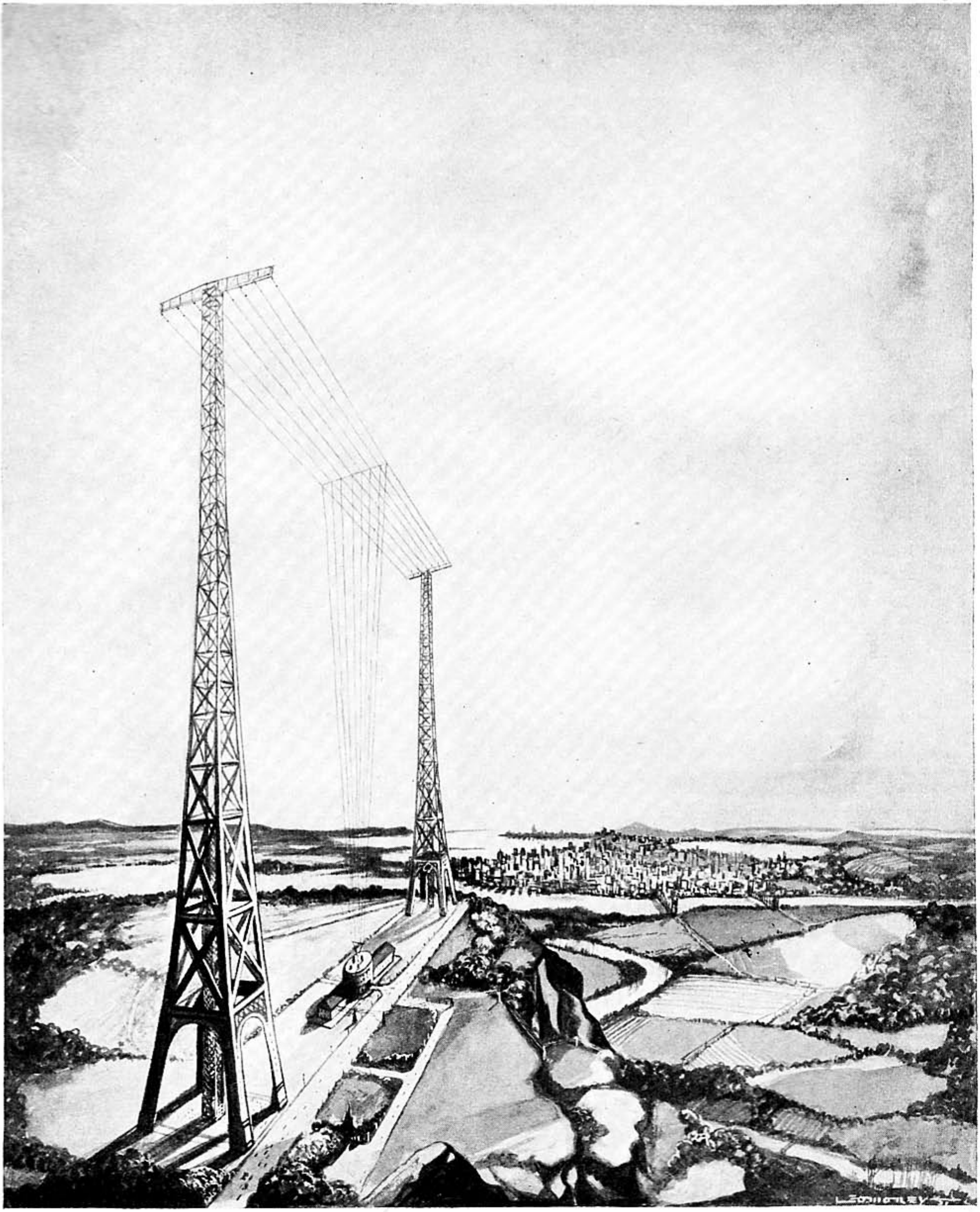


A Super-Broadcasting Station of the Future?

To cover the whole country by direct waves, towering antennas 800 feet high, located in a central radiating position, would be fed by a 1,000-kilowatt transmitter operating on 1,500 meters, according to Lieut. Wenstrom's plan. This system would not rely on the sky wave with its effect in producing fading in distant receivers

Super Broadcasting *on* Long Waves

This month Lieutenant Wenstrom goes into a more detailed study of some of the problems involved in the system of long-wave super-power broadcasting which he proposed in the April issue

By Lieut. W. H. Wenstrom

IN the April issue of RADIO NEWS we put forward a plan for the betterment of American broadcasting. It calls for something like seven national stations operating at power levels approaching one thousand kilowatts on wavelengths around 1500 meters. It is a foregone conclusion that some readers will oppose the plan as visionary and impractical, while others will support it as logical and promising. Few who are genuinely interested in broadcasting can regard it with complete indifference.

One can easily get too excited about a new and untried idea. On the other hand, one can also be so much in a rut that new and promising ideas are automatically shunted away from the mind. Human beings have thrown away their savings on schemes to extract gold from sea water, and other human beings used to stand around and laugh at Robert Fulton when he was building the first American steamboat, to say nothing of the early airplane experimenters. The formula for a reasonable middle course, so far as it can be stated in words, seems to be that everything must be examined on its merits.

The Long-Wave Super-Broadcasting Idea

Briefly summarized for the convenience of readers this month joining the discussion, the outline of our national broadcasting idea is as follows: On present broadcasting wavelengths signals begin to fade badly from sixty to one hundred miles from the transmitter, depending upon the wavelength and the type of ground over which the signals pass. This fading is erroneously ascribed to various causes even in the semi-technical press, but is probably due to amplitude equality between the constant-path ground wave and the variable-path sky wave and the phase differences between the two. Further out, where the sky wave predominates, fading is less severe but usually present in some degree. There is another type of fading called "hashing" which is caused by unequal fading of the two sidebands of a telephone signal. As neither kind of fading can be tolerated under improving standards of true broadcasting service, station service areas are arbitrarily limited by the occurrence of first fading rings and power increases are only useful (aside from extension of doubtful space-ray service) in so far as they extend reasonable signal strength out to these fading zones. The useful power limit at present broadcast frequencies appears to be around 50 kw.

Our present broadcasting system is laid out on metropolitan rather than rural or truly national lines, and the thirty-odd two-hundred-mile circles representing the possible service areas of our larger transmitters cover only a small fraction of the entire United States, as shown in Figure 4, page 880, of the April article. While the indefinite extension of synchronized 50-kw. transmitters would be a possible way to bring city reception to the country dwellers who need it most, it is in general much cheaper to cover a given area with few large stations rather than many small ones.

On 1500 meters the signals do not begin to fade until they are something like 400 miles out from the transmitter. This enormous non-fading area permits the efficient use of very high power (perhaps 1000 kw.) to distribute true service broadcasting to every isolated listener in half a million square miles of territory. About seven such stations should bring clear, loud and non-fading reception, night and day, summer and winter, to practically everyone in the United States regardless of location. Of course, the present largely metropolitan system would continue in undisturbed operation. While the plan entails such difficulties as receiver changes and wavelength assignments, the prospective benefits are probably great enough to justify them if experiment bears out our preliminary theory.

Far from glossing over the disadvantages of the scheme, we have been at some pains to discover them and point them out. In the same spirit we welcome criticism and discussion of the idea.

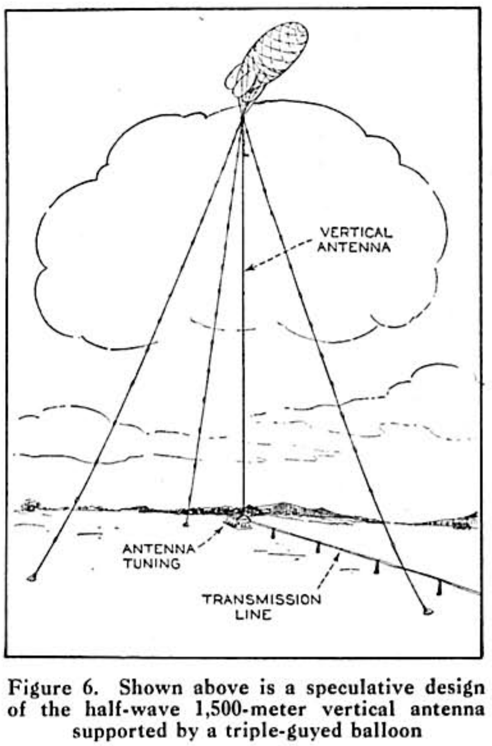


Figure 6. Shown above is a speculative design of the half-wave 1,500-meter vertical antenna supported by a triple-guyed balloon

Preliminary Experimental Work

Even more important than discussion is experiment, particularly along two lines indicated last month. There is need of quantitative measurements of the intensity of static, in the seven districts of the United States: Northeast, southeast, north central, northwest central, southwest central, northwest and southwest. These measurements should run at least a year to determine seasonal variations. Longer studies would give the year-to-year changes, which might follow the trend of long-wave atmospherics as observed for some years at the Bureau of Standards. Observations should be made at 200 kc., at 750 kc. or other frequencies within the present broadcast band, and at some other frequencies as well. This research, aside from its value in the present discussion, would be an important contribution to the scientific background of radio transmission.

Such measurements are within the scope of any well-equipped radio laboratory. Probably the simplest and most efficient method is that used by the Bureau of Standards. An autodyne detector feeds several stages of audio amplification. An audio tone of definitely adjustable amplitude is introduced into the

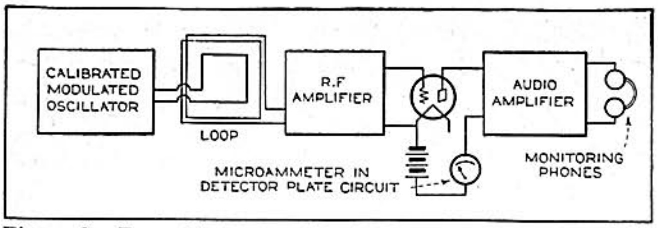


Figure 2. Essential parts of a field strength measuring set as used for measuring transmission from broadcasting stations, usually in portable form and mounted in an automobile

audio amplifier, and compared either visually or audibly at the amplifier output with the atmospherics picked up by the detector. A separate modulated oscillator is used to check the detector sensitivity, which remains fairly constant for long periods if filament and plate voltages remain constant. More complicated automatic recording methods have been described by H. T. Friis in the Bell System *Telephone Journal* for April, 1926, by E. H. Kincaid in the Proceedings I. R. E. for October, 1927, and by S. W. Dean in the Proceedings I. R. E. for July, 1929.

The other experimental field in which we should like to see our predictions verified is 200 kc. telephone transmission in various parts of the United States. While some of this has already been done in the northern Appalachian section, we need information particularly on the shape and size of the first fading ring not only along the eastern seaboard, but also in the flat mid-west, in the northern Rockies and southwestern deserts, and over the steep mountains and wide, flat valleys of the Pacific coast. For every transmitting station there must be several field strength measurement sets continuously in action.

Field measurements are now becoming standardized. Present methods are quite fully described in the *General Radio Experimenter* for January, 1931. Even a single set, costing as much as the automobile which carries it, is likely to be beyond the means of the average experimenter. The principle, however, is simple. A microammeter in the detector plate circuit, as in Figure 2, increases its reading in proportion to the strength of the received carrier wave. These increases are quite small compared to the no-signal plate current, which is balanced out in the more sensitive arrangements. For instance, at New Haven, with a normal plate current of 0.4 ma. or 400 μa, WOR at Newark, N. J., produces about 10 μa increase, while WEAF at Bellmore, Long Island, produces a 100 μa increase. Of course, a good radio-frequency amplifier is necessary in front of the detector, particularly for a portable set, which must use a loop antenna. The expensive part of the installation is a modulated oscillator, which is used for calibrating the receiving system.

Such a program of 200 kc. transmission tests as we suggest could be successfully completed only by some suitable agency such as a government department or a large electrical company. It is a logical and necessary step before the building of the first national long-wave transmitter.

Technical Possibilities

Most people with whom we have discussed the long-wave super-broadcasting idea have regarded it at first as "startling" and "upsetting to present notions." Others have termed it "radical." There is nothing radical or new about long-wave broadcasting—it has been done in Europe for years—but its application on so grand a scale to the United States is undoubtedly new. When one realizes how great a part thought-habits and even inertia play in our lives, these reactions can only be regarded as natural. In addition, however, the plan might be criticized from a transmitting viewpoint as idealized and not practical. It might be said that the system is on too grand a scale for present technical possibilities, that it would cost too much to build and run, and that inasmuch as national advertisers care little about covering the less inhabited districts of Nevada or Alabama, no one would pay large amounts of money for such a system.

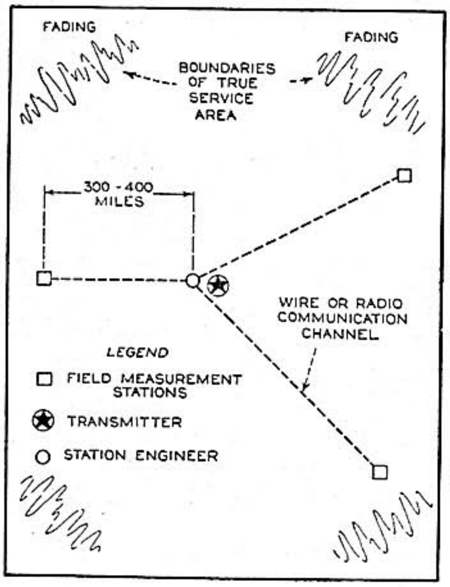


Figure 7. Possible wave economies in long-wave super-broadcasting. Field measurement stations continually report actual signal strength to station engineer, who regulates output power accordingly to maintain constant intensity

By way of answering some of these questions, let us first turn to the technical possibilities of broadcasting transmission as they are at present. The standard high-power broadcast transmitter of the present has an output of 50 kw. Figure 5 shows a block diagram of such a station. The crystal oscillator is followed by a buffer amplifier which feeds into a 50-watt amplifier tube. The radio-frequency currents in this 50-watt tube, called the modulating amplifier, are modulated by a 250-watt audio power amplifier which is fed by the audio speech amplifier. The audio tube is larger than the radio tube which it modulates so that modulation may be 100 per cent.—or, in other words, so that the steady radio-frequency carrier may be varied at audio frequency between twice its normal amplitude and zero.

The older broadcast transmitters used to step up the audio and radio currents to kilowatt levels separately, modulating the output stage. This design, of course, entailed duplication of amplifiers all the way up the line, and a tremendous amount of audio energy in the modulator, which in the case of a 50-kw. transmitter consisted of twelve large water-cooled tubes in parallel modulating eight of these tubes connected as the final radio amplifier stage. Under this system, also, the modulation was not over 60-70 per cent.

The more modern 50-kw. transmitter shown in the diagram therefore does its modulating at an intermediate level

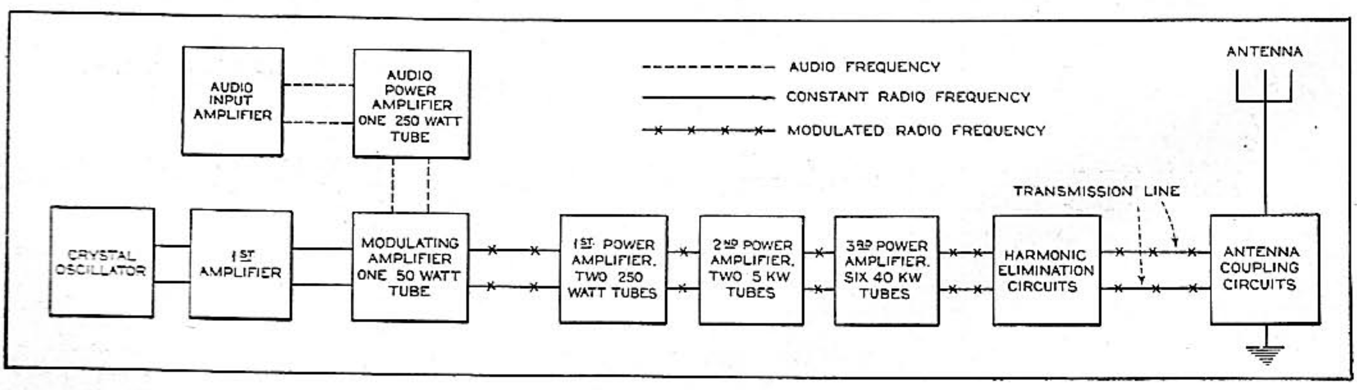
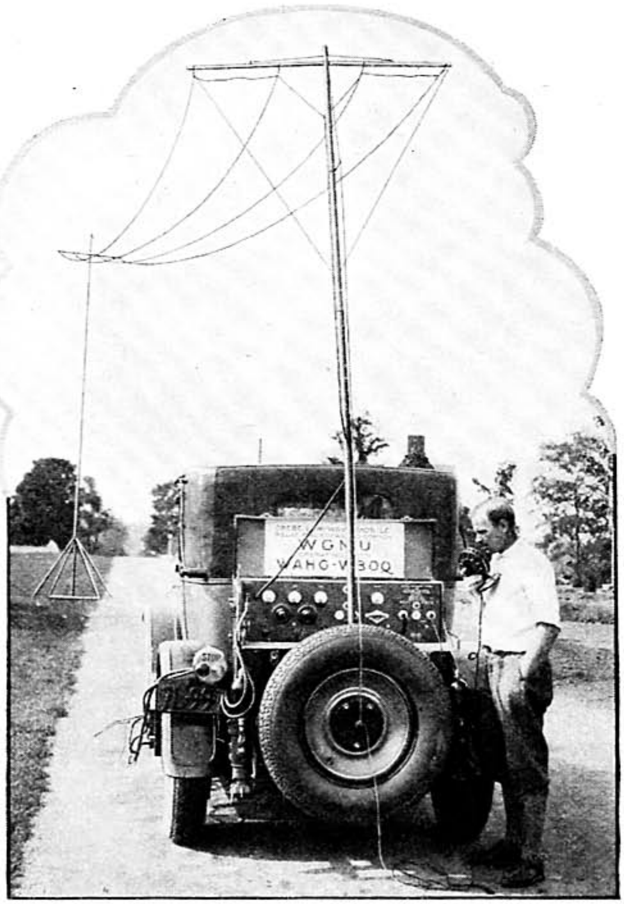


Figure 5. Block diagram of a typical 50-kw. broadcast transmitter, showing successively larger stages to handle increasing power. Modulation takes place in an early stage, thus eliminating the duplication of amplifiers and high-power modulator stages formerly required

represented by the 50-watt modulating amplifier tube. From here on the modulated radio frequency is amplified in exactly the same way that the incoming signal is amplified in the radio-frequency stages of a receiver; the only difference is that the receiver tubes are handling microