IN THE MATTER OF ALLOCATION OF FREQUENCIES TO THE VARIOUS CLASSES OF NON-GOVERNMENTAL SERVICES IN THE RADIO SPECTRUM FROM 10 KILOCYCLES TO 30,000,000 KILOCYCLES (Docket No. 6651)

(June 27, 1945)

On May 25, 1945, the Commission made public its final report of allocations above 25,000 kilocycles, except for the region of the spectrum from 44 to 108 megacycles. With respect to this region, the Commission proposed three alternative allocations for FM, television, facsimile, non-government fixed and mobile services, and the amateur service. In its report, the Commission stated that the final decision among the three alternatives could be made with a great deal more assurance if more factual data were available. The Commission also pointed out that a program of experimentation during the summer months designed to collect further data was possible, since the War Production Board had assured the Commission that the radio industry would not resume production of AM, FM, and television transmitters and receivers in 1945 or even in the first part of 1946 unless Japan capitulated, and that the War Production Board would give the Commission 90 days' advance notice in the event of any change in its production estimates.

However, in view of the fact that the War Production Board subsequently advised the Commission that the manufacture of AM, FM, and television transmitters and receivers might commence at an earlier date than was originally indicated to the Commission, and that it would probably not be possible for the War Production Board to give 90 days' advance notice to the Commission before production was resumed, the Commission on June 5, 1945, ordered a further argument and hearing in order that a final decision might be reached at the earliest possible date. Such a hearing was held on June 22 and 23, 1945, marking the culmination of an extended series of hearings and oral arguments which began in September, 1944.

As the Commission noted in its report of May 25, 1945, its primary concern in making allocations between 44 to 108 megacycles is that FM shall be assigned the frequencies best adapted to its needs. All of the other services for which provision is made in this portion of the spectrum, have allocations in other portions of the spectrum, so that they are not wholly dependent upon their assignments here. FM, on the other hand, is receiving assignment only in this portion of the spectrum, and accordingly it is essential that it receive an allocation which will give it a permanent locus, as free as possible from interference and other shortcomings.

The three alternatives proposed for FM are:

(1) 50–68 megacycles
(2) 68–86 megacycles
(3) 84–102 megacycles

There was unanimity that alternative No. 2 (68–86 mc.) is completely unfeasible. Accordingly, the choice lies between alternatives Nos. 1 and 3.

The primary objection to alternative No. 1 is the amount of sky-wave interference which will result among FM stations if FM is placed in the 50–68 megacycle region. The nature and extent of this anticipated interference was set forth in great detail in Section 8 of the Commission's report of May 25, 1945 (pp. 49–72). The tables showing such interference are reproduced at the end of this report. For example, interference among 50 kilowatt FM stations at 58 megacycles from sporadic E transmissions alone, assuming a 10/1 ratio of desired to undesired signal and full occupancy of the channel, might be expected for 140 to 480 hours per year at the 50 microvolt contour from stations 900 and 1000 miles distant, respectively. At 84 megacycles, in contrast, interference under these conditions would be anticipated for only 6.5 to 25.5 hours per year. It should be noted that the 140–480 hours per year of anticipated interference would not be spread out evenly throughout the entire year but that the great bulk of it would be concentrated in two or three summer months.

The existence and extent of such sporadic E interference is not merely a matter of abstract calculation. In addition to the measurements of such interference made by the Commission, there is the experience of the amateurs, who have heretofore utilized both the 56–60 megacycle and the 112–116 megacycle bands. Mr. Grammer of the American Radio Relay League stated that there have been thousands of communications via sporadic E in the 56–60 megacycle amateur radio band but that there have been no recorded instances of such transmission in the 112–116 megacycle band (Ol. Tr. 144).

The amount of sporadic E interference will vary with the particular frequency involved, the power of the transmitters, the distance between transmitters, the number of transmitters on a channel, and other factors; but regardless of these factors, the region of the spectrum above 84 megacycles is markedly superior to the region below 68 megacycles with respect to sporadic E.

In addition to this interference from sporadic E transmissions, interference from F2 transmission at 53 megacycles may be anticipated for as may as 470 hours per sunspot cycle—concentrated in a period of three years—in the case of a sunspot cycle the same as the last one; or interference may exist for as much as 2,650 hours per sunspot cycle if the next sunspot cycle is as severe as the highest on record. These figures for F2 transmission, it should be noted, assume only two stations on a channel; more than two stations on a channel would double or treble the number of hours during which F2 interference would be expected at 53 megacycles. In contrast, no F2 interference whatever is to be anticipated above 84 megacycles.

