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MM 87-268

Federal Communications Commission
Office of Engineering and Technology
Washington, D.C.

INTERIM REPORT: FURTHER STUDIES ON THE AVAILABILITY OF SPECTRUM FOR ADVANCED TELEVISION

Topics Addressed-

1) Repacking
2) Interference Limited Transmission Approach
3) Impact of Retaining the Image Taboos
4) Noncommercial Educational Reservations

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OET Technical Memorandum
FCC/OET TM89-1
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Introduction

The Commission currently is investigating issues relating to advanced television (ATV) service in MM Docket No. 87-268.[1] A primary concern in this matter is the impact that introduction of this new service would have on the Commission's allocation and allotment policies for broadcast television. ATV service may require additional spectrum, depending on the technical system used. In this context, issues arise concerning whether sufficient additional spectrum can be made available for all existing television stations to operate ATV service, how that spectrum is to be allocated, and the potential for ATV service to cause interference to conventional (NTSC) TV service.[2]

The Office of Engineering and Technology (OET) is conducting a series of studies to develop information to aid the Commission and others in addressing these issues. This report summarizes the results of our initial research released in August of 1988 and presents the major findings of further studies of alternatives for providing ATV spectrum. It also discusses general observations for ATV spectrum policy based on the results of our studies to-date and plans for additional study.

ATV System Designs and Spectrum Requirements

The several ATV systems currently under development have varying spectrum requirements. These systems generally fall into three categories: 1) those that can operate within a 6 MHz channel and require no additional spectrum;

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1 See Notice of Inquiry in MM Docket No. 87-268, 2 FCC Rcd 17 5125 (1987); Tentative Decision and Further Notice of Inquiry in MM Docket No. 87-268, 3 FCC Rcd 23 6520 (1988); and, Policy Decision and Second Further Notice of Inquiry in MM Docket No. 87-268, FCC 89- ___, released August , 1989.

2 In the Tentative Decision and Further Notice of Inquiry in MM Docket No. 87-268 (supra), the Commission made three tentative decisions related to spectrum use that narrow the policy issues concerning ATV use. Specifically, the Commission indicated that it would: 1) limit its consideration of additional spectrum for ATV service to the existing broadcast television frequencies; 2) permit ATV service to be implemented by existing broascast stations; and, 3) require that ATV signals, at least initially, to be compatible with existing (NTSC) receivers or, alternatively, that ATV broadcasters duplicate their service on both ATV and NTSC channels. The Commission made these tentative findings final in the Policy Statement and Further Notice of Inquiry in that proceeding (supra).

2) those that require an additional 3 or 6 MHz of augmentation bandwidth; and 3) those that require an additional 6 MHz of bandwidth and simulcast NTSC and ATV signals. Systems that can operate within 6 MHz and are compatible with NTSC do not need additional spectrum. However, where 6 MHz systems are not compatible with NTSC, preservation of service to NTSC receivers would necessitate simulcasting of the ATV and NTSC signals on separate channels. Examples of some of the systems under development and their spectrum requirements are shown in Appendix A.

August 1988 Interim Reports

1) "Study of the Availability of Spectrum for ATV in the Existing Broadcast Bands," FCC/OET TM88-1 (Spectrum Study-1988)

The Spectrum Study-1988 examined the number of existing full service broadcast television stations,[3] that could be provided an additional 3 or 6 MHz of spectrum for ATV service. The additional spectrum would be made available by eliminating the current restrictions on UHF channel usage known as the "UHF taboos" and/or by reducing the geographical separation distances now required between co-channel and adjacent channel assignments.[4] Easing of these assignment criteria would generally require improvements in television receiver interference rejection capabilities and could result in ATV service areas smaller than conventional NTSC service areas.[5] The study assumed the elimination of all UHF taboos. The availability of spectrum was examined for a number of alternative co-channel spacing requirements ranging from the current standard of 300 km (186 mi) down to

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3 Existing stations includes licensed stations, stations for which construction permits have been issued, and pending applications that have been accepted by the Commission for filing. The data base used in these studies includes 1760 such stations. Note that the 369 vacant allotments currently reserved for noncommercial educational use are not included in this data base. However, as described below, we have performed a separate study that examines the effects of maintaining these vacant allotments.

4 The Commission's Rules currently restrict the use of specific channels above and below an allocated UHF channel. These restrictions are imposed because existing TV receivers lack sufficient interference immunity to signals on certain channels above and below the channel to which they are tuned.

5 Some techniques that could be employed in ATV transmissions to reduce further the potential for interference to NTSC service are carrier suppression, frequency offset, reduced power and directional antennas.

