September 12, 2017

VIA ECFS

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: *Authorizing Permissive Use of the "Next Generation TV" Broadcast Television Standard, and Subsequent Calls for Mandating ATSC 3.0 Receivers in Consumer Devices*, GN Docket No. 16-142

Dear Ms. Dortch,

As a leading innovator in the mobile Internet and consumer electronics sectors, Motorola Mobility ("Motorola") welcomes the advent of the "Next Generation" broadcast television ("Next Gen TV") transmission standard and the new opportunities and benefits it will afford to broadcasters, equipment manufacturers, and ultimately consumers. As an equipment manufacturer, Motorola agrees with the FCC's tentative conclusion that this technological transition should occur on a "voluntary, market-driven basis" without need for any government "mandate."[1]

Consequently, Motorola is concerned about calls from some parties (none of them equipment manufacturers) that the FCC mandate the inclusion of ATSC 3.0 receivers in smartphones and other mobile devices.[2] Mandating equipment functionality without regard to consumer demand is not in the public interest. Moreover, and as explained in more detail below, inclusion of an ATSC 3.0 receiver in smartphones and other mobile devices would present significant technical challenges and limitations, which to overcome would negatively impact device design, performance, and cost. While equipment manufacturers routinely face tradeoffs in developing products, they should be resolved to meet customer demand, not dictated by government fiat.

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[1] Authorizing Permissive Use of the "Next Generation" Broadcast Television Standard, *Notice of Proposed Rulemaking*, GN Docket No. 16-142, FCC 17-13, ¶¶ 1, 71-72. (rel. Feb. 24, 2017) ("*NPRM*").

[2] Comments of Advanced Television Broadcast Alliance 4-10 (May 9, 2017); Reply Comments of Free Access & Broadcast Telemedia, LLC at 3 (June 8, 2017); Comments of One Media LLC at 52-53 (May 9, 2017).

I. Physics Limits Available Antenna Performance in a Mobile Device.

Since the publication of Maxwell's Equations unifying electromagnetic theory 150 years ago, it is well understood that antenna performance (in terms of efficiency, gain, operating bandwidth, etc.) is fundamentally linked to the size of the radiating structure relative to the wavelength at the operating frequency.[3] In general, for an antenna to perform reasonably well, its dimensions must be at least as large as a significant fraction of a wavelength. For cellular networks and ATSC 3.0 reception, antennas need to have a size approaching one-half of the free space wavelength at the operating frequency.

In the United States, mobile devices must operate in frequencies between 617 and 894 MHz (as well as several higher bands in the 1710 to 2700 MHz range) to facilitate cellular operations. To facilitate broadcast TV reception, mobile devices would need to operate at additional frequencies down to 470 MHz.[4] Thus, to support cellular operation and ATSC 3.0 reception, free space wavelength would need to be in the range of 335 to 638 mm. To effect efficient antenna operation in that range, an antenna would need to be between 150 and 300 mm long – in other words, as large as the entire smartphone itself.

In modern smartphone practice, for frequencies below 1 GHz, the internal antenna element itself can take the form of a monopole or loop antenna, which has a maximum effective height (away from the ground plane) of around 10 mm or less. To the extent these antennas work below 1 GHz, they do so by exciting to some degree the entire conductive structure of the phone as a radiating structure. The physics-based ramification of the small size of the antenna element is that the matched operating bandwidth of this radiating structure is in the range of 25 to 50 MHz (around 3 to 5 percent fractional bandwidth), for the frequencies below 1 GHz. Exciting the phone structure to realize sufficient aperture for efficient radiation also makes it infeasible to implement more than one or two independent antennas in the below 1 GHz frequency range, because each antenna shares the same fundamental radiating structure.

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[3] This concept is captured in the well-known Chu-Harrington Limit, which sets a lower limit on the Q factor for a small radio antenna. *See generally* Roger F. Harrington, *Effect of Antenna Size on Gain, Bandwidth, and Efficiency*, Journal of Research of the National Bureau of Standards- D. Radio Propagation Vol. 64D, No.1 (Jan.-Feb. 1960).

