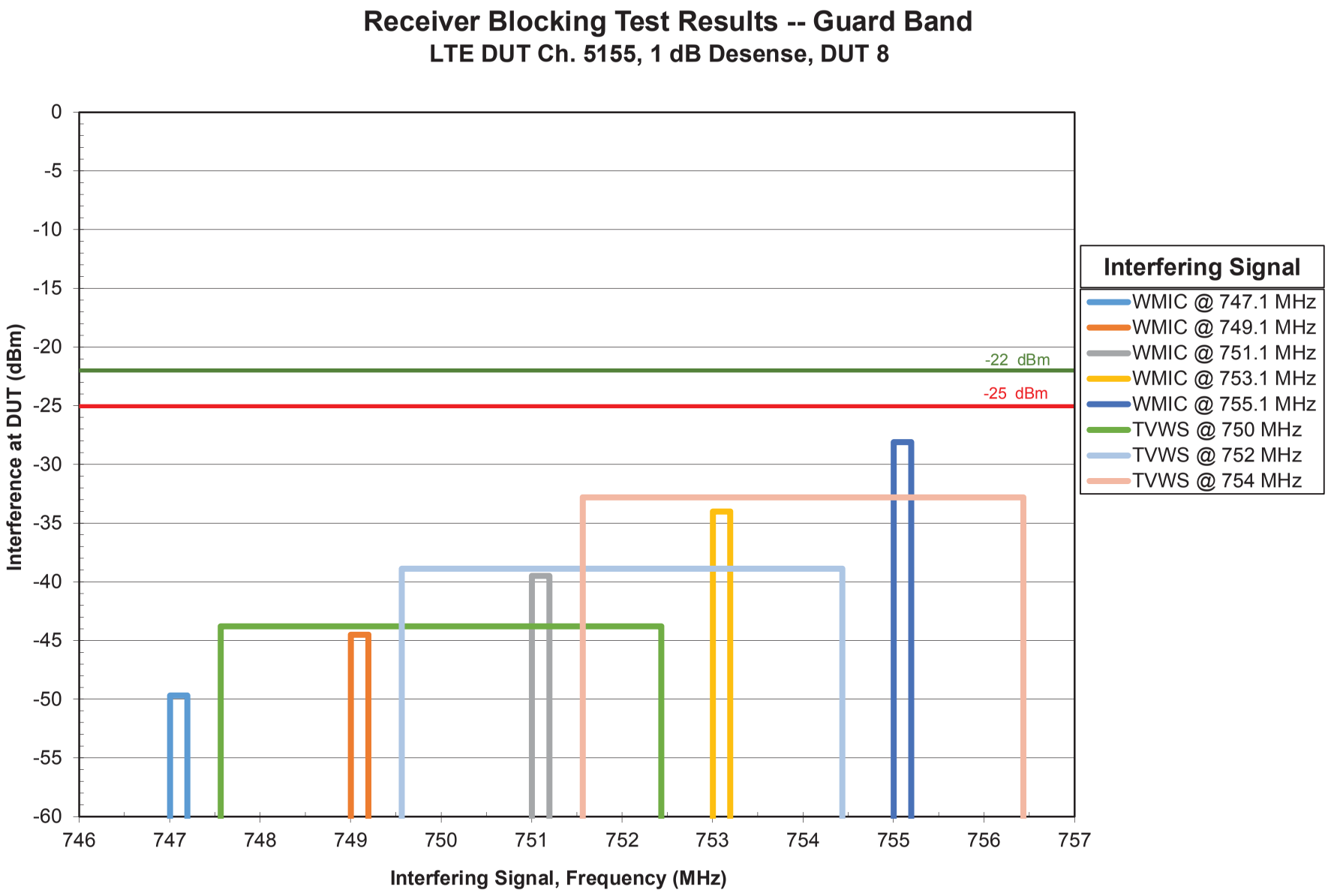

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, DUT 5
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

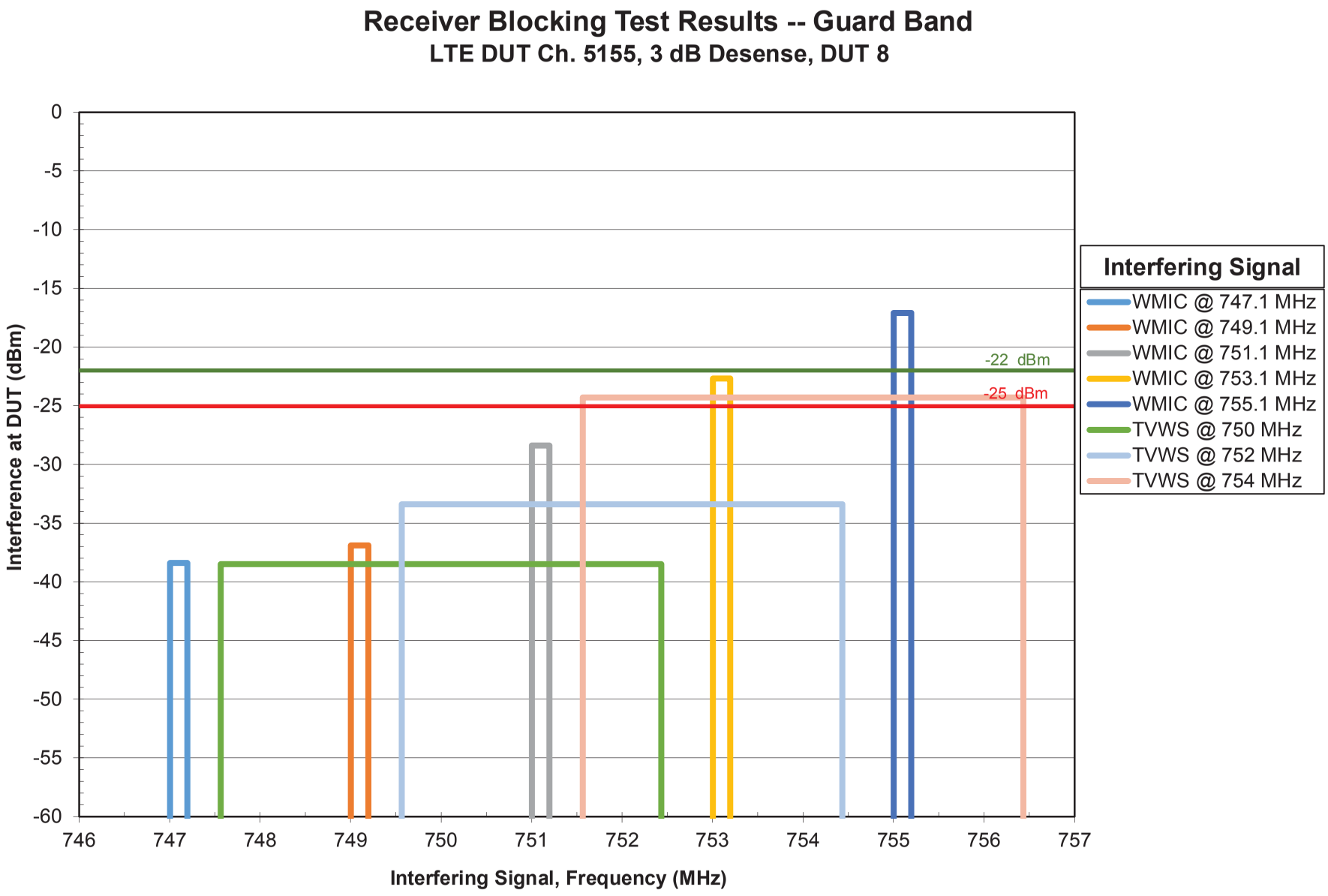

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 1 dB Desense, DUT 6
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-22 dBm
-25 dBm
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

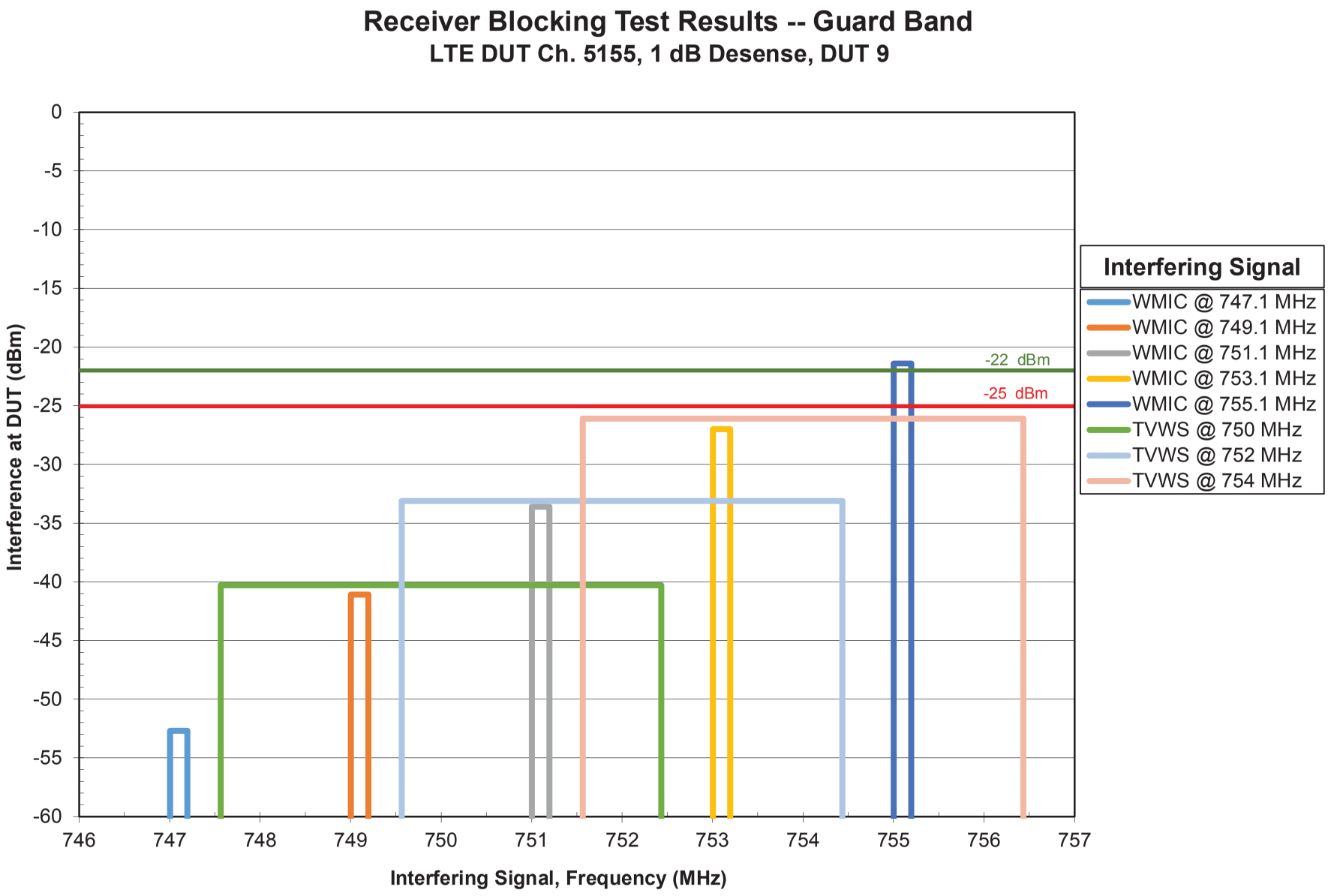

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, DUT 6
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

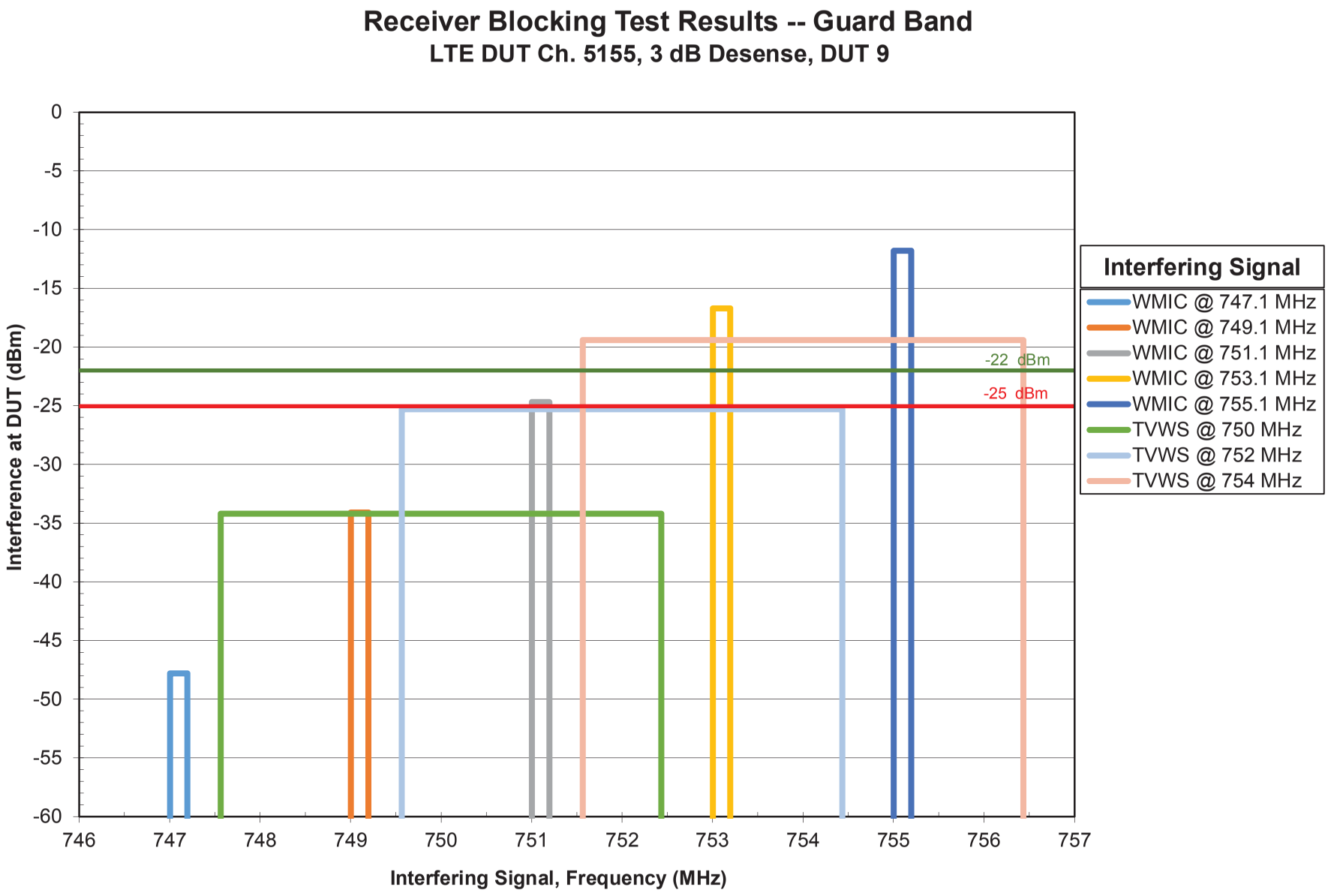

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 1 dB Desense, DUT 7
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