160 km (100 mi). The computer program used in the study takes into account constraints for stations in Canada and Mexico and land mobile reservations and uses a number of algorithms that attempt to find the largest number of stations that can be accommodated nationwide. The results of this study, for the nation as a whole, are summarized on the following table:

PERCENTAGE OF STATIONS THAT COULD BE PROVIDED ADDITIONAL SPECTRUM FOR ATV

AMOUNT OF ADDED SPECTRUM (MHZ)	STATIONS ACCOMMODATED FOR MINIMUM SEPARATION AS INDICATED: 160 km (100 mi)	300 km (186 mi)	CONDITIONS
3	77%	22%	Added spectrum contiguous with the
6	63%	17%	current assignment of each station
3	94%	50%	VHF stations augmented in VHF; UHF in
6	84%	38%	UHF; contig. assignments where possible
3	100%	77%	VHF stations may be augmented in UHF and
6	96%	60%	vice-versa; no preference for contiguity

While the study found that 100% of the stations could be accommodated if transmitter spacings were reduced and there were no requirement for the ATV spectrum to be in the same frequency band as the primary signal, it would be difficult to design economical ATV receivers that would tune to two different bands simultaneously. A more desirable approach, from the standpoint of receiver design, would be to allot ATV spectrum contiguous with stations' primary channels.

The Spectrum Study-1988 also found that there may be problems in providing additional spectrum for ATV in some major markets. While its analyses did not provide for prioritizing allotments in major markets, the study results nonetheless indicated that the percentage of stations that could be provided additional spectrum in major cities may be significantly less than the percentage across the nation as a whole. For example, while 94% of the existing stations nationwide could be provided with 3 MHz of augmentation spectrum within the same frequency band as their primary channel and at co-channel spacings of at least 100 miles, only 50% and 80% of the stations in New York and Los Angeles, respectively, could be provided with such spectrum.

2) "Analyses of UHF TV Receiver Interference Immunities Considering Advanced Television," FCC/OET TM88-2 (Receiver Study- 1988)

The Receiver Study-1988 examined the potential interference to conventional NTSC TV receivers if UHF taboo channels are used for ATV. The study assumed that the ATV transmitter would be collocated with the station's NTSC transmitter; the desired and undesired signals would be conventional NTSC television signals; and that the augmentation signals would be transmitted at power levels 4 to 6 dB below the primary signal. Because ATV signals are likely to use additional techniques to avoid interference as discussed above, the study results probably provide conservative estimates of the interference potential of ATV augmentation signals. These results indicate that, with current receiver designs, channels +2, -2, +3, -3, +4, -4, +5, -5, +14, and -14 from the tuned channel appear to be the best candidates for ATV use. Taboo channels N+7, -7, +8 and -8 appear less desirable for use as augmentation channels. Finally, the channels + and -15 from the tuned channel, the picture image taboo channels, appear to be the least likely candidates for augmentation channel use. In fact, it may be necessary to retain these taboos, at least until the interference immunity of the TV receiver population improves.

The Receiver Study-1988 also observed that advanced technology to enable receivers to avoid taboo related interference already exists. Tests of the RF Monolithics advanced technology conventional television receiver show that general use of such receivers might allow all UHF taboo channels to be used for ATV augmentation signals.

New Studies

In the second phase of our study program (1988-1989), we have refined our analytical tools for developing potential allotment plans and examined alternate strategies for alloting additional spectrum for ATV. The basic methodology used in these further studies is essentially the same as that used in the Spectrum Study-1988.[6] Also, the data base of existing stations used in these studies is the same as that used in the earlier study.[7] However, we have made a number of modifications to extend the capabilities of our computer program and to improve its algorithm for optimizing the number of stations that can be provided additional spectrum. In addition, we have developed computer programs for displaying study

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6 A description of the methodology used in these studies is provided in the Spectrum Study (FCC/OET TM88-1).

7 See Footnote 3, supra.

results on maps of the U.S. We have used the improved allotment program in developing the studies of alternate allocation strategies described below:

1) Repacking of Existing Stations

As discussed above, the Spectrum Study-1988 indicated that it was not likely that stations could be provided contiguous ATV spectrum by alloting unused frequencies and reducing separation distances. An additional step for improving the availability of contiguous spectrum would be to "repack" the existing TV allotments.[8] A study was performed to determine if through repacking it would be possible to provide each existing television station 9 MHz of contiguous spectrum rather than the 6 MHz now allotted. This study assumed the same adjacent channel minimum separation distance as that used in the spectrum study and varied the co-channel separation distance. The results of the repacking study are:

REPACKING EXISTING STATIONS WITH 9 MHZ CONTIGUOUS SPECTRUM

STATIONS ACCOMMODATED FOR MINIMUM SEPARATION AS INDICATED: 160 km (100 mi)	300 km (186 mi)	CONDITIONS
99.5%	85%	Adjacent channel protection 60 miles
100%	89%	No adjacent channel protection

The inability to provide full accommodation at the existing minimum co-channel separation distance of 300 km (186 mi) is due to problems in the VHF frequencies only. In particular, the study found that the VHF frequencies in the Northeast Corridor already are utilized so efficiently that it is not possible to construct alternate assignment tables that would provide space for ATV use. Moreover, even ignoring all the taboos, the UHF assignments could not be repacked to provide a full 9 MHz of contiguous spectrum for all existing stations. More detailed information on the results of this study is provided on Tables 1, 2 and 3 in Appendix B.

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8 To "repack" means to reallot the broadcast spectrum. This would involve changing the channels of existing stations.

2) Interference Limited Transmission Approach

Previous studies by OET and others have assumed that all stations or transmitters (NTSC and ATV) would receive the same level of interference protection from other co-channel channel stations or transmitters. Zenith Electronics Corporation and several other parties have suggested that ATV systems could be developed that would pose less of an interference threat to NTSC signals and be more immune to interference from NTSC signals.[9] This would permit an ATV transmitter to be located closer to a co-channel NTSC transmitter.

