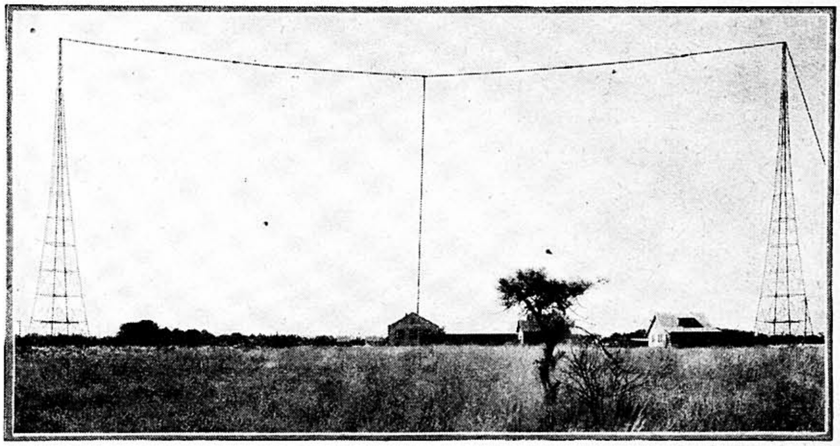
A Plan for Making National Broadcast



Shown above is a modern antenna installation for present-day high-powered broadcast transmitter—in this case the antenna at WEAF, Bellmore, Long Island, N. Y.

By Lieut. Wm. H. Wenstrom

In spite of the ever-increasing power employed by broadcast stations, a large portion of the country is still outside the dependable range of the better class of stations. In fact, much of the country is not dependably reached by any broadcasters. Lt. Wenstrom in this article presents some rather startling facts in this connection. What is more important, he suggests a remedy which, though somewhat radical, nevertheless holds much logic and is worth careful consideration

THEORETICALLY the northeastern section of the United States enjoys excellent radio broadcasting service. Eight 10-kw. to 50-kw. transmitters are spaced with fair regularity from Massachusetts to Maryland. No section of the country is better served except the environs of Chicago, where four high power stations are located practically on top of one another. As a criterion of what we can expect of future broadcasting development under the present system, then, we might look for a moment at actual present receiving conditions in this favored northeastern area.

Let us first visit in imagination a suburb of New York City. A listener here can turn to any one of four powerful near-by stations. Any program selected will issue from a good receiver practically as well as if it were coming in by a private wire line. The same listener can also find, one or two blocks away, a large talkie theatre. He can attend dances, concerts and other entertainments by walking or driving a few more blocks. Half an hour away is the great city, with all the theatres of Broadway and its by-streets.

Now let us change the scene to Cape Cod, whence in days gone by tall whaling ships sailed for the seven seas. A howling northeaster spatters cold rain across a sodden countryside; it is a good night to stay home and listen to the radio. In one of the modest houses surrounding Dark Harbor a fisherman tunes for his favorite dance orchestra. The program is on several stations, but the best signal comes from a 50-kw. transmitter on Long Island, 150 miles away across salt marsh and salt water. These terrain factors are favorable to transmission, but nevertheless the program fades badly. Now it is too loud, now it sinks to a whisper, and occasionally it goes mushy. There are no movies or theatres among the sand dunes of Cape Cod, and the fisherman goes disgustedly to bed.

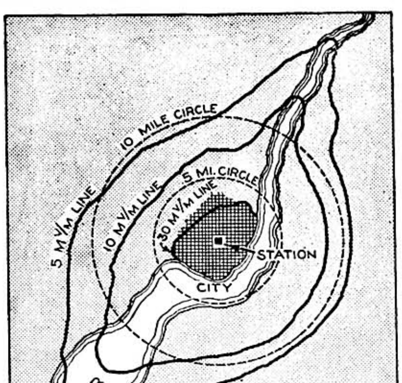


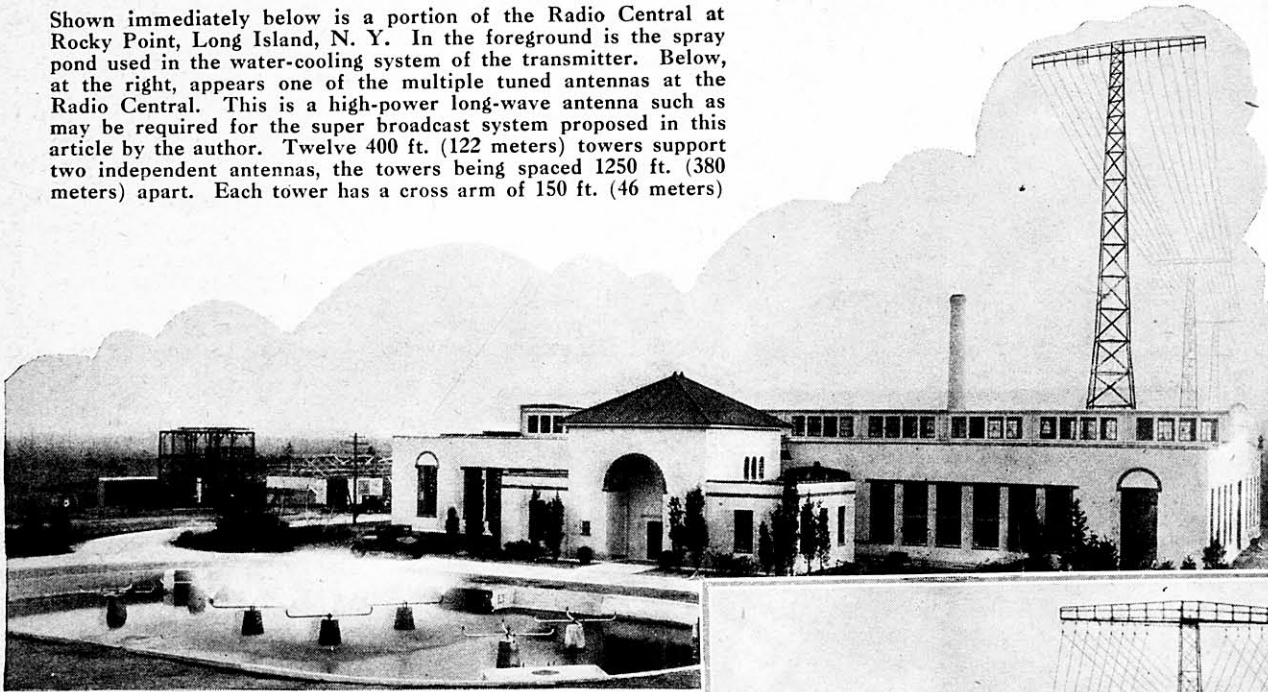
Figure 1. This is a typical map showing the service area of a 500-watt broadcast station. It is made by taking field strength measurements at numerous points, then joining together with lines the points showing similar field intensity