For listeners buying FM receivers in reliance on a belief that FM is an interference-free service, these figures are extremely serious. They mean, for example, that a listener tuned to a station which is carrying the program of his choice may suddenly find, either that the program to which he has been listening is being interfered with by

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a station hundreds or even thousands of miles away, or else that control of his receiver has been seized altogether by a distant station completely obliterating the desired program of the local station. These distant transmissions, moreover, are sporadic in nature, with the result that his enjoyment may be further destroyed by an alternation of first one program and then another as trasmission vagaries decree. The effect may well be to render FM receivers useless to many listeners for substantial periods of time.

It has been argued that the bulk of the interference anticipated will be found in outlying rural areas which rely upon low-intensity signals for their radio reception and that if these areas be excluded, FM service will be more than 99 percent perfect. The tables make it clear that urban as well as rural service will be subject to substantial interference on the lower frequencies. This Commission, moreover, is under a statutory duty to make available to *all* the people of the United States an efficient nationwide radio service. The Commission's duty is not fulfilled if its provision for FM service is such as to make it impossible for rural areas to enjoy satisfactory FM service.

The tables and data upon which the Commission's interference predictions are based were set forth in full in the May 25 report and were the particular topic for the oral argument on June 22 and 23. Practically without exception all persons appearing at the hearing stated either that they agreed with the Commission's predictions or that in determining the best allocation for FM they were willing to assume that the predictions as to interference contained in the Commission's report were accurate. In those cases where exception was taken, no substantiating data were offered. Indeed, the testimony at the June 22–23 argument indicated that the Commission's predictions might understate in at least one respect the number of hours of interference to be anticipated at particular contours. The Commission's predictions were based upon the assumption that receivers will be generally available which are capable of rejecting an undesired signal one half as strong as the desired signal. Manufacturers generally appearing at the hearing were unwilling to state that their post-war receivers would meet this standard. With inferior receivers, an even greater number of hours of interference can be anticipated. The issue, accordingly, is whether the freedom from long-range interference which FM will enjoy at the higher frequencies is to be sacrificed by reason of other considerations.

Various objections to assigning the higher frequencies to FM have been raised in this record. For example, it has been alleged that tropospheric interference may be worse in the vicinity of 100 megacycles than in the 50 megacycle region. The Commission in its report of May 25, 1945, specifically pointed out that there would be some difference in tropospheric propagation; but this difference would be only slight and that tropospheric interference at the higher frequencies could be eliminated by slightly increasing the geographical separation between stations. This evidence was not controverted at the oral argument on June 22 and 23, 1945, and Dr. Beverage, one of the propagation experts chiefly relied upon by persons favoring alternative No. 1, testified that tropospheric effects

change slowly and that they would not be greatly different throughout of range of frequencies under consideration (Tr. 5583).

The point has also been made that equipment for use in the vicinity of 100 megacycles will cost more than equipment for use in the vicinity of 50 megacycles. This will no doubt be true at least temporarily, but it seems equally clear that competition will reduce the differential substantially, and that the benefit to the public resulting from an interference-free service will more than outweigh the slight increase in initial cost for service in the 100 megacycle region.

At the earlier hearings, some contended that FM might be delayed for two years or even longer if FM were assigned to the higher frequencies. At the time of the oral argument, June 22–23, 1945, the estimates of delay were reduced to four months. It may well be that competition will markedly reduce even this four-month estimate. Moreover, this report makes it possible for manufacturers to begin at once their planning and design for the higher frequencies. The War Production Board has not yet authorized construction of AM, FM, or television equipment for civilian use; and some months may still elapse before manpower or materials become available in sufficient quantities for such production to begin. If so, the planning and design of equipment for the higher frequencies can be completed before civilian production of any AM, FM, and television equipment is authorized.

Manufacturers, of course, are desirous of marketing FM receivers at the earliest possible moment; and the Commission, too, is concerned that FM receivers shall be freely available to the public early enough to supply the immediate post-war demand. However, the Commission has a duty to consider the long range effects of its action as well as the effects during the months immediately ahead, and it does not propose to provide an inferior FM service during the decades to come merely because of the transitory advantages which may be urged for an inferior type of service.

Earlier in these proceedings, much emphasis was placed on the presumed hardship which would result to the approximately 400,000 persons who had purchased FM receivers before the war. Most of these receivers are combination AM–FM and the AM part of the receiver will continue to be used. There is now substantial agreement that the band (42–50 Mc.) for which these receivers were made is wholly inadequate and unsuited to FM reception. Accordingly, no one today argues that post-war FM should be degraded to the point necessary to accommodate these receivers. However, interim operation in the present band from 42 to 44 megacycles is being provided until such time as equipment for the higher frequencies is freely available to the public and until owners of existing receivers have had equal opportunity to adapt or convert them to the new band. In this connection, a converter was demonstrated to the Commission which would make existing FM receivers capable of tuning to the higher frequencies and which should retail for approximately $10.00.

