Recommendations on the Use of Spectrum Bands Above 24 GHz for Mobile Radio Services

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August 5, 2015
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I. Purpose and Content Summary

This paper formulates a set of recommendations to the Federal Communications Commission’s (FCC) staff, in advance of their preparation of a Notice of Proposed Rulemaking (NPRM) allocating millimeter wave (mmW) frequencies for possible 5G use. Section II lays out Intel’s recommendations for a future NPRM, including the benefits of expedition, our band and licensing recommendations, and reference policy positions. This is followed by details on possible alternative band plans, should that be necessary, and concludes with technical recommendations.

II. Intel’s Recommendations for a Future mm-wave NPRM

A. Benefits of Expedition

Intel believes the record in the NOI justifies moving forward with an NPRM. We believe it would be beneficial to marketplace developments if the FCC were to expeditiously make mmW frequencies available for 5G, and importantly, under flexible rules which incentivize incumbent license holders to put the spectrum to its highest-value use. FCC launch of an NPRM before the WRC-15 in November could encourage other countries to become more supportive in the new 5G agenda item discussions at the WRC-15. It will be crucial that the U.S. support the principle that other countries and/or regions could include additional frequency bands to the scope of the 5G agenda item during these
discussions. Subsequently, the expeditious promulgation of rules for use of the mmW frequencies in the 2016 timeframe would also serve to promote USG effectiveness during ITU-R deliberations in the WRC-19 preparatory process. Quick actions by the FCC will reduce investment risk and uncertainty in the U.S. especially as to particular bands. We believe the above arguments provide a compelling public interest rationale for action by the FCC, to foster added investment, innovation, and competition in the U.S.

B. Recommended Bands

We recommend the FCC include all the NOI’s proposed bands for consideration in the NPRM. While we considered alternatives which focused on a subset of the proposed bands, we believe there are greater marketplace benefits in including all bands from the NOI. Further, we note that 5G supporters have targeted their R&D efforts in different locations across the proposed bands, and excluding any of the proposed bands would potentially divide 5G supporters. Innovation will be enhanced if the FCC permits all ongoing work and investment in mmW R&D to continue, rather than favoring or disfavoring the investments certain companies have made prior to this NOI.

C. Overview of Licensing Recommendations

Along with many commenters in the record, Intel recommends that the NOI’s stated spectrum bands below the 60 GHz band generally should be licensed, and the NOI spectrum bands above and including 60 GHz (in the 57-86 GHz range) should be
unlicensed. Besides being consistent with most of the commenters’ recommendations, this approach to the licensed/unlicensed question has the added advantage of preserving the existing licensing approaches on these bands. Converting a currently unlicensed band to licensed, or vise-versa, would create unnecessary delay and conflict in the rulemaking process.

Additionally, we suggest the FCC consider spectrum sharing approaches for certain licensed bands or band segments (for example, based on AWS-3 and LSA (licensed shared access) approaches), providing certain criteria justifying a shared approach are met. This could be applicable, for example, in the presence of primary (federal or non-federal) incumbent deployments that may need interference mitigation and that do not use the spectrum intensively. Suggesting particular band segments for a shared licensed approach seems prudent, given the potential incumbent interference issues in some bands, and also because shared small cell deployments may be particularly practical in some of these higher frequencies.

On license size, while the FCC should seek comments, Intel recommends large, contiguous, aggregatable licenses, because they may efficiently internalize interference tradeoffs and facilitate achievement of economies of scale. The currently licensed bands proposed in the NOI cover a range of license sizes. This should be maintained to the

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1 Although the NOI also makes brief mention of frequencies above 92 GHz, this analysis does not consider those frequencies.
extent it is practical for 5G deployments. In cases where smaller license sizes or different geographic arrangements are believed to foster a more productive market outcome, Intel would evaluate those on a case by case basis and comment accordingly.