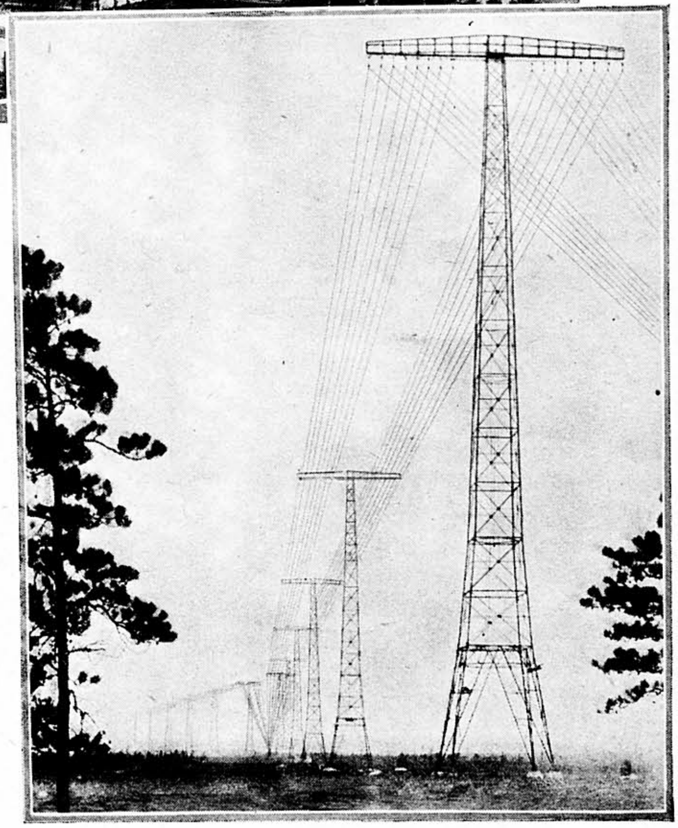
Not far from the fisherman's home is a country house whose owner, wishing to have the best in reception, has paid the radio industry something like the price of a Ford. He wants to hear the same dance program, and tunes his expensive set to the same station. His automatic volume control smooths out some of the fading, but it leaves all the mush in. By no stretch of the imagination can he feel that he is listening to the original orchestra, or forget the technical means of hearing and its frailties in the enjoyment of what is heard.

The imaginary pictures above are based on actual observation in the favored northeastern area. In Idaho the nearest station using more than 10 kw. is 600 miles away. National broadcasting seems at present to be more of a name than a reality.

Before examining some possible means of improving the situation, it is necessary to agree on a few fundamental definitions

Shown immediately below is a portion of the Radio Central at Rocky Point, Long Island, N. Y. In the foreground is the spray pond used in the water-cooling system of the transmitter. Below, at the right, appears one of the multiple tuned antennas at the Radio Central. This is a high-power long-wave antenna such as may be required for the super broadcast system proposed in this article by the author. Twelve 400 ft. (122 meters) towers support two independent antennas, the towers being spaced 1250 ft. (380 meters) apart. Each tower has a cross arm of 150 ft. (46 meters)





Coverage Direct

and principles. First of all, what is true broadcasting service and what is the true service area of a broadcasting station? This question is potent for argument among engineers, experimenters and listeners alike.

Changing Standards of True Service

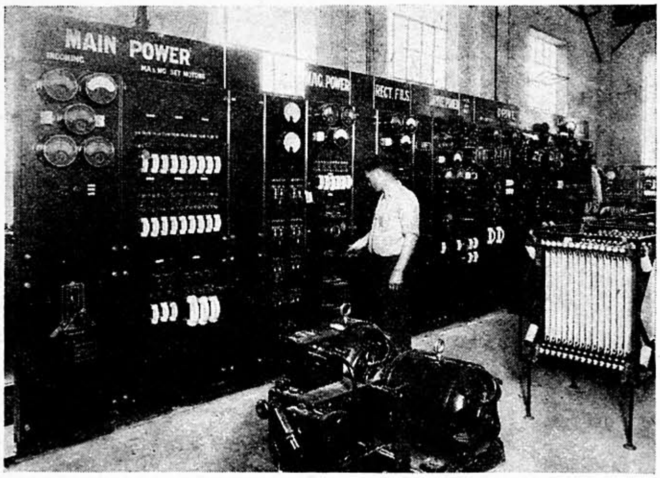
Broadcasting, along with all the other arts of our modern age, is in a state of change. What is excellent today will not do tomorrow. In 1922 a fifty-watt station used to transmit nightly from Denver, Colorado. A handful of listeners tuned for it in Arizona, 600 miles south, and were delighted beyond measure to hear once in a while the Denver announcer's voice emerge understandably from their loud speakers, amid snatches of music which sometimes steadied into a half-hour concert. Of course they never heard anything in daylight. They might have said that they were getting true broadcasting service on nights when the Denver station was on the air, and were missing it on nights when the transmitter was shut down.

