Appendix A

Preliminary Coverage Analysis

The coverage analysis summarized on pages 7 and 8 of the Joint Comments was conducted using an allotment/assignment model described in the attached Appendix B.[1/] The model, implemented in software developed by the broadcast industry, was designed to determine the "best" ATV service area accommodation results for each of the proposed ATV systems. The software is capable of generating its own optimized allotment/assignment plans, improving existing plans or simply evaluating proposed allotment plans -- such as the one appended to the Second Further Notice.

To illustrate the ATV coverage implications under the FCC approach vis-a-vis the replication/maximization approach, a study was conducted to examine the difference, if any, in the cumulative total coverage for all ATV stations in the U.S. between the two approaches. The study also examined the percentage of stations that would achieve coverage areas at least as large as their current service areas as well as the percentage of stations that achieve an exact replication of their existing service area. In analyzing the Second Further Notice approach, referred to herein as the random pairing/UHF/55-mile analysis, the study utilized the sample Table of Allotments attached to the Second Further Notice, ATV station parameters identified in the Extension Order, Attachment at 2, and recent test data. The second approach, referred to herein as the replication/maximization analysis, used the same starting point but changed channel assignments as needed to achieve the best matching between the ATV service area and the NTSC service area. The analyses were conducted taking into account only co-channel interference, not adjacent-channel or taboo interference.

Random Pairing/UHF/55-mile Analysis

To determine the total coverage under the FCC approach it was necessary to pair all the channels identified in the FCC sample table with the corresponding NTSC stations. Since the FCC sample table already paired those sites with a single station at them, only sites with multiple ATV channels required pairing. Those ATV channels were randomly assigned NTSC channels by the computer and a complete paired FCC sample table was generated. The software then used the paired table

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[1/] Also include in Appendix B are the recommended planning factors for the new ATV service. The parameters described in the appendix are slightly different from the ones described in the Extension Order, Attachment at 2.

to compute the ATV coverage area for all the station in the U.S. using the technical parameters listed below. The parameters used in this analysis were obtained from the FCC Extension Order, with the exception of the co-channel D/U ratio which was acquired from recent test data. Statistics on percentage of ATV stations achieving coverage equal or exceeding coverage and replication were computed.

ATV Height Above Average Terrain (feet)		1200 feet
ATV Effected Radiated Power	Low VHF	0.8 kW
	High VHF	3.2 kW
	UHF	327.9 kW
ATV maximum service area		55.0 miles
Carrier-to-Noise ratio		16 dB
Co-channel D/U		
ATV into NTSC		34 dB
NTSC into ATV		7 dB
ATV into ATV		15 dB

Replication/Maximization Analysis

Starting with the FCC paired sample table generated from the previous analysis, the software examined each paired ATV assignment with its companion NTSC assignment to determine the degree to which the assigned paired ATV channel matched the interference-free service area of its companion station. For locations where additional channels could be assigned for ATV use, the software analyzed those channels to determine if a substitution would allow a better match and, if so, changed the assignment appropriately. Once the replication process was completed and a modified table of allotment generated, the software expanded the service areas of smaller ATV stations (up to 55 miles) so long as they did not cause any additional interference to existing NTSC service. ATV coverage was computed based on the existing NTSC station height and the power required to achieve the same NTSC grade B service area.

SPECTRUM UTILIZATION ANALYSIS FOR ATV SYSTEMS

1. Introduction

The analysis of spectrum usage of the ATV Systems employs an allotment/assignment model with algorithms similar to those used by the FCC staff and a service and interference computer program conforming to a model developed by Specialist Group 11 of PS/WP3.[1] Combining the two programs permitted the development of approximately optimum allotment/assignment plans and comparison of service expected to be provided by each ATV system, if implemented, with service provided by the NTSC system currently in use.