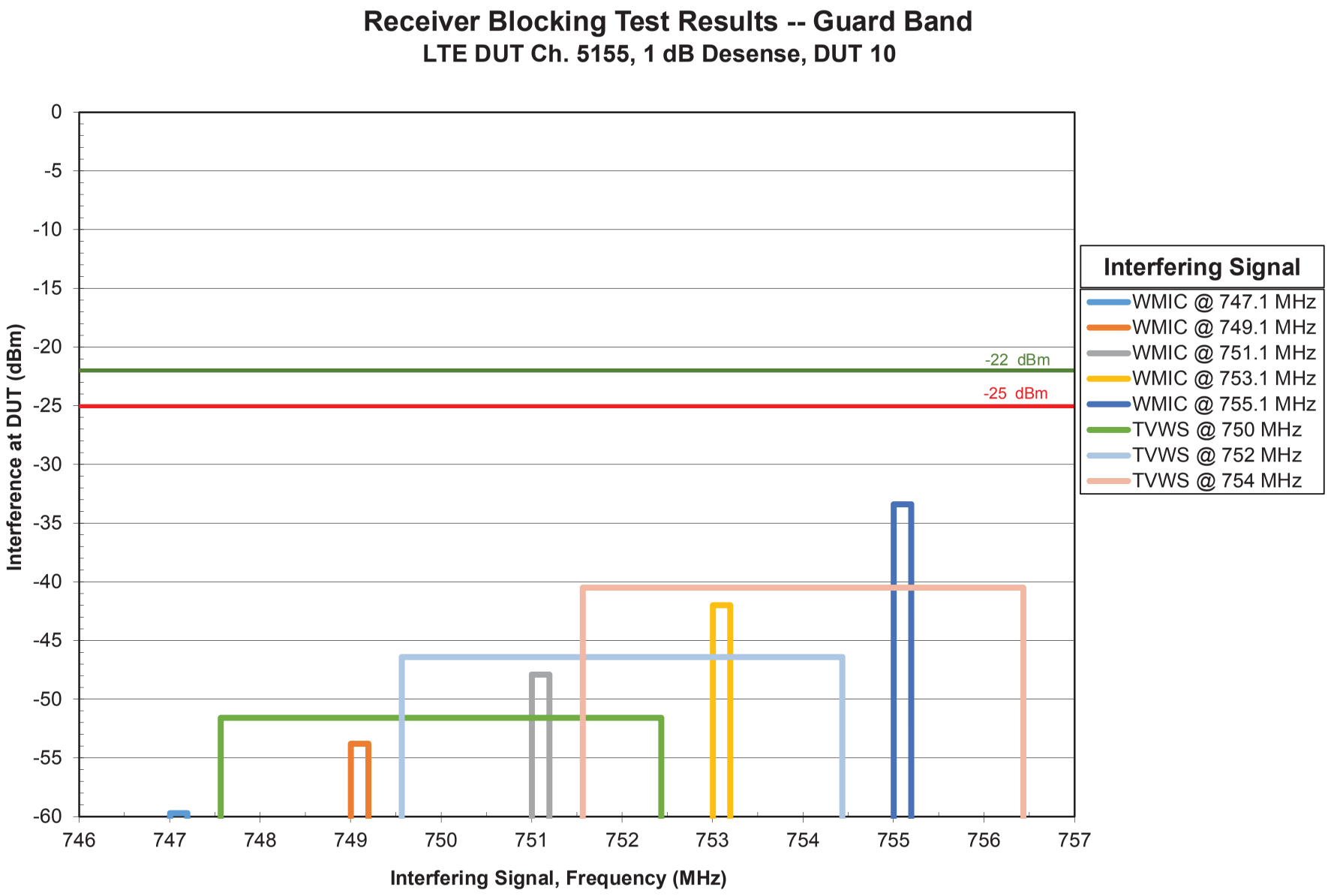

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, DUT 7
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

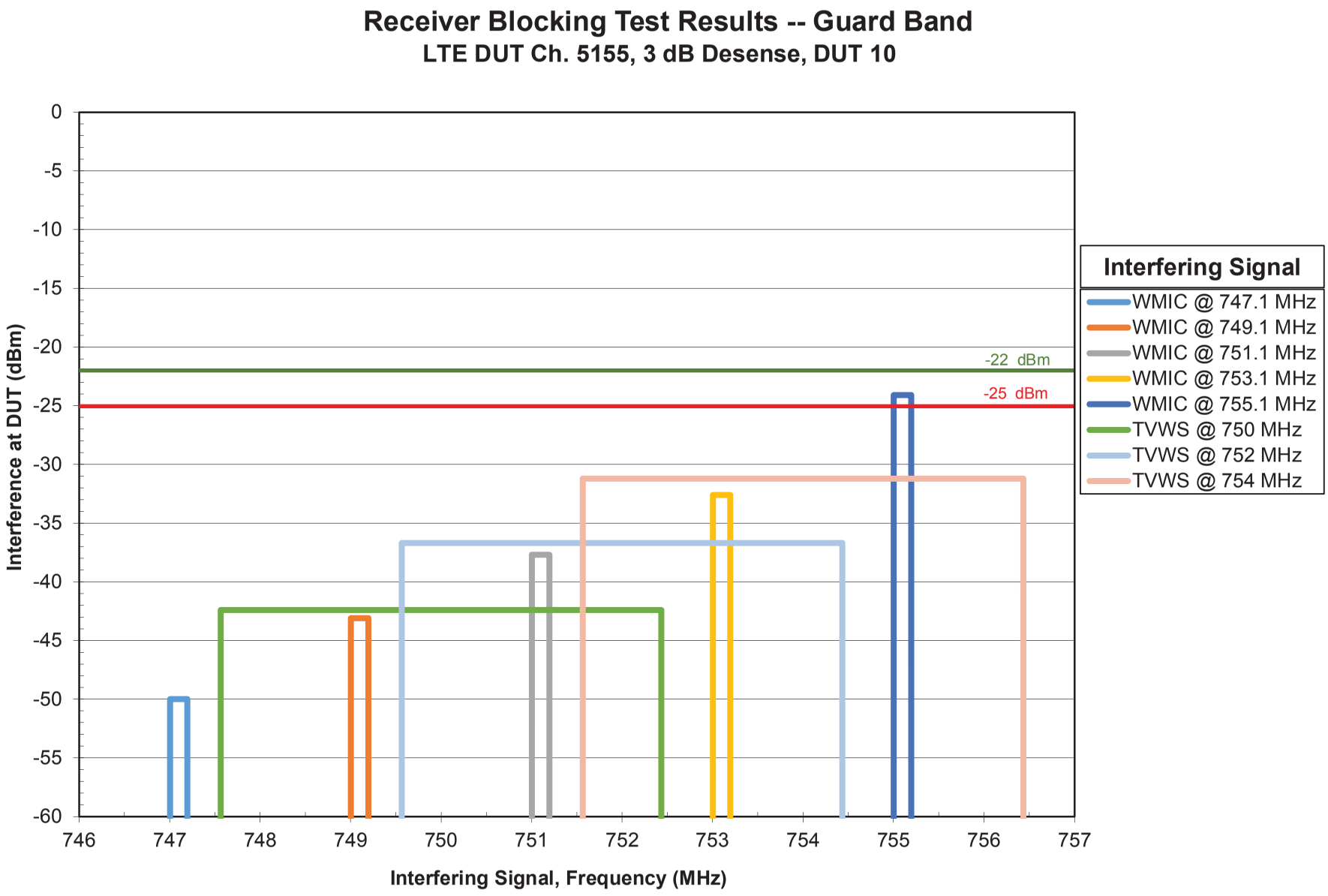

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 1 dB Desense, DUT 8
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-22 dBm
-25 dBm
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

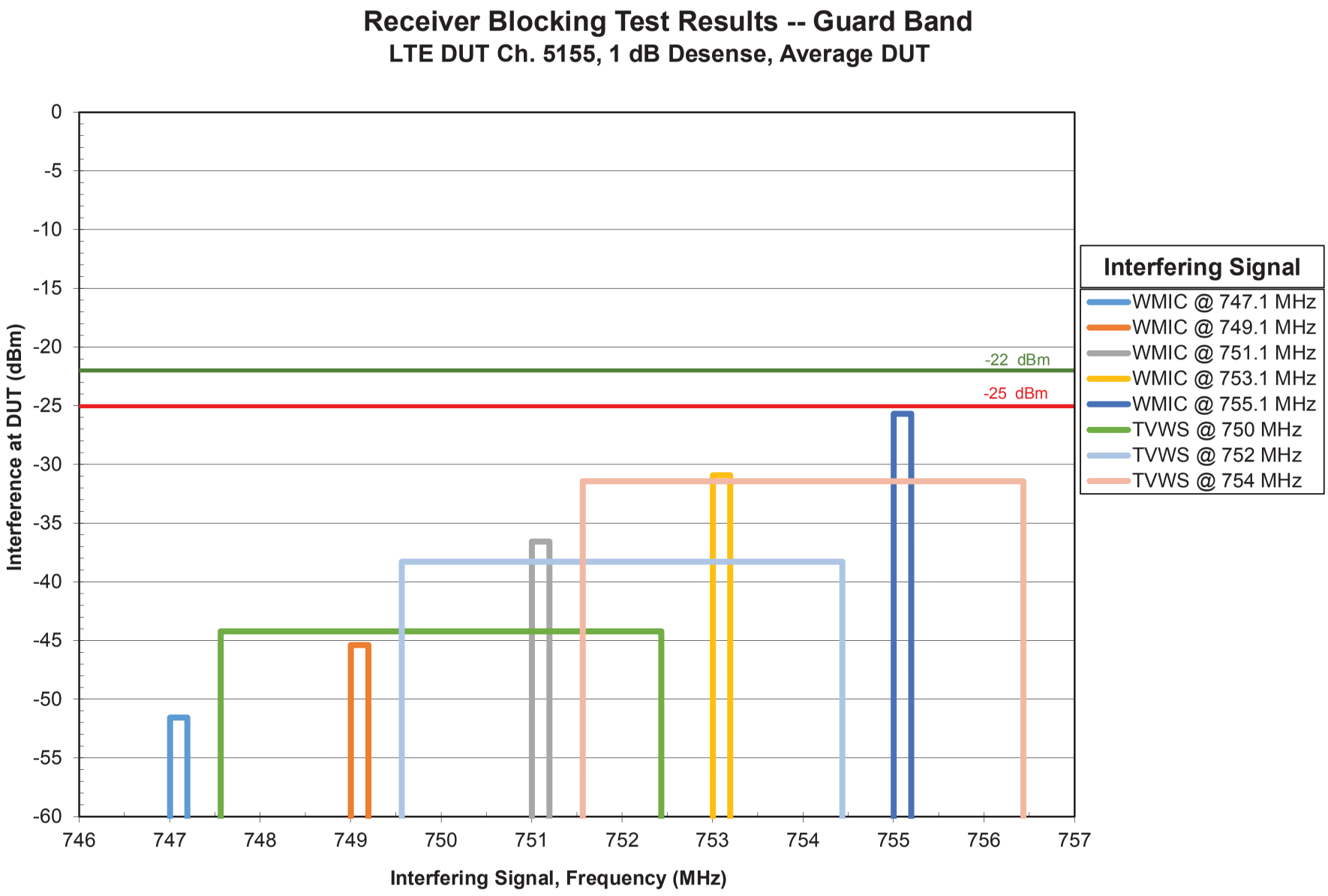

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, DUT 8
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

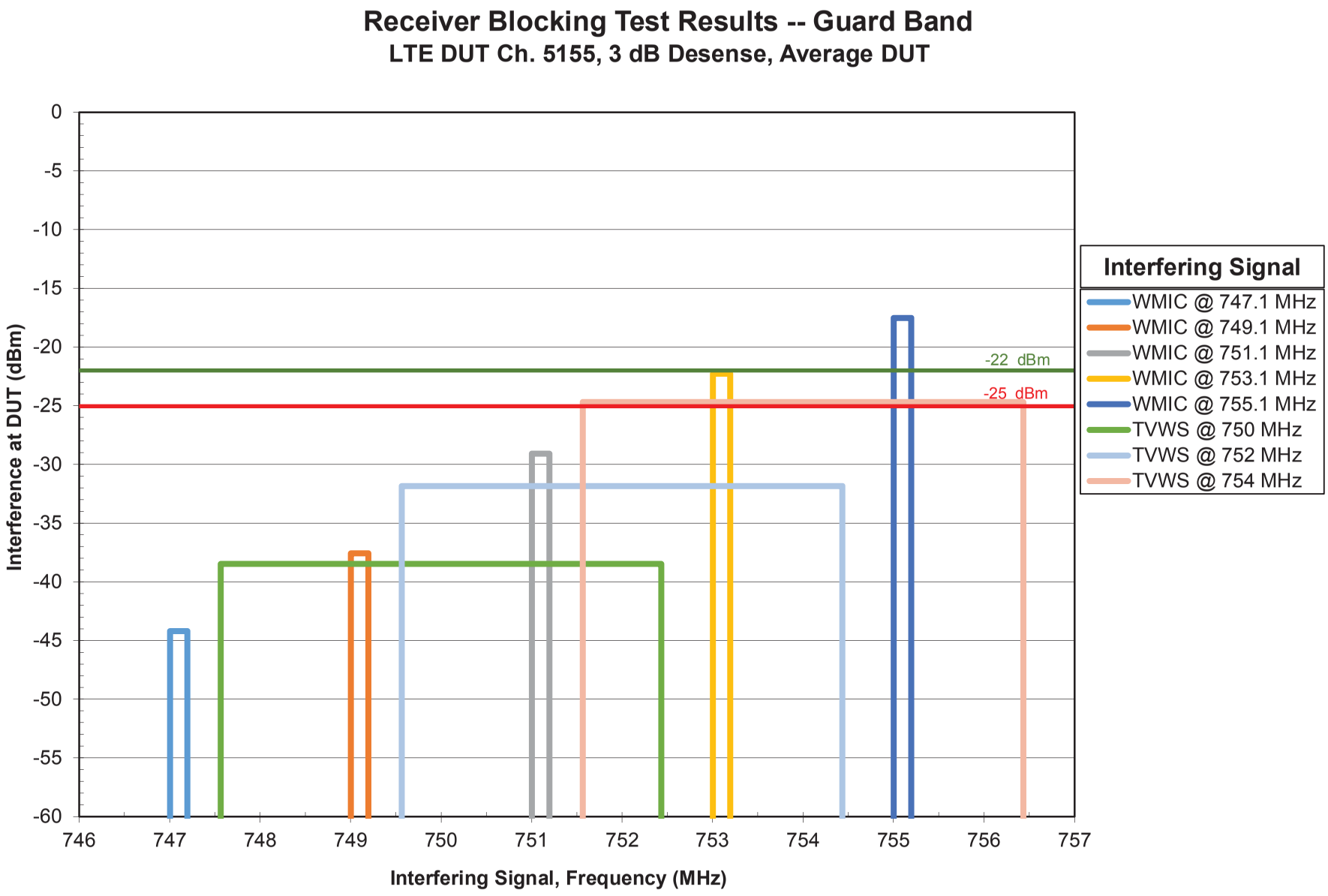

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 1 dB Desense, DUT 9
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz

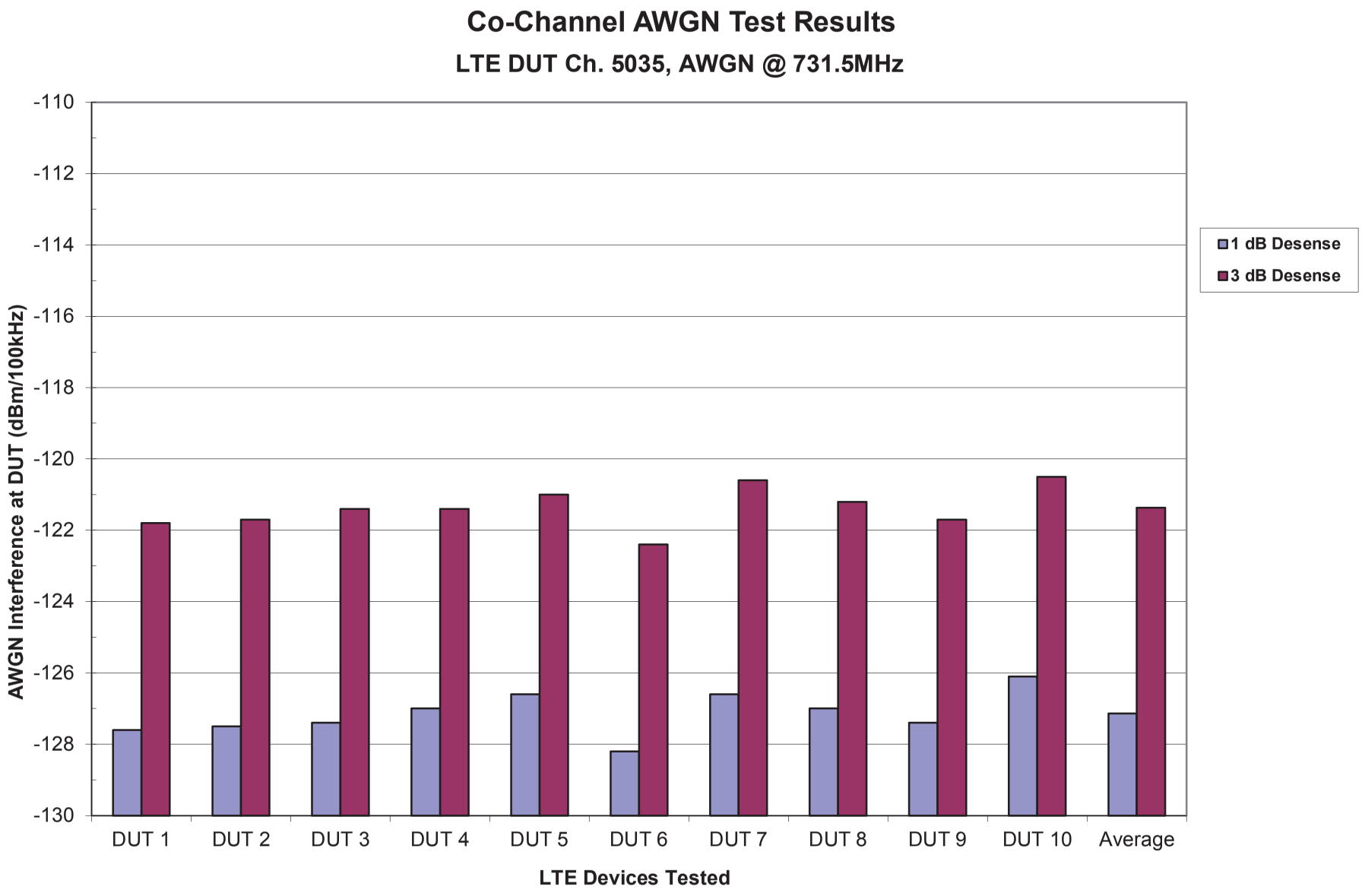

Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, DUT 9
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz


Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 1 dB Desense, DUT 10
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-22 dBm
-25 dBm
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz


Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, DUT 10
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-22 dBm
-25 dBm
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz


Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 1 dB Desense, Average DUT
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-22 dBm
-25 dBm
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz


Receiver Blocking Test Results -- Guard Band
LTE DUT Ch. 5155, 3 dB Desense, Average DUT
Interference at DUT (dBm)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
746
747
748
749
750
751
752
753
754
755
756
757
Interfering Signal, Frequency (MHz)
-22 dBm
-25 dBm
Interfering Signal
WMIC @ 747.1 MHz
WMIC @ 749.1 MHz
WMIC @ 751.1 MHz
WMIC @ 753.1 MHz
WMIC @ 755.1 MHz
TVWS @ 750 MHz
TVWS @ 752 MHz
TVWS @ 754 MHz


Co-Channel AWGN Test Results
LTE DUT Ch. 5035, AWGN @ 731.5MHz
AWGN Interference at DUT (dBm/100kHz)
-110
-112
-114
-116
-118
-120
-122
-124
-126
-128
-130
DUT 1
DUT 2
DUT 3
DUT 4
DUT 5
DUT 6
DUT 7
DUT 8
DUT 9
DUT 10
Average
LTE Devices Tested
1 dB Desense
3 dB Desense

Summary of Test Results

(Receiver Blocking Tests in Duplex Gap at 1 dB Desense)

- Receiver Blocking test results for the average LTE device with interfering signals in the Duplex Gap, at 1 dB desense interference threshold, occurred at the following received interference levels:

Average DUT Results, 1 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
Wireless Microphone @ 727.9 MHz	1	-51.5	21.4	-13.5
Wireless Microphone @ 725.9 MHz	3	-42.5	7.6	-4.5
Wireless Microphone @ 723.9 MHz	5	-26.0	1.1	12.0
Wireless Microphone @ 721.9 MHz	7	-8.9	0.2	29.1
Wireless Microphone @ 719.9 MHz	9	-0.4	0.1	37.6
TV White Space Device @ 721 MHz	5	-17.9	0.6	20.1

  - The table above provides the average results for the LTE devices tested, the frequency separation (buffer) from the CMRS downlink band, the received interference level at the LTE devices, the required separation distance to LTE devices from an interfering signal at the FCC proposed power level (i.e. 16 dBm for TVWS, 13 dBm for WMIC), and the required interference Power Limit to protect to LTE devices at 1 meter.
- Based on test results for the average LTE device at 1 dB desense threshold:
  - Wireless Microphones and TV White Space devices operating at the FCC proposed power levels require a 5 MHz buffer in the Duplex Gap to prevent interference to LTE devices at 1 meter. (1.1 meters in the table above)
    - This protects the average LTE device to 1 dB desense interference threshold, and individual LTE devices (i.e. DUT 8 & 10) to approx. 2 to 3 dB desense interference.
  - With less than 5 MHz buffer in the Duplex Gap, wireless microphone and TV white space Power limits are too low (i.e. < 1 mW) to support normal operations, and at FCC proposed power levels would cause interference to LTE devices within 21 meters.

Summary of Test Results

(Receiver Blocking Tests in Duplex Gap at 3 dB Desense)

- Receiver Blocking test results for the average LTE device with interfering signals in the Duplex Gap, at 3 dB desense interference threshold, occurred at the following received interference levels:

Average DUT Results, 3 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
Wireless Microphone @ 727.9 MHz	1	-43.6	8.6	-5.6
Wireless Microphone @ 725.9 MHz	3	-33.7	2.8	4.3
Wireless Microphone @ 723.9 MHz	5	-18.9	0.5	19.1
Wireless Microphone @ 721.9 MHz	7	-2.6	0.1	35.4
Wireless Microphone @ 719.9 MHz	9	0.8	0.1	38.8
TV White Space Device @ 721 MHz	5	-9.8	0.2	28.2

  - The table above provides the average results for the LTE devices tested, the frequency separation (buffer) from the CMRS downlink band, the received interference level at the LTE devices, the required separation distance to LTE devices from an interfering signal at the FCC proposed power level (i.e. 16 dBm for TVWS, 13 dBm for WMIC), and the required interference Power Limit to protect to LTE devices at 1 meter.
- Based on test results for the average LTE device at 3 dB desense threshold:
  - Wireless Microphones and TV White Space devices operating at the FCC proposed power levels require a 5 MHz buffer in the Duplex Gap to prevent interference to LTE devices at 1 meter. (5 MHz case requires a minimum of 0.5 meters in the table above)
    - This protects the average LTE device to 1 dB desense interference threshold, and individual LTE devices (i.e. DUT 8 & 10) to approx. 2 to 3 dB desense interference.
  - With less than 5 MHz buffer in the Duplex Gap, wireless microphone and TV white space Power limits are too low (i.e. < 1 mW) to support normal operations, and at FCC proposed power levels would cause interference to LTE devices within 9 meters.

Summary of Test Results

(Receiver Blocking Tests in Guard Band at 1 dB Desense)

- Receiver Blocking test results for the average LTE device with interfering signals in the Guard Band, at 1 dB desense interference threshold, occurred at the following received interference levels:

Average DUT Results, 1 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
Wireless Microphone @ 747.1 MHz	1	-51.6	21.6	-13.6
Wireless Microphone @ 749.1 MHz	3	-45.4	10.6	-7.4
Wireless Microphone @ 751.1 MHz	5	-36.6	3.8	1.4
Wireless Microphone @ 753.1 MHz	7	-30.9	2.0	7.1
Wireless Microphone @ 755.1 MHz	9	-25.7	1.1	12.3
TV White Space Device @ 750 MHz	1	-44.2	13.0	-6.2
TV White Space Device @ 752 MHz	3	-38.3	6.6	-0.3
TV White Space Device @ 754 MHz	5	-31.4	3.0	6.6

- The table above provides the average results for the LTE devices tested, the frequency separation (buffer) from the CMRS downlink band, the received interference level at the LTE devices, the required separation distance to LTE devices from an interfering signal at the FCC proposed power level (i.e. 16 dBm for TVWS, 13 dBm for WMIC), and the required interference Power Limit to protect to LTE devices at 1 meter.
- Based on test results for the average LTE device at 1 dB desense threshold:
  - Wireless Microphones operating at the FCC proposed power level require a 9 MHz buffer in the Guard Band to prevent interference to LTE devices at 1 meter. (1.1 m above)
    - This protects the average LTE device to 1 dB desense interference threshold, and individual LTE devices (i.e. DUT 1 & 10) to approx. 2 to 3 dB desense interference.
  - TV White Space devices require a 5 MHz buffer and a Power Limit of 6.6 dBm (5 mW) in the Guard Band to prevent interference to LTE devices at 1 meter.
    - When operating at the FCC proposed limit of 16 dBm the required separation distance for TVWS devices is 3 meters to prevent interference to LTE devices.

Summary of Test Results

(Receiver Blocking Tests in Guard Band at 3 dB Desense)

- Receiver Blocking test results for the average LTE device with interfering signals in the Guard Band, at 3 dB desense interference threshold, occurred at the following levels:

Average DUT Results, 3 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
Wireless Microphone @ 747.1 MHz	1	-44.2	9.2	-6.2
Wireless Microphone @ 749.1 MHz	3	-37.6	4.3	0.4
Wireless Microphone @ 751.1 MHz	5	-29.1	1.6	8.9
Wireless Microphone @ 753.1 MHz	7	-22.3	0.7	15.7
Wireless Microphone @ 755.1 MHz	9	-17.5	0.4	20.5
TV White Space Device @ 750 MHz	1	-38.5	6.8	-0.5
TV White Space Device @ 752 MHz	3	-31.9	3.2	6.1
TV White Space Device @ 754 MHz	5	-24.7	1.4	13.3

- The table above provides the average results for the LTE devices tested, the frequency separation (buffer) from the CMRS downlink band, the received interference level at the LTE devices, the required separation distance to LTE devices from an interfering signal at the FCC proposed power level (i.e. 16 dBm for TVWS, 13 dBm for WMIC), and the required interference Power Limit to protect to LTE devices at 1 meter.
- Based on test results for the average LTE device at 3 dB desense threshold:
  - Wireless Microphones operating at FCC proposed power level require a 7 MHz buffer in the Guard Band to prevent 3 dB desense interference to LTE devices at 1 meter.
    - However, individual LTE devices (i.e. DUT 5 & 10) would exceed 3 dB desense interference (estimated at 4 and 8 dB desense interference, respectively).
  - TV White Space devices require a 5 MHz buffer and a Power Limit of 13 dBm in the Guard Band to prevent 3 dB desense interference to LTE devices at 1 meter.
  - When operating at the FCC proposed limit of 16 dBm the required separation distance for TVWS devices is 1.4 meters to prevent 3 dB desense interference to LTE devices.
    - However, individual LTE devices (i.e. DUT 1, 3, 4, 5 & 10) would exceed 3 dB desense interference (estimated at 5 to 10 dB desense interference).

Summary of Test Results

(Intermodulation Tests in Duplex Gap at 1 dB Desense)

- Intermodulation test results for the average LTE device with interfering signals in the Duplex Gap, at 1 dB desense interference threshold, occurred at the following received interference levels:

Average DUT Results, 1 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
Wireless Microphone @ 721 MHz	8	-7.0	0.1	31.0
TV White Space Device @ 721 MHz	5	-17.6	0.6	20.4

  – The table above provides the average results for the LTE devices tested, the frequency separation (buffer) from the CMRS downlink band, the received interference level at the LTE devices, the required separation distance to LTE devices from an interfering signal at the FCC proposed power level (i.e. 16 dBm for TVWS, 13 dBm for WMIC), and the required interference Power Limit to protect to LTE devices at 1 meter.
- On average, intermodulation test results showed interference occurring to LTE devices at similar levels as compared to receiver blocking interference.
  – Some LTE devices tested showed more sensitivity to intermodulation interference as compared to receiver blocking interference, while others devices showed less.
  – On average, the intermodulation test results for LTE devices were similar to receiver blocking. These results also support Wireless Microphones and TV White Space devices operating at the proposed FCC power levels require a 5 MHz buffer in the Duplex Gap to prevent interference to LTE devices at 1 meter.
- The intermodulation test results shows interference occurs to LTE devices operating on channels within the band, and away from the downlink band edge, at similar levels as compared the receiver blocking interference.

Summary of Test Results

(Intermodulation Tests in Duplex Gap at 3 dB Desense)

- Intermodulation test results for the average LTE device with interfering signals in the Duplex Gap, at 3 dB desense interference threshold, occurred at the following received interference levels:

Average DUT Results, 3 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
Wireless Microphone @ 721 MHz	8	-2.0	0.1	36.0
TV White Space Device @ 721 MHz	5	-10.5	0.3	27.5

  - The table above provides the average results for the LTE devices tested, the frequency separation (buffer) from the CMRS downlink band, the received interference level at the LTE devices, the required separation distance to LTE devices from an interfering signal at the FCC proposed power level (i.e. 16 dBm for TVWS, 13 dBm for WMIC), and the required interference Power Limit to protect to LTE devices at 1 meter.
- On average, intermodulation test results showed interference occurring to LTE devices at similar levels as compared to receiver blocking interference.
  - Some LTE devices tested showed more sensitivity to intermodulation interference as compared to receiver blocking interference, while others devices showed less.
  - On average, the intermodulation test results for LTE devices at 3 dB desense were similar to receiver blocking. These results also support Wireless Microphones and TV White Space devices operating at the proposed FCC power levels require a 5 MHz buffer in the Duplex Gap to prevent interference to LTE devices at 1 meter.
- The intermodulation test results shows interference occurs to LTE devices operating on channels within the band, and away from the downlink band edge, at similar levels as compared the receiver blocking interference.