1. Licensed Spectrum: Reference Policy Positions

In some of the discussion that follows, we note in advance that incumbents will have different incentives and interests relative to 5G. We use the term incumbents generally, but it is likely that certain incumbents, e.g. radio astronomy, may not be interested in adding mobility and other aspects of flexibility. Therefore, our preferred position is to give all appropriate incumbents the flexibility to provide mobile services, and where practical, leave any current band plans and channel plans as-is. This would likely foster expeditious investment and deployment.

Interference rules should be based on protecting adjacent operations at the band edges. Interference protections within the bands would be based on formal licensee consensus (e.g. similar to the 2.5 GHz MMDS/ITFS band), and subject to protecting co-primary operations such as radio-astronomy and Fixed Satellite Service (FSS). We also recommend giving licensees the ability to aggregate and disaggregate (and to swap/trade) licenses subject to public interest review (note that the rules for some of the bands already have this capability). We believe this approach would expedite the FCC decision process and most quickly enable efficient new 5G services on these mmW frequencies.
Certain incumbents (e.g. fixed point-to-point licensees) may value the ability to repurpose their spectrum, giving them maximum latitude to design band plans, pick technology, and otherwise structure their use of this spectrum most efficiently. In many cases, these incumbents have large licenses and therefore can internalize the tradeoffs and avoid transaction costs inherent in designing and negotiating the optimal band plan.

Certain federal and non-federal incumbents (such as radio-astronomy and FSS) with co-primary status will continue operations as-is, without any interest in mobility. These incumbents are entitled to interference protection from potentially harmful interference brought about by mobility. We believe the advantages in granting flexibility and mobility—while maintaining the requirement to protect co-primary incumbents—strikes the right balance.

**Unassigned licenses:** Any remaining unassigned licenses should be auctioned so that collectively licensees could reach deals covering large contiguous areas, if efficient. This will allow the FCC to more easily set technical interference parameters at the edge of the band, which in turn allows the licensees to decide channel and related technical parameters.

**License take-backs and Incentive Auctions:** Although not recommended, if either incentive auctions or license take-backs are used for some of the bands, then the band
plan could be designed from the ground up. In such a case, the Commission should strive to create the optimal band plan upfront. However, the resulting licensees should be given the flexibility to aggregate and disaggregate their licenses to meet the changing market and technology circumstances. Even in the absence of take-backs or incentive auctions, it may be the case that some incumbents (especially those without any significant deployments) will not have any objections to repacking of certain bands, so long as they do not lose anything that goes uncompensated in the process.

**Current band plan efficiency versus 5G needs:** Transaction costs (for carriers) in assembling a deployment footprint are often a key consideration in band plan designs. If there were substantial transaction costs and negotiation delays in making the existing band plans more applicable to large contiguous unpaired channels (noting that the 39 GHz and 24 GHz bands are currently licensed as paired channels, while the apparent consensus for 5G bands is unpaired), the existing band plans may be sub-optimal for 5G. However, many bands have consolidated ownership and most bands appear to be lightly deployed and some have many unassigned licenses. For those reasons we do not currently believe that transaction and negotiation costs should be a significant problem for the proposed bands as a whole. If the NPRM comments present evidence that these costs could be significant, the rationale for a band plan change from the current status quo could be re-evaluated.
It would seem prudent for an NPRM to seek comment on whether there are alternative band plans that would be preferable over the long run, and provide greater ongoing certainty. Currently, there is not sufficiently granular information on incumbent deployments and the band plan desires of future licensees to estimate the extent of transaction costs per band. The NPRM comments may reveal significant new information and call for recommendations on new approaches.

**Exclusion zones:** Another area where there is currently insufficient information to assess the impact to expeditious deployment of 5G services is with regard to exclusion zones that will be required for certain co-channel, co-primary incumbents (in particular, in the presence of mobile operations). For example, radio-astronomy locations (due to their highly sensitive receivers) can sometimes demand exclusion zones on the order of hundreds of kilometers, and certain satellite ground stations can demand up to 100 kilometers.