We performed a study to investigate the possibility of applying different spacing requirements to co-channel ATV to ATV transmitter distances and ATV to NTSC transmitter distances. Specifically, this study of an interference limited transmission approach examined the number of stations that could be provided ATV spectrum under conditions where the minimum distance between co-channel ATV transmitters and between co-channel ATV and NTSC transmitters was varied from 160 to 300 km. The results of this study are:[10]

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9 The Zenith system employs an NTSC-friendly format that is transmitted at an average power level less than 0.2% of that needed by an NTSC signal to serve the same area. Other systems, such as those proposed by the Massachusetts Institute of Technology and North American Philips, also use robust ATV signals and may be able to use taboo channels as efficiently as the Zenith system.

10 This study examined two conditions for adjacent channel separation: a minimum adjacent channel spacing requirement of 96 km (60 mi) and no minimum adjacent channel spacing requirement. However, with other conditions held constant, the absence or presence of the adjacent channel restriction did not have any substantial effect on the number of stations that could be provided additional spectrum for ATV. These tables show the results for cases where no adjacent channel restriction was imposed.

PERCENTAGE OF STATIONS THAT COULD BE PROVIDED ADDITIONAL SPECTRUM

ATV-ATV SEPARATION DISTANCE km	miles	NTSC-ATV SEPARATION DISTANCE 160 km (100 mi)	180 km (112 mi)	200 km (124 mi)	250 km (155 mi)	300 km (186 mi)	CONDITIONS
3 MHz ADDITIONAL SPECTRUM:							
160	100	79%	68%	57%	37%	24%	ADDED
300	186	76%	67%	56%	37%	23%	SPECTRUM
							CONTIGUOUS
6 MHz ADDITIONAL SPECTRUM:							
160	100	73%	63%	53%	34%	22%	
300	186	66%	57%	48%	31%	20%	
3 MHz ADDITIONAL SPECTRUM:							
160	100	97%	93%	89%	72%	60%	VHF STATIONS
300	186	96%	92%	87%	68%	54%	AUGMENTED IN
							VHF; UHF IN
6 MHz ADDITIONAL SPECTRUM:							UHF; CONTIG.
160	100	92%	87%	81%	65%	52%	ASSIGNMENTS
300	186	87%	82%	75%	56%	41%	WHERE POSSIBLE
3 MHz ADDITIONAL SPECTRUM:							
160	100	100%	100%	99.7%	96%	90%	VHF MAY BE
300	186	100%	99.9%	99%	93%	81%	AUGMENTED IN
							UHF AND VICE-
6 MHz ADDITIONAL SPECTRUM:							VERSA; NO PREF.
160	100	99.8%	99%	97%	89%	78%	FOR CONTIGUITY
300	186	99.2%	98%	93%	78%	65%	

The above results clearly indicate that the spacing between NTSC and ATV transmitters is a dominant factor in successfully providing additional spectrum for ATV. The study also indicates that greater spacing may be possible between co-channel ATV transmitters without significantly affecting the number of stations that can be accommodated. This greater spacing likely would enable a station's ATV service area to be the same as its NTSC service area. More detailed information on the results of this study is provided on Tables 4 to 8 in Appendix B.

3) Impact of Retaining the Image Taboos

The Receiver Study-1988 indicated that the picture image taboo, i.e., the prohibition against using channels + and -15 channels from the tuned channel, was the least likely candidate for elimination. That study assumed that both the desired and undesired signals would be in a format with

characteristics similar to those of the NTSC system.[11] If ATV signals are in a different format, as they may well be, it is possible that the audio image taboo, i.e., the prohibition against using channels + and -14 channels from the tuned channel, could also be a poor candidate for elimination.[12] We performed a study to examine the sensitivity of our spectrum availability estimates to retaining the image taboos.[13] This study indicated that the percentage of stations that could be provided with additional spectrum for ATV would decrease from our full taboo elimination estimates by 2-4% if the image taboos were retained. Specifically, the results of the study show:

PERCENTAGE OF STATIONS THAT COULD BE ACCOMMODATED WITH ADDITIONAL SPECTRUM IF THE UHF IMAGE TABOOS WERE RETAINED

AMOUNT OF ADDED SPECTRUM (MHz)	STATIONS ACCOMMODATED FOR MINIMUM SEPARATION AS INDICATED: 160 km (100 mi)	Chg	300 km (186 mi)	Chg	CONDITIONS
3	74%	-4%	18%	-3%	Added spectrum contiguous with the
6	59%	-4%	15%	-2%	current assignment of each station
3	93.9%	-0.1%	49%	-1%	VHF stations augmented in VHF; UHF
6	83.7%	-0.3%	36%	-2%	in UHF; contig. assgts. where poss.
3	99.3%	-0.7%	75%	-2%	VHF stations may be aug. in UHF and
6	94%	-2%	57%	-3%	vice-versa; no pref. for contiguity

The maximum number of potential ATV assignments that would be lost in retaining the image taboos was 75.

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11 The primary characteristics of the NTSC format that are likely to affect inteference potential are the transmission of carrier frequency and local oscillator signals.