What would be the response of a listener who was offered such service today? Our ideas of true broadcasting service have advanced greatly in the last few years. In 1927 S. W. Edwards, the Radio Supervisor at Detroit, Michigan, completed a series of measurements on broadcasting stations. His results, described by S. R. Winters in Radio News for July of that year, probably seemed revolutionary to listeners accustomed to nothing better than doubtful night-time service.

The definition of true service accompanying this investigation came from no less an authority than President Hoover, then Secretary of Commerce: "By 'complete service area' I mean the territory within which the average set can depend upon getting clear, understandable and enjoyable service from the station day or night, summer or winter. I do not include radio golf around the edge of these areas in our conception of public service—that game is an exercise of skill. . . . Actual operation of high-powered stations has proven advantageous in broadening the 'complete service area,' but this area is much more limited than many expected. Subjected to the test of positive and reliable service at all times and in all weather it will be found that the real effectiveness of a station falls within a comparatively small zone."

Edwards found for one thing that the service areas of stations were usually far from circular, though in a location free from tall steel buildings the lines of equal field strength may approach circular form. Figure 1 is a typical map showing the service area of a 500-watt station. Such a map is made by taking at various points a large number of measurements of the signal strength rated in millivolts per meter. The lines of equal field strength, corresponding to contours on a topographic map, are then drawn in between the points. In this investigation, which was mostly in or near cities, the 5 millivolts per meter line was taken as the outer boundary of the complete service area.

In the case of every station investigated this area turned out to be pitifully small. WTAM at Cleveland, radiating 5000



This is a close-up view of the control panels of the Marconi beam system at Rocky Point

watts, pushed the 5 mv/m line out less than 20 miles on the average. WSB of Atlanta, a 1000-watt station, showed a service range of four to nine miles. The fact that some listener in Saskatchewan picked up either or both of these stations every other night has little bearing on the subject. We are considering a service which is good enough to make the listener feel, provided the receiver does its share, that the artist is almost present in the home.

If broadcasting had been content with those five- and ten-mile ranges of 1927, what a sickly infant it would be now! However, it was the admirable desire of engineers to bring true service not only to the suburban areas immediately surrounding the cities, but to some millions of farmers, small town residents and other rural dwellers out in the comparatively open country that is most of the United States. Higher power was the logical answer. When WJZ, first of the great metropolitan broadcasters, went on the air with 50 kilowatts near-by listeners probably felt as if all the white horses of Niagara were being unleashed over their heads. But they lived to tell the tale, their receivers declined to go up in smoke, and they soon found that they could still tune in distant stations by using a simple wavetrap.

In the greatly increased coverage area of WJZ around New York City and New Jersey, the high-power idea immediately proved its worth. At the present time there are about 30 stations in various parts of the country radiating 7 kw. to 10 kw. or more. Those minute true service areas of 1927 have been considerably extended in many cases. The generally accepted idea of true service range compared with power is now about as follows:

5 watts	1 mile
500 watts	10 miles
50 kilowatts	100 miles

This table is seen at once to follow the inverse square law, which is only approximate in actual cases. Other factors, such as wavelength and type of ground, enter the picture. But for distances under 100 miles, the foregoing table will do for the present.

Suppose that we wish to extend further this splendid idea of rural coverage. Let us extend city reception to those who need it most—the tired lumber crew in the northwoods, the levee gang camping beside the Mississippi, the original American on a desert reservation. Suppose that we wish a true service range of 1000 miles. This is ten times the range of a 50-kilowatt station, and if the inverse square law works, we should get the desired results with 100 times the power, or 5000 kilowatts. Would operating such a station in Kansas, on 400 meters for example, bring true broadcasting service to most of the United States?

It would not. It would be instead a monumental waste of power, for in all probability the true service area would not be much different from that of a 50-kilowatt station.

Fading Restrictions

Another element has entered the picture, and that is fading. Most listeners have noticed that stations less than 60 to 80 miles distant rarely fade, while for those 80 to 100 miles away fading is often quite severe—more so, in fact, than for more distant stations. The reason is that whereas the ground wave dies away roughly in accordance with a curve of familiar exponential shape, as shown in Figure 2, the sky wave, reflected from the ionized layer sixty miles or so above the earth, is very weak at the transmitter and begins to come down strongly some miles out. Due to changes in the ionized layer, the path traveled by the sky wave is continually changing in length while the length of the ground wave path remains constant. The result is that the sky wave is now in step with the ground wave, now opposing it; the phase relations between the two are constantly changing.

Close to the transmitter where the ground wave predominates it does not matter much what happens to the sky wave. But in a region approximately 80 miles out the ground wave and sky wave are of about equal strength. When they are in phase the signal is twice as strong as it ought to be; when they are just out of phase the signal vanishes, as shown in Figure 3. Several hundred miles out where the sky wave alone counts, the fading is less severe, but the constancy of the signal rarely reaches true service standards. It is also apparent from Figure 2 that power increase has little effect on fading because the intensity of the sky wave is increased along with that of the ground wave.

These forms of fading can be smoothed out to some extent by the automatic volume control, but another vagary of the sky wave leaves this device powerless. Between a given transmitter and receiver at any instant different wavelengths will fade differently. The two side bands of a telephone signal are in effect two signals of slightly different frequency, and when these fade unequally the result is destructive distortion, variously known as "hashing" or "mush," but ruinous to the program on which it appears. This distortion sets in at about the same distance as ordinary fading—60 to 80 miles—and the indications are that it is seldom entirely absent beyond this first fading ring. Even in the programs originating from powerful stations several hundred miles distant, which seem fairly constant, this differential sideband fading is usually present in great enough degree noticeably to mar quality.