We propose that the NPRM seek inputs from all such incumbents, including information on all fixed locations (in particular their adjacency to highly populated areas) and activity levels (to judge the feasibility of sharing). The Commission should apply the latest terrain-based propagation models and other lessons learned from the recent AWS-3 and 3.5GHz proceedings in determining protection criteria as well as coordination mechanisms.
D. Possible “Alternative Band Plans”

As noted above, we recommend the existing band plans should be maintained in order to expeditiously move to future 5G use. Below we describe alternative band plans for all the bands listed in the NOI. This alternative would only be applicable if the bands were voluntarily re-organized, or if incentive auctions or license take-backs are used.

In this alternative, we sought to create larger contiguous blocks (see Figure 1, later in this section). We also suggest some initial channelization schemes for these bands, but those serve more as an indicator for band plan boundary and sizing purposes rather than as requirements. Channelization schemes are more fluid and should be open to change as 5G applications and services are better characterized.

We believe the NPRM should seek comment from equipment manufacturers, new licensees, and current incumbents on their willingness (or difficulty) in adopting any alternative plan, including changes from paired to unpaired spectrum. Interference concerns and exclusion zones would be particularly important to seek inputs on. This would give the FCC and interested parties a clearer picture on the future of the various NOI bands, as well as giving a relative indication on how the NOI bands stack up competitively, as substitutes for each other on a “per MHz-POP” basis.

In general a new “consensus band plan” for each band should:

- Allow mobility and flexibility;
- Consist of unpaired spectrum (perhaps defining a minimum channel size increment);
- Have interference rules solely for the band edges (to protect adjacent operations), while relying on consensus negotiations for intra-band service rules;
- Allow future aggregation/disaggregation, swaps and other secondary market transactions, and leasing.
- Allow external pairing (the 5G channel would be exclusively for supplemental downlink). Note SDL pairing may not be technically feasible today, but should not be foreclosed.
- Not designate any portion of spectrum as guard band spectrum.

Some NOI bands may present particularly challenging interference scenarios and certain band segments may be more efficient if carved out for a future phase, and/or identified as more suitable for a shared licensed approach. For example, the 29.10-29.25 GHz, and 42.0-42.5 GHz bands appear to present such challenges. The NPRM record may also provide useful information for potential bidders in the auctioning of unassigned licenses in the NOI bands, in terms of cross-band fungibility.

On guard bands, we recommend against designating any spectrum as guard band, due to the lost deployment opportunity it would present. Furthermore, the spotty current deployments in many of these bands do not justify nationwide guard bands, as it would be highly inefficient geographically. Any spectrum that might traditionally be designated as guard band due to adjacent incumbent interference concerns should instead seek rules for a conditionally usable license (size as small as technically practical, but large enough for meaningful 5G use), where mobile licensees would have primary coexistence obligations. Designating this spectrum for unlicensed use instead of licensed
use would just add unnecessary complications, and there will be ample dedicated unlicensed spectrum available in other proposed bands. The restrictions on this conditional license would likely vary by geography. In some geographic areas, where there is no adjacent incumbent, this conditional license would in effect be an exclusive license. In license areas with high usage/coverage by an adjacent incumbent, self-imposed exclusion zones may be called for. Still other geographic areas for the conditional license may have light usage by an adjacent incumbent, and may be suitable for a licensed shared approach. Any restrictions could be fine-tuned via collaboration between the incumbent(s) and the licensee. Note that future sensor-based networks may allow this fine tuning to be measurement-based, and possibly dynamic (this should not be foreclosed).

The figure below shows a graphical representation of the FCC’s NOI bands next to the alternatives proposed in the text that follows, in the event such alternatives are necessary:
Figure 1. Band plan comparison: FCC NOI vs possible alternatives

The following sections discuss the details of the above band plan comparisons.