12 ATV signals using alternative formats and lower power such as those proposed by Zenith and others apparently would be able to use the image channels without increasing the potential for interference to NTSC transmissions.

13 The image taboos require that UHF assignments differing by 14 channels be separated by at least 120 km (75 mi) and that those separated by 15 channels be separated by at least 96 km (60 miles).

4) **Noncommercial Educational Reservations**

Our studies have assumed that all vacant allotments would be available for ATV use. This includes allotments that currently are reserved for use by noncommercial educational stations but are not activated or in the process of being activated. Parties representing noncommercial educational interests have argued that the vacant non-commercial allotments should remain reserved for future growth. We performed a study to investigate the effect of maintaining these allotments. The analysis assumed that the vacant noncommercial allotments would eventually have the same needs for additional spectrum for ATV as the existing stations. Thus, we added the current 369 vacant noncommercial allotments to the population of stations to be provided ATV spectrum. The percentage of existing stations plus vacant noncommercial educational allotments that could be provided ATV spectrum under varying conditions is:

PERCENTAGE OF STATIONS AND VACANT NONCOMMERCIAL ALLOTMENTS THAT COULD BE ACCOMMODATED WITH ATV SPECTRUM

AMOUNT OF ADDED SPECTRUM (MHz)	STATIONS ACCOMMODATED FOR MINIMUM SEPARATION AS INDICATED: 160 km (100 mi)	300 km (186 mi)	CONDITIONS
3	77%	16%	Added spectrum contiguous with the
6	71%	14%	current assignment of each station
3	97%	50%	VHF stations augmented in VHF; UHF
6	93%	39%	in UHF; contig. assgts. where poss.
3	100%	72%	VHF stations may be aug. in UHF and
6	99.6%	55%	vice-versa; no pref. for contiguity

Because of the change in the population of stations in our simulations, the percentage estimates above cannot be directly compared to those of our initial Spectrum Study-1988. However, we can generally see that in those cases where our initial study indicated that all or nearly all existing stations could be accommodated, it also appears possible to accommodate all or nearly all of both the existing stations and the vacant noncommercial

allotments.[14] The complete results of the noncommercial reservations study are presented on Table 9 in Appendix B.

Observations

In reviewing the results of our studies thus far and the record in the Commission's ATV proceeding, a number of observations can be made regarding the factors and conditions affecting the availability of spectrum for ATV:

* Use of the UHF taboo channels for ATV spectrum appears feasible.

  - It appears that implementation of ATV service is likely to occur over an extended period of time during which TV receiver interference immunity could be improved. Under this scenario, the use of UHF taboo channels could be phased in as receiver performance improves and older receivers gradually are removed from service. This would allow ATV spectrum to be made available on a gradual basis as the number of stations offering this service grew over time. Of course, this assumes that the number stations desiring to offer ATV service would increase at a rate lower or equal to the rate at which spectrum could be made available through elimination of the taboos. If a phased-in approach could be used, it would permit even the image taboos, the least likely candidates for ATV spectrum, to be used.

  - If the UHF image taboos were retained, the percentage of stations that could be provided ATV spectrum would decline from our full taboo elimination estimates by only 2-4%.

* ATV to NTSC co-channel spacing is by far the dominant, if not the only significant, factor in determining the availability of spectrum for ATV.

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14 In fact, this study indicates that, for the 160 km minimum co-channel separation distance, the estimated percentages of existing and vacant noncommercial allotments together that could be provided non-contiguous spectrum are higher than the estimates for these cases for existing stations by themselves. The higher percentages generally result from the fact that the vacant noncommercial allotments are generally located in areas where the density of spectrum usage is lower, i.e., rural areas, so that additional spectrum is available for a relatively higher portion of these allotments.

- As the minimum required spacing between ATV and NTSC transmitters is decreased, the number of stations that can be provided with
- ATV spectrum increases substantially. If transmitter spacing were decreased, it could have an affect service areas. In order to maintain service areas equivalent, or nearly equivalent, to those provided now, it might be necessary to improve the interference immunity of the receiver population.

- It may be possible to accommodate all, or nearly all, existing stations with either 3 or 6 MHz of spectrum for ATV if the ATV-NTSC minimum separation distance is 180 km and the additional spectrum is assigned with VHF stations possibly augmented with UHF spectrum and vice-versa.

- A very high percentage of stations can be provided augmentation spectrum in the same frequency band as their NTSC channel if the ATV-NTSC minimum separation distance is 160 km.

*. Providing an additional 3 or 6 MHz for ATV does not significantly affect the number of stations that can be accommodated under many circumstances, particularly those in which very high percentages of stations can be accommodated.

* Wholesale repacking does not offer a solution for providing ATV spectrum for all existing stations.

* It may be possible to maintain the vacant noncommercial allotments and to include them in the population of facilities to be provided ATV spectrum without significantly affecting the number of existing stations that could be provided ATV spectrum.

We are planning additional work to improve our analytical tools for examining ATV spectrum availability, to consider alternative formulations of the interference limited transmission approach, and to examine additional technical and policy questions. With respect to the Zenith approach, one alternative we intend to investigate is a plan that would provide stations with 9 MHz of contiguous spectrum, but with reduced spacing requirements between ATV transmitters operating on the 3 MHz of additional spectrum and co-channel 6 MHz NTSC transmitters. This study may include some limited repacking of existing assignments to enable all stations to be provided with contiguous spectrum. We also plan an expanded study that would include Canadian and Mexican stations to provide a hypothetical "North American" ATV implementation plan.

Interested parties are invited to comment on this research project and its results and to submit any supplementary information they may wish to provide concerning this research. We specifically request information on the the ability of the ATV signals of systems currently under development to withstand interference from co-channel signals at reduced spacing. We seek information on this ability to withstand interference, or "robustness", for both ATV to ATV and ATV to NTSC interactions. Comments and information in response to this request are to be filed directly with the Office of Engineering and Technology at the following address:

Federal Communications Commission
Office of Engineering and Technology
1919 M Street, N.W.
Washington, D.C. 20554

All comments and information received will be placed in the record in the Commission's proceeding on the ATV matter, MM Docket No. 87-268.

APPENDIX A

ILLUSTRATIVE EXAMPLES OF ATV SYSTEMS CURRENTLY UNDER DEVELOPMENT

SYSTEM PROPONENT	SPECTRUM REQUIREMENT/COMMENT
1. David Sarnoff Research Center	
ACTV-I	No additional spectrum required
ACTV-II	6 MHz to augment NTSC channel
2. Faroudja Laboratories	No additional spectrum required
3. Massachusetts Institute of Technology	
Receiver Compatible System	No additional spectrum required
Channel Compatible System	6 MHz simulcasting
4. NHK-Japan Broadcasting Corp.	
MUSE-6	No additional spectrum required
MUSE-9	3 MHz to augment NTSC channel
Narrow-MUSE	6 MHz simulcasting
5. New York Institute of Technology	3 or 6 MHz to augment NTSC channel
6. North American Philips	3 MHz to augment NTSC channel
7. Production Services	No additional spectrum required
8. Zenith Electronics Corp.	6 MHz simulcasting

Table 1

CHANNEL LOADING IN ACTUAL AND HYPOTHETICALLY REPACKED VHF TELEVISION ASSIGNMENT TABLES

The current table of assignments is characterized by fairly uniform loading, in contrast to the heavier packing at lower frequencies found in hypothetical computer-generated tables. Although the revised tables seem to make room for more ATV assignments at the higher channel numbers, no such benefit was found for the Northeastern Corridor.

The total number of stations for cochannel separations up to 260 km should be the same as the actual number of present stations, because stations this close are presently allowed everywhere. Discrepancies are due to about fourteen current assignments that violate current cochannel or adjacent channel separation criteria.

VHF TV CHANNEL	NUMBER OF PRESENT STATIONS	NUMBER OF ALTERNATE 6-MHZ ASSIGNMENTS IN COMPUTER-DERIVED ASSIGNMENT TABLE AT INDICATED COCHANNEL SEPARATION (km)					
		320	300	280	260	240	220
2	58	54	62	70	76	73	91
3	60	55	63	71	77	77	89
4	62	58	59	68	76	74	87
5	56	55	57	61	70	69	80
6	57	52	55	61	68	72	78
7	58	52	56	62	65	68	74
8	61	50	55	58	63	66	70
9	57	47	54	55	57	62	54
10	55	45	52	52	54	57	42
11	55	45	45	46	43	39	25
12	60	43	42	38	29	26	10
13	67	33	35	31	16	18	6
TOTALS	706	589	635	673	694	701	706

Table 2

CHANNEL LOADING IN ACTUAL AND HYPOTHETICALLY REPACKED UHF TELEVISION ASSIGNMENT TABLES

At most, UHF TV assignments could be repacked to vacate the upper one-fourth of the band as shown in this table developed without considering UHF taboos. In Zone I, the most heavily congested northeastern area, UHF stations are permitted at cochannel separations of 250 km, so the 240- and 260-km columns are most relevant. Minimum adjacent channel separation is 88 km in all cases.

UHF TV CHANNEL	NUMBER OF PRESENT STATIONS	NUMBER OF ALTERNATE 6-MHZ ASSIGNMENTS IN COMPUTER-DERIVED ASSIGNMENT TABLE AT INDICATED COCHANNEL SEPARATION (km)					
		320	300	280	260	240	220
14	32	40	44	50	60	63	76
15	30	36	44	44	51	56	69
16	28	42	46	46	50	51	63
17	26	37	36	39	40	43	57
18	25	32	34	37	39	46	55
19	21	36	37	40	41	46	56
20	27	31	33	39	43	49	51
21	27	32	33	41	38	44	53
22	30	34	31	42	46	47	52
23	29	37	37	40	39	42	50
24	32	33	34	38	41	44	45
25	26	33	34	34	41	39	41
26	27	29	31	31	33	40	40
27	31	29	34	33	34	36	38
28	24	26	27	30	31	36	33
29	23	31	29	30	32	32	32
30	20	29	28	28	31	29	30
31	19	30	30	31	28	31	32
32	19	21	25	27	27	29	25
33	24	26	28	25	26	29	24
34	17	21	27	25	24	24	21
35	21	25	22	26	26	27	19
36	22	22	22	22	24	21	14
38	21	19	19	23	24	24	15
39	14	21	21	24	22	17	11
40	25	20	19	17	22	17	7
41	14	19	19	18	22	15	8
42	17	17	21	16	15	11	8
43	18	20	20	17	15	11	7
44	22	18	19	18	15	9	4
45	18	15	16	14	12	7	3
46	16	15	15	16	10	5	4
47	14	15	14	12	8	6	4
48	16	13	13	8	7	7	3
49	20	15	15	10	6	4	3