For the foregoing reasons and upon the basis of data set forth in Section 8 of the report of May 25, 1945, the Commission is adopt-

ing alternative No. 3, with certain modifications. The allocation between 42 and 108 megacycles is as follows:

Freq. Band (Mc.)	*Proposed Allocation*
42–44	Non-Government Fixed and Mobile.
44–50	Television—Channel No. 1.
50–54	Amateur.
54–60	Television—Channel No. 2.
60–66	Television—Channel No. 3.
66–72	Television—Channel No. 4.
72–76	Non-Government Fixed and Mobile.
76–82	Television—Channel No. 5.
82–88	Television—Channel No. 6.
88–92	Non-commercial educational FM.
92–106	FM.
106–108	Facsimile.

This allocation is essentially the allocation proposed as alternative No. 3 of the earlier report, except that the non-government fixed and mobile services have been moved from 104–108 megacycles to 72–76 megacycles, and FM and television have been adjusted accordingly. The advantage of this change is that it makes possible immediately the use of all 13 television channels below 300 megacycles. Under alternative No. 3, as originally proposed, the entire 6 megacycle television channel between 72 and 78 megacycles could not be used until the aviation markers centering on 75 megacycles were moved. The non-government fixed and mobile services are not under the same disability. They can use the entire band between 72 and 76 megacycles at once, with the exception of approximately one-half megacycle in the vicinity of 75 megacycles to protect the aviation markers. This shift of the non-government fixed and mobile services from 104–108 megacycles to 72–76 megacycles also results in a possible increase in the number of channels available to the non-government fixed and mobile services, since a 40 kilocycle channel is adequate in the 72–76 mc portion of the spectrum, whereas a 50 kilocycle channel was proposed in the 104–108 megacycle region.

Table I.—Approximate hours per year of interference at the 50 UV/M contour from sporadic E layer transmissions [1]

mc.	2:1 ratio, one co-channel station	2:1 ratio, full channel occupancy	10:1 ratio, one co-channel station	10:1 ratio, full channel occupancy
	A. 50 kw stations with an antenna power gain of 6 (300 kw effective radiated power)			
43	132–298 hours	660–1490 hours	166–482 hours	830–2410 hours.
58	22–56 hours	110–280 hours	28–96 hours	140–480 hours.
48	75–166 hours	375–830 hours	95–280 hours	475–1400 hours.
66	8. 9–23 hours	44. 5–115 hours	11–38 hours	55–190 hours.
84	1. 1–3. 1 hours	5. 5–15. 5 hours	1. 3–5. 1 hours	6. 5–25. 5 hours.
104	0. 1–0. 32 hours	0. 5–1. 6 hours	0. 13–0. 52 hours	0. 65–2. 6 hours.
	B. 1 kw stations with no antenna gain			
43	0.58–0.87 hours	2.9–4.35 hours	57–86 hours	285–430 hours.
58	0.1–0.16 hours	0.5–0.8 hours	9.7–15 hours	48.5–75 hours.
48	0.33–0.51 hours	1.65–2.55 hours	33–49 hours	165–245 hours.
66	0.03–0.07 hours	0.15–0.35 hours	3.8–6.1 hours	19–30.5 hours.
84	less than 1 min	less than 1 min	0.5–0.87 hours	2.5–4.35 hours.
104	less than 1 min	less than 1 min	0.05–0.087 hours	0.25–.43 hours.

[1] Based upon measurements and methods previously described.

Table II.—Approximate hours per year of interference at the 100 UV/M contour from sporadic E layer transmissions [1]

mc.	2:1 ratio, one co-channel station	2:1 ratio, full channel occupancy	10:1 ratio, one co-channel station	10:1 ratio, full channel occupancy
	A. *50 kw stations with an antenna power gain of 6* (300 kw effective radiated power)			
43	95–173 hours	475–865 hours	157–429 hours	785–2145 hours.
58	16–32 hours	80–160 hours	27–81 hours	135–405 hours.
48	54–100 hours	270–500 hours	90–247 hours	450–1235 hours.
66	6.4–13 hours	32–65 hours	10–33 hours	50–165 hours.
84	0.75–1.7 hours	3.75–8.5 hours	1.2–4.5 hours	6.0–22.5 hours.
104	0.07–0.18 hours	0.35–0.9 hours	0.12–0.46 hours	0.6–2.3 hours.
	B. *1 kw stations with no antenna gain*			
43	Negligible	Negligible	18–22 hours	90–110 hours.
58	Negligible	Negligible	3.1–4.1 hours	15.5–20.5 hours.
48	Negligible	Negligible	10–13 hours	50–65 hours.
66	Negligible	Negligible	1.2–1.7 hours	6–8.5 hours.
84	Negligible	Negligible	0.15–0.23 hours	0.75–1.15 hours.
104	Negligible	Negligible	0.013–0.024 hours	0.065–0.120 hours.