Development of service rules for non-interfering mobile operation in all NOI bands is a key goal of the proposed 5G mmW NPRM.
1. **Band 1: 24.25-24.45GHz / 25.05-25.25 GHz (This is called the “24 GHz bands” in the FCC’s NOI)**

   The band is currently designated as paired spectrum (24.25-24.45 GHz and 25.05-25.25 GHz), licensed as paired 40 MHz channels in EA or EA-like geographic size (176 EAs).

   We propose unpaired licenses covering the two 200 MHz segments. One possible channelization plan would be 100 MHz channels (i.e. 2 x 100 MHz in each segment), but this is subject to change in order to accommodate co-primary incumbents. In practice, interference avoidance may limit this band to indoor IoT and short-range low-power applications, as the most expeditious means of dealing with the rights of incumbent operations.

2. **Band 2: 27.5-31.3 GHz (This is called the LMDS band in the FCC’s NOI, and consists of 5 sub-bands)**

   For this spectrum there are three non-contiguous segments: 27.50-28.35 GHz; 29.10-29.25 GHz; 31.000-31.300 GHz. In the A1 block of the LMDS band (27.50-28.35 GHz), because of adjacent FSS operations at 28.35 GHz, coupled with the 850 MHz overall bandwidth, we believe a proposal of an 800 MHz segment (from 27.50-28.30 GHz) plus an “interference buffer” channel of 50 MHz (28.30-28.35 GHz), makes sense. The 800 MHz segment could be channelized as licensees see fit, for example, four 200 MHz channels. The interference buffer channel could for example implement a licensed shared approach if interference with the adjacent FSS operations proves problematic. In
this way, the band has a relatively large segment which is safely distant from adjacent FSS, and separates out the band segment where interference concerns with adjacent operations are more probable.

As noted in the earlier discussion, we do not believe it is necessary to specifically designate any portion of the NOI bands as guard bands, since it is more efficient to let market participants decide on the extent of non-interfering use per geographic area, and/or any time of day usage limitations. The 50 MHz swath would be a candidate for the conditionally usable license described earlier.

In the A2 block (29.10-29.25 GHz), we believe it would be most expeditious if this A2 block were reserved for a future proceeding to determine its sharing possibilities.

In the B1/A3/B2 contiguous block (31.000-31.300 GHz, with segment edges at 31.075 and 31.225 GHz), we believe this can be treated as a contiguous block where licensees determine channelization. One example channelization could be three 100 MHz unpaired channels. Alternatively, a 200 MHz channel could be grouped with the four 200 MHz channels suggested for the A1 block.

3. Band 3: 37.0-40 GHz (This is called the 37/42 bands, and the 39 GHz band, in the FCC’s NOI)
For this spectrum, there are two contiguous blocks: 37.0-40.0 GHz and 42.0-42.5 GHz. Similar to the A2 block in the LMDS band, we believe the 42.0-42.5 GHz segment presents incumbent or adjacent channel interference complications and it would be most expeditious if this block were reserved for a future proceeding to determine its sharing possibilities. Further details on the extent of adjacent radio-astronomy at 42.5 GHz and its protection requirements are needed.

In the 37.0-40.0 segment, we believe the 39.5-40.0 GHz segment presents some interference difficulties and may be better suited for licensed shared operations (for example, five 100 MHz LSA channels) in areas where exclusion zones are not required. The 37.0-39.5 GHz segment is not considered a contiguous segment in the NOI (the Commission considers the 37.0-38.6 portion as the 37 GHz band, and the 38.6-40.0 portion as the 39 GHz band). However, we believe there are advantages to considering it a contiguous 2500 MHz block, which could be channelized, for example, as five 500 MHz unpaired channels. We believe there is value in the NPRM seeking comments on this different partitioning, and assessing the costs and benefits.