The upshot of all these facts is that the ground wave only is useful for extending the true service area. Listeners put

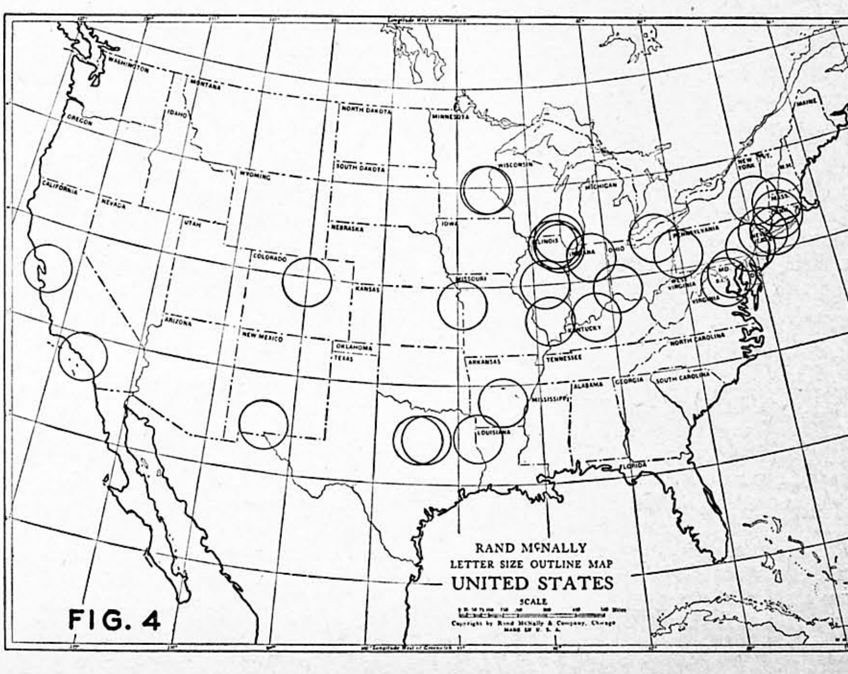


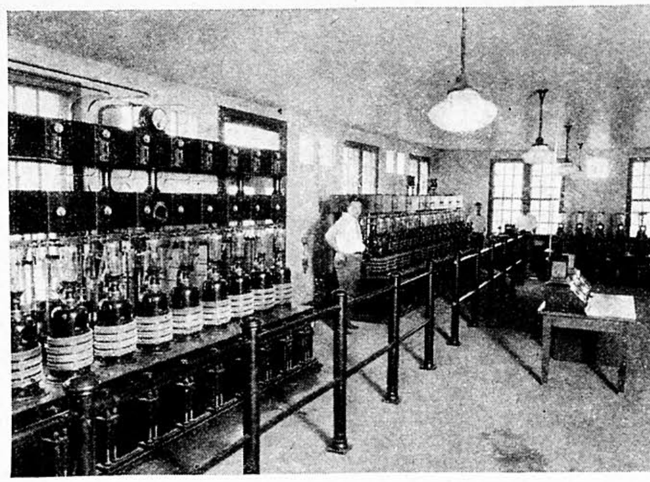
Figure 4. A map of the United States showing the coverage area of thirty present-day high-powered broadcast transmitters. Compare this with Figure 6. (Reproduction licensed, copyrighted by Rand McNally and Co.)

up with sky wave service now in the absence of anything better, but its vagaries cannot be tolerated in the broadcasting of the future. This means that a station's maximum true service area is limited by the occurrence of its first fading ring.

In the interests of clearness and understanding it might be well at this point to summarize as follows our basic assumptions:

1. In the radio communication field broadcasting now ranks next in importance after government, sea-air safety and primary inter-continental message services. The relative importance of broadcasting is increasing.
2. Our present system of broadcasting coverage is laid out on metropolitan rather than rural or truly national lines.
3. True service broadcasting is defined as a ground-propagated day and night signal free from fading and of sufficient intensity to override any ordinary atmospherics or interference.
4. As an ideal limit the entire United States should be covered by such service. In practice the ideal limit should be approached as closely as technology and economics permit.
5. It is more economical to cover a given area with few large stations than with many small ones.

We have hinted above at our present paucity of rural coverage. Now, with these definitions in mind, let us have present conditions out in the open where we can look at them. No station using less than 7 kw. to 10 kw. need be considered. Figure 4 shows the locations of the 30 stations using 7 kw. or more, and surrounding them circles of eighty mile radius. The true service areas of these stations, on the average, lie within these circles. Some non-fading ranges are greater, some less, but eighty miles is about the United States' average, as detailed below. These thirty circles then, mostly clustered in the northeast and north central states, give a true generalized picture of our present national coverage. The picture would not be greatly altered if all these stations increased power to 50 kw. We can see at a glance how far from national our coverage actually is.



A general view of the thirty-two high-powered tubes with which station WEAF of the National Broadcasting Company is equipped

Synchronization and Antenna Design

The scarcity of channels in our present broadcasting spectrum has spurred engineers to develop practical means of synchronization—running two or more transmitters on exactly the same wavelength. For moderate distances at least, the frequency synchronization problem has been solved. WBZ at Springfield and WBZA at Boston have been synchronized for several years. The occurrence of peculiar fading patterns in the mid-distance between synchronized stations, however, has limited the method's possibilities.

These difficulties have recently been disposed of by the combined frequency and phase synchronization described by C. W. Horn in *Electronics* for December, 1930. Not only do the inter-station interference patterns disappear, but the ordinary single-station type of fading appears to be somewhat mollified. This advanced synchronization technique has great possibilities, but as applied to the problem of national coverage it meets two objections. Present-day stations are not logically located for national coverage, and excessive multiplication of small stations violates the primary economic law.

We should mention also that there is a way of pushing out somewhat these troublesome first fading rings by improved antenna design. As first fading is caused by approximate ground wave and sky wave equality, any system which tends to put more radiation into the ground wave at the expense of the sky wave will be helpful. It has been found that a one-half wave antenna, for example, radiates more strongly in a horizontal direction than the conventional quarter wave or Marconi antenna now used by most broadcasters. This effect is shown in Figure 5. In 1928 the Budapest station in Hungary went on the air with an antenna approaching half a wave in length. The fading ring was definitely pushed out, though not to any great distance. The new non-fading service range of the station was about 90 miles, as against 60 miles with a conventional antenna. In New Jersey, WABC is said to be building a half-wave antenna—another interesting experiment along this line.

