Introduction – Positive Train Control (PTC) Systems and Television Interference

Positive train control (PTC) systems operating in the 217-222 MHz frequency band offer active collision avoidance mechanisms as a means to protect the lives of passengers and crew aboard trains. This frequency band includes the Automated Maritime Telecommunications Service (AMTS, 217-218 MHz and 219-220 MHz), the 218-219 MHz Service, and the 220-222 MHz Service. The PTC Enforcement and Implementation Act requires all trains providing passenger service and freight trains operating on lines carrying toxic and poisonous-by-inhalation hazardous materials to implement interoperable PTC systems by December 31, 2018.[1] The Commission, having jurisdiction in approving the use of spectrum in the 217-222 MHz band and radio systems inherent in PTC systems, seeks to facilitate implementation of these important safety systems. However, because of the proximity of the PTC spectrum to TV broadcast spectrum, PTC systems must be properly designed to avoid causing harmful interference to television reception on TV Channel 13 (See Figure 1 below). The Commission's rules also restrict AMTS base stations from causing harmful interference to TV Channel 10. Licensees seeking to deploy PTC in the AMTS and 218-219 MHz Service bands are required to provide technical analyses with their applications showing how their PTC system is designed to avoid potential interference to television reception on those channels.

We note that 220 MHz Service licensees are not required to submit interference studies or mitigation plans, although they do have a general obligation to design and operate their systems to minimize the potential for causing harmful interference to other licensees, including television channels.

The Commission seeks to strike a balance between facilitating PTC deployment while minimizing the potential for interference to the broadcast television service. With a recent influx of applications to the Commission requesting approval of PTC systems, OET offers applicants a set of best practices to consider when evaluating the potential of PTC systems to cause harmful interference to television receivers. We emphasize that this is non-binding technical guidance and PTC applicants may submit any reasonable technical analysis to show how their PTC implementations mitigate potential interference to television reception.

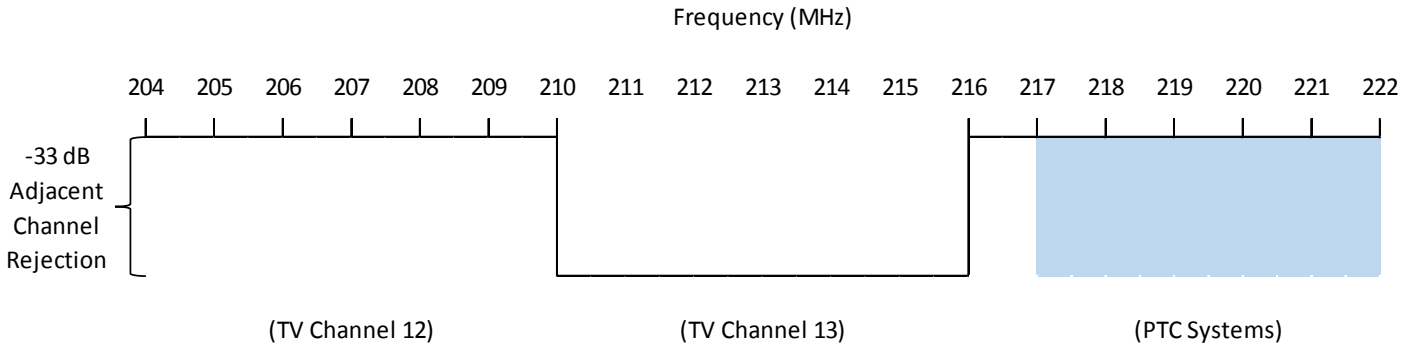

Figure 1. *Relationship between PTC and TV Channel 13 frequency assignments.*

[1] 49 U.S.C. § 20157(a)(1). Railroads may request up to a 24-month extension of the deadline in limited circumstances to implement PTC.

Best Practices – Gathering Existing Guidance Applicable to PTC System Studies

These best practices for assessing potential interference to television reception are found in a mix of OET Bulletins and other guidance documents available on the Commission's website. This guidance document collects these principles into a single reference for ease of use, but the reader should refer to OET Bulletin Nos. 69 and 74 (OET-69 and OET-74, respectively) for a complete description of applicable procedures.[2] OET also makes available the *TVStudy* software program which implements the technical guidance provided in OET-69 and OET-74. PTC applicants may wish to use this software to predict the extent of potential interference to TV reception. The recommended analysis process to determine the number of households potentially affected by the proposed PTC system is summarized as follows:

1) As defined in OET-69 and following the methodology specified in 47 CFR § 73.625(b)(1), the noise-limited service contour defining the TV station's area) subject to interference calculation is determined, using F(50,90) 36 dBµV/m for full-power VHF digital TV stations and F(50,90) 48 dBµV/m for VHF digital Class A stations.