The plan seeks, station-by-station, to match or exceed the current interference-limited NTSC service area with a future companion ATV service area. The analysis includes consideration of vacant noncommercial allotments as well as authorized stations and pending applications.[2] Station locations and antenna heights above average terrain are assumed to be the same for the NTSC and ATV services. The software was designed to achieve, to the extent possible, the twin objectives of avoiding unacceptable interference to the NTSC service and optimization of the ATV service. Other input parameters to the program are the planning factors developed by Specialist Group 10 of PS/WP3[3] and factors specific to each ATV system as determined by the test programs at the ATTC and ATEL.

2. Model Description

Working Party 3 was given the responsibility for carrying out studies on the availability of spectrum for advanced television systems. To support this activity, two computer models were developed to determine the "best" ATV accommodation results, including the service area expected, for each of the proposed ATV formats. The first model, the allotment/assignment model, was that developed by the FCC, but modified to take into account taboo restrictions for both NTSC and ATV. The second model, the coverage and interference model, was developed to evaluate the various allotment/assignment plans generated by the first model. The coverage

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[1] Fifth Interim Report of the Spectrum Utilization and Alternatives Working Party of the ACATS Planning Subcommittee; Doc. PS/WP3-199; pp. 29-45; February 3, 1992.

[2] The data base for the reference NTSC analysis, and for the ATV analysis, is as of August 1, 1992. The need to maintain comparability for the five ATV systems studied requires that the same data base be retained throughout the analysis process. Although data base changes occur with time, those changes are moderate. The ultimate allotment/assignment table, using a current data base, will differ very little from the tables developed system-by-system.

[3] Fifth Interim Report; Doc. PS/WP3-199; pp. 22-29; February 3, 1992.

and interference model was first proposed by Specialist Group 11 of PS/WP3, then implemented in software by the broadcast industry.

a. Allotment/Assignment Model

The allotment/assignment model used in this analysis is an offspring of the FCC allotment/assignment model given to the Advisory Committee in the spring of 1990. The model uses minimum separation distances to determine the number of existing TV stations that can be accommodated with an additional ATV channel under different co-channel and adjacent-channel input conditions. Specifically, the model uses a heuristic approach to determine the "best" ATV accommodation statistics for each input condition. This is accomplished by first ordering the existing NTSC stations according to the apparent difficulty of finding a channel for them and using a number of different mathematical algorithms that try to find the largest number of stations that can be accommodated nationwide, i.e., the "best" solution. The output of the model is an allotment/assignment table that pairs NTSC stations with ATV assignments.

The allotment/assignment model is comprised of two basic modules. The first module, the constraint generator module, determines for each existing NTSC station all possible ATV channels that could be assigned for that station based on user selected minimum co-channel and adjacent- channel separation distances or constraints. The second module, the optimizer/evaluator module, assigns ATV channels to existing NTSC stations based on mathematical algorithms[4], generally referred to as successive augmentation algorithms, that iteratively search for the lowest number of ATV channels that could be assigned to accommodate the entire set of NTSC stations in a given area. These new ATV assignments satisfy both the NTSC and ATV separation distance constraints.

The FCC version of the allotment/assignment software is capable of using all of the successive augmentation algorithms mentioned in footnote 4. However, based on extensive studies and experimentation, it was determined that the Frank Box algorithm almost always achieves the highest ATV accommodation statistics. The Frank Box algorithm was therefore selected to conduct all of the allotment/assignment studies for PS/WP3.

The HDTV allotment/assignment problem is so large and so complex that it is impossible, even with the fastest computers, to examine all possible permutations to determine the best solution. Furthermore, the various permutations and solutions are somewhat related to where the analysis is started. For example, if the software is biased to start by finding ATV channels for Roanoke, Va. before finding channels for New York City, the outcome will be different than achieved with the study starting at New York City. Most likely, the overall accommodation statistics will suffer. Selection of the right starting point or points is important so as to achieve optimum or near-optimum solutions, i.e., the best ATV accommodation statistics. Again, based on extensive

[4] They include: [1] the LF (largest first) algorithm of Welsh and Powell, [2] the SL (smallest last) algorithm of Matula, [3] the DSATUR (degree of saturation) algorithm of Brelaz, [4] the RLF (recursive largest first) algorithm of Leighton, and [5] an iterative algorithm by Frank Box.

experimentation, ten starting points were selected by order of importance[5] and used as starting points for running the model.