Summary of OOBE Test Results

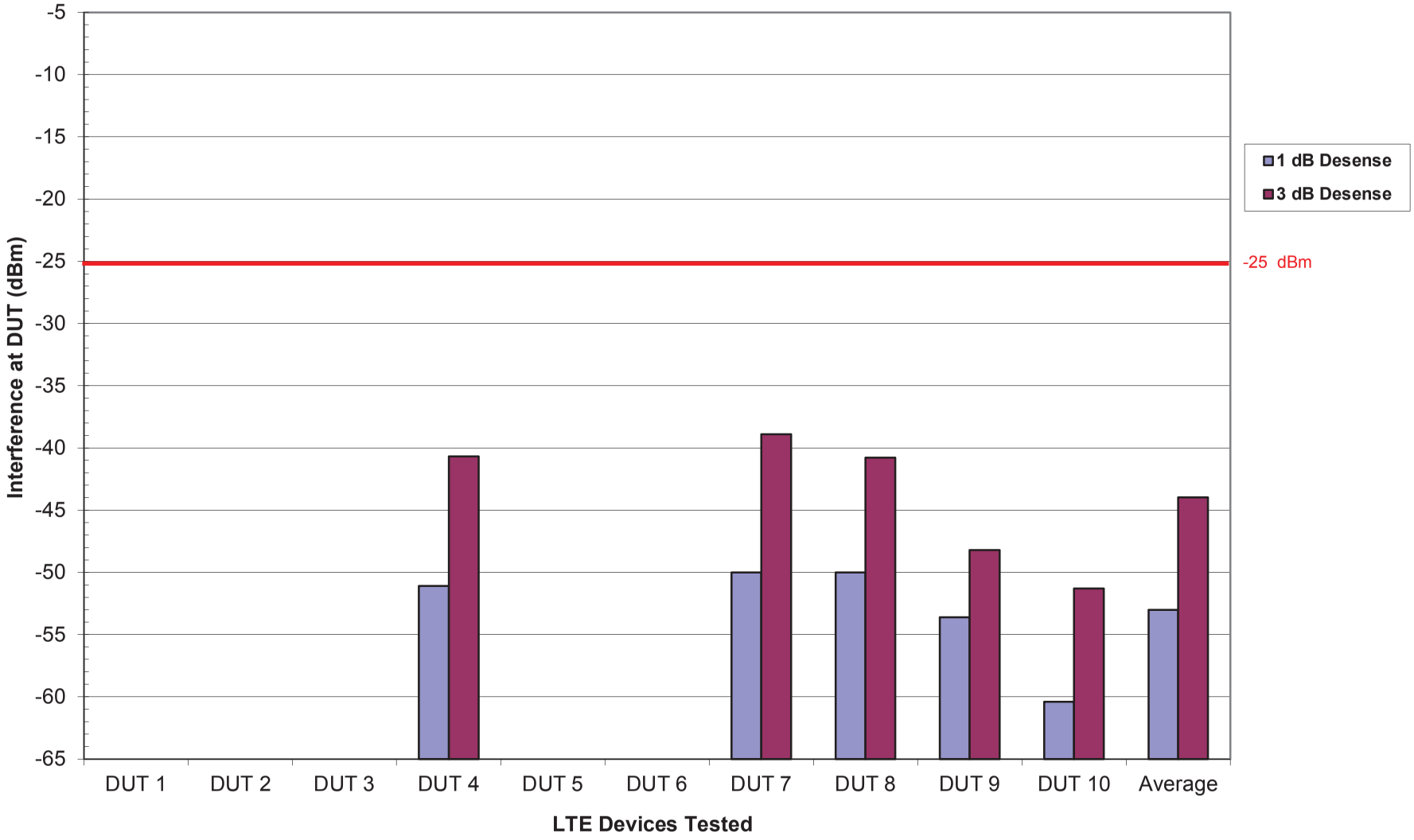
- Co-channel AWGN test results with LTE devices at 1 dB desense interference threshold occurred at:
  - AWGN interference levels at -126 to -128 dBm/100kHz for all LTE devices tested with an average level of -127 dBm/100kHz.
  - This represents an out-of-band emissions (OOBE) limit of -89 dBm/100kHz into CMRS downlink spectrum, for interference sources operating on adjacent bands in 600 MHz spectrum to protect LTE devices at 1 meter.
- Co-channel AWGN test results with LTE devices at 3 dB desense interference threshold occurred at:
  - AWGN interference levels at -120 to -122 dBm/100kHz for all LTE devices tested with an average level of -121 dBm/100kHz.
  - This represents an out-of-band emissions (OOBE) limit of -83 dBm/100kHz into CMRS downlink spectrum, for interference sources operating on adjacent bands in 600 MHz spectrum to protect LTE devices at 1 meter.
- The NPRM proposes an OOBE limit of approx. -57 dBm/100kHz for TV White Space devices and Wireless Microphones operating in the Duplex Gap and Guard Band of 600 MHz spectrum.
  - TVWS device OOBE proposed at -56.8 dBm/100kHz, and Wireless Microphone OOBE per ETSI mask at -90dBc in 1 kHz, below +13 dBm, is -57 dBm/100kHz.
  - This OOBE limit is 32 dB and 26 dB higher than the level required to protect LTE devices to 1 dB and 3 dB desense interference thresholds at 1 meter separation, respectively.
  - This OOBE limit would cause 26 dB of desensitization to LTE devices at 1 meter. This is a significant level of interference that significantly degrades LTE service, and impairs coverage and performance for all LTE devices within the area.
  - At the FCC proposed OOBE limit for Wireless Microphones and TV White Space devices, 3 dB desense interference will occur to all LTE devices within 20 meters. (Distance required for OOBE to decrease to -121 dBm/100kHz for 3 dB desense interference.)

Supplemental Test Results

- Supplemental testing was also performed on a subset of LTE devices using 2 interfering signal sources simultaneously in receiver blocking tests.
  - Both interference signals were received at the same level at the devices under test.
  - These tests show the impact to LTE devices from multiple interference sources.
- The following test cases were performed with 2 interfering signals in the duplex gap, with LTE devices operating on channel 5035:
  - With a 1 and 2 MHz buffer below Band 12 downlink, at the center frequencies 727.9 MHz and 726.9 MHz for two wireless microphones signals.
  - With a 5 MHz buffer below Band 12 downlink, at the center frequencies 723.9 MHz and 721 MHz for the wireless microphone and TV white space signals, respectively.
- The following test cases were performed with 2 interfering signals in the guard band, with LTE devices operating on channel 5155 :
  - With a 1 and 2 MHz buffer above Band 12 downlink, at the center frequencies 747.1 MHz and 748.1 MHz for two wireless microphones signals.
  - With a 5 MHz buffer above Band 12 downlink, at the center frequencies 751.1 MHz and 754 MHz for the wireless microphone and TV white space signals, respectively.
- The results of the supplemental testing is provided in the charts below.

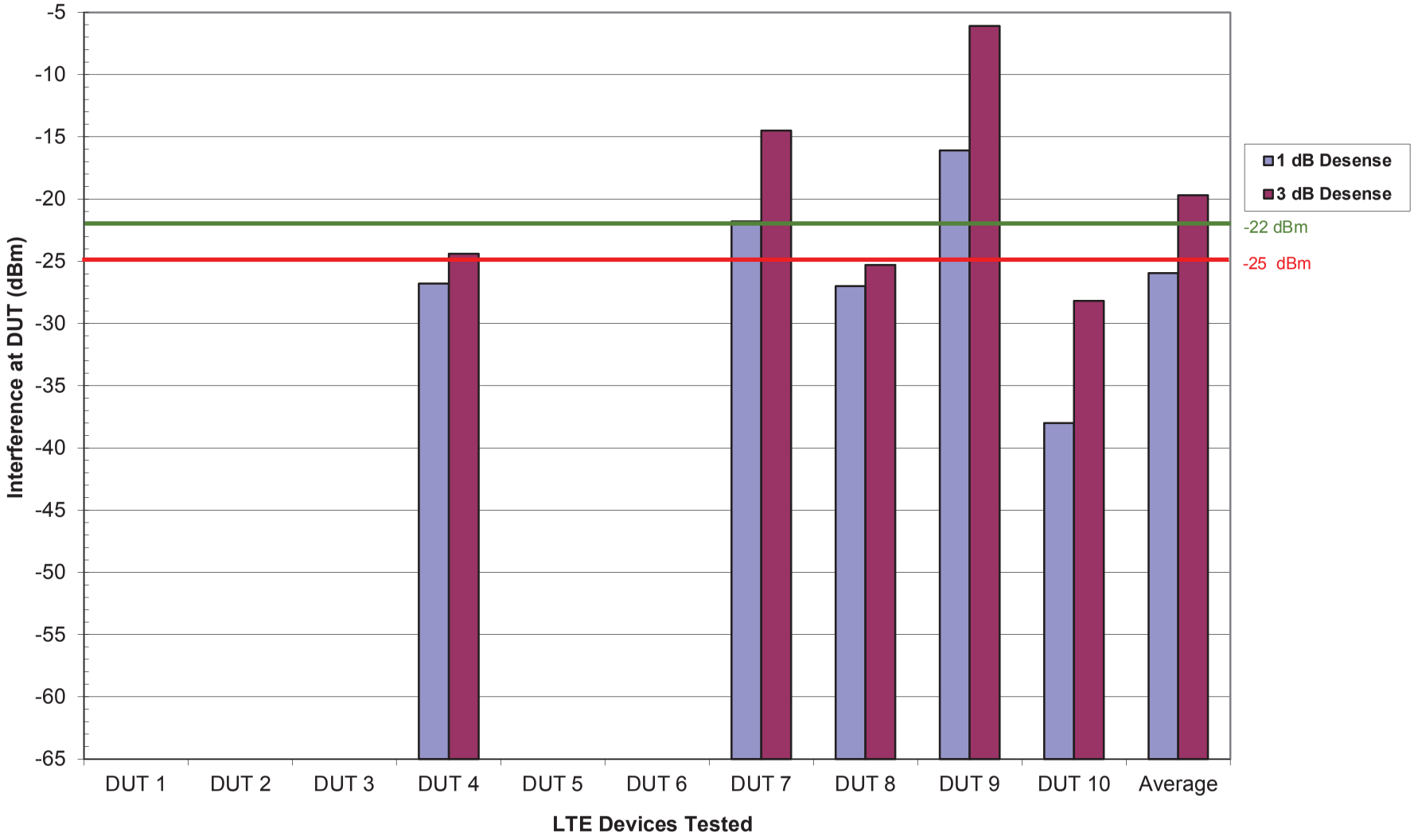
Receiver Blocking Test Results -- Duplex Gap

LTE DUT Ch. 5035, 2x Wireless Microphones @ 727.9MHz and 726.9MHz, 1MHz and 2MHz Buffer



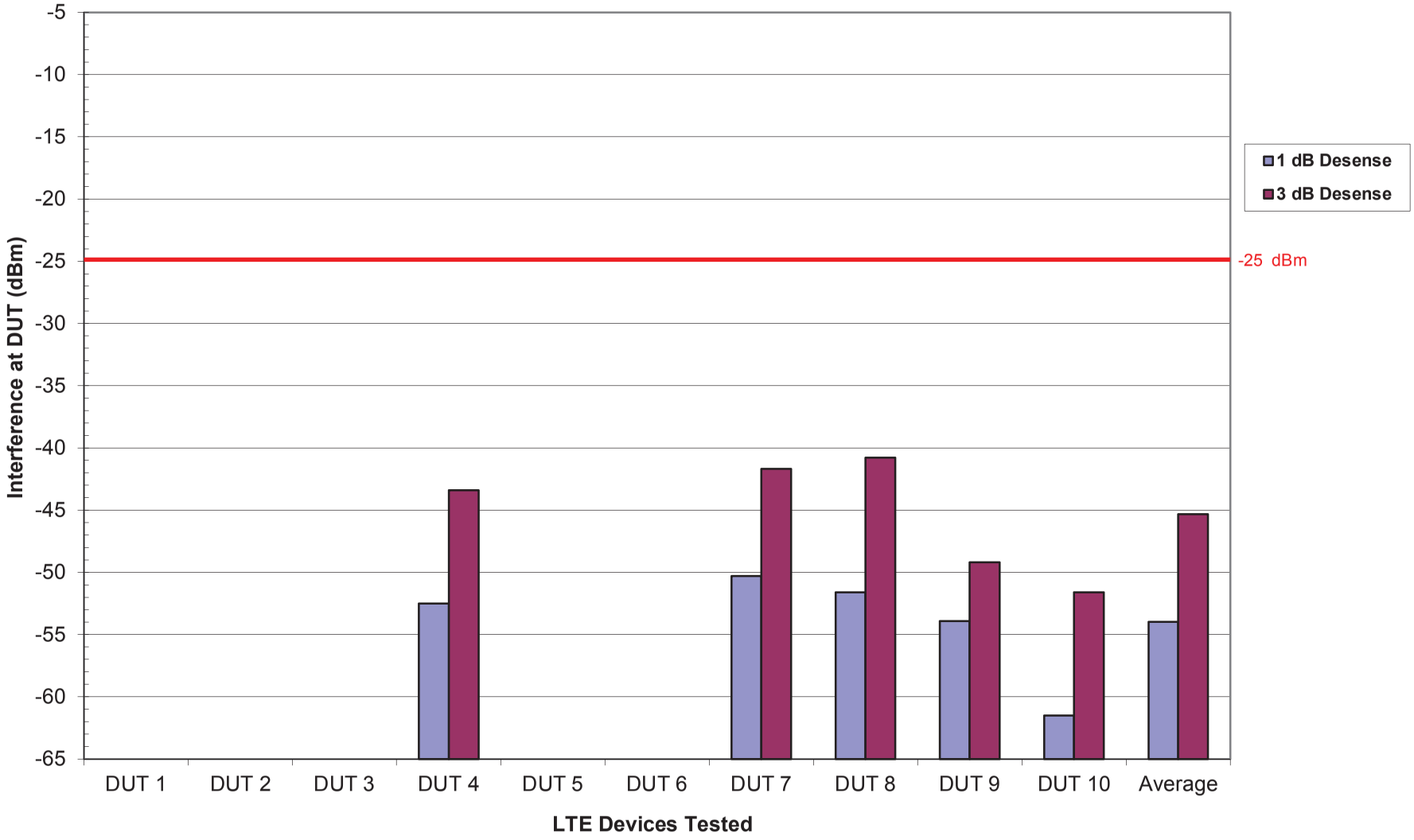
Receiver Blocking Test Results -- Duplex Gap