Combining the 37 GHz band with the 39 GHz band would provide the opportunity for large 5G channels of 500 MHz each. Without this combination there would not be enough spectrum for several licensees each having one 500 MHz block in any of the bands below 60 GHz.
4. **Band 4: 57-71 GHz (This is called the 60 GHz bands in the FCC’s NOI)**

This band is the expansion of the current ‘60 GHz’ unlicensed band from 57-64 GHz, up to 71 GHz. We do not propose any changes from the NOI recommendations for this band. The 64-71 GHz segment should be treated exactly the same (with the same rules) as the 57-64 GHz Part 15 segment, including extension of outdoor use. Our technical analysis indicates that designs covering the 57-64 segment can be extended to cover the 64-71 segment. IEEE 802.11ay is already considering the possibility of channel bonding with carrier bandwidths up to 6.75 GHz, assuming this band would become available.

5. **Band 5: 71-76 / 81-86 GHz (This is called the 70/80 GHz bands in the FCC’s NOI)**

This band currently has 270 non-exclusive nationwide licenses active. Each permits an unlimited number of pencil beams. The spectrum is managed by 3rd party database managers. The extent of deployment and utilization is not currently disclosed in detail. It might be the case that the licenses are better broken down into finer granularity geographic regions for 5G purposes, since there are a very limited number of nationwide carriers.

While the band is allocated as co-primary for mobile, there are no mobile service rules and thus no mobile operations. There is also no channel plan.
There are also 28 military bases and 18 Radio-astronomy sites entitled to protection (co-primary), as well as some FSS and MSS sites. The NPRM would need to develop mobile service rules and develop a record of greater detail on incumbent usage and interference issues. We would initially propose the 71-76 GHz and the 81-86 GHz segments each get considered as (non-contiguous) unpaired bands, 5 GHz wide, and based on the existing non-exclusive licensing regime. One possible channelization scheme could be fifty 100 MHz channels in each segment, but the channelization could for example be left up to standardization processes by IEEE, 3GPP, etc.

Although 100 MHz seems small compared to the amount of bandwidth in this band, there are two considerations. 1) the 100 MHz unit size could be aggregated up to 4800 MHz (e.g. 100, 200, 400, 800, 1600, 3200, 4800 MHz) depending on licensing and interference situations, and 2) given the light licensing nature of the band, smaller bandwidth and smaller scale deployments (e.g. lower cost residential or commercial deployments) could be supported.

E. Technical Recommendations

To the extent possible, licensed mmW bands should strive for common specifications derived from existing rules which have historically provided a good balance between interference protection and service quality. Unlicensed bands should strive for adherence to existing Part 15 rules.
In general, the Commission should use existing or comparable bands as a specification baseline, and ask interested parties to provide detailed comments on the adequacy of such proposed technical rules, including assumptions made, testing and simulations performed, interference impact, and current technology or manufacturing limitations.

1. Transmit power:

The Commission’s rules should be technology neutral, i.e. they should not require compliance with or implementation of a particular industry standard. For certain bands or in certain geographic areas, the power limits could impact (or be impacted by) the size of any exclusion/protection zones. It is also common in the Commission’s rules that power limits can be higher for rural areas, but again subject to any protection zones. Power limits greater than the non-rural limits may require coordination with licensees in the affected areas. Thus, coordination rules (e.g. similar to the AWS-3 case) should be proposed in the NPRM.

The Commission should propose EIRP (maximum total transmit power (regardless of the number of elements used, and not on a per-beam basis)) levels which are consistent with current mobile deployments. Commenters should be encouraged to provide analysis supporting these levels, or in deviating from them, on a band-by-band basis if there are band-related differences. Commenters should address base station EIRP, mobile station EIRP, and fixed station EIRP.
The Commission should seek comment on which incumbents are entitled to protection zones, and/or will require coordination agreements, as well as technical details on their operations, to aid in determining appropriate protections. Those incumbents who are entitled to protection zones should provide a written record of their protection criteria into the Comment record. Once available, commenters can provide analysis and recommendations on the technically-necessary size of protection zones based on those criteria, or other protection mechanisms and/or coordination agreements, as required.

