Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Office of Engineering and Technology Seeks to Supplement the Incentive Auction Proceeding Record Regarding Potential Interference Between Broadcast Television And Wireless Services	)	ET Docket No. 14-14
	)	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	)	GN Docket No. 12-268

COMMENTS OF SINCLAIR BROADCAST GROUP, INC.

Sinclair Broadcast Group, Inc. ("Sinclair") submits these comments in response to the *Public Notice* seeking comment on a methodology for predicting potential interference between broadcast television stations and licensed wireless services.[1] Sinclair brings to the Commission's attention the need to thoroughly test digital television and wireless receivers and account for their sensitivity to Taboo Channel Interference ("TCI"), which appears otherwise to have been ignored in the development of the methodology for repacking broadcast stations. Strong evidence exists that, if comprehensive tests are conducted, they will show that TCI will have a substantial impact on how tightly broadcast channels can be repacked and how closely wireless carriers can operate without interference. If comprehensive testing is not done or TCI is not properly accounted for, it could render millions of DTV receivers useless, diminish the coverage area and population served by broadcast television stations, and greatly de-value the mobile services bands the FCC intends to allocate and sell.

[1] *Office of Engineering and Technology Seeks to Supplement the Incentive Auction Proceeding Record Regarding Potential Interference Between Broadcast Television and Wireless Services*, Public Notice, ET Docket No. 14-14, GN Docket No. 12-268, DA 14-98 (rel. Jan. 29, 2014) ("*Public Notice*").

The need to account for TCI highlights the complexity of the Commission's task in developing auction rules and the need for a holistic approach in considering both inter-service and intra-service interference issues. More to the point, it dictates that the Commission take the necessary time to get the technical issues right. The questions raised by the prospect of assigning broadcast and wireless service to operate in the same bands in different markets and in adjacent bands in the same markets are too varied and complex to be addressed adequately in the short time frame the Commission has permitted for these comments. The FCC must ask confront these questions, identify the issues, and find workable solutions *before* it conducts the auction.

Congress has given the FCC only one opportunity to get the auction right,[2] but appropriate to the complexity of the task, Congress gave the FCC more than ten years, until the end of federal fiscal year 2022, to complete the auction.[3] The mandate that the FCC use "all reasonable efforts"[4] must be read in the context of the ten year time frame Congress allowed for the auction. The FCC does not have discretion to compromise fundamental statutory requirements simply because it wishes to complete the auction seven years ahead of the deadline with a particular set of auction rules, and with repacking planning that is based on uncertain "feasibility" predictions that may not prove out in actual repacking.

The Commission's recent experience with receiver-related interference in the cases of LightSquared and GPS, and SDARS and WCS, have made clear that spectrum management

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[2] Spectrum Act §6403(e).

[3] *Id.* at §6403(f)(3).

[4] Section 6403(b)(2) of the Spectrum Act provides that:

> In making any reassignments or reallocations… the Commission shall make **all reasonable efforts to preserve,** as of the date of the enactment of this Act, **the coverage area and population served of each broadcast television licensee**, as determined using the methodology described in OET Bulletin 69 of the Office of Engineering and Technology of the Commission. (emphasis added).

Sinclair believes this "all reasonable efforts" standard requires the Commission, notwithstanding its characterization of "mobile" and "broadcasting" as co-primary in the band, to ensure that broadcasting is fully protected in the event of interference disputes between mobile and broadcast operations resulting from a hastily-conducted auction.

requires a thorough understanding of receiver performance and resilience. The recent efforts of the Technological Advisory Committee to develop recommendations for receiver harm claim thresholds reinforce this principle. Those lessons must be incorporated into this proceeding, representing as it does perhaps the most important spectrum management exercise the Commission has ever conducted.

We are aware that some stakeholders have misinterpreted Sinclair's position that the FCC should proceed more deliberately as an agenda to "delay" the auction.[5] This is categorically wrong. Sinclair is eager to have this proceeding resolved as soon as possible, both to enable much-needed service improvements across the full breadth of the "television" band, and to provide certainty to all stakeholders. We do not suggest that the auction should be scheduled at the latest possible date consistent with the statute. All other things being equal, sooner is much better, and we believe the critical issues can be resolved in a time frame consistent with an auction in 2016 or 2017, still five or six years ahead of the statutory deadline (and with plenty of margin). But the auction must be done right the first time, and the Commission should use whatever portion of the statutory period it needs to get the auction right. An auction that is rushed will leave the nation with a band plan and assignments that are inferior to what is possible. At the same time, it will compound the three most basic risks that the auction rules should seek to mitigate: (i) that the auction simply will not close, (ii) that the resulting services will suffer significant harmful interference, and (iii) that the auction will not meet the statutory requirements and will face valid challenges from aggrieved parties. TCI elevates each of these risks.

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[5] The word "delay" itself is a misnomer. The FCC has established a target date of 2015 for the auction, but that is simply an arbitrary target.

Discussion

TCI was well understood in the context of analog TV assignments, based on an appreciation of the potential for certain adjacent channel signals to overload or block the analog receiver. With the development of digital television, concern for this adjacent channel interference receded. But recent testing has demonstrated that it remains a critical consideration, particularly given the trend towards lower-cost and less resilient digital receivers.[6] Moreover, that recent testing has itself been somewhat limited and does not reflect the full extent of the interference that is likely to be generated in a post-repacking world.