LTE DUT Ch. 5035, Wireless Microphone @ 723.9MHz and TV Whitespace Device @ 721MHz, 5 MHz Buffer



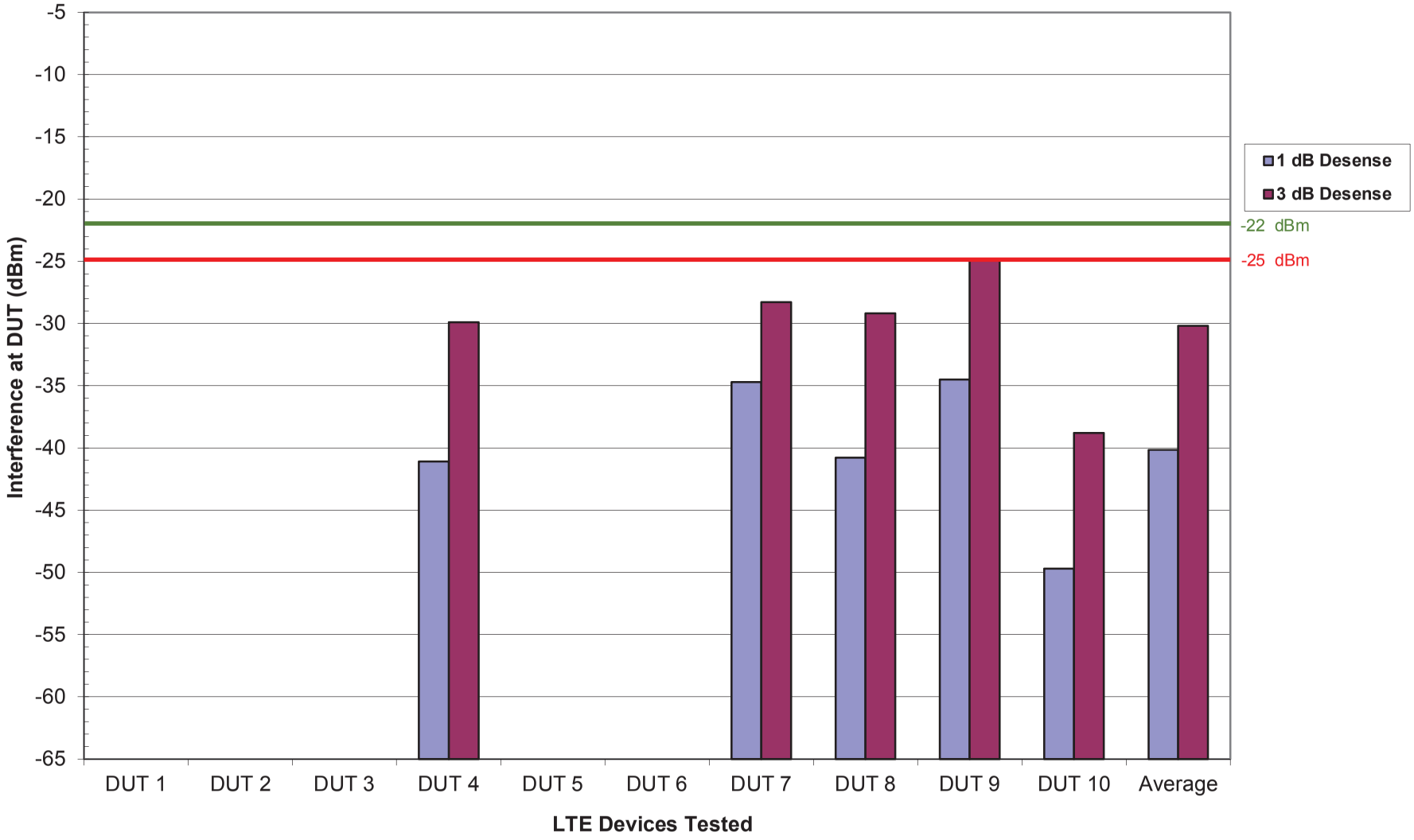
Receiver Blocking Test Results -- Guard Band

LTE DUT Ch. 5155, 2x Wireless Microphones @ 747.1MHz and 748.1MHz, 1MHz and 2MHz Buffer



Receiver Blocking Test Results -- Guard Band

LTE DUT Ch. 5155, Wireless Microphone @ 751.1MHz and TV Whitespace Device @ 754MHz, 5 MHz Buffer



Summary of Supplemental Test Results

- Receiver Blocking test results with 2 interfering sources in the Duplex Gap, for the average of the LTE devices tested at 1 dB desense interference threshold, occurred at interference levels provided in the table below:

Average DUT Results, 1 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
2 x Wireless Microphone @ 727.9 MHz and 726.9 MHz	1, 2	-53.0	25.4	-15.0
Wireless Microphone @ 723.9 MHz and TVWS Device @ 721 MHz	5	-25.9	1.1	12.1

- Receiver Blocking test results with 2 interfering sources in the Guard Band, for the average of the LTE devices tested at 1 dB desense interference threshold, occurred at interference levels provided in the table below:

Average DUT Results, 1 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
2 x Wireless Microphone @ 747.1 MHz and 748.1 MHz	1, 2	-54.0	28.5	-16.0
Wireless Microphone @ 751.1 MHz and TVWS Device @ 754 MHz	5	-40.2	5.8	-2.2

- The test results at the 1 dB desense interference threshold show that LTE devices are 1 to 2 dB more sensitive on average with 2 interference sources, as compared to results for the same devices with 1 interfering source.
  - In some cases, individual devices showed to be 3 dB more sensitive with 2 interfering sources in the duplex gap and guard band, as compared to 1 interfering source.

Summary of Supplemental Test Results

- Receiver Blocking test results with 2 interfering sources in the Duplex Gap, for the average of the LTE devices tested at 3 dB desense interference threshold, occurred at interference levels provided in the table below:

Average DUT Results, 3 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
2 x Wireless Microphone @ 727.9 MHz and 726.9 MHz	1, 2	-44.0	9.0	-6.0
Wireless Microphone @ 723.9 MHz and TVWS Device @ 721 MHz	5	-19.7	0.5	18.3

- Receiver Blocking test results with 2 interfering sources in the Guard Band, for the average of the LTE devices tested at 3 dB desense interference threshold, occurred at interference levels provided in the table below:

Average DUT Results, 3 dB Desense	Buffer (MHz)	Interference Level (dBm)	Separation Distance at FCC Power (m)	TX Power Limit at 1 meter (dBm)
2 x Wireless Microphone @ 747.1 MHz and 748.1 MHz	1, 2	-45.3	10.5	-7.3
Wireless Microphone @ 751.1 MHz and TVWS Device @ 754 MHz	5	-30.2	1.8	7.8

- The test results at the 3 dB desense interference threshold show that LTE devices are 1 to 2 dB more sensitive on average with 2 interference sources, as compared to results for the same devices with 1 interfering source.
  - In some cases, individual devices showed to be 3 dB more sensitive with 2 interfering sources in the duplex gap and guard band, as compared to 1 interfering source.

Conclusions

- These test results show impact of Wireless Microphones and TV White Space devices operating in guard bands and duplex gap to Band 12 LTE devices operating in Lower 700 MHz spectrum. Similar rejection is expected for LTE devices operating in 600 MHz spectrum.
  - Analysis of test results show the Power and Emission limits required for Wireless Microphones and TV White Space devices operating in guard bands and duplex gap to prevent interference to LTE devices in 600 MHz spectrum.
  - Setting limits for both are equally significant to protect LTE devices. Otherwise, this will create a dominant source of interference that impacts LTE devices.
- Based on receiver blocking test results for the average LTE device at 1 dB desense interference threshold, Wireless Microphones and TV White Space devices operating at the FCC proposed power levels require a 5 MHz buffer in the duplex gap to prevent interference to LTE devices at 1 meter.
  - This protects the average LTE device to 1 dB desense interference threshold, and individual LTE devices (i.e. DUT 8 & 10) to approx. 2 to 3 dB desense interference.
- With less than 5 MHz buffer in the duplex gap, Wireless Microphone and TV White Space Power limits are too low (i.e. < 1 mW) to support normal applications, and at FCC proposed power levels would cause interference to LTE devices within 21 meters.

Conclusions

- Test results show LTE devices have less rejection of interference sources in the guard band as compared to interference sources in the duplex gap.
  - Thus, larger frequency buffers are required on the guard band side of the CMRS downlink band, as compared to the duplex side of the CMRS downlink band.
- Based on receiver blocking test results for the average LTE device at 1 dB desense interference threshold, Wireless Microphones operating at the FCC proposed power levels require a 9 MHz buffer in the guard band to prevent interference to LTE devices at 1 meter.
  - This protects the average LTE device to 1 dB desense interference threshold, and individual LTE devices (i.e. DUT 1 & 10) to approx. 2 to 3 dB desense interference.
- With less than or equal to 7 MHz buffer in the guard band, Wireless Microphone and TV White Space power levels would need to operate at very low levels (i.e. 1 to 7 dBm range) to protect LTE devices at 1 dB desense, which would not be suitable for most applications. At FCC proposed power levels, this would cause 1 dB desense interference to LTE devices up to 21 meters away.

Conclusions

- Intermodulation test results in the duplex gap showed interference occurs to LTE devices at similar levels as receiver blocking interference.
  - Intermodulation test results also support Wireless Microphones and TV White Space devices operating at the proposed FCC power levels require a 5 MHz buffer in the Duplex Gap to prevent interference to LTE devices at 1 meter.
- The intermodulation test results shows interference occurs to LTE devices operating on channels within the band, and away from the CMRS downlink band edge. Thus, additional CMRS spectrum blocks in 600MHz spectrum are potentially impacted due to intermodulation interference.
- Receiver blocking test results with 2 interfering sources in the duplex gap or guard band, show LTE devices are 1 to 2 dB more sensitive on average (up to 3 dB for some devices), as compared to the impact with 1 interfering source. Thus, operation of multiple interference sources in the same area will increase the range of interference and impact to LTE devices.

Conclusions

- Co-channel AWGN test results with LTE devices at 1 dB desense interference threshold occurred at -127 dBm/100kHz on average.
  - This requires an out-of-band emissions (OOBE) limit of -89 dBm/100kHz into CMRS downlink spectrum to protect LTE devices at 1 meter.
- Therefore, the OOBE limit of -89 dBm/100kHz is required for Wireless Microphones and TV White Space devices operating in the 600 MHz guard band and duplex gap to protect LTE devices.
  - This is for OOBE into the CMRS downlink band, which may be several MHz away from the interfering signal's channel edge. In general, this OOBE will require greater filtering for many Wireless Microphones and TVWS devices as compared to the normal emissions mask when operating in 600MHz spectrum.
  - OOBE cannot be removed at the victim device and must be mitigated at the interfering source, which is the Wireless Microphones and TVWS devices.
- The NPRM proposes an OOBE limit of approx. -57 dBm/100kHz for TV White Space devices and Wireless Microphones operating in the duplex gap and guard band of 600 MHz spectrum.
  - This OOBE limit is 32 dB higher than the level required to protect LTE devices to 1 dB desense interference thresholds, and would result in 26 dB desensitization to nearby LTE devices. This is a significant level of interference that significantly degrades and impairs service, coverage and performance for LTE devices.
  - At the FCC proposed OOBE limit for Wireless Microphones and TV White Space devices, 3 dB desense interference will occur to all LTE devices within 20 meters.

APPENDIX

Analysis of Interference Thresholds

- CMRS industry, ITU and regulatory analyses typically use 1 dB desense interference thresholds for assessment of impact to primary licensed services, from other licensed and/or unlicensed sources.
  - For example, CMRS industry, FCC's and NTIA's analysis of harmful interference to fixed and mobile receivers in AWS-3 spectrum bands use a 1 dB desense interference threshold. See CSMAC Working Group interference assumptions.
  - In other examples, CMRS and satellite licensees' analysis of harmful interference to fixed and mobile receivers in WCS and SDARS spectrum used a 1 dB desense interference threshold. Analysis of interference includes WCS interference to SDARS mobile receivers, and SDARS terrestrial repeaters to WCS receivers. This criteria was also used in interference analysis to protect CMRS devices in the Lower 700 MHz spectrum and PCS H Block proceedings.
- CMRS networks operate under noise-limited conditions in many rural and suburban markets, particularly for indoor users. Indoor use represents greater than 80% of CMRS customers uses.* Indoors is where interference is likely to occur with devices operating in close proximity to each other.
- LTE networks use a variety of advanced features (such as enhanced inter-cell interference coordination) to optimize the use of spectrum and operate at very low noise conditions even in cell overlap areas.
  - Adjacent sites coordinate with each other to efficiently use and allocate spectrum in frequency (resource blocks), time (timeslots), and space for devices in overlap areas. This results in low noise conditions at LTE devices even at cell edges.

* Note: Indoor use percentage from Nokia Siemens Networks "Improving 4G coverage and capacity indoors and at hotspots with LTE femtocells".

Analysis of Interference Thresholds

- The 1 and 3 dB desense interference thresholds represents significant impairments and harmful interference to CMRS service.
  - For example, the 1 dB and 3 dB desense interference levels represent 14% and 37% reduction (loss) in network coverage area, respectively. (Assumes propagation loss factor of 30 log distance.)
- The 1 dB and 3 dB desense interference levels also represent significant degradation (reduction) in data throughput and device's signal to noise (SNR) performance.
  - For example, at the 1 dB desense interference threshold, the LTE device SNR reduces by 1 dB, which represents a 10% to 15% loss in data throughput. (This is for LTE 16QAM and QPSK modulation with 1/2 code rate at 7 and 1 dB SNR, respectively.)
  - In addition, at the 3 dB desense interference threshold, the LTE device SNR reduces by 3 dB, which represents a 30% to 40% loss in data throughput. (This is for LTE 16QAM and QPSK modulation with 1/2 code rate at 7 and 1 dB SNR, respectively.)
  - These impact assessments use typical LTE throughput performance. Similar results can be derived using Shannon's law. (R=BW*Log2(1+SNR))
- In addition, consistent with industry standards 1 meter separation is used in the analysis for device to device interference.
  - Unlicensed TVWS devices are used in similar applications as CMRS devices and are used in close proximity. Wireless microphones may also be used in close proximity to CMRS devices. Thus, 1 meter separation is used in the analysis for protection of nearby CMRS devices from these interference sources.