Preliminary Intel-specific information: Analysis from our technical staff (specific to the LMDS (28 GHz) licensed band) indicates that 58 dBm EIRP for base station transmitters, and 34 dBm for mobile devices, could achieve the performance and range for the applications targeted for these bands. These EIRP figures are based on an assumption of 11 dBm conducted transmit power per element, 5 dBi antenna element gain, and for base station transmitters, 21 dBi of array gain (128 elements), and for mobile stations, 9 dBi of array gain (8 elements).

Mobile operation has a lower power allowance due to more difficult device size and cost constraints compared to base stations, as well as more difficult deployment/interference conditions due to mobility. While higher EIRP levels are possible by using larger arrays, this is limited by the size of the array on the user terminal, and potentially by RF exposure limits.
We expect the EIRP limits for the 37-42 GHz spectrum to be similar to the 28 GHz band. In the 60 GHz band, existing Part 15 rules for base and mobile EIRP should be acceptable, according to our analysis.

We do not currently believe there should be any restrictions on conducted power in any of the bands. The advantage of not specifying conducted power is that it provides flexibility in antenna and RF design.

There might be use cases in 5G which differ from traditional cellular (e.g. requiring a mesh topology where there is no clear distinction between a user terminal and a base station). The NPRM should consider such use cases as well.

2. Antennas:
The Commission should propose flexible antenna height rules similar to other bands, and that no antenna height rules unique to this band should be set, other than the general requirements against heights that would present an air navigation hazard. The limitation of field strength at the geographic boundary of the license could also effectively limit antenna height. The Commission should ask commenters to provide rationale for any band-specific or broader deviation from these flexible rules on antennas.
With the exception of the 60 GHz band (for which existing Part 15 rules should apply), we propose that the Commission not place any restrictions on antenna gain, and no restrictions on antenna height or beam width. By not specifying antenna gain maximum or minimum, flexibility in antenna and RF design is provided.

3. OOBE (out of band emissions):

The Commission should ask whether the standard $43 + 10 \log_{10} (P)$ dB requirement is attainable in all licensed bands and all geographic areas. Due to the large number of bands proposed in the NOI, in addition to the varying geographic license area sizes in different bands, as well as the variation in incumbent operations, the NPRM should be organized in distinct subsections dealing with each band.

Preliminary Intel-specific information:

Our internal analysis for the 28 GHz band indicates the standard $43 + 10 \log_{10} (P)$ dB requirement can be met for base stations (based on three bandwidths: 100, 200, and 800 MHz). We believe this could also hold for the 39 GHz band.

However, mobile stations require a different OOBE level since our analysis shows a stepped mask specified as $43 + 10 \log_{10} (P)$ dB on the channel edge cannot be easily met. This holds true for a range of bandwidths. Instead, a scaled version of the WiGig/IEEE 802.11ad mask (see figure 2 below) is more achievable for the stated power levels.
Figure 2 – WiGig/IEEE 802.11ad Mask

Figure 3 shows a scaled version of the mask in Figure 2, to a bandwidth of 800 MHz. We have analyzed 100 MHz and 200 MHz carrier bandwidths as well.

We would tentatively propose that this scaled mask should be applicable for both base and mobile stations. Base stations for these bands are not expected to have the same
flexibility in absorbing costs of tighter filtering (compared to mobile stations) as the lower frequency bands where far fewer base stations are deployed. We therefore believe it is beneficial to use a single common mask as described in Figure 3, applicable to both base and mobile stations.

4. Spurious Emissions:

Until future coexistence scenarios are better defined for the final band plans, we recommend use of the generalized ITU-R recommendation of -30dBm/MHz as a starting point for test and simulation purposes. Minimum separation distances for derivation of spurious emissions levels can vary by bands and applications.

Preliminary Intel-specific information:

Our internal analysis shows that spurious emission limits of -30 dBm/MHz can be met for each of the 100, 200, and 800 MHz bandwidth test cases at 28 GHz. This holds for both base and mobile stations. The results could also be applicable to 39 GHz band.