The methods mentioned above, or other technical advances, may ultimately solve the national coverage problem. The remainder of this article sets forth a different solution which the writer believes is simpler and more logical. It is not claimed that our method positively will work or that other methods will not work. It is claimed that our basic idea is technically sound, and that it presents enough possibilities of great public service to be well worth investigating.

A Powerful Idea

In an epochal paper in the July, 1930, Proceedings of the Institute of Radio Engineers entitled "Service Area of Broadcast Stations," P. P. Eckersley of England, former Chief Engineer of the British Broadcasting Corporation, has shown the fading limitations mentioned above. He has also shown that the fading ring radius, which limits the true service range, is a function of wavelength and type of ground, and is substantially independent of transmitter power. In addition Eckersley has suggested that the obvious remedy for these fading (*Continued on page 927*)

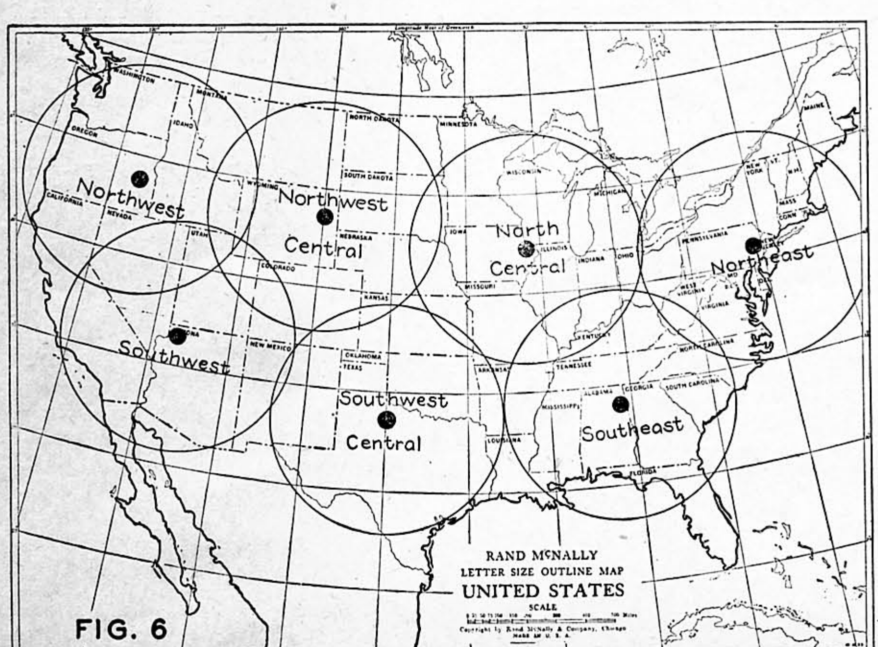


Figure 6. Seven national super-power stations, located as shown in the map at the left, could supply substantially complete national coverage. (Reproduction licensed, copyrighted by Rand McNally and Co.)

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limitations is to raise the wavelengths of the more important broadcasting stations of the world, so that really high power can be efficiently used. The writer has developed and investigated this idea as applied to the problem of national broadcasting coverage in the United States.

The first consideration was to determine just how far Eckersley's figures and curves, based on observations in northern Europe, correspond with actual transmission as observed over various types of the highly diversified American terrain—in other words, how well they will serve as a basis for American coverage predictions. At the start we need a simplified table of fading radii corresponding to various wavelengths and common American terrain types (Table 1). From this table we would predict, for example, that in flat country the non-fading range of a 300-meter station should be 80 miles, while that of a 400-meter station should be 120 miles. In hilly or broken country, on the other hand, the range of the 400-meter station would be reduced to 62 miles.

American Data

In order to check this table with transmitting conditions in the eastern United States, observations on high-power eastern transmitters were made at New Haven by the writer and at West Point by Lieut. H. W. Serig, Signal Corps, U. S. A. These observations, covering average conditions over several weeks, are summarized in Table 2. New Haven is surrounded by flat to hilly terrain, and the country immediately surrounding West Point is mountainous. However, both sets of observations point to the same general conclusion. There is little perceptible fading in the case of stations less than 60 miles distant from the receiver, frequent fading in the case of stations 60 to 90 miles distant, and continual fading in the case of stations more than 90 miles away. At longer ranges the fading decreases but, as we have pointed out above, the signal is rarely up to true service standards. These general conclusions check closely with generalized predictions from Table 1.

The next step in the investigation was to see if Table 1 predictions could be verified, not only in the eastern area, but also over the whole United States. The writer communicated with the chief engineers of representative broadcasting stations all over the United States, enclosing convenient reply cards for the desired data. In addition to such details as wavelength and power, the particular information wanted for each station was the type of country surrounding the transmitter and the estimated radius of the first night fading ring. The results of this survey are shown in Table 3. The terrain and observed fading radii are listed as reported by station engineers, while from the reported terrain and Table 1 the predicted fading radii were worked out.

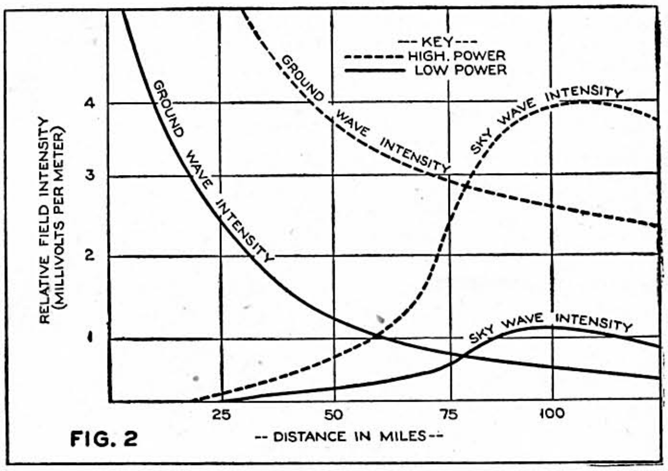

FIG. 2

The relatively higher field intensity of higher power transmission does not necessarily eliminate fading, for reasons explained in the text

The general agreement between prediction and observation is surprisingly close. The widest divergence, in the case of WJZ in New Jersey, can be partly explained by the fact that although the transmitter itself is located in broken country and is so listed, much of its service area is flat ground. Another wide divergence, in Florida, is perhaps explained by the presence of sandy terrain of low conductivity. The average of predicted values (83.8 miles) and the average of observed values (89.2 miles) are in very close agreement considering the precision of the methods employed, probably not over ± 10 per cent. The general conclusion is clear: *Eckersley's curves, drawn from data taken in northern Europe, can be applied reliably to approximate predictions of non-fading coverage in the United States.* If anything they are too conservative.