Analysis of OOBE Impacts to CMRS Devices

- Test results show OOBE interference occurs to LTE devices at -127 dBm/100kHz on average at 1 dB desense interference threshold.
- This requires an OOBE limit of -89 dBm/100kHz into CMRS downlink spectrum in 600 MHz to protect LTE devices at 1 meter.
  - The total path losses between devices at 1 meter is 38 dB, with free-space path loss of 29 dB at 665 MHz. (See pages 9-10 for additional information)
  - CMRS devices operating in 600 MHz spectrum will have significantly less path loss than devices operating in higher frequency bands. For example, 600 MHz spectrum will have approximately 10 dB less path loss than higher frequency bands (i.e. free-space path loss at 665 MHz is 29 dB vs. 38.5 dB at 2 GHz)
  - Therefore, CMRS devices operating in 600 MHz spectrum will require greater protection from OOBE, due to operating in lower frequency band, and will require lower OOBE limits from interfering sources in adjacent bands. (i.e. OOBE limits in 600 MHz need to be 10 dB lower than OOBE limits in 2 GHz for an equivalent level of protection to CMRS devices.)
  - This is for OOBE into the CMRS downlink band, which is further away (i.e. 5 MHz) and potentially lower than OOBE occurring at the interfering signal's channel edge.
  - The NPRM proposes an OOBE limit of approx. -57 dBm/100kHz, referenced to the interfering signal's channel edge. At 5 MHz away, the OOBE will likely be at lower levels (i.e.~12 dB lower to -69 dBm/100kHz into the CMRS downlink band), however may still require additional filtering (i.e. 20 dB) to meet the OOBE limit of -89 dBm/100KHz. This level of attenuation may be achieved using SAW filter technology.
- In comparison, the OOBE limit to protect SDARS mobile receivers in 2.3 GHz spectrum from WCS devices previously was in similar ranges,* for a 1 dB level of interference protection, which was 110 + 10*Log P equal to -80dBm/MHz, or -90 dBm/100kHz.

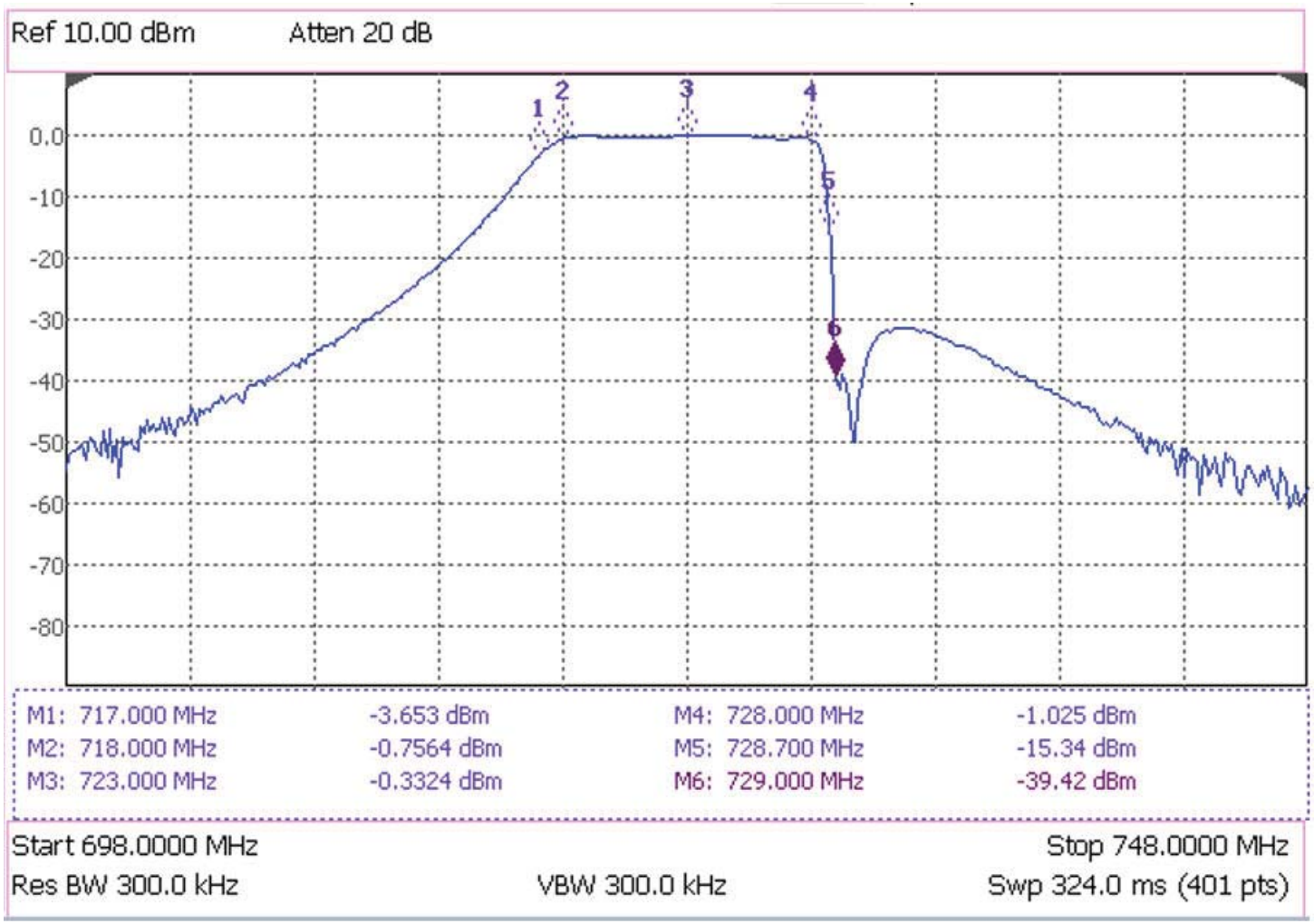
* Note: This previous OOBE limit has been revised in the FCC's 2nd R&O released in May 20, 2010 (FCC 10-82).

Analysis of OOBE and Sensitivity Test Results

- Test results show OOBE interference occurs to LTE devices at -127 dBm/100kHz on average at 1 dB desense interference threshold.
  - Based on test results, the LTE device noise figure is approx. 6 dB. This is for Lower 700 MHz LTE devices; similar performance is expected in 600 MHz.
  - LTE devices tested use 2 antennas, which improves the OOBE performance by 3 dB as compared to using 1 antenna (i.e. OOBE at -127 dBm at 2 antenna ports is equivalent to -124 dBm at 1 antenna port). (Noise figure calculation uses signal antenna results, device noise floor of -118 dBm/100KHz, KTB of -124 dBm/100kHz, and I/N = - 6 dB for 1 dB desense)
- Test results show receive sensitivity at -105.1 dBm on average for all LTE devices tested on 3 channels in Lower 700 MHz spectrum.
  - Pursuant to 3GPP standards (36.101), receive sensitivity is measured at LTE devices on 2 antenna ports and results are reported per antenna port.
  - LTE devices use 2 antennas, which improves receiver sensitivity performance by 3 dB as compared to using 1 antenna (i.e. receive sensitivity at -105 dBm at 2 antenna ports is equivalent to -102 dBm at 1 antenna port). The required SNR at receive sensitivity at QPSK1/3 is approx. -1 dB. Using signal antenna results, the LTE device noise floor is approx. -101 dBm/5MHz (KTB is -107 dBm/5MHz), which also corresponds to an LTE device noise figure of approx. 6 dB.

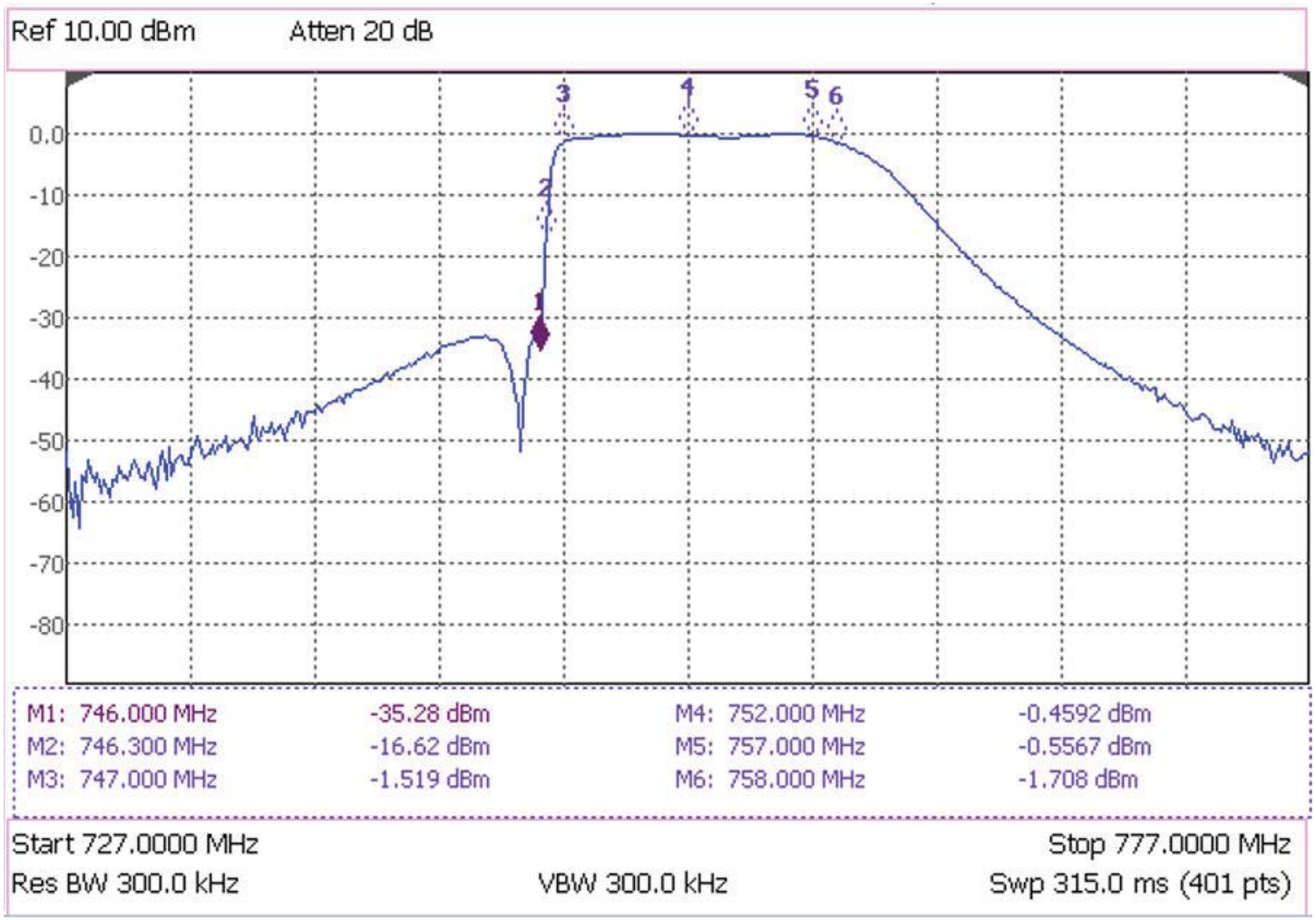
Filter Trace -- Duplex Gap

Band pass rejection filter used in Receiver Blocking and Intermodulation tests to remove the interfering signal's emissions into the CMRS downlink band to capture the rejection of CMRS devices under test to interfering signals in the Duplex Gap.



Filter Trace -- Guard Band

Band pass rejection filter used in Receiver Blocking tests to remove the interfering signal's emissions into the CMRS downlink band to capture the rejection of CMRS devices under test to interfering signals in the Guard Band.

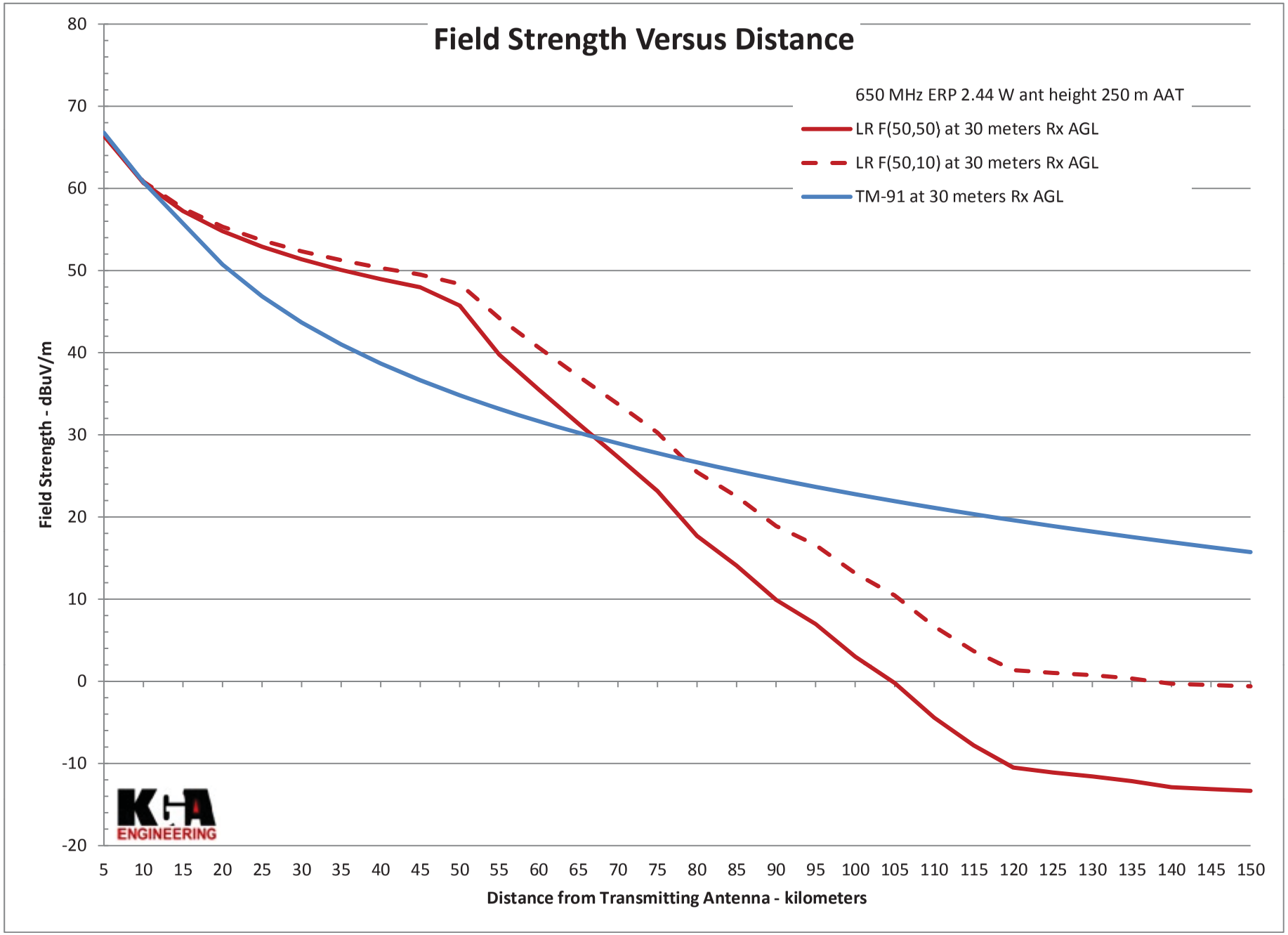


V-COMM is a leading provider of wireless engineering consulting services to the wireless telecommunications industry with offices in Cranbury, NJ and Exton, PA. V-COMM's engineering staff is experienced in Cellular, Personal Communications Services (PCS), Advanced Wireless Services, 2G, 3G and 4G Wireless Broadband Data Services, Microwave Radio, Broadcast TV engineering. We have provided our expertise to wireless operators in engineering, system design, implementation, performance, optimization, evaluation of new wireless technologies, and spectrum interference assessments.