.... continued

Table 2 (Continued)

UHF TV CHANNEL	NUMBER OF PRESENT STATIONS	NUMBER OF ALTERNATE 6-MHZ ASSIGNMENTS IN COMPUTER-DERIVED ASSIGNMENT TABLE AT INDICATED COCHANNEL SEPARATION (km) 320	300	280	260	240	220
50	17	15	12	9	5	3	1
51	20	14	12	8	3	3	0
52	17	12	10	7	3	3	0
53	14	13	5	4	2	3	0
54	15	9	6	3	2	3	0
55	14	8	7	4	4	2	0
56	13	7	5	5	4	0	0
57	12	7	6	5	3	0	0
58	13	6	3	4	2	0	0
59	8	5	3	4	3	0	0
60	13	3	2	3	0	0	0
61	12	6	5	3	0	0	0
62	17	4	5	2	0	0	0
63	11	3	3	2	0	0	0
64	15	2	3	0	0	0	0
65	9	3	4	0	0	0	0
66	10	3	3	0	0	0	0
67	8	5	3	0	0	0	0
68	14	1	0	0	0	0	0
69	7	2	0	0	0	0	0
TOTALS	1054	1054	1054	1054	1054	1054	1054

Table 3

NUMBER OF STATIONS ACCOMMODATED WITH 9-MHZ REPLACEMENT CHANNELS
IN HYPOTHETICALLY REPACKED TELEVISION ASSIGNMENT TABLE

MINIMUM SEPARATION DISTANCE		NUMBER OF STATIONS ACCOMMODATED WITH 9-MHZ REPLACEMENT CHANNELS	
km	miles	With Adj Chan Protection	Without Adj Chan Protection
300	186	1496 (85%)	1561 (89%)
280	174	1550 (88%)	1627 (92%
260	162	1600 (91%)	1673 (95%)
240	149	1642 (93%)	1714 (97%)
220	137	1683 (96%)	1737 (99%)
200	124	1718 (98%)	1757 (99.8%)
180	112	1738 (99%)	1760 (100%)
160	100	1752 (99.5%)	1760 (100%)

Table 4-A. APPROXIMATE UPPER BOUND ON NUMBER OF STATIONS TO WHICH CONTIGUOUS SUPPLEMENTAL SPECTRUM CAN BE ASSIGNED WITH 96 KILOMETERS SEPARATING ATV-ATV ADJACENT CHANNELS

Conditions on ATV-NTSC separations: at least 160 km (100 miles) between cochannel assignments, adjacent channel interference possibilities ignored.

MINIMUM ATV-ATV SEPARATION		NUMBER OF STATIONS FOR WHICH CONTIGUOUS SUPPLEMENTAL SPECTRUM IS AVAILABLE					
		6-MHz Supplement			3-MHz Supplement		
km	miles	VHF	UHF	Total	VHF	UHF	Total
300	186	386	768	1154 (66%)	432	863	1295 (74%)
290	180	391	778	1169 (66%)	437	871	1308 (74%)
280	174	394	785	1179 (67%)	440	876	1316 (75%)
270	168	396	799	1195 (68%)	442	881	1323 (75%)
260	162	398	802	1200 (68%)	444	885	1329 (76%)
250	155	399	806	1205 (68%)	445	887	1332 (76%)
240	149	401	808	1209 (69%)	445	887	1332 (76%)
230	143	406	813	1219 (69%)	446	888	1334 (76%)
220	137	409	817	1226 (70%)	446	888	1334 (76%)
210	131	411	819	1230 (70%)	447	888	1335 (76%)
200	124	412	821	1233 (70%)	447	888	1335 (76%)
190	118	417	829	1246 (71%)	447	888	1335 (76%)
180	112	417	834	1251 (71%)	447	888	1335 (76%)
170	106	418	838	1256 (71%)	447	888	1335 (76%)
160	100	421	848	1269 (72%)	447	888	1335 (76%)

Table 4-B. UPPER BOUND ON NUMBER OF STATIONS TO WHICH CONTIGUOUS SUPPLEMENTAL SPECTRUM CAN BE ASSIGNED IN THE ABSENCE OF ADJACENT-CHANNEL CONSTRAINTS

Conditions on ATV-NTSC separations: at least 160 km (100 miles) between cochannel assignments, adjacent channel interference possibilities ignored.