The FCC initially conducted limited testing of UHF Taboo Channel Interference with only one Undesired (U) DTV signal on what were regarded as the most sensitive channels, N+/-2, and N+/-3. Those tests showed that for a single undesired signal the (then optimal prototype) receiver rejected TCI when the Undesired signal was up to 60 dB stronger (D/U = - 60 dB) than the desired signal at - 68 dBm (a weak desired signal test). Based on this limited assessment, the FCC concluded that there would be no need for establishing protection ratios (D/U limits) for interference from an undesired DTV signal two or more channels from a desired channel.[7]

The FCC also conducted tests of consumer DTV receivers available in 2005 and 2006 to measure their robustness against interference.[8] Those tests again included tests for TCI from a single DTV signal, which seemed to confirm the above conclusion. By then, the effect of third order non-linearity in the tuners of DTV receivers was becoming increasingly well known.[9]

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[6] "Interference Rejection of Late Model DTV Receivers," by Linley Gumm and Charles Rhodes, IEEE Broadcast Technology Society Newsletter http://bts.ieee.org/images/files/bts-sprg2014-Web.pdf, pages 11-17 (Spring 2014) (attached as Exhibit 1) ("Gumm & Rhodes").

[7] *See Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service*, MM No. 87-268, Sixth Report and Order, 12 FCC Rcd 14588, Appendix B (1997).

[8] OET Report 07-TR-1003, "Interference Rejection Thresholds of Consumer Digital Receivers Available in 2005 and 2006" (March 30, 2007).

[9] G. Sgrignoli, C.W. Rhodes, "Interference mitigation for improved DTV reception," IEEE Transactions on Consumer Electronics, vol. 51, no. 2, pp. 463–470.

Two undesired signals on channels N+K and N+2K (regardless of the occupied bandwidth) generate 3rd order distortion products falling in channels N and N+3K. A desired signal on either of these channels is subject to interference from pairs of undesired ("Taboo") channels. Tests by Gumm and Rhodes with such pairs of undesired DTV signals offset from the desired signal by 2, 3, 5, and 10 channels caused significantly more interference than a single undesired DTV signal on channel N+/-1 (Adjacent Channel Interference), a parameter which the FCC regulates.[10] Further tests by the FCC Laboratory in 2009 showed that the tested set top converter boxes were also subject to Taboo Channel Interference from pairs of Undesired signals on such channel pairs.[11]

Over time, the tuners used in ATSC receivers have changed dramatically in a way that makes them more susceptible to blocking. First, the tuners in modern ATSC receivers are fabricated as Integrated Circuits ("ICs"). Gone are traditional tuned circuits to provide RF selectivity to reject undesired signals two (2) or more channels from the desired signal. There is no space available on an IC chip for high quality inductors. Instead, a new tuner topology was developed to eliminate the need for such tuned circuits to reject interference. The new topology was first described in 2007,[12] and by 2012 it was in a variety of new receivers. By 2013, it had become the dominant tuner topology.[13]

Charles W. Rhodes and his colleagues, having already gained experience in testing of NTIA approved converter boxes,[14] are conducting additional work. Because of the new topology of tuners in ATSC receivers they have obtained 24 current receiver models and

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[10] *See* Gumm & Rhodes, *supra*.
[11] IEEE Transactions on Broadcasting Vol. 56, No. 4 pages 444-449, Dec. 2010.
[12] Tutorial: "Modern Receiver Architectures from Superheterodyne to Zero IF Digital Receivers" by W. Weltersbach of NXP, at the 2007 International Conference on Consumer Electronics, January, 2007.
[13] *See also*, Comments of Linley Gumm and Charles Rhodes, ET Docket No. 14-4, GN Docket 12-268 (Feb. 24, 2014).
[14] IEEE Transactions on Consumer Electronics, Vol. 59, N0. 2, pages 303-309 (May, 2013).

continue to conduct tests to better understand their robustness to interference. Some of those tests and the results have been published by the IEEE Broadcast Technology Society in its Spring 2014 Newsletter, and those tests confirm the performance constraints of IC tuners.[15]

It should be of considerable concern to the FCC that these same mechanisms that produce interference as described above can also contribute to similar interference within the reclaimed 600 MHz band plan spectrum and vastly impact its new wireless occupants. This cannot be ignored by potential bidders, and demands that the FCC fully understand the potential for impact and spend the necessary resources to better understand the mechanisms required to mitigate the damage that otherwise would surely diminish the value of the 600 MHz assignments to be auctioned.

The post-auction band plan generally and each post-repacking assignment (and thus the FCC's intra-round feasibility checks) must carefully consider and account for the impact of TCI. This arises for three major reasons.

First, as discussed above, the actual DTV receivers now deployed in the field have vastly inferior rejection as compared to the prototype that was used in initial testing.[16]

Second, much closer adjacencies of broadcast assignments that will necessarily occur in a smaller post-repacking assignment plan will result in a far greater number of N+/- taboo channel combinations, including many taboo combinations at greater N+/- levels.

Third, the potential for deployment of tightly packed, site-licensed, high power, 6 MHz broadcast assignments with geographic licensed, lower power, "flexible use" assignments of 5, 10 or 20 MHz with low-cost mobile transmit/receive handsets in an adjacent market or on

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[15] *See* Gumm & Rhodes, *supra*.