[1] Based upon measurements and methods previously described.

Table III.—Approximate hours per year of interference at the 200 UV/M contour from sporadic E layer transmissions [1]

mc.	2:1 ratio, one co-channel station	2:1 ratio, full channel occupancy	10:1 ratio, one co-channel station	10:1 ratio, full channel occupancy
	A. *50 kw stations with an antenna power gain of 6* (300 kw effective radiated power)			
43	47–70 hours	235–350 hours	139–333 hours	695–1665 hours.
58	8–13 hours	40–65 hours	24–63 hours	120–315 hours.
48	27–40 hours	135–200 hours	80–192 hours	400–960 hours.
66	3.2–5.3 hours	16–26.5 hours	9.4–25 hours	47–125 hours.
84	0.38–0.7 hours	1.9–3.5 hours	1.1–3.5 hours	5.5–17.5 hours.
104	0.03–0.07 hours	0.15–0.35 hours	0.1–0.36 hours	0.5–1.8 hours.
	B. *1 kw stations with no antenna gain*			
43	Negligible	Negligible	1.8–2.5 hours	9–12.5 hours.
58	Negligible	Negligible	0.3–0.46 hours	1.5–2.3 hours.
48	Negligible	Negligible	1–1.4 hours	5–7 hours.
66	Negligible	Negligible	0.12–0.19 hours	0.6–0.95 hours.
84	Negligible	Negligible	0.015–0.02 hours	0.075–0.1 hours.
104	Negligible	Negligible	0.0013–0.002 hours	0.0065–0.01 hours.

[1] Based upon measurements and methods previously described.

Table IV.—Approximate hours per year of interference at the 1000 UV/M contour from sporadic E layer transmissions [1]

50 kw stations with an antenna power gain of 6
(300 kw effective radiated power)

Mc.	10:1 ratio, one co-channel station	10:1 ratio, full channel occupancy
43	47–70 hours	235–350 hours.
58	8–13 hours	40–65 hours.
48	27–40 hours	135–200 hours.
66	3.2–5.3 hours	16–26.5 hours.
84	0.38–0.7 hours	1.9–3.5 hours.
104	0.03–0.07 hours	0.15–0.35 hours.

[1] Based upon measurements and methods previously described.

NOTE: The values in case of a 2:1 ratio for 300 kw stations, and for 1 kw stations for both the 2:1 and 10:1 ratios, are very small at the 1000 microvolt per meter contour and are not included in this table.

TABLE SHOWING APPROXIMATE NUMBER OF LISTENING HOURS (6 AM TO MIDNIGHT) PER 11 YEAR SUNSPOT CYCLE THAT F2 LAYER INTERFERENCE WOULD BE RECEIVED FROM ONE CO-CHANNEL STATION. (Most of this interference will be concentrated during approximately three years of the sunspot cycle.)

	Band 1	Band 2				Band 3	
	43 Mc	48 Mc	53 Mc	58 Mc	66 Mc	84 Mc	104 Mc
120 sunspots	1550 hrs [1]	155 hrs	9 hrs	1 hr	0	0	0
	4000 hrs	2170 hrs	470 hrs	38 hrs	1.2 hrs	0	0
155 sunspots	4000 hrs [1]	2170 hrs	470 hrs	38 hrs	1.2 hrs	0	0
	5000 hrs [1]	4100 hrs [1]	2650 hrs	860 hrs	30 hrs	0	0

[1] Extrapolated values.

For the indicated transmitter powers of co-channel stations and ratios of desired to undesired signal intensities, the above interference would be at the following contours:

300 kw		1 kw	
2 to 1 ratio	10 to 1 ratio	2 to 1 ratio	10 to 1 ratio
2160 uv/m	10800 uv/m	124 uv/m	620 uv/m.

Tropospheric effects

Height of Transmitting Antenna	Height of Receiving Antenna	Power in Kilowatts	Frequency in Megacycles	Separation in Miles For Ratio of Desired to Undesired Signal Shown	
				2/1	10/1
In feet	*In feet*				
500	30	300	58	257	290
500	30	300	66	259	295
500	30	300	104	276	306
1000	30	300	58	271	312
1000	30	300	66	272	313
1000	30	300	104	281	319
500	30	1	58	98	170
500	30	1	66	100	176
500	30	1	104	104	193
1000	30	1	58	121	183
1000	30	1	66	123	187
1000	30	1	104	132	213

Ground wave coverage—Distance in miles to 50 uv/m contour

	Power								
	1 kw			10 kw			50 kw		
Antenna height	200′	500′	1000′	200′	500′	1000′	200′	500′	1000′
46 mc	40	52	65	56	67	82	67	80	95
95 mc	43	56	68	57	68	83	68	81	92