MINIMUM ATV-ATV SEPARATION		NUMBER OF STATIONS FOR WHICH CONTIGUOUS SUPPLEMENTAL SPECTRUM IS AVAILABLE					
		6-MHz Supplement			3-MHz Supplement		
km	miles	VHF	UHF	Total	VHF	UHF	Total
300	186	389	771	1160 (66%)	465	880	1345 (76%)
290	180	395	782	1177 (67%)	471	887	1358 (77%)
280	174	398	789	1187 (67%)	473	892	1365 (78%)
270	168	400	803	1203 (68%)	475	897	1372 (78%)
260	162	402	807	1209 (69%)	477	900	1377 (78%)
250	155	405	811	1216 (69%)	477	903	1380 (78%)
240	149	406	813	1219 (69%)	477	903	1380 (78%)
230	143	410	819	1229 (70%)	480	904	1384 (79%)
220	137	413	824	1237 (70%)	481	904	1385 (79%)
210	131	416	826	1242 (71%)	482	904	1386 (79%)
200	124	417	828	1245 (71%)	482	904	1386 (79%)
190	118	423	837	1260 (72%)	482	904	1386 (79%)
180	112	423	843	1266 (72%)	482	904	1386 (79%)
170	106	424	846	1270 (72%)	482	904	1386 (79%)
160	100	427	856	1283 (73%)	482	904	1386 (79%)

Table 4-C. APPROXIMATE UPPER BOUND ON NUMBER OF STATIONS TO WHICH SAME-BAND SUPPLEMENTAL SPECTRUM CAN BE ASSIGNED WITH 96 KILOMETERS SEPARATING ATV-ATV ADJACENT CHANNELS (VHF STATIONS SUPPLEMENTED WITHIN VHF; UHF WITHIN UHF)

Conditions on ATV-NTSC separations: at least 160 km (100 miles) between cochannel assignments, adjacent channel interference possibilities ignored.

MINIMUM ATV-ATV SEPARATION		NUMBER OF STATIONS ASSIGNED SUPPLEMENTAL SPECTRUM					
		6-MHz Supplement			3-MHz Supplement		
km	miles	VHF	UHF	Total	VHF	UHF	Total
300	186	490	1034	1524 (87%)	606	1054	1660 (94%)
290	180	498	1032	1530 (87%)	607	1054	1661 (94%)
280	174	502	1035	1537 (87%)	608	1054	1662 (94%)
270	168	508	1035	1543 (88%)	608	1054	1662 (94%)
260	162	515	1036	1551 (88%)	609	1054	1663 (94%)
250	155	518	1038	1556 (88%)	610	1054	1664 (95%)
240	149	519	1039	1558 (89%)	610	1054	1664 (95%)
230	143	524	1041	1565 (89%)	610	1054	1664 (95%)
220	137	529	1042	1571 (89%)	610	1054	1664 (95%)
210	131	531	1044	1575 (89%)	609	1054	1663 (94%)
200	124	538	1044	1582 (90%)	609	1054	1663 (94%)
190	118	542	1044	1586 (90%)	609	1054	1663 (94%)
180	112	547	1046	1593 (91%)	609	1054	1663 (94%)
170	106	547	1046	1593 (91%)	609	1054	1663 (94%)
160	100	550	1045	1595 (91%)	609	1054	1663 (94%)

Table 4-D. APPROXIMATE UPPER BOUND ON NUMBER OF STATIONS TO WHICH SAME-BAND SUPPLEMENTAL SPECTRUM CAN BE ASSIGNED IN THE ABSENCE OF ADJACENT-CHANNEL CONSTRAINTS (VHF STATIONS SUPPLEMENTED WITHIN VHF; UHF WITHIN UHF)

Conditions on ATV-NTSC separations: at least 160 km (100 miles) between cochannel assignments, adjacent channel interference possibilities ignored.

MINIMUM ATV-ATV SEPARATION		NUMBER OF STATIONS ASSIGNED SUPPLEMENTAL SPECTRUM					
		6-MHz Supplement			3-MHz Supplement		
km	miles	VHF	UHF	Total	VHF	UHF	Total
300	186	500	1038	1538 (87%)	640	1054	1694 (96%)
290	180	508	1037	1545 (88%)	641	1054	1695 (96%)
280	174	513	1039	1552 (88%)	641	1054	1695 (96%)
270	168	519	1041	1560 (89%)	641	1054	1695 (96%)
260	162	528	1040	1568 (89%)	641	1054	1695 (96%)
250	155	533	1044	1577 (90%)	641	1054	1695 (96%)
240	149	531	1046	1577 (90%)	643	1054	1697 (96%)
230	143	536	1047	1583 (90%)	644	1054	1698 (96%)
220	137	540	1048	1588 (90%)	644	1054	1698 (96%)
210	131	543	1050	1593 (91%)	644	1054	1698 (96%)
200	124	551	1051	1602 (91%)	644	1054	1698 (96%)
190	118	553	1051	1604 (91%)	645	1054	1699 (97%)
180	112	559	1052	1611 (92%)	645	1054	1699 (97%)
170	106	560	1052	1612 (92%)	645	1054	1699 (97%)
160	100	566	1052	1618 (92%)	645	1054	1699 (97%)

Table 4-E. APPROXIMATE UPPER BOUND ON NUMBER OF STATIONS TO WHICH SUPPLEMENTAL UHF OR VHF SPECTRUM CAN BE ASSIGNED WITH 96 KILOMETERS SEPARATING ATV-ATV ADJACENT CHANNELS (PREFERENCE GIVEN TO CONTIGUOUS SPECTRUM)

Conditions on ATV-NTSC separations: at least 160 km (100 miles) between cochannel assignments, adjacent channel interference possibilities ignored.