We have extensive experience in analyzing interference in various spectrum bands including Cellular, SMR, PCS, AWS, Air-to-ground, Public Safety, 600MHz and 700 MHz spectrum bands. We have engineering experience in all commercial wireless technologies, including LTE, HSPA, UMTS, EVDO, CDMA, GSM, WiMAX, DVB-H, and Public Safety wireless technologies including analog and digital Project 25, EDACS, Opensky, and other trunking and conventional radio networks. V-COMM has studied interference and spectrum issues for many spectrum licensees for numerous FCC proceedings, and V-COMM was selected by the FCC & Department of Justice to provide expert analysis and testimony in the Nextwave and Pocket Communications Bankruptcy cases.

For additional information, visit V-COMM's web site at www.vcomm-eng.com.

APPENDIX C: TM 91-1 FIELD STRENGTH GRAPHS


Field Strength Versus Distance
650 MHz ERP 2.44 W ant height 250 m AAT
LR F(50,50) at 30 meters Rx AGL
LR F(50,10) at 30 meters Rx AGL
TM-91 at 30 meters Rx AGL
Field Strength - dBuV/m
80
70
60
50
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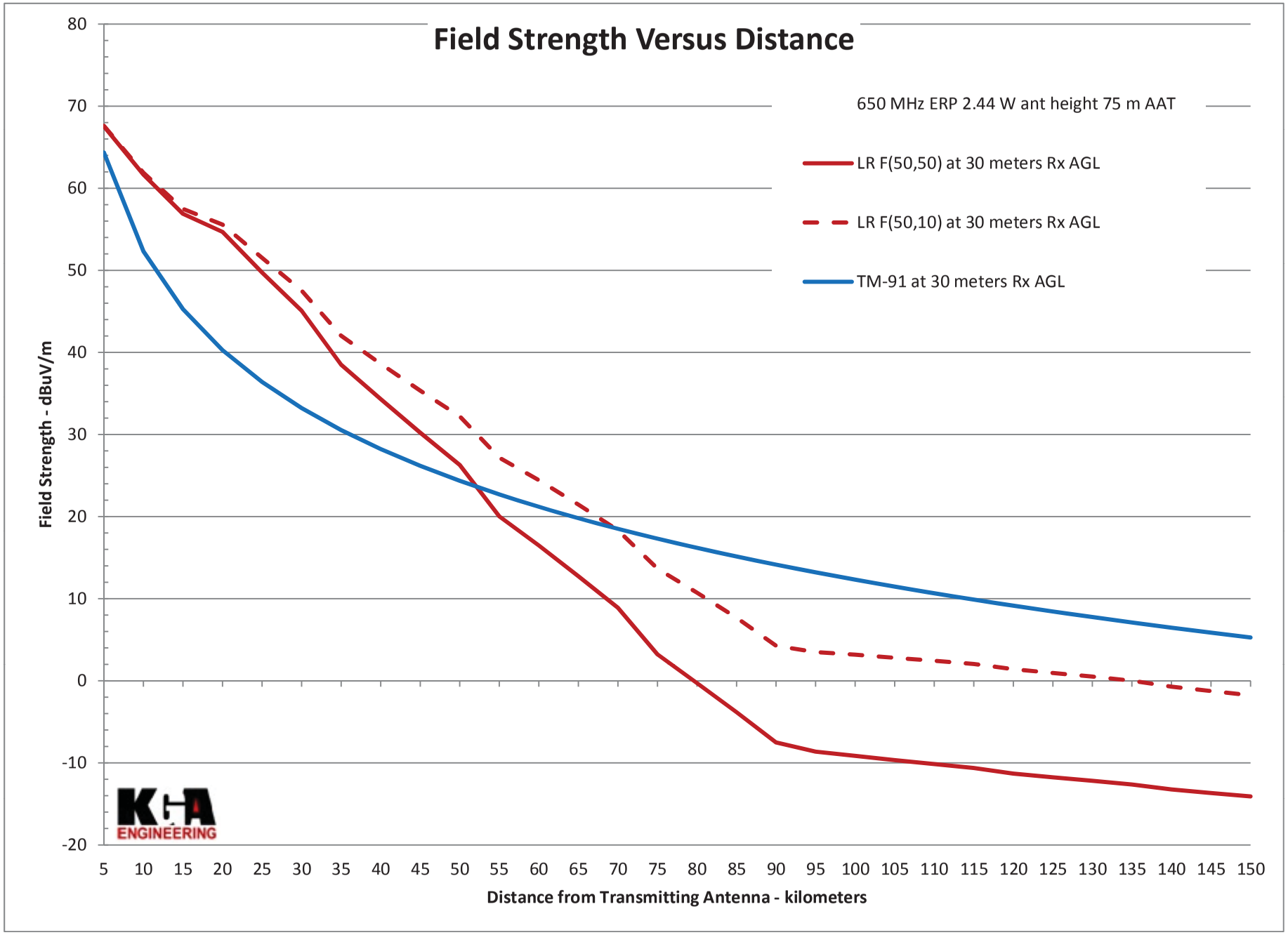
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150
Distance from Transmitting Antenna - kilometers
K&A ENGINEERING


Field Strength Versus Distance
650 MHz ERP 2.44 W ant height 75 m AAT
LR F(50,50) at 30 meters Rx AGL
LR F(50,10) at 30 meters Rx AGL
TM-91 at 30 meters Rx AGL
Field Strength - dBuV/m
80
70
60
50
40
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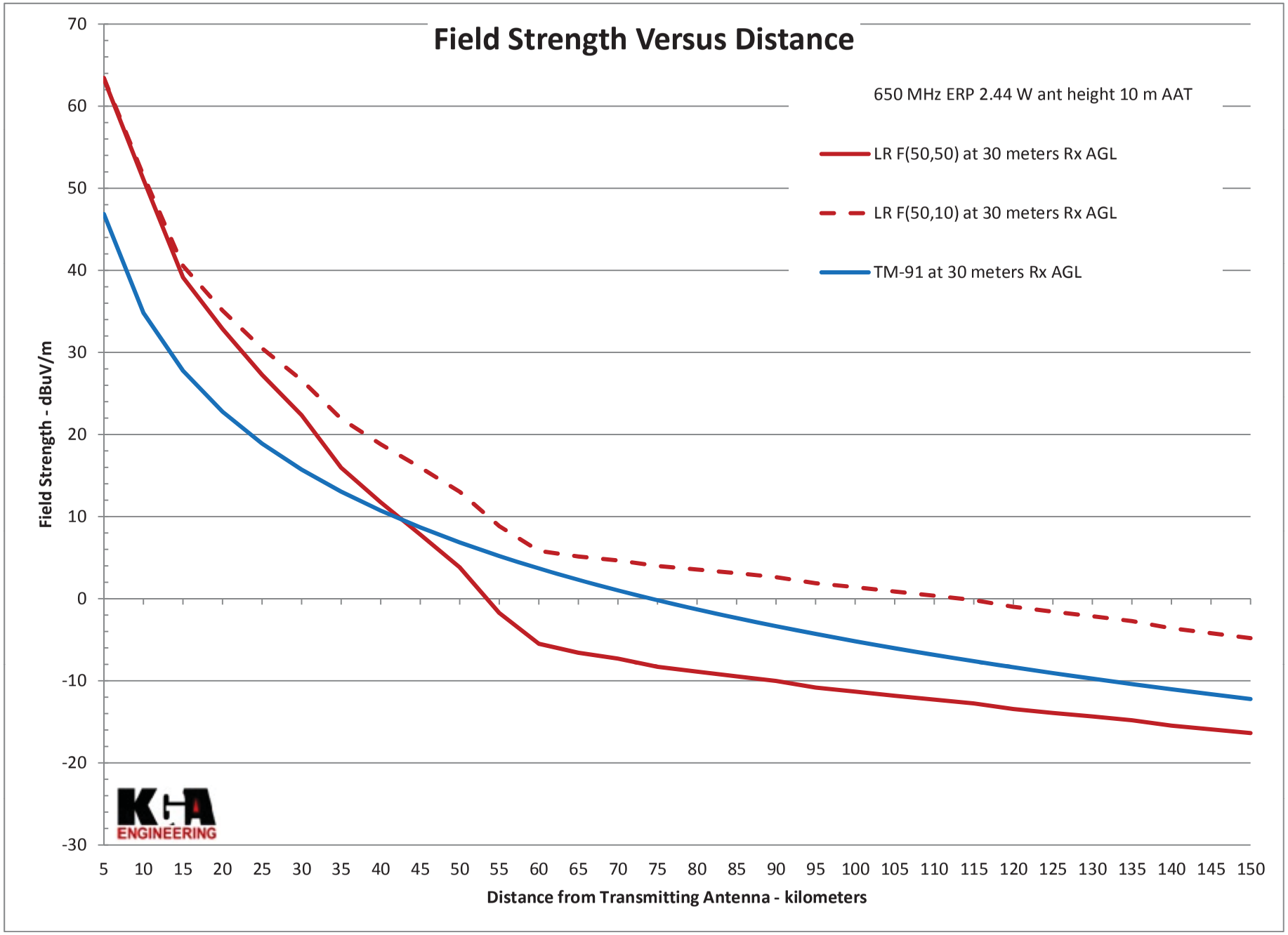
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150
Distance from Transmitting Antenna - kilometers
K&A ENGINEERING


Field Strength Versus Distance
650 MHz ERP 2.44 W ant height 10 m AAT
LR F(50,50) at 30 meters Rx AGL
LR F(50,10) at 30 meters Rx AGL
TM-91 at 30 meters Rx AGL
Field Strength - dBuV/m
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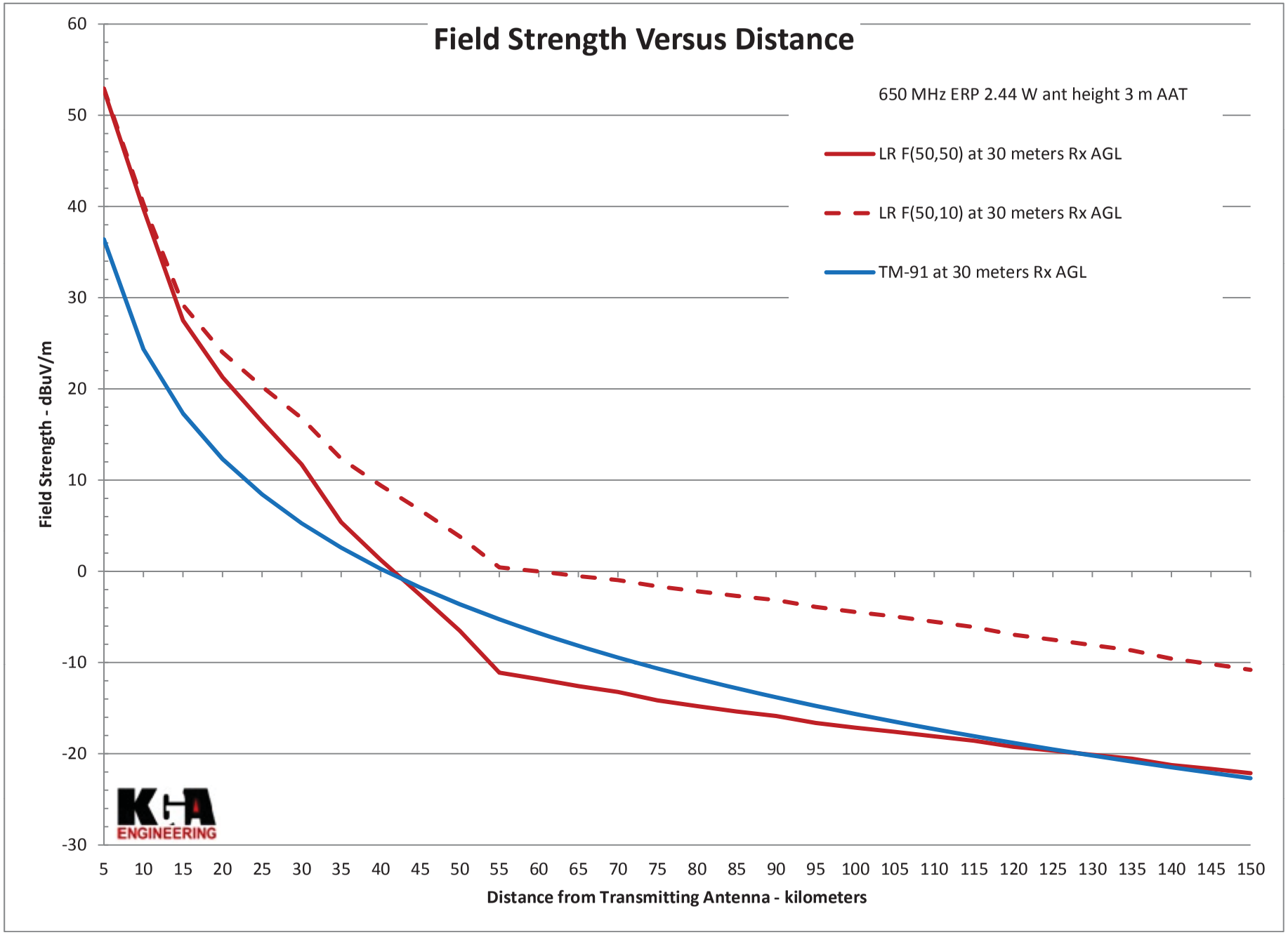
Distance from Transmitting Antenna - kilometers
K&A ENGINEERING