[4] This assumes the possibility of only adding UHF-TV reception capability (470 – 608 MHz). If VHF-TV reception is also required, the low VHF-TV band (54 – 88 MHz) and high VHF-TV band (174 – 216 MHz) would need to be taken into account. It will be seen that VHF could only be considered by connecting the smartphone to an external antenna.

II. Available Antenna Performance in Mobile Devices is Already Fully Exploited to Support Cellular Service.

The modern smartphone must support the following bands below 1 GHz in the U.S. market (using 3GPP designations): Band 71 (617 to 698 MHz); Band 12 (699 to 746 MHz); Band 29 (717 to 728 MHz); Band 13 (746 to 787 MHz); and Band 26 & Band 5 (814 to 894 MHz). Additional bands for roaming in other regions are also required, including, for example, Band 8 from 880 to 960 MHz.

Given the constraint on instantaneous antenna bandwidth described above, even these bands cannot be covered simultaneously. In fact, most modern devices (where size and industrial design are at a premium) must employ active antenna tuning to move the antenna's available response dynamically on to only one of these bands at a time. Active device tuning includes, for example, variable/switchable capacitors in the matching circuit and/or as adjustable loads on the antenna element. Current state-of-the-art RF tuning technology has sufficient tuning range only to enable moving the typical antenna's response across the range of frequencies listed above. (In fact, the industry is challenged to add even the new Band 71).

Additionally, modern smartphones support receive diversity or multiple-in multiple-out ("MIMO") operation on all these bands (in fact, MIMO is a standards requirement in the LTE system employed in these bands). As a result, not one but two independent antennas must be incorporated into the device and tuned to operate across all the above-referenced bands. Given the limitation on exciting independent antenna modes below 1 GHz, an acceptable level of "independence" is barely achieved in these bands.

III. Manufacturers Have Not Incorporated Additional Cellular Features Below 1 GHz into Mobile Devices Because of Limitations on Antenna Performance.

The very real nature of the limitations described above is evident in what manufacturers have *not* implemented in modern smartphones. The 3GPP LTE standard defines several advanced features that can be employed to increase throughput. In particular, increasing from 2x2 to 4x4 MIMO operation within a single band can increase throughput by average rates of 50 to 100%. In addition, Carrier Aggregation can allow simultaneous operation on more than one band at a time, again potentially doubling (or more) throughput.

Carrier Aggregation has been deployed in the U.S. for a few years, with various combinations of up to four downlink channels aggregated in a single link dynamically.

The combination of bands used varies by carrier and region, but in general includes one or more of the mid/high bands in the 1710 to 2700 MHz range, and optionally one low band below 1 GHz. Importantly, no smartphone device currently supports aggregation of two or more low bands below 1 GHz, even though this arrangement would be considered a valued capability by our carrier customers and would improve throughput in many scenarios for the end user. The absence to date of this potentially valuable feature is due to the limitations on instantaneous antenna bandwidth discussed above.

Similarly, 4x4 MIMO has also recently been deployed to good effect in some premium tier smartphone devices, demonstrating superior throughput.[5] However, this increases the number of required receive antennas from two to four and can only be deployed in smartphones in the mid/high bands from 1710 to 2700 MHz.

IV. Adding an ATSC 3.0 Receiver Would Substantially Hurt Cellular Performance.

Adding an ATSC 3.0 receiver to smartphones would require extending the operation of one of the smartphone's internal cellular antennas to cover additional TV frequencies down to 470 MHz. Due to the asynchronous nature of cellular and TV frequencies, doing so would require simultaneous operation of the cellular modem and the ATSC 3.0 receiver. Simultaneous operation would negatively impact cellular performance in several fundamental respects.

First, as discussed above, the instantaneous bandwidth of the antenna is not sufficient to cover both an ATSC 3.0 channel at, say, 470 MHz, and an LTE channel at, say, 835 MHz. If the antenna were tuned to the ATSC 3.0 band, there would be more than 10 dB of degradation in the cellular band,[6] and vice-versa if the antenna were instead tuned to the LTE channel. This degradation when tuned to ATSC would devastate a customer's cellular experience. Given the modest gains/efficiencies of the antenna to begin with, it seems doubtful that ATSC 3.0 reception when the antenna is tuned for cellular operation would be acceptable, either.