Long Wave Super-Broadcasting

What have all these facts to do with the great problem of national broadcasting coverage? Everything. Those inexorable first fading circles, which have been obstinately holding down our true service areas and our economically justifiable transmitter powers, are now going to roll back like morning mists under a climbing sun. They are to be pushed out, not a paltry fifty miles or so, but something like three hundred miles. Returning to Table 1, we find that at 200 kc. or 1500 meters, the expected non-fading range is 330 miles in hilly to broken country, which may be called the general American average. In flat country a 1500-meter station should not fade inside of 620 miles. In a letter to the writer Dr. A. Hoyt Taylor, internationally famous investigator of the Naval Research Laboratory, estimates that at 200 kc. fading will not be severe inside of 500 miles from the transmitter. From another authoritative source we have learned that actual 200 kc. broadcasting experiments in the United States at very limited power have shown no fading inside of 300 to 350 miles. Striking a general average of all these estimates, we assume that the average fading radius of a 200 kc. American broadcasting station will be about 400 miles. In mountainous regions it will be less, in flat regions more; these inequalities can be somewhat levelled by using wavelengths longer than 1500 meters in mountainous country and wavelengths shorter than 1500 meters in flat country. 1500 meters is merely the center point of a contemplated broadcasting band.

Now as in Figure 6 we apply these 800-mile circles to a map of the United

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TABLE 1

Approximate Radii of Fading Rings: (After Eckersley)

	200	300	400	500	1200	1500 meters w.l.
Flat country..........	50	80	120	160	480	620 mi.
Hilly or broken.......	24*	37	62	75	260	330 mi.
Mountainous	10*	17*	26	34	110	160 mi.

*Probably too low.

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first approximation it appears that about seven national super-power stations, located respectively in the northeast, southeast, north central, northwest central, southwest central, northwest and southwest regions, will deliver true service broadcasting, night and day, to practically the entire United States. The actual limits would of course not be circular, and the arbitrary circles are not finite limits anyway. On a good night any listener in the United States might call the roll of national stations in a minute's time. But our calculations are based on dependable, non-fading night and day service that will give the loneliest ranch in the Rockies something comparable to what the suburban New York residents enjoy now.

The final number of stations, as well as their final location, can only be determined by detailed topographic surveys and experimental work with portable transmitters and field measurement stations. The northeastern station, for example, might better be located at the tip of Long Island (facetiously suggested by a listener in 1926 as a desirable location for the then super-powered WJZ), than among the hills and other obstructions encountered farther inland. There are indications that where flat country immediately surrounds the transmitter, fading is less severe at all distances than in the case of a mountain transmitter where the radiation is badly distorted at the start. With the power levels we are going to recommend the transmitters must be located in sparsely settled country to avoid excessive interference. At each station great towers would probably rise from a small community complete in itself, and connected to civilization only by an auto road, power lines, and the telephone lines over which come programs from distant city studios.

One principle of location must be emphasized. Some argue: Who is going to pay for a large station located north of the Grand Canyon where inhabitants are few and far between? But the southwest station is not a state or local station at all; it is a link in the national chain. In addition to the desert area near by, it serves California towns, the Salt Lake City region of Utah, and all the country between. We must go beyond the local and metropolitan viewpoint if national broadcasting is ever to become a reality. Similarly, local and political claims must be ignored in the location of these national stations. They must be placed in accordance with engineering principles so as to bring true service to the widest territory and the greatest present and potential population.

Long-wave broadcasting has other transmission advantages besides the en-

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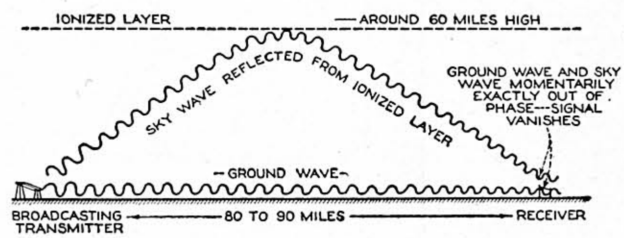

FIG. 3

Illustrating the reason why fading is most severe at a point about 80 miles distant from a broadcast transmitter

TABLE 2

Fading in East

	Distance Miles	*Station*	*Fading*
New Haven:	35	WITC	Constant—practically no fading.
	55	WEAF	Practically constant—rare fading.
	55	WBZ	Very severe fading and hashing.
	60	WABC	Frequent fading, rapid.
	75	WOR	Fairly frequent fading.
	95	WJZ	Severe fading, hashing.
	115	WGY	Very severe fading, some hashing.
	350	KDKA	Very severe fading, severe hashing.
	600	WLW	Slow fading, quite severe, quality marred somewhat by slight hashing or loss of high and low notes.
West Point:	45	WOR	Constant—absolutely no fading.
	45	WABC	Constant—slight interference at times.
	55	WEAF	Constant—some weak signals—some hashing at times.
	65	WJZ	Frequent fading, slight to extreme, hashing.
	70	WITC	Frequent fading.
	85	WBZ	Severe and frequent fading.
	95	WGY	Severe and frequent fading.