Field Strength Versus Distance
650 MHz ERP 2.44 W ant height 3 m AAT
LR F(50,50) at 30 meters Rx AGL
LR F(50,10) at 30 meters Rx AGL
TM-91 at 30 meters Rx AGL
Field Strength - dBuV/m
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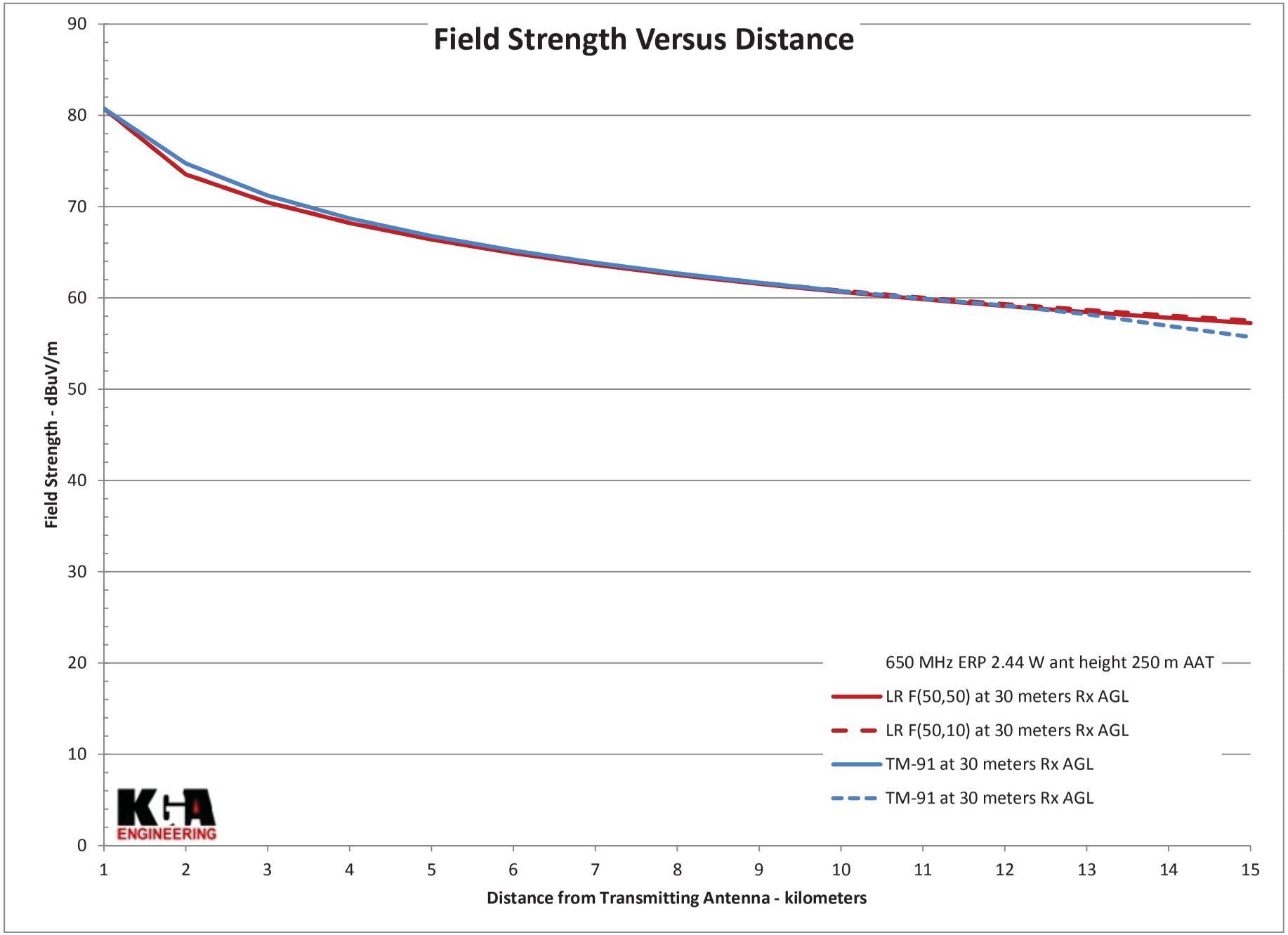
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150
Distance from Transmitting Antenna - kilometers
K&A ENGINEERING


Field Strength Versus Distance
Field Strength - dBuV/m
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Distance from Transmitting Antenna - kilometers
650 MHz ERP 2.44 W ant height 250 m AAT
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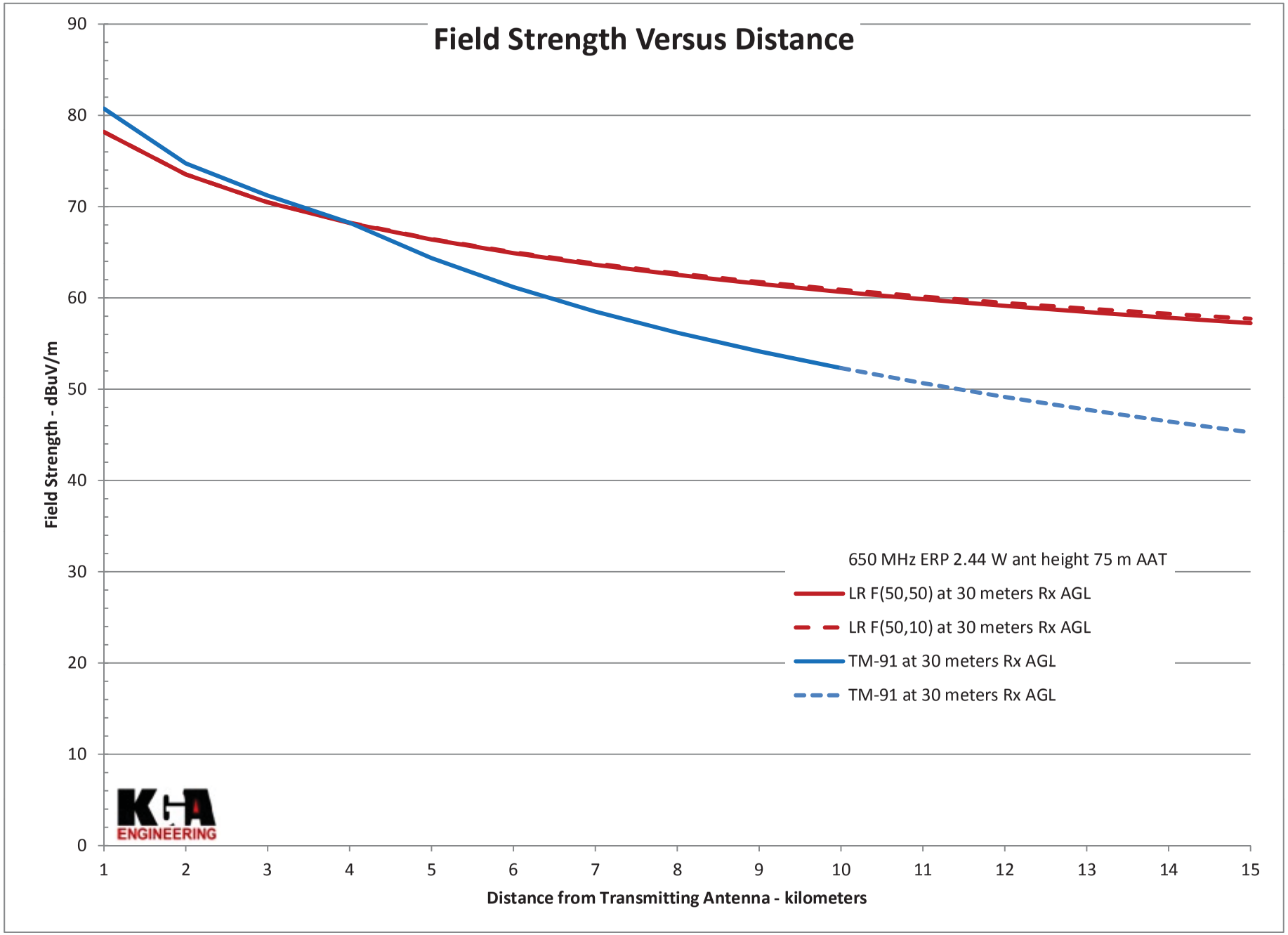
TM-91 at 30 meters Rx AGL
TM-91 at 30 meters Rx AGL
K&A ENGINEERING


Field Strength Versus Distance
Field Strength - dBuV/m
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Distance from Transmitting Antenna - kilometers
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LR F(50,50) at 30 meters Rx AGL
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TM-91 at 30 meters Rx AGL
TM-91 at 30 meters Rx AGL
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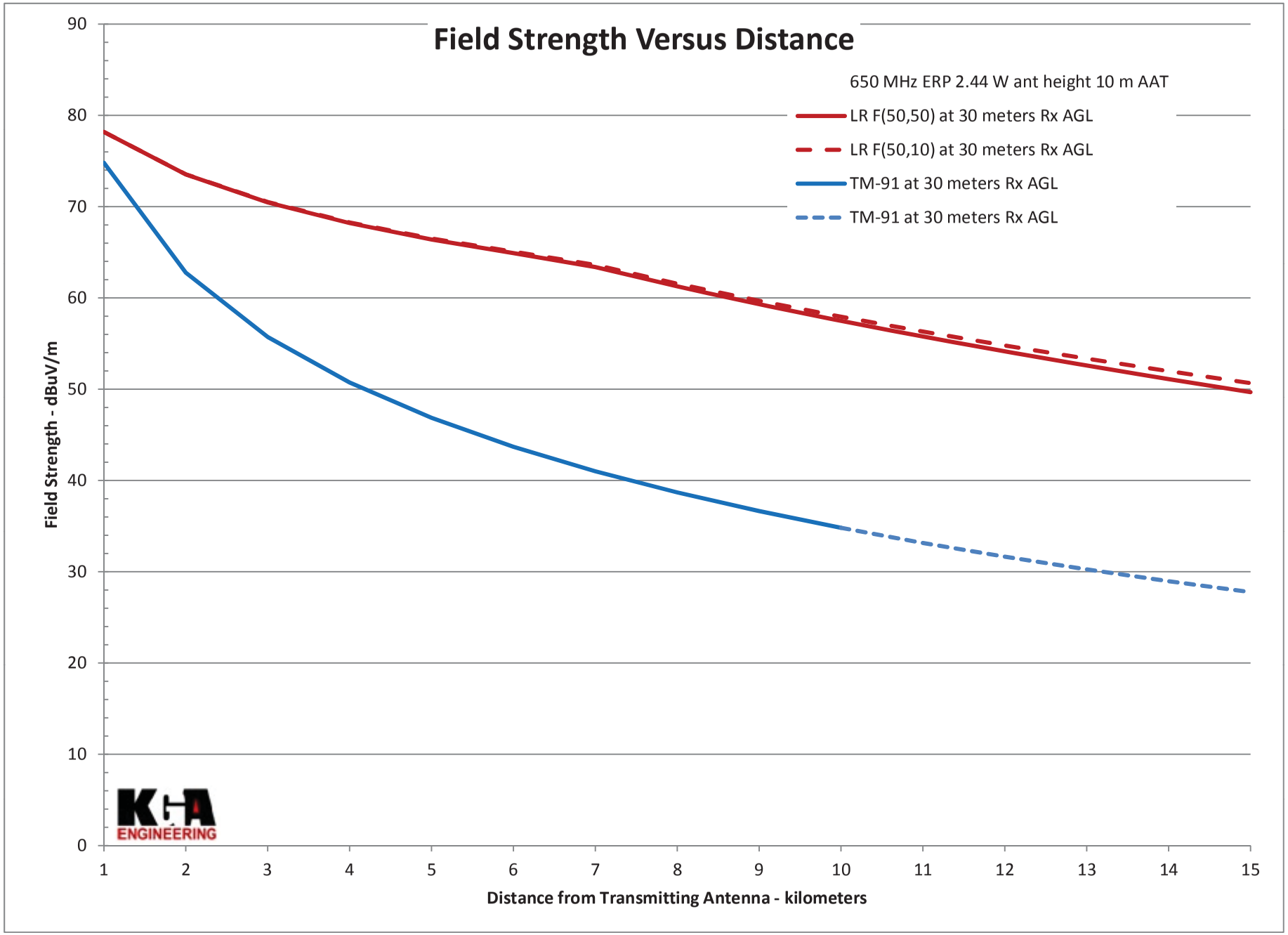
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LR F(50,50) at 30 meters Rx AGL
LR F(50,10) at 30 meters Rx AGL
TM-91 at 30 meters Rx AGL
TM-91 at 30 meters Rx AGL
Field Strength - dBuV/m
Distance from Transmitting Antenna - kilometers
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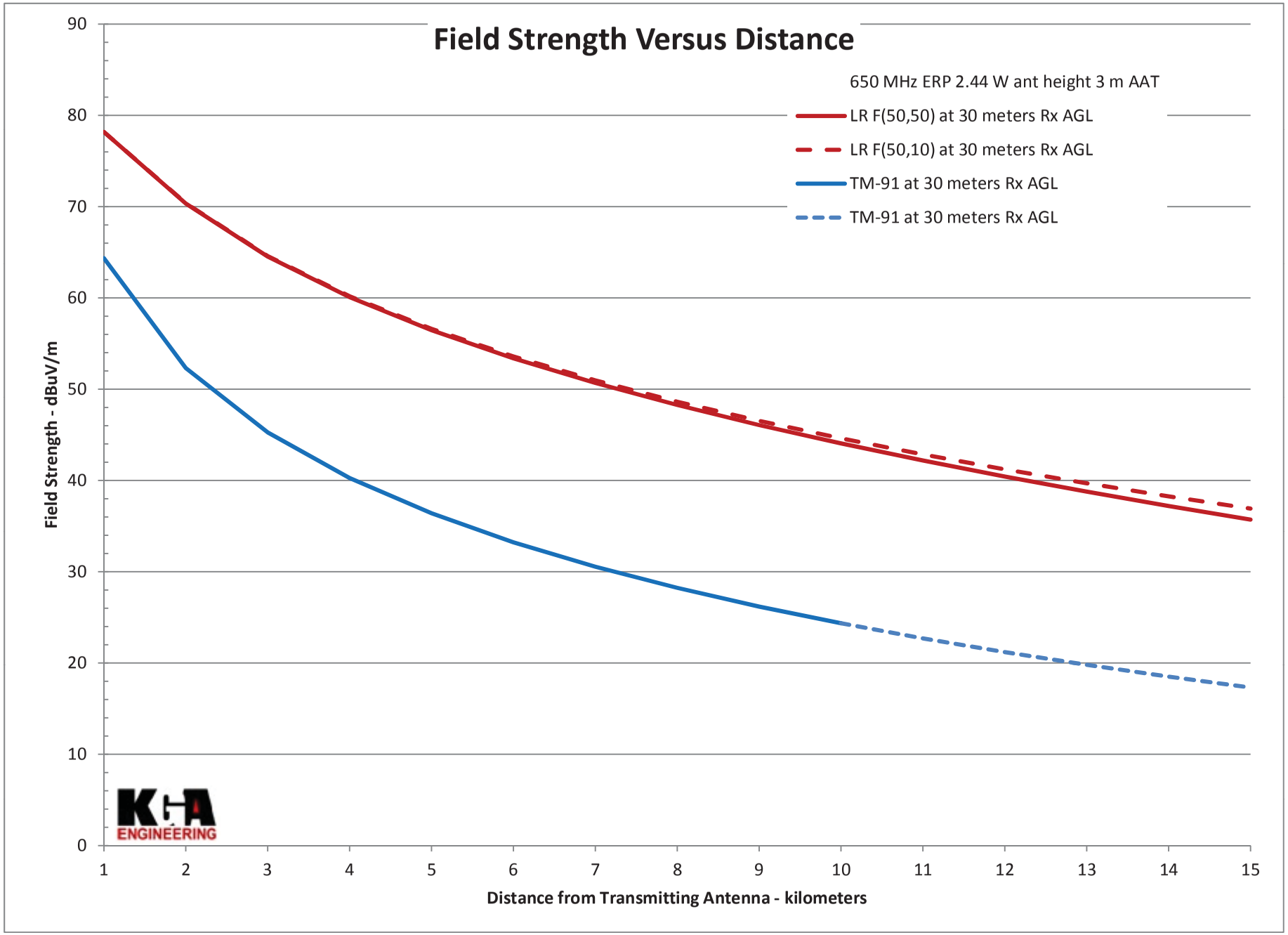
K&A ENGINEERING


Field Strength Versus Distance
650 MHz ERP 2.44 W ant height 3 m AAT
LR F(50,50) at 30 meters Rx AGL
LR F(50,10) at 30 meters Rx AGL
TM-91 at 30 meters Rx AGL
TM-91 at 30 meters Rx AGL
Field Strength - dBuV/m
Distance from Transmitting Antenna - kilometers
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ENGINEERING