As stated earlier, the 1990 version of the FCC model was based on fixed separation distance criteria to ascertain the availability of spectrum for ATV. The model did not attempt to consider UHF taboo restrictions between ATV assignments. A series of modifications and additions have been made to the FCC version of the model.

The modified software offers the user the following options for analysis:

1) The ability to select co-channel separation distance. The default is 155 km.

2) The ability to use different first adjacent-channel spacings for VHF and UHF as well as the ability to allow for the use of an adjacent channel with any co-located station or within a user-specified distance of any station. Both VHF and UHF first adjacent-channel restrictions default to 87.7 km.

3) The ability to consider any or all of the UHF taboos when making ATV allotments.

4) The ability to adjust any of the taboo minimum separation distances.

5) The ability to permit the use of a co-located taboo channel or the use of a taboo channel within a distance selected by the users. The default is to apply all taboo channel restrictions, including adjacent channels.

6) The ability to select the image, IF-Beat and Inter/Cross modulation taboo channels to be used in the analysis.

7) The ability to apply the adjacent-channel and any of the UHF taboo separation constraints toward both NTSC and ATV allotments. The default is to apply the constraints only toward the existing NTSC allotments.

Changes in the FCC software were limited primarily to the constraint generator module. No changes were made to the optimizer/evaluator module with the exception of generating a list of available ATV channels for each NTSC station after the allotment process was completed. No attempt was made to improve the optimizer/evaluator module. Output from the modified software program was presented in PS/WP3 document 174 entitled: "Preliminary Analysis of VHF and UHF Scenarios Part III (NTSC Taboos)".

b. Coverage and Interference Model

The coverage and interference model was developed for the purpose of comparing proponent transmission systems based on ATTC and ATEL test data, and analyzing proposed allotment plans generated by the allotment/assignment model. Specifically, the model provides the user

[5] The selected cities are: Boston, Chicago, Dallas, Detroit, Houston, Los Angeles, New York, Philadelphia, San Francisco and Washington.

with the tools to use measured RF receiver interference and noise thresholds for the various ATV systems, and translate those thresholds into expected geographical service and interference areas. The model is useful also in exploring the trade-off between the coverage areas of new ATV stations and the degree of interference protection afforded to the present television service.

The coverage and interference model comprises five basic modules and a number of integration and support modules. The first module, the input module, was designed to allow the user, through the use of menus, to specify the type of analysis desired such as a coverage and interference analysis or an ERP calculation analysis, etc., by manually inputing all necessary parameters or retrieving the information from various data bases. For example, the user has the option of conducting coverage and interference analyses for NTSC, ATV, or both NTSC and ATV for two stations or the entire United States. Station parameters could be either manually entered by the user, selected from an ASCII file specified by the user, retrieved from the FCC engineering data base, or retrieved from the allotment/assignment plan. Appropriate default values for various technical parameters were furnished, but the user has the option of modifying the default parameters as desired.

The second module, the service and interference contour calculation module, was designed to compute the sets of points that define the service and interference contours. The computation uses the FCC 50/50 and 50/10 propagation curves, the 30-second terrain data base, and the methods specified in the FCC's Rules and Regulations. The module was also designed to generate FCC 50/90 curves for digital system service calculations. In addition, the module, if specified by the user, is capable of calculating the coverage and interference using the terrain roughness correction factor specified in the FCC Rules. The terrain roughness correction factor, however, was not applied in the PS/WP3 spectrum utilization analysis.

The third module, the service and interference area calculation module, was designed to calculate the coverage area enclosed by specified contours (Grade B for NTSC, noise-limited threshold for ATV), and the portion of the coverage area that is free of interference i.e., the interference-limited service area of a station. Specifically, this module determines the amount of interference received (if any) as well as the severity of the interference, including the area within the coverage contour where interference is present, the direction from the interference source, and identification of the station or stations causing the interference. The interference-limited service area is determined taking into account co-channel, and any or all of the adjacent and taboo channels.