Second, as mentioned, current RF tuner technology is fully exploited to tune the smartphone antenna across the cellular bands. The available tuning range is not

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[5] *See Finding MIMO, Quantifying of 4x4 MIMO in a Commercial LTE Network*, Signals Ahead (Jan. 9, 2017); *A Force to Be Reckoned With, A Third-Party Performance Analysis of the Motorola Z2 Force, the Samsung Galaxy S8, and the Apple iPhone 7 Plus*, Signals Ahead (Aug. 18, 2017).

[6] This is based on the response of a realistic antenna and matching circuit having 3 - 5% bandwidth as described above. It is also confirmed via simulation data generated for real phone form factors in internal studies at Motorola.

adequate to extend the antenna tuning range to include 470 MHz without causing performance across all the bands below 1 GHz to suffer.

Finally, because the antenna would be shared between the cellular transceiver and the ATSC 3.0 receiver, substantial additional RF front end diplexing and filtering circuitry would be required to separate the two signals and to assure acceptably low interference between them. While it is difficult to quantify the performance impact without doing a detailed design, based on similar design problems encountered in diplexing the cellular bands, one can expect additional losses in the range of 2 dB in the sub-1 GHz cellular bands and/or the ATSC 3.0 bands.

In light of these considerations, adding ATSC 3.0 bands to the existing cellular antenna is not technically feasible. In other words, it is not feasible to add ATSC 3.0 to a smartphone without impacting its industrial design significantly.

V. The Market Should Determine When, and Whether, ATSC 3.0 Receivers are Incorporated into Smartphones.

As envisioned by the Commission, the transition to ATSC 3.0 should be voluntary and market-driven.[7] The incorporation of ATSC 3.0 receivers into smartphones and mobile devices likewise should be market-driven. Unless and until there is substantial consumer demand for ATSC 3.0-capable smartphones, manufacturers should not be expected to devote the resources and incur the costs associated with attempting to overcome the technological issues and negative design impacts discussed above. It would make no sense for the government to compel manufacturers to modify *all* mobile devices to incorporate ATSC 3.0 receivers in the absence of consumer demand for this functionality.

Even with consumer demand, designing ATSC 3.0-capable mobile devices would result in some design features that American consumers likely would view as undesirable. For example, in some non-US markets where there is a large demand for broadcast TV reception in cell phones, Motorola and other cellular OEMs have developed devices that incorporate DTV receivers. To overcome the limitations discussed above, OEMs incorporate a relatively large, dedicated external antenna for DTV, and a dedicated internal RF front end and DTV receiver system that can operate independently of the cellular transceiver.[8] The external antennas are either telescopic whip antennas, or

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[7] *NPRM* ¶ 1.

[8] In fact, the use of such external antennas is the only viable choice if the VHF TV bands were to be included in the capabilities of the receiver, because of their very large wavelengths.

cable "dongles" that plug into a jack in the housing of the phone. The addition of external antennas has a very obvious and negative impact on the size and industrial design of the smartphone, to which U.S. consumers of premium-tier devices would react negatively. In addition, the external antenna and internal components necessary for broadcast TV reception increase the cost of a smartphone, which consumers may find unpalatable.

If, in the future, there is sufficient consumer demand for ATSC 3.0 receivers in smartphones in the U.S., Motorola could certainly develop, test, and bring to market a device to meet such demand. In fact, Motorola currently offers a unique opportunity, through its Mods partner development program, for any interested third party to develop an ATSC 3.0 receiver add-on that could be marketed to consumers for use with higher-tier smartphones.[9] The market can readily signal consumer demand for ATSC 3.0-capable mobile devices and spur the development and marketing of such devices in the U.S., without the need for a regulatory mandate.

VI. Conclusion.

An ATSC 3.0 receiver mandate for smartphones and other mobile devices is neither appropriate nor necessary. Accordingly, Motorola urges the Commission to decline invitations to adopt such a mandate.

Respectfully submitted,

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