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largement of fading rings. Dr. E. B. Judson, well-known radio research engineer of the Bureau of Standards, points out the longer wave fading will be slower—more of a day-to-day change. Dr. Taylor estimates that differential side band fading ("hashing" or "mush") will be less bothersome on the longer wavelengths. In addition, present local signal inequalities should be smoothed out somewhat. At present frequencies the signal may be 100 times as strong on a hilltop as in an adjacent valley bottom. Longer waves bend around obstructions better and fill in these radio shadows.

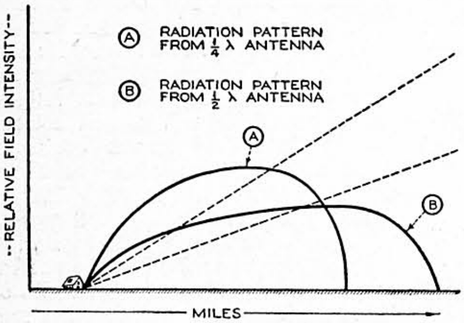

FIG. 5

Some experiments show that the non-fading distance can be definitely pushed back through the use of a half-wave antenna, as indicated by the increased ground wave service area indicated here

Static

Having so far demolished the fading bogie in our approach to national broadcasting, let us investigate the most serious technical objection to the whole scheme—static. It is known that atmospherics at 200 kc. or 1500 meters are worse than similar disturbances at 600 kc. or 500 meters, and that at both frequencies American static is somewhat worse than the north European variety. Dr. L. W. Austin of the Bureau of Standards, one of the greatest authorities on radio transmission in the world, estimates that static at the longer wavelength is more than twice and less than four times as intense as the common broadcasting variety. Dr. Taylor independently estimates that atmospherics at 200 kc. are at least twice as bad as those at 600 kc., and will be particularly noticeable in the southern part of the United States and in the midwest during its hot summers. When two such distinguished authorities agree so closely, their estimates certainly carry weight.

Dr. Judson states that on wavelengths around 17,000 meters, where the static is about twenty times as bad as that at 3000 meters and below, the worst average afternoon atmospherics measured at the Bureau of Standards seldom run above 1 millivolt per meter. He experiences no interference from this level of disturbance while measuring American high-power telegraph signals at the 3m.v./meter level. 200 kc. summer static in the south and southwest is certainly bad, but present broadcasting band interference in these regions is also quite intense. The writer's experience operating field sets around 300 kc. in Arizona and Texas

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TABLE 3
Fading Radii Over the United States

Wavelength	*Station*	*Power*	*Terrain*	*Predicted fading radii Miles*	*Observed fading radii Miles*
*	*	5 kw.	Mountainous	17	25
333	WJAX, Fla.	1 kw.	Flat, sandy	95	50
344	WENR, Ill.	50 kw.	Flat	100	125
*	*	50 kw.	Broken	55	60
361	KOA, Colo.	12.5 kw.	Flat (east)	105	150
361	KOA, Colo.	12.5 kw.	Broken (west)	55	75
394	WJZ, N. J.	30 kw.	Broken	60	120
405	WSB, Ga.	5 kw.	Broken	65	70
422	WOR, N. J.	5 kw.	Flat	130	100
428	WLW, Ohio	50 kw.	Flat	130	120
454	WEAF, N. Y.	50 kw.	Flat	140	100
468	KFI, Calif.	5 kw.	Broken—mountainous	55	80
					Averages:
				83.8	*89.2*

*Permission to publish not received.

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during the summer season indicates that higher wave static in the southwest is not prohibitive. Using an oscillating detector and two stages of audio, the head phones could be worn with comfort most of the time.

The static question can be more fully answered only from comprehensive quantitative data not now available. There is need for quantitative measurements of atmospherics, not only at 200 kc. but also at various frequencies within the present broadcasting band, at all seasons of the year in various sections of the United States.

High interference levels call for high signal levels. From a consideration of all the data given above, it appears that in the case of the average national station we must figure on putting down a signal strength of about 3 m.v./meter at the boundary of the true service area—that is, 400 miles from the transmitter. Of course much higher signal levels will obtain in the large areas nearer the transmitter. In the case of one or two stations in the southern states where static is more intense, we must be prepared to put down signal levels approaching 10 m.v./meter at the service area boundaries.

High Power

Returning to Eckersley's curves, we find that such signal levels at such distances call for high power. Perhaps the average listener and broadcast engineers will gasp a little (but let us hear the worst at the start) when we say that the indicated upper limit of antenna power is 1000 kilowatts. However, this power is not considered at all excessive in some other branches of applied physics. The passenger in a large transport airplane sits within a few feet of the continuous delivery of nearly 2000 kw. in mechanical torque. One or two southern stations may have to radiate powers approaching 10,000 kw.

It might seem at first that such broadcasting power levels are scarcely possible. If they are not possible now, there is reason to expect that they will be shortly. At Saxonburg, Pennsylvania, KDKA is now building a 400-kw. transmitter for operation within the present broadcasting band. It is also true that high powers are somewhat easier to obtain at lower frequencies, and that the trend of broadcasting power has been constantly upward. To the great question whether they are economically justified, low frequency non-fading ranges give a favorable answer. Our estimates are purposely near the maximum expected limits. The American transmission experiments mentioned above appear to indicate somewhat lower powers on the order of 100 kw. to 1000 kw. Dr. Taylor estimates that 200 kw. to 500 kw. should be sufficient for the purpose.

At the start moderate powers around 100 kw. would probably be ample, to be increased gradually as the demand for higher powers developed and the economic basis for them became available. A more detailed treatment of the technical and economic aspects of these high broadcasting powers must wait until a later article.