[16] *Id*. It seems likely that because of cost and "real estate" (form factor) considerations, the receivers used on 600 MHz mobile broadband devices will suffer from similarly poor performance, making them highly vulnerable to TCI from adjacent broadcast operations.

adjacent frequencies in the same market, introduces the likelihood of substantial inter-service interference. The nature of broad bandwidths (up to 20 MHz) contemplated for future adjacent (600 MHz bandplan) wireless services and the already understood mechanisms that will result in interference being generated from the interaction of multiple adjacent broadcast channel allocations have the potential to negatively impact both broadcast and wireless services.

The FCC has not previously investigated the co-existence of these services. Based on what is already known about the nature of the interference mechanisms in the DTV spectrum, it is reasonable to expect that problems will extend across large swaths of the prospective mobile band and most likely will extend beyond the "variable" portion of the band into portions with "mobile-only" assignments. Notably, in the United Kingdom, Ofcom has recognized at least since 2011 the potential for LTE services in the 800 MHz band to interfere with digital television transmissions. Even after "extensive" tests, Ofcom failed to determine the full nature and scale of the interference, and launched an additional consultation to include the mobile operators.[17] The Commission must understand and account for inter-service interference that will exist in real-world operating environments.[18]

Conclusion

The point of this submission is not to identify solutions to the TCI problem. The issue is too complex and the FCC has allowed too little time in this comment cycle. At a minimum, more receivers (both DTV and LTE) need to be tested and the testing must consider all possible combinations of channel assignments, power levels, and geographic separations. In the meantime, the evidence – much of it from tests in the FCC's own labs – suggests

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[17] *See* FierceWirelessEurope,"Ofcom: LTE at 800MHz will cause TV interference, £100m fix needed", June 3, 2011 (available at http://www.fiercewireless.com/europe/story/ofcom-lte-800mhz-will-cause-tv-interference-100m-fix-needed/2011-06-03#ixzz2wM8l2VZq).

[18] *See, e.g.,* Comments of the Society of Broadcast Engineers, Incorporated, ET Docket No. 14-4, GN Docket 12-268 (Mar. 17, 2014).

overwhelmingly that TCI is a major problem that must be addressed in the context of avoiding both inter-service and intra-service interference. Sinclair is confident that the Commission, with the input of industry stakeholders, has the means to address and account for TCI within the statutory framework, which requires all reasonable efforts to preserve broadcast service area and population served.

The prospect of millions of over-the-air viewers losing access to broadcast signals that they received before repacking is antithetical to Congress' mandate to the FCC, as is the prospect of the auction being undermined by interference to wireless systems. That is particularly true if the loss of service results from problems that can adequately be addressed well within the statutory timeframe for the auction. Haste makes waste, and in this case, rushing greatly compounds the risk that the auction will fail, either by failing to close or by failing to comply with the requirements of the statute.

Respectfully submitted,

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Exhibit 1

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This year's International Consumer Electronics Show filled every square foot of the vast Las Vegas Convention Center and spilled out into adjacent parking lots and hotel suites.

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IEEE

Will 2014 Be Remembered As 'The Year of 4K' at CES?

Show attracts more than 150,000 attendees

By James E. O'Neal

LAS VEGAS

This year's International Consumer Electronics Show (CES) drew more than 150,000 visitors to inspect the latest in developments from more than 3,200 exhibitors. The amount of floor space and foot traffic strained the vast Las Vegas Convention Center to the utmost and many exhibitors elected to pitch tents in neighboring parking lots or set up 'hospitality suites' in nearby hotels to show off their new technologies. According to the Consumer Electronics Association (CEA) which owns and produces the show, this year's CES was spread over a record two million square feet of exhibition space.

While not a show for broadcasters, per se (it's primarily geared to buyers from major retail outlets), the CES does attract many in our profession as it's a very good place for gauging industry trends to determine what the broadcasting industry may have to prepare for in terms of emerging consumer products.

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Interference Rejection of Late Model DTV Receivers

By Linley Gumm and Charles Rhodes

Introduction

In the spring and summer of 2013, the authors performed tests on 24 modern DTV receivers to determine their ability to withstand interference from other DTV signals. The tests were performed using the facilities in Mr. Rhodes' laboratory with the equipment shown in Figure 1. The goal was to determine how well these receivers might operate in a post re-packing environment when the density of channels in the UHF band probably will be much greater than today.

Congress directed the FCC to use the allocation standards set forth in OET-69 [1] in the law authorizing the FCC to conduct the auctions. In Table 5A of this document and in the FCC's rules [2] interference protection is provided against co-channel interference (CCI), D/U = +15 dB and adjacent interference (ACI, D/U ≈ −27 dB[1]) and not any other. As for interference from undesired signals on channels further away, the FCC concluded that DTV receivers would have few problems with dealing with desired to undesired signal ratios (D/U) of about −60 dB on these channels (page 8). As far as is known these rules will be applied in the re-packing process.

[A note about D/U: D/U is the Desired power (D) to Undesired power (U) ratio, a very useful metric. Receivers often exhibit a roughly constant D/U for a wide range of U powers. It is computed by subtracting the U amplitude from the D amplitude, both in dBm. Since, for all but CCI interference, a DTV receiver can tolerate a much larger U signal than the D signal, the D/U ratios are always negative numbers. What is desired is a receiver that operates to a very small D/U value; −50 dB is smaller than −40 dB.]

In 2010, the FCC's Steve Martin published the results of an extensive program at the Commission's laboratory to test the RF performance of DTV set-top converters [3]. His tests showed that the median set-top box could not operate when the D/U ratio for one interfering signal two channels away from the D channel (i.e., N+2 or N−2) was below about −50 dB. These receivers performed almost to a D/U ratio of −60 dB for greater offsets.

His paper went on to report the D/Us when two interfering signals were present and arranged to maximize any third order intermodulation created within the receiver itself. Any third-order intermodulation product created in the receiver by the two undesired signals will then fall at 2*F1−F2 and 2*F2−F1. Assume that D is on channel N. If the closest (in frequency) undesired signal U1 is on channel N+K, and if the second undesired signal U2 is on channel N+2K, the center of any third-order intermodulation product will be on channel N occupied by the D signal and channel N+3K. (K can be positive or negative.) A complication is that the spectral width of that product is three channels wide. For a receiver to be completely free of the intermodulation issues requires that the second undesired signal *not* be on channels N+(2K±1).

When Mr. Martin tested the set-top converters with U1 = N+2 and U2 = N+4, the median set-top box failed when the D/U ratio was less than about −45 dB well short of OET-69's −60 dB assumption. We performed similar tests on 26 set top converters and confirmed the FCC lab's findings.

Since the tuners in these set-top boxes mostly used discrete technology and since the currently available DTV receivers appear to use application specific IC tuners, we wondered how their performance might compare with the set-top converters? With the aid of donated and loaned hardware, plus several grants of cash allowing us to purchase needed filters and the modern DTV receivers themselves, we were able to find out.

To provide a comprehensive evaluation, we desired to test with a single U signal, two U signals in a N+K and N+2K arraignment and, to simulate what may well happen after re-packing, a block of contiguous U signals. Using all of our resources, we were able to create a test set that features seven contiguous channels. Figure 1 shows how the test set was configured.

Our block of seven U signals spans from Ch. 30 to Ch. 36. The U signals on Ch. 30, Ch. 33 and Ch. 36 were obtained by directly filtering and amplifying off-air signals. Mr. Rhodes' laboratory is 14 miles line-of-sight from Portland, Ore. TV towers and these signals are virtually free of multipath. The U signal on Ch. 35 was obtained by receiving an off-air Ch. 22 signal, frequency converting it to Ch. 35, and then filtering and amplifying it. The U signals on Ch. 31, Ch. 32 and Ch. 34 are locally generated instrumentation-grade 8-VSB signals. All signals have completely independent modulation to avoid any complications due to correlated sources.

As will be seen, to test to very small D/U ratios, the amplitude of the D signal is often near the kTB noise level. To get to the power levels necessary for our testing, a good deal of amplifier gain was necessary—amplification that created a wide band noise floor. To keep this noise from flooding the D channel and thus limiting how small of a D/U ratio that could be measured, great care was taken with filtering the U signals. With the current configuration of filtering in our test set, we are able to only test situations where the U signals are above the D signal in frequency. We anticipate similar results when U is below D but it would be important to have proof. An expensive low-pass filter is needed before we can make those measurements.

[1] The FCC's limit is −28 dB when U is on the lower adjacent channel and −26 dB when it is on the upper adjacent channel.

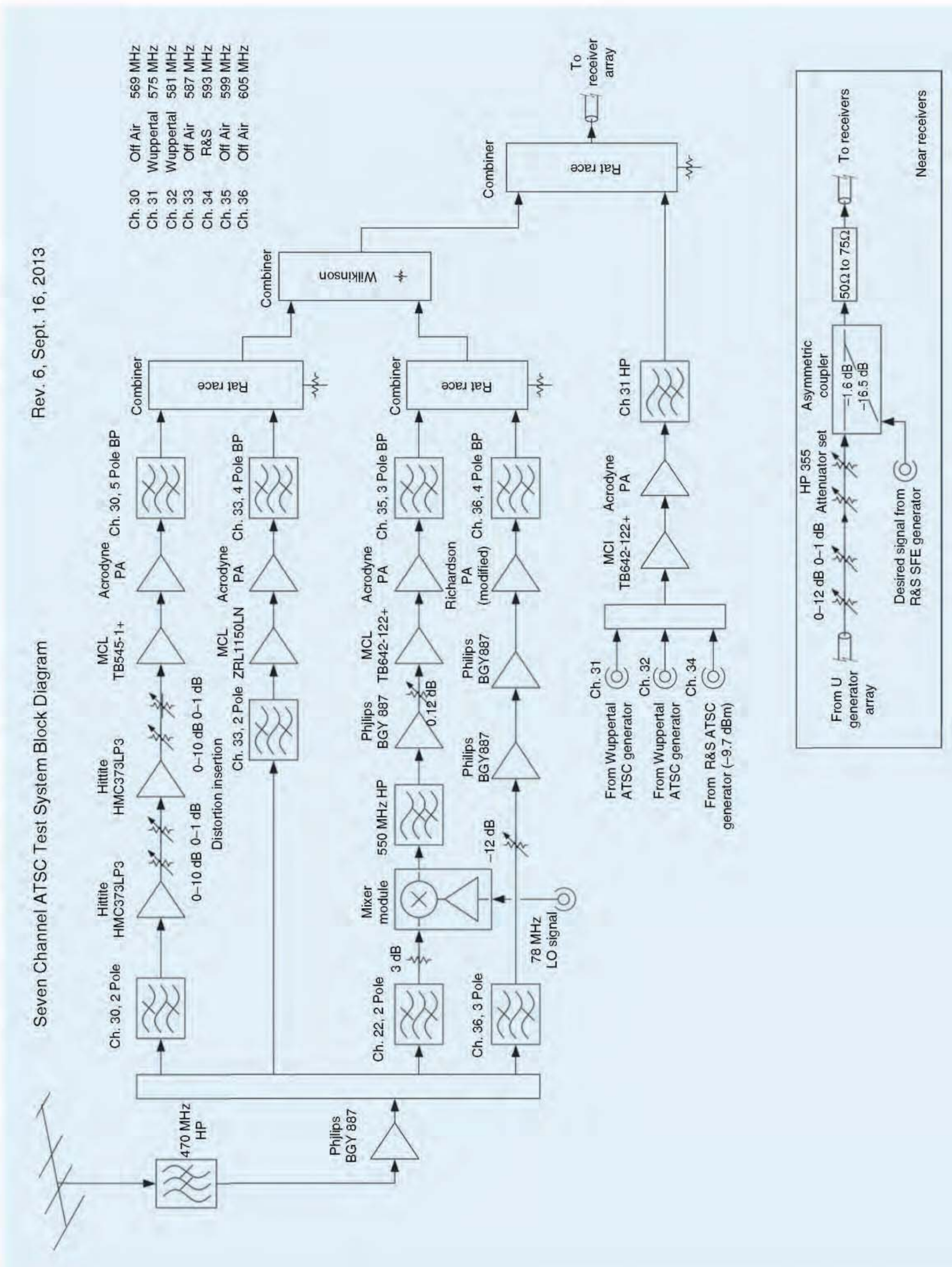

Figure 1. Block Diagram of Undesired Signal Generation System.

The D signal was generated by a laboratory quality 8-VSB generator. It creates a 8-VSB signal with an accurate amplitude consisting of a color bar picture accompanied by an audio tone. During testing, the U signal's amplitude was held constant at a known amplitude while the D signal's amplitude was slowly increased. As each receiver's threshold was reached, the D signal's amplitude was noted. We monitored picture quality to determine when each set was above threshold. The receivers were tested in four groups. The first group had three receivers while each of the following groups each had seven. The last group of receivers was not tested at all U signal offsets.

Due to the complications in generating multiple U signals, to test the receivers' performance at various channel offsets, the D signal's channel was shifted. For example, to test the receivers' response to a N + 1 U signal, the D frequency would be set to Ch. 29; for N + 2, Ch. 28, and so on. At any given offset, we first measured each receiver's noise limited threshold power with no interference present. This insured that the receivers were working correctly and that there were no other problems.

When testing for N+1 performance, the D = Ch. 29 and the first U = Ch.30. A filter was used to separate this signal from the other off-air signals and to remove the amplifier noise. It also removed most of this signal's existing adjacent channel interference (ACI). As we wished to determine receiver D/U performance limitations caused by typical ACI, this interference was carefully added back by overloading an amplifier and filtering the result. Our Ch. 30 thus exhibited typical transmitter ACI in shape and amplitude. This ACI was adjusted to about −49.5 dBc when measured in the central 5.38 MHz of the lower adjacent channel (i.e. Ch. 29). This is about 3 dB below the maximum value allowed by the FCC's RF Mask, but typical for the transmitters in the Portland area.

Note that because a different D channel was used to obtain each offset, the frequency of the first U channel was always on Ch. 30. The first measurement at a given offset would be with only Ch. 30 enabled. After the amplitude of the U signal was adjusted to a selected value, the amplitude of the D signal was raised from a low value in 0.5 dB increments until each set reached threshold D/U. From the threshold data thus obtained, the threshold D/U of each receiver was calculated and then statistically combined to determine the D/U values for 50 percent of the receivers operating (i.e. the median value) and 90 percent of the receivers operating. This data is labeled "1U" and shown with a blue trace in the charts.

Then, a second undesired signal was added. If we were testing with U1 = Ch. N+K, the second signal was added on U2 = Ch. N + 2K. For example, if the test was being performed with U1 = N + 2 the second signal would be added on U2 = Ch. N + 4. That is, D = Ch. 28, and as always, U1 = Ch. 30 and U2 = Ch. 32. The data from those measurements is labeled "2U" and shown in red in all of the charts. When there were two or more U signals, they were of equal power.

Lastly, the tests would be repeated with all seven of the test set's signals from Ch. 30 to Ch. 36 enabled. This data is labeled "7U" and shown in green in the charts.

A final test was included to determine receiver's D/U performance when the D signal was imbedded in the middle of a contiguous block of Undesired DTV signals. For this test, the laboratory U generator operating on Ch. 34 was moved to Ch. 37 and the D signal was inserted on Ch. 34. A Ch. 34 band-stop filter replaced the high-pass filter in the output path of the three locally generated signals to ensure that their broadband noise did not affect the outcome. The adjacent channel U signals on Ch. 33 and Ch. 35 deliberately exhibited typical adjacent channel ACI (about −47 dBc), producing similar results to that obtained when N + 1 was tested.

When multiple U signals were present, all were within 1 dB of being equal in amplitude. All U amplitude data is shown on a per-channel basis. That is, in the 2U test, the *total* U power is 3 dB greater than that shown; 9 dB greater for the 7U tests. The signal amplitudes used are thought to be accurate to within ±1.5 dB at each receiver's input terminals. Receiver thresholds were measured using 0.5 dB amplitude steps. Seven receivers were tested at the same time using a 8-way power splitter. A power meter was connected to the eighth splitter port via an impedance transformer. It was used to set the Undesired power to the correct maximum U amplitude; a set of step attenuators was then used to set the U amplitude to smaller values.