MINIMUM ATV-ATV SEPARATION		NUMBER OF STATIONS ASSIGNED SUPPLEMENTAL SPECTRUM					
		6-MHz Supplement			3-MHz Supplement		
km	miles	VHF	UHF	Total	VHF	UHF	Total
300	186	677	1022	1699 (97%)	706	1051	1757 (99.8%)
290	180	678	1026	1704 (97%)	706	1051	1757 (99.8%)
280	174	681	1028	1709 (97%)	706	1051	1757 (99.8%)
270	168	685	1028	1713 (97%)	706	1051	1757 (99.8%)
260	162	683	1031	1714 (97%)	706	1051	1757 (99.8%)
250	155	683	1034	1717 (98%)	706	1051	1757 (99.8%)
240	149	688	1030	1718 (98%)	706	1052	1758 (99.9%)
230	143	686	1035	1721 (98%)	706	1052	1758 (99.9%)
220	137	690	1031	1721 (98%)	706	1052	1758 (99.9%)
210	131	690	1034	1724 (98%)	706	1053	1759 (99.9%)
200	124	690	1035	1725 (98%)	706	1054	1760 (100%)
190	118	685	1039	1724 (98%)	706	1054	1760 (100%)
180	112	687	1040	1727 (98%)	706	1054	1760 (100%)
170	106	687	1041	1728 (98%)	706	1054	1760 (100%)
160	100	689	1039	1728 (98%)	706	1054	1760 (100%)

Table 4-F. APPROXIMATE UPPER BOUND ON NUMBER OF STATIONS TO WHICH SUPPLEMENTAL VHF OR UHF SPECTRUM CAN BE ASSIGNED IN THE ABSENCE OF ADJACENT-CHANNEL CONSTRAINTS (PREFERENCE GIVEN TO CONTIGUOUS SPECTRUM)

Conditions on ATV-NTSC separations: at least 160 km (100 miles) between cochannel assignments, adjacent channel interference possibilities ignored.

MINIMUM ATV-ATV SEPARATION		NUMBER OF STATIONS ASSIGNED SUPPLEMENTAL SPECTRUM					
		6-MHz Supplement			3-MHz Supplement		
km	miles	VHF	UHF	Total	VHF	UHF	Total
300	186	685	1030	1715 (97%)	706	1054	1760 (100%)
290	180	685	1031	1716 (98%)	706	1054	1760 (100%)
280	174	688	1030	1718 (98%)	706	1054	1760 (100%)
270	168	684	1039	1723 (98%)	706	1054	1760 (100%)
260	162	689	1034	1723 (98%)	706	1054	1760 (100%)
250	155	688	1039	1727 (98%)	706	1054	1760 (100%)
240	149	693	1039	1732 (98%)	706	1054	1760 (100%)
230	143	696	1038	1734 (99%)	706	1054	1760 (100%)
220	137	690	1044	1734 (99%)	706	1054	1760 (100%)
210	131	699	1038	1737 (99%)	706	1054	1760 (100%)
200	124	697	1044	1741 (99%)	706	1054	1760 (100%)
190	118	698	1043	1741 (99%)	706	1054	1760 (100%)
180	112	699	1045	1744 (99.1%)	706	1054	1760 (100%)
170	106	697	1047	1744 (99.1%)	706	1054	1760 (100%)
160	100	697	1048	1745 (99.1%)	706	1054	1760 (100%)

Table 4-G. APPROXIMATE UPPER BOUND ON NUMBER OF STATIONS TO WHICH SUPPLEMENTAL UHF OR VHF SPECTRUM CAN BE ASSIGNED WITH 96 KILOMETERS SEPARATING ATV-ATV ADJACENT CHANNELS (NO PREFERENCE FOR CONTIGUOUS SPECTRUM)

Conditions on ATV-NTSC separations: at least 160 km (100 miles) between cochannel assignments, adjacent channel interference possibilities ignored.

MINIMUM ATV-ATV SEPARATION		NUMBER OF STATIONS ASSIGNED SUPPLEMENTAL SPECTRUM					
		6-MHz Supplement			3-MHz Supplement		
km	miles	VHF	UHF	Total	VHF	UHF	Total
300	186	701	1030	1731 (98%)	706	1054	1760 (100%)
290	180	696	1032	1728 (98%)	706	1054	1760 (100%)
280	174	696	1041	1737 (99%)	706	1054	1760 (100%)
270	168	697	1038	1735 (99%)	706	1054	1760 (100%)
260	162	701	1039	1740 (99%)	706	1054	1760 (100%)
250	155	698	1037	1735 (99%)	706	1054	1760 (100%)
240	149	699	1041	1740 (99%)	706	1054	1760 (100%)
230	143	702	1040	1742 (99%)	706	1054	1760 (100%)
220	137	699	1043	1742 (99%)	706	1054	1760 (100%)
210	131	699	1043	1742 (99%)	706	1054	1760 (100%)
200	124	703	1040	1743 (99%)	706	1054	1760 (100%)
190	118	702	1044	1746 (99.2%)	706	1054	1760 (100%)
180	112	701	1045	1746 (99.2%)	706	1054	1760 (100%)
170	106	701	1043	1744 (99.1%)	706	1054	1760 (100%)
160	100	701	1045	1746 (99.2%)	706	1054	1760 (100%)