The fourth module, the co-channel ERP calculation module, calculates the maximum ERP allowed for a proposed ATV facility based on HAAT and a specified penetration distance of interference from the undesired station into the coverage contour of the desired station. Calculations can be made over a range of heights above average terrain.

The fifth and last module is a graphical display module that provides a plot or plots of the particular analysis selected. The module was designed to support an HP-GL plotter protocol. Plotting parameters, such as color selection and scaling, are user specified.

c. Integration of Allotment/Assignment Model with Coverage and Interference Model

SG-11 of PS/WP3 was tasked with the responsibility of developing a coverage and interference model to evaluate and compare ATV transmission systems and evaluate proposed allotment plans. Specifically, the group was tasked with implementing a model that is capable of meeting the following three reasonable, but conflicting, objectives for an ATV simulcast service[6] :

1) All, or nearly all, present NTSC assignments should have an assigned ATV simulcast channel.

2) An ATV simulcast station should have a service area that is at least comparable to the service area of the NTSC station to which it is paired.

3) Reception of existing NTSC stations should not be impacted significantly by interference from new ATV stations.

To assess how well these objectives are met for the various ATV formats, further software development was deemed necessary. The concept of pairing ATV assignments with NTSC stations based on comparable coverage necessitated linking the output of the allotment/assignment model to the coverage and interference model so as to determine how ATV channels that are available for assignment could be used to achieve the best matching with NTSC service areas.

The process of improving the assignment plan by incorporating the concept of automatic interference matching required the use and continuous update of the list of available channels generated by the allotment/assignment model. In addition to linking both models, new software was developed to perform two essential functions. The first function is to analyze the existing NTSC environment and create a data base (baseline) of existing NTSC interference. The second is to analyze and improve the ATV plan generated by the allotment/assignment model.

The exercise of creating a baseline of existing NTSC interference needed to be made only once. The data base created takes into consideration co-channel, adjacent-channel and UHF taboo interference and will be used throughout the analyses of the several ATV formats. A more detailed description of the NTSC parameters is described in the next section.

The analysis of improving the ATV allotment plan is a multi-step iterative process. Some steps occur simultaneously, while others are sequential.

Step 1: Using an ATV plan generated by the allotment/assignment model, the model analyzes each paired ATV assignment with its companion NTSC assignment to determine whether the assigned paired ATV channel matches the interference area of its companion NTSC station. For locations where additional channels could be assigned for ATV use, the software analyzes those channels to determine if a substitution would allow a better match. The analysis is conducted using the criteria described in steps 3 and 4.

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[6] See contribution of Specialist Group-11 to 5th Interim Report; Doc. PS/WP3-197, December 11, 1991.

Since there are many cases where a large number of additional channels are available, and since the time taken to conduct each analysis is significant, substitution of channels was not made in the event of no interference or non-matching interference of less than a specified amount or percentage selected by the user. In addition, since a channel may be assigned at more than one location, assignments with ATV service areas departing by the greatest amounts from their companion NTSC station service areas were considered first when performing this analysis. Selection of a starting point(s) is similar to the process described in the allotment model.

Step 2: For NTSC stations that are co-located (or those within a user-specified distance), the software reexamines the ATV assignments made to the co-located stations to determine whether a different channel pairing scheme would produce further improvements by looking for an optimum local solution (all the stations that are co-located) rather than each station individually. The technique used to look for an optimum local solution is a max/min service area trade-off technique.

Step 3: For each NTSC station, the program compares the baseline interference of that NTSC station to the interference that would be received from the current plan's ATV assignments, and attempts to change the ATV assignments and/or change the ATV or NTSC power or both[7], to minimize interference to NTSC. Determination of the area of interference from the ATV assignment not overlapped by interference from NTSC sources is achieved by subtraction using two-dimensional service area array techniques.