All the sets were purchased at retail in the last year. Twelve of them had nameplate manufacturing dates in 2013; three in 2012. The remaining nine had no manufacturing date information.

N+1 Data

In testing for N + 1 performance, D = Ch. 29. For 1U, U = Ch. 30. For 2U, U = Ch. 30 and Ch. 31. For 7U, U is a contiguous block from Ch. 30 to Ch. 36. The Ch. 30 signal exhibited about a −49.5 dBc ACI signal in Ch. 29 when measured in the central 5.38 MHz of the D channel. An ATSC signal conforming exactly to the full service mask as a maximum ACI = −46.5 dB when similarly measured.

In Figure 2, the solid curves show the D/U necessary for 90 percent of the receivers to decode the D signal; the dotted lines are the D/U for 50 percent of receivers working. Keep in mind that higher U amplitudes cause the D/U to be smaller, or lower on the chart. Further, receivers function when the D/U is above the trace; they fail if the D/U is below the trace.

The median receiver performance D/U performance at −34 dB corresponds closely to the measured Ch. 29 U signal ACI of −49.5 dB minus the required ≈15 dB S/N required to decode the DTV signal. Comparing these curves with the N + 2 data below clearly shows that N + 1 performance is limited by the transmitter, not the receivers. (We have also measured receiver data taken with a clean Ch. 30 source that shows the same thing.)

The dotted lines in Figure 2 show the FCC ACI requirements: the line at D/U = −26 dB for U = N + 1 and the line at D/U = −28 dB for U = N−1). Note that in the 7U case that

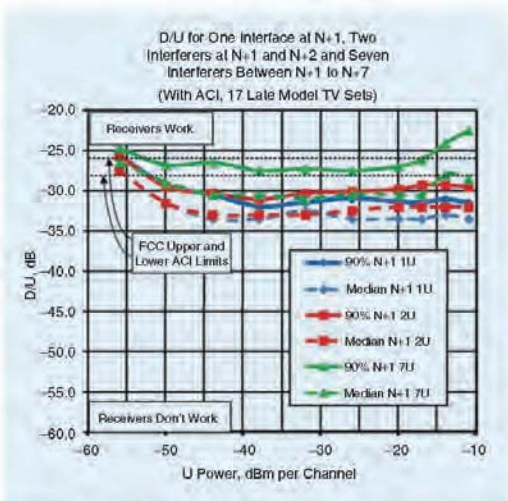

Figure 2. N + 1 Data.

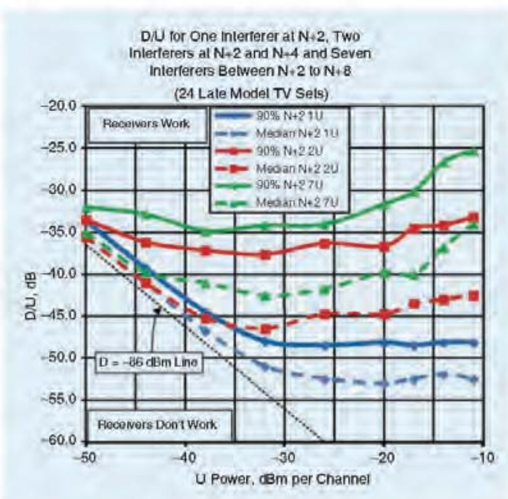

Figure 3. N + 2 Data.

10 percent of the receivers require more protection than the FCC provides. This will not be a problem if all of the signals (both D and U) are transmitted from a common site with the same ERP. Co-siting maximizes the D/U throughout the service area, minimizing reception problems.

N+2

Testing for N + 2, the D = Ch. 28. For 1U, U = Ch. 30. For 2U, U = Ch. 30 and Ch. 32. For 7U, U is a contiguous block from Ch. 30 to Ch. 36. Here we see performance limited by the receiver, not the transmitter.

In Figure 3, at the lowest U amplitude at the left on the chart, all of the median (dotted) traces converge to a D/U value of about −35 dB. This is a reflection of the receivers' inherit sensitivity, not their performance. Remember that D/U in dB is equal to the D amplitude in dBm minus the U amplitude, also in dBm. Therefore, at any point on the chart, one can determine the D amplitude by adding the U amplitude to the D/U value. Thus when U = −50 dBm and the D/U = −36 dB, then D = −86 dBm, or roughly the noise limited sensitivity of the receiver.

Note that D is constant all along a 1:1 slope down and to the right as shown by the dotted black line. This line connects all the points on the chart where D = −86 dBm. Thus, following the dotted blue trace from left to right, as it travels downward just above the dotted line, it indicates that 50 percent of the receivers are operating at their noise limited sensitivity and are completely unaffected by the presence of one U signal until the U amplitude reaches a value of about −35 dBm.

The other traces show how much the receivers are affected by the presence of first a signal on 2K and then the presence of seven contiguous signals.

The receiver's performance is well short of that assumed by OET-69. Further, reviewing transmitter frequencies and locations in many U.S. markets, it is relatively easy to find situations with frequency and amplitude relationships similar to the parts of this chart where the receiver performance is unsatisfactory.

N+3

For N + 3, D = Ch. 27. For 1U, U = Ch. 30. For 2U, U = Ch. 30 and Ch. 33. For 7U, U is a contiguous block from Ch. 30 to Ch. 36. Figure 4 shows that the late model TV sets exhibit an excellent D/U ability for a single interferer, but still have problems with multiple signals. The 90 percent curves are nearly the same as in the N + 2 case, but the median performance is much better.

N+4

For N + 4, D = Ch. 26. For 1U, U = Ch. 30. For 2U, U = Ch. 30 and Ch. 34. For 7U, U is a contiguous block from Ch. 30 to Ch. 36.

Figure 5 shows the median performance is getting better while the 90 percent performance is only slightly improved. One of the interesting features is that the 2U performance is often poorer than the 7U performance. A working theory is that there is some selectivity between the receiver's input amplifier and mixer, where the signal for the RF AGC (automatic gain control) pickoff is located. Thus, in the 2U case, the second U signal is eight channels from the D signal and thus partially overloads the amplifier with a signal that the AGC system does not respond to. The 7U measurement provides signals much closer to D's frequency. The AGC does respond to these signals and reduces the amplifier's gain, thus reducing the overload. Keep in mind this is our conjecture and only the receiver's designer knows for sure.

N+5

For N + 5, D = Ch. 25. For 1U, U = Ch. 30. For 2U, U = Ch. 30 and Ch. 35. For 7U, U is a contiguous block from Ch. 30

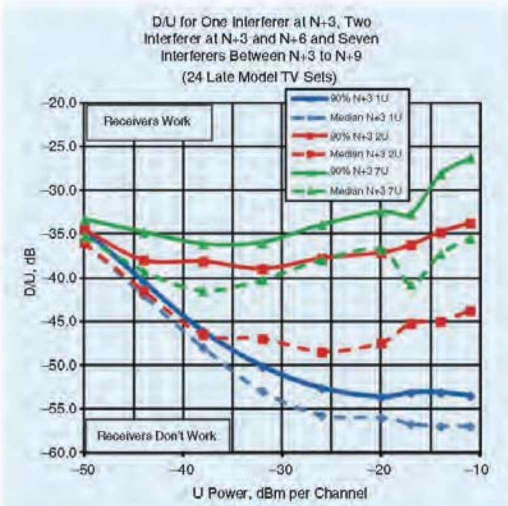

Figure 4. N + 3 Data.

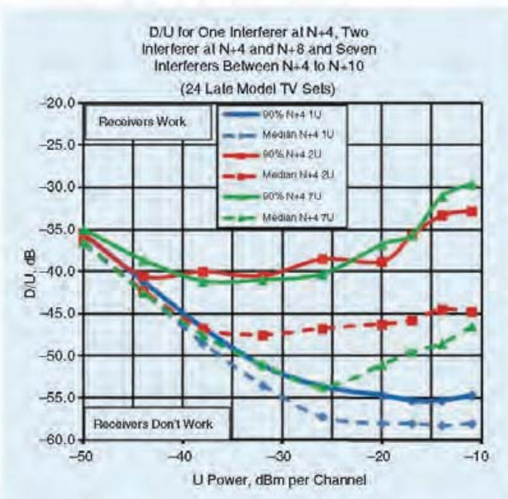

Figure 5. N + 4 Data.

to Ch. 36. Figure 6 shows that the median performance is getting good while the 90 percent performance is only slightly improved. The 2U 90 percent performance is now clearly poorer than the 7U. Even so, the D/U = −40 dB, while ACI is only protected even under FCC adjacent channel rules by about −27 dB.

N + 6

For N + 6, D = Ch. 24. For 1U, U = Ch. 30. For 2U, U = Ch. 30 and Ch. 36. For 7U, U is a contiguous block from Ch. 30 to Ch. 36. Figure 7 shows that again, the median performance is getting better while the 90 percent performance is only slightly improved. The 2U performance continues to be poorer than the 7U.

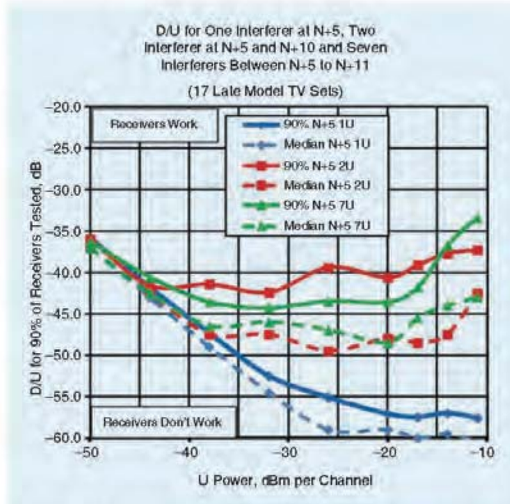

Figure 6. N + 5 Data.

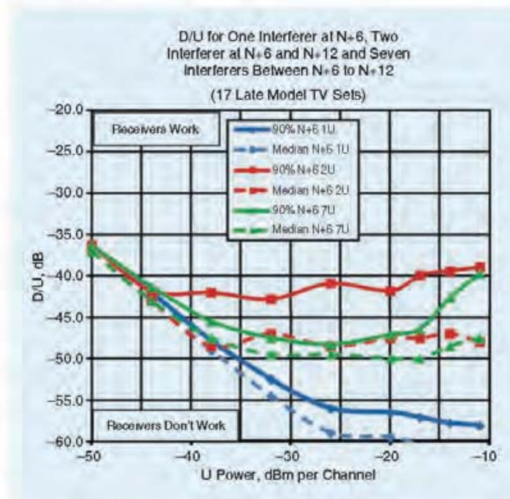

Figure 7. N + 6 Data.

N + 10

For N + 10, D = Ch. 20. For 1U, U = Ch. 30. There is no 2U data since we have no source that high in frequency. For 7U, U is a contiguous block from Ch. 30 to Ch. 36. Figure 8 shows that by N + 10 there are clearly no performance issues.

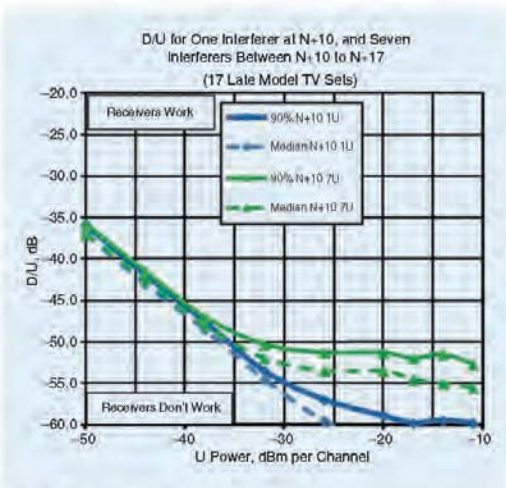

Figure 8. N−10 Data.

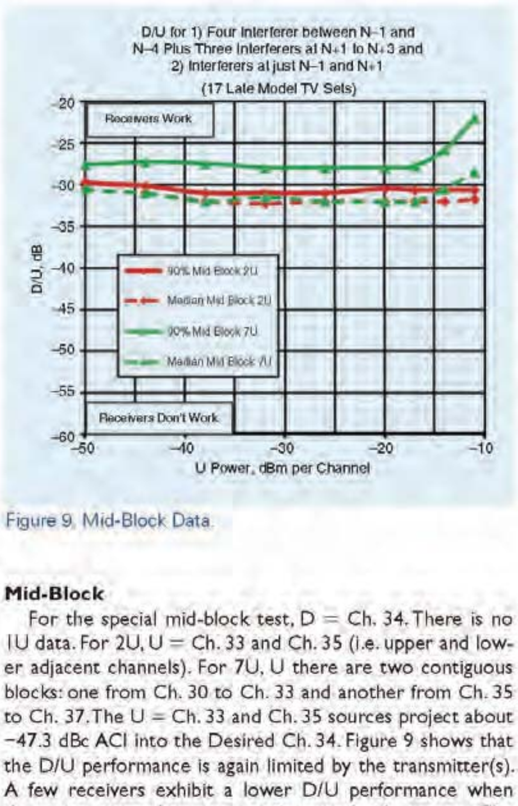

Figure 9. Mid-Block Data.

Mid-Block

For the special mid-block test, D = Ch. 34. There is no 1U data. For 2U, U = Ch. 33 and Ch. 35 (i.e. upper and lower adjacent channels). For 7U, U there are two contiguous blocks: one from Ch. 30 to Ch. 33 and another from Ch. 35 to Ch. 37. The U = Ch. 33 and Ch. 35 sources project about −47.3 dBc ACI into the Desired Ch. 34. Figure 9 shows that the D/U performance is again limited by the transmitter(s). A few receivers exhibit a lower D/U performance when there are more than two contiguous signals present. The green 7U trace at D/U ≈ −27 dB is similar to the FCC's protection ratio for ACI.

Conclusions

We have clearly shown that there currently is and there will be *at least* some additional interference problems under the FCC's current DTV allocation D/U protection ratios. How severe the problems will be needs a good deal of further study. Our receiver performance data should be a place to start.

The difficulties that will be encountered in the field are illustrated by our one computed example, an example that has given equivocal results. Our example is a co-sited N + 2, N + 4 pair of DTV U signals located 35 miles from the D station on channel N. Two different CAD programs were used to predict the signal strengths at a series of locations that were within a few miles of the two U stations, falling on a line between the two sites. A bidirectional dipole antenna was assumed since the field strength of the D signal was great enough to use a simple antenna. Computing the D/U ratios based on the data from the first CAD program indicated about 90 percent of our receivers would work. The data from the other CAD program showed only 50 percent of them would operate properly. We have no measured data so there is a complete uncertainty if either CAD program actually reflects reality.

Until the full extent of the interference problem is known, when given the opportunity, station owners should consider co-siting their facilities with other stations in their service area—especially stations on nearby channels—which minimizes the differences in receive powers between stations. It also promotes the efficient use of the TV spectrum while minimizing interference and other reception problems.

More work needs to be done. Our intent is to continue measuring receiver performance. We have only measured the RF performance with the U signals above the D signal, and we would like to ultimately measure their performance when the D signal is above. We would also like look into other problems such as FM signals interfering with DTV receivers tuned to high-band VHF stations [4] and to investigate how DTV receivers respond to LTE sources in the 700 MHz band.

For others, the location and extent of the areas that will experience problematic D/U ratios needs a great deal of study. And, at last, the correspondence of results with CAD tools to actual field measured data needs determined. In any case, we hope our data will prove useful.

References

[1] FCC, "OET-69, Longley Rice Methodology for Evaluating TV Coverage and Interference," Feb. 6, 2004.
[2] CFR47 § 73.616, e, 1, ii and iii
[3] S. Martin, "RF Performance of DTV Converter Boxes-An Overview," IEEE Transactions on Broadcasting, vol. 56, no 4, Dec. 2010, pp. 441–451.
[4] ATSC document A/74, revised 2010. See p. 79, Annex E.

The Authors

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