2) The area within a station's contour is divided into grid cells based on a global grid, 2-kilometers per side for full-power TV stations and 1-kilometer per side for Class A stations.

3) Each grid cell is then evaluated at a single calculation point based on the centroid of population that falls within each cell, or if the cell does not cover any population, the point is determined based on the geometric center of the cell.

4) The PTC base stations outside of the distance defined in Table 12 of OET-74 are removed from the interference analysis, based on their geographic coordinates, effective radiated power (ERP) and computed antenna height above average terrain (HAAT).

5) The desired (TV) F(50,90) and undesired (PTC) F(50,10) field strengths are then predicted at each calculation point by applying the Longley-Rice propagation model between the TV and PTC transmitters. Each cell is considered to be included as part of a TV station's service area and thus subject to interference protection if its F(50,90) field strength determined at a given calculation point exceeds its noise-limited service threshold. The antenna discrimination as specified in OET-69 is applied to the undesired PTC F(50,10) field strength, assuming the TV receive antenna is oriented toward the TV transmitter.

6) Desired-to-undesired (D/U) field strength ratios are determined at each calculation point within the TV service area based on the ratio of the desired TV station's predicted field strength to the root-sum-square (RSS) of the predicted interfering field strengths from the PTC base stations which remain after the culling specified in Step 4 above.

7) Finally, the predicted interference at each calculation point in the desired station's coverage area is examined to determine if interference is predicted from the cumulative interference power of the PTC base stations. The D/U ratio threshold for interference of -33 dB is used to

[2] OET Bulletin Number 69 is available at: https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet69/oet69.pdf; OET Bulletin Number 74 is available at: https://transition.fcc.gov/bureaus/oet/info/documents/bulletins/oet74/OET74.pdf.

assess the extent of predicted interference at each calculation point. Interference is considered to exist in any grid cell if the desired signal provides service to the cell and the D/U ratio determined by the previous step is less than -33 dB.

Discussion of Additional Study Factors

OET also provides the following description of additional factors that applicants have considered when requesting approval to deploy PTC systems, and how best to configure each factor to be consistent with Commission rules, policies, guidance, and precedents. These factors are:

- *Viewership percentage*. Over-the-air TV viewership rates, typically given as a percentage of the overall population in a market, are available from various sources, including Nielsen, National Association of Broadcasters (NAB), Consumer Technology Association (CTA), and the TV Bureau of Advertising (TVB), to name a few. Although we recognize that not all TV viewers receive their signals over-the-air, applying a single percentage across the market does not appropriately account for statistical variations of those percentages within the market itself. Specifically, it ignores the possibility that there might be a different over-the-air viewership rate (higher or lower) than the market average in the area in which potential interference to TV is predicted to occur due to the PTC system. For this reason, consistent with precedent, OET does not recommend that viewership rate adjustments be applied when performing PTC interference analyses.
- *Narrowband adjustments*. Laboratory measurements show very little difference in how a TV receiver responds to a signal in an adjacent 6 MHz channel when it is shifted away from the receiver center frequency or if its bandwidth changes. Additionally, precedent shows the Commission has relied on -33 dB as an adjacent channel interference threshold for other similarly narrowband systems as PTC. (See Amtrak, LoJack, Avista, *etc.*) Therefore, OET does not recommend adjusting the interference D/U threshold or reducing the undesired signal power based on the relative bandwidth or channel edge separation of the PTC signal as compared to a 6 MHz TV channel.
- *Polarization loss*. PTC systems are typically vertically polarized while most TV stations are horizontally polarized, although some TV station antennas also have a vertical polarization component. (See, e.g., ITU-R BT.419) Ascertaining an appropriate value of cross-polarization loss in various environments is challenging, particularly across an entire TV service area where signals will normally encounter obstacles (*i.e.*, buildings, trees, hills, *etc.*) prior to reception. While OET does not dismiss in principle that a cross-polarization loss factor could be reasonably applied under certain circumstances, there is no Commission precedent at this time for applying such a factor. Thus, an applicant wishing to use a specific cross-polarization loss factor must demonstrate why that particular factor should apply and under which conditions, as well as provide supporting documentation such as measurements across the area of potential interference
- *Additional Filter loss*. When a PTC applicant that plans to use AMTS or 218-219 MHz Service spectrum predicts that its deployment would potentially cause interference within a TV station's service area, our rules require that the applicant develop a plan to control any interference to reception within that area. (See 47 CFR §§ 80.215(h) and 95.861.) An example component of an interference mitigation plan would be to provide free installation of filters that effectively

attenuate the interfering PTC signal to any households experiencing interference to over-the-air TV reception. The interference analysis done by the PTC applicant must show the extent of predicted interference within a TV station's service area prior to implementation of an interference mitigation plan, whereas the additional filter losses would be applied subsequently as a mitigating strategy after deployment.

- *Clutter loss*. The Commission's precedent of predicting interference to TV receivers using OET-69 and OET-74 is not based on specific locations, but rather a uniform grid of points across the TV station's service area. OET acknowledges that losses due to ground clutter can and often are reasonably applied under certain conditions. However, because of the grid-based method used to evaluate TV service areas, the clutter types and associated losses may vary widely across the one to four square kilometer areas of study in each grid cell, depending on what type of TV station is being analyzed. Thus, it is not appropriate to apply a single clutter loss factor across an area that may contain several different clutter types. (See ISIX Order.)
- *Population data*. When assessing whether a requested PTC base station potentially causes interference to TV reception, our AMTS rules define interference to a maximum of 100 residences as the threshold under which no additional mitigation action is necessary. Therefore, households, rather than persons, based on 2010 U.S. Census population data, should be used as the metric for determining whether the predicted interference is significant enough to require the development of an interference mitigation plan. (See 47 CFR § 80.215(h)(3)).
- *Power/height adjustments*. Some applicants have applied the rationale that either their requested effective radiated power (ERP) or antenna height above average terrain (HAAT) is less than the maximum permitted by the rules, and so their potential interference should be reduced by a corresponding amount that their ERP or antenna HAAT is below the maximum. However, because analyses conducted using OET-69 and OET-74 are based on the actual ERP and antenna HAAT for each transmitter, such derating is unnecessary. Therefore, OET does not recommend adjusting the interference D/U threshold or reducing the undesired signal power based on the amount by which a requested transmitter is below the maximum ERP or antenna HAAT permitted by the rules; rather, applicants should instead rely on actual ERP and antenna HAAT values for the requested deployment.
- *Assessment grid*. The complete area within the service contour should be divided into a uniform grid before interference predictions are made. This facilitates comparison of different configurations. OET recommends following the procedures defined in OET-69 and OET-74, using a global grid as described in OET-74 to evaluate interference within the TV station's service area.
- *Television receive antenna*. The TV receive pattern defined in OET-69 for VHF is a directional antenna that has a directional azimuth pattern with 10 dBd gain and a 12 dB front-to-back ratio. Undesired signals are proportionally reduced based on the off-axis gain of this antenna while it is pointing toward the direction of the TV transmitter. See OET-69 for more details of this receive antenna pattern. In addition, the TV receive antenna is assumed to be at a 10 meter receive height (about 30 feet) above ground level at the calculation point.
- *Masking interference*. When considering if a PTC system will cause new interference to a TV station's service area, interference predicted from existing TV stations may be considered to the extent that any such co-channel (*e.g.*, TV Channel 13) or adjacent channel (*e.g.*, TV Channel 12) TV-to-TV interference already exists at the grid cell calculation point. This existing interference may be considered to "mask" the predicted interference due to PTC in that grid cell. (See *TVStudy* Manual.) In other words, in a grid cell where interference to one television station

from another is predicted to occur, PTC applicants may ignore any interference predicted in that grid cell due to the PTC system deployment. This approach is consistent with the treatment of interference between television stations under our rules. (See 47 CFR § 73.616(e).)

- *Determination of service*. When considering if a PTC system will cause interference in a TV station's service area, OET-69 and OET-74 only consider grid cells for which the desired TV signal is above the service threshold. That is, after the Longley-Rice model is applied, some of the points within the TV contour may not be considered part of a station's service area due to terrain losses. As specified in OET-74, determination of service should ignore Longley-Rice error code (kwx code) flags and determine whether TV service exists based on the predicted field strength and service threshold at each calculation point.
- *Mobile PTC transmitters.* Mobile PTC transmitters installed on trains have the potential to generate harmful interference to TV receivers, however the extent of detail required to be submitted by PTC applicants to demonstrate compliance with our rules limiting such potential interference varies by band. For instance, our 218-219 MHz Service rules specifically require licensees to submit an interference analysis of mobile transmissions (as well base station transmissions) when making interference prediction calculations (47 CFR §§ 95.815(a), 95.861(c)). However, our 220-222 MHz Service and AMTS rules do not contain a similar requirement for mobile transmitters. Regardless of these differences in applicant requirements, we again remind all PTC applicants of their general obligation to design and operate their systems to minimize the potential of causing harmful interference to TV reception. While it is likely that any interference from mobile PTC transmitters will be intermittent, licensees required to submit interference studies and mitigation plans may find it beneficial to address the potential for their mobile PTC transmitters to interfere with TV reception and related mitigation strategies.
- *TV Channel 10*. Our rules require that PTC applicants submit interference mitigation plans accounting for potential interference to both TV channel 10 (*see* 47 CFR § 80.215(h)) and TV channel 13. These rules were written to protect <u>analog</u> TV receivers from intermodulation effects, which can be caused by the mixing of signals transmitted on "taboo" channels. However, with respect to <u>digital</u> TV reception, OET Bulletin No. 69 and our DTV protection rules (*see* 47 CFR § 73.623 (c)(2)) do not contain interference criteria to account for potential intermodulation interference such as that caused by transmissions on "taboo" channels**.** Therefore, to assert compliance with the protection and mitigation requirements in our rules regarding potential interference to channel 10, PTC applicants intending to operate in the AMTS band should briefly explain that the transition to digital TV results in a lack of criteria to assess potential interference to channel 10, that harmful interference to TV Channel 10 is unlikely, and that if such interference is caused by PTC operations, it will be cured at the applicant's expense. For TV Channel 13, the interference environment differs, with PTC systems operating adjacent in frequency, and thus a full analysis is required as outlined by the general guidance provided throughout this document. As noted above, all PTC applicants have a general obligation to design and operate their systems to minimize the potential of causing harmful interference to TV reception.

Using *TVStudy* Software to Setup PTC to TV Interference Analyses

The FCC's Office of Engineering and Technology (OET) has released software, called *TVStudy*, which interfaces with data contained in FCC Media Bureau's CDBS/LMS databases. *TVStudy* software is provided for both Mac and Linux platforms with Java and C source code freely available under a BSD (Berkley Software Distribution) license.

1) Create a database of the PTC base station locations following the procedures in the *TVStudy* Manual for the creation of a fixed wireless dataset. (See Appendix B of *TVStudy* Manual.) Make sure your *TVStudy* database includes a version of the LMS or CDBS database that contains the TV station(s) you wish to study.
2) Create a new 'Wireless->TV Interference' study. A setup wizard will launch to help you set up your scenario.
3) In wizard screen: Right hand side – search for the TV station you are studying. Select (highlight) the TV station from the list of search results.
4) In wizard screen: 'Study Build Settings' group – Select your PTC dataset in the Wireless Station Data drop-down box. Enter your PTC system center frequency and bandwidth in the 'WL Freq. MHz' and 'WL B/W, MHz' boxes.
5) In wizard screen: 'Study Build Settings' group – Enter study name or accept default name.
6) In wizard screen: Click the "output settings" button and select your output options. It is recommended that "Detailed results, CSV", "Parameters, CSV" and "Detailed cell data, CSV" be included. See the *TVStudy* Manual for a complete list of output file options.
7) The default study template will appropriately set the contour thresholds and set the grid size to 2 kilometers. If you want to change the grid size to 1 kilometer or make any other study parameter changes, click the "Build" button and wait for the study to build then proceed to Step 9. Otherwise, click the "Build & Run" button and skip the following steps.
8) Once the study is built, close the build log window and open the study. Click on the 'Parameters' tab and select 'Analysis' from the Study Parameters drop-down window. Change the cell size from 2 to 1 and save and close the window. By selecting the 'Wireless-to-TV' interference type in TVStudy, the Longley-Rice kwx code flags are automatically ignored when determining service.
9) Run the study.

The "U_iRSSCelData.csv" output file will provide information on the number of households impacted for each grid cell. Appendix C and D of the *TVStudy* Manual contains descriptions of the output files and formats.

Conclusion – What to Include in PTC Applications

PTC applications[3] must contain sufficient information regarding analyses conducted, assumptions made, results, and, if necessary, any interference mitigation tools or processes that will be used so that the Commission can make an informed decision regarding the extent and impact of any potential interference from a proposed PTC system to television reception, depending on the specific spectrum used. The procedure outlined above is designed to produce such an analysis. While we are not requiring rigid adherence to the procedure outlined above, analyses that use other methods must provide a detailed explanation for deviations from the assumptions and procedures outlined above, including why those variations would reasonably apply to the proposed PTC system at hand.

If using *TVStudy*, we request that the summary results file be included in the application, along with the settings file to ascertain the software settings used in the analysis. We may ask for additional details about how the study was conducted. Technical information on each PTC transmitter site will be obtained based on the application submitted to WTB's Universal Licensing System (ULS). If antennas are not sufficiently described, either in horizontal (azimuth) or vertical (elevation) directions, omnidirectional (isotropic) antenna pattern(s) will be assumed. When the amount of predicted interference using the method described above exceeds 100 households, the applicant must include an interference mitigation plan that, when implemented, would reasonably diminish concerns of potential interference to television reception along the train tracks where the PTC system is proposed to be deployed. Appropriate mitigations include but are not limited to actions such as installing filters in homes where interference is reported, using directional transmit antennas, lowering transmit power or antenna height, and/or considering alternate transmitter locations.

[3] This guidance applies to 218-219 MHz Service and AMTS licensees only; as discussed above, 220-222 MHz Service licensees are not required to provide this information outside of their general obligation to avoid the potential for causing interference to other licensees, including television stations.