Step 4: For all ATV stations, the interference received by each of the proposed ATV stations from existing NTSC stations and other ATV assignments, is compared with the baseline for the paired NTSC station. The comparison is made to determine where a proposed ATV assignment would receive interference that is different from that of the paired NTSC station. The comparison is used for the analyses in steps 1 and 2 and to evaluate the modified plan once completed. Results of the comparison were used to plot figures 1 through 6 in this report.

Step 5: For all ATV stations, the interference received by the proposed ATV stations from other ATV assignments is compared with the baseline of the paired NTSC station. In addition to comparing the total amounts of interference received, the comparison determines where the proposed ATV assignments would receive interference to areas within their coverage contours that would be different from interference areas of the paired NTSC stations (non-overlapping interference).

3. Baseline NTSC Parameters

An initial NTSC computer run (baseline) provides the reference for each of the ATV systems tested. The run includes Grade B coverage and interference-limited service for each of the approximately 1700 authorized and applied-for television facilities in the FCC data base.

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[7] The procedure of changing the ATV and/or NTSC power to reduce the interference is not being applied in the PS/WP3 analysis. Such a method will make comparison among systems more difficult, and was developed primarily to allow stations with smaller NTSC and ATV service areas (less than 35 in miles) to increase their service areas. One advantage of this technique is to reduce significantly the interference to NTSC stations.

Interference-limited NTSC service areas were determined on the basis of a co-channel desired-to-undesired (D/U) ratio of 28 dB, and first adjacent D/U ratios of -6 dB for interference from the lower adjacent channel and -12 dB for interference from the upper adjacent channel. Taboo considerations are based on threshold of interference (TOV) data from ATTC[8]. Subjective tests at ATEL of NTSC/NTSC interference showed that a 28 dB co-channel ratio corresponded to a CCIR impairment rating of 3 for NTSC stations using precise offset[9]. Accordingly, co-channel interference from ATV to NTSC is based also on impairment grade 3. NTSC receiving antennas beyond the City Grade contour are assumed to have a front-to-back (F/B) ratio of 6 dB. No directivity is assumed for receiving antennas within the City Grade contour. NTSC service is based on median (f(50,50)) signal strength. Interfering signals for both NTSC and ATV employ 10 percent of the time (f(50,10)) propagation data.

The outer limit of NTSC service in the absence of interference is considered to be the Grade B level. As specified by the FCC, the median field strengths corresponding to Grade B are: 47 dBμ for low VHF, 56 dBμ for high VHF, and 64 dBμ for UHF. The outer limit of ATV service in the absence of interference is that determined by the carrier-to-noise ratio yielding a CCIR impairment grade of 4. For digital signal, calculations of service are based on FCC f(50,90) propagation curves for both noise and interference-limited conditions.

4. Receiver Planning Factors Applicable to All ATV Systems

	Low VHF	High VHF	UHF
Antenna Impedance (ohms)	75.0	75.0	75.0
Bandwidth (Mhz)	6.0	6.0	6.0
Thermal Noise (dBm)	-106.2	-106.2	-106.2
Noise Figure (dB)	10.0	10.0	10.0
Frequency (Mhz)	69	194	615
Antenna Factor (dBm/dBμ)	-111.7	-120.7	-130.7
Line Loss (dB)	1.0	2.0	4.0
Antenna gain (dB)	4.0	6.0	10.0
Antenna F/B Ratio (dB)*	10	12	14

* In addition to F/B ratio, a formula is employed for the forward lobe simulating an actual receiving antenna pattern.

[8] The TOV taboo data used for the baseline analysis were obtained from the ATTC N-MUSE report.

[9] The same subjective tests showed that a 40 dB co-channel ratio corresponded to a CCIR impairment rating of 3, and that 28 dB corresponded to a rating of approximately 2, for NTSC stations using the worst possible offset. Neither the FCC's TV station data base nor the data base used in these calculations show which NTSC stations are actually employing offset. Consequently, the NTSC baseline interference-limited service area calculations may overstate the actual NTSC service areas by some unknown amount.

References

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