Receiver Design and Other Matters

Many other questions arise, also to be more fully discussed when more space and time are available. One of the most important is how receiver manufacture and the present heavy receiver investment of the American people will be affected by a proposed opening of a long-wave broadcasting band. The answer is: Favorably, if changes are intelligently made. It must be emphasized that long-wave superbroadcasting will supplement rather than replace our present broadcasting structure, giving an added service and taking nothing away. The long-wave system should be inaugurated gradually, with perhaps a single 100-kw. station in the north central region where rural coverage is now quite inadequate. In addition to giving true broadcasting service to millions now without it, this transmitter should on favorable nights cover the United States with a service good enough to interest thousands of experimenters and to stimulate the sale of adapters. Gradually, as the system filled out and increased power, provision could be made for the addition of long-wave tuners to existing sets both old and new. The final development would of course be combination receivers, employing band-changing switches or separate tuners. The long-wave tuners may be of very simple design due to relaxed sensitivity and selectivity requirements. All these technical receiver problems, in fact, are simple compared to the design difficulties presented by our present overcrowded broadcast spectrum.

It is of course true that the frequencies required for long-wave broadcasting are used by other services at present. With each of the seven stations allocated to a separate channel, a band 70 kc. wide, say between 155 kc. and 225 kc. (1935-1330 meters) is indicated. With partial synchronization, tuning to common frequencies the alternate pairs northeast-northwest central, north central-northwest and southeast-southwest, a 40 kc. band say between 175 and 215 kc. (1715-1395 meters) should suffice. These bands are located so as to coincide with those now used for long-wave broadcasting in Europe. With complete synchronization the national chain might be operated on a single program within a single 10 kc. channel. Canada must also be considered. Although she has no long-wave stations at present, she would naturally want some if the plan works out well on American soil. Mexico would probably not be interested because Central American static favors shorter waves or wired wireless. At the powers we recommend

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All-Wave A. C. Superheterodyne

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all wiring before inserting the tubes.

The aerial should be short, not over forty feet, and a good ground should be provided. Tubes in the receiver take the usual time to warm up, and in addition, there is a certain amount of drift during the first ten to fifteen minutes. On broadcast it is not noticeable, but on short waves it is sometimes great enough to detune a station completely. This only happens when the receiver is first turned on and after the oscillator has become completely heated, there is no further drift. If the local-distance switch reduces the sensitivity too much, connecting 1000 ohms in series will lessen its effect.

Since the operation is simple, no special tuning instructions need be given.

Performance

An L-32 ultradyne operating in New York City brings in WLW in Cincinnati any evening without a trace of interference from WOR, Newark. Likewise, WMAQ, Chicago, without interference from WEAF, New York. XEN, Mexico City; KFI, Los Angeles; KOA, Denver; KSL, Salt Lake City, have been received regularly. On short waves, stations all over the world have been logged.

List of Parts

1 Pilot Antenna coil, L1, L2.
1 Pilot oscillator coil, L3.
1 Amerchoke Type 3842, L4.
1 Amerchoke Type 709, L5.
1 National S.E. 50 condenser, C1.
1 National E.C. 250 condenser, C2.
1 National special condenser, C3, C4.
3 Aerovox special 0-.1-.1 condenser, C5, C6, C7.
1 Aerovox special 0-1, 0-1-1-1 condenser, C8.
1 Aerovox Type 1460 .0005 condenser, C9.
1 Aerovox Type 480 .05 condenser, C10.
1 Aerovox Type 250 .25 condenser, C11.
1 Aerovox Type 1450 .01 condenser, C13.
1 Aerovox Type E5-4444 0-4-4-4-4 condenser, C14, C15, C16, C17.
1 Aerovox Type E5-4 4.0 condenser, C18.
3 Ultraformers Type L-32, T1, T2, T3.
1 Amertran Type 151 Trans., T4.
1 Amertran Type Pf 245A Trans., T6.
2 Lynch resistors .5 megohm Type LF4, R1, R17.
1 Aerovox resistor 750 ohm Type 991, R2.
2 Lynch resistors 15,000 ohm Type LF4, R3, R12.
4 Lynch resistors 50,000 ohm Type LF4, R4, R7, R10, R14.
6 Lynch resistors 1000 ohm Type LR4, R5, R6, R8, R9, R11, R13.
1 Aerovox resistor 2000 ohm Type 992, R15.
1 Lynch resistor .25 megohm Type LF4, R16.
1 Clarostat resistor 3000 ohm Type M-3-T5P, R17.
1 Aerovox resistor 1500 ohm Type 992, R18.
1 Aerovox resistor 2000 ohm Type 992, R19.
1 Aerovox resistor 3000 ohm Type 992, R20.
1 Aerovox resistor 1000 ohm Type 992, R21.
1 Aerovox resistor 2500 ohm Type 992, R22.
3 Aerovox resistors 20 ohm Type 986, R23, R24, R25.
1 Aerovox resistor 790 ohm Type 992, R26.
1 Chassis drilled.
1 National dial 270 degree.
4 National tube shields.
1 Alcoa box shield.
1 length ¼-inch rod.
8 UY sockets Eby.
4 UX sockets Eby.
1 UX loud speaker plug.
2 National knobs for ¼-inch shaft.
5 National screen grid clips.
1 antenna ground binding post.
50 feet of hook-up wire.
2 feet rosin core solder.
Screws, nuts, lugs, washers, etc.
1 instruction book.
5 –24's.
1 –27.
2 –45's.
1 –80.
1 d.c. dynamic speaker 2000-ohm field with input PP trans, T5.

Making National Broadcast Coverage Direct

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there might be possibility of inter-continental interference.

The general answer to all these questions is: The greatest good for the greatest number. If long-wave super-broadcasting proves itself experimentally, if it will bring new standards of service to immense rural areas and to millions of farm and small town dwellers which can be reached in no other way, then the system will overcome all objections. In the light of national broadcasting as a realized dream, all difficulties will vanish.

Value of National Coverage

No one can say positively at the present time that long-wave superbroadcasting will solve our rural radio problems, or that other methods will fail. But the national coverage plan does open up immense and interesting possibilities. It is well worth careful consideration. It should lead not only to academic discussion, but to unbiased experiments which can alone prove or disprove its validity. It may be the technical answer to the expressed desire of Congress for "equality of radio broadcast service, both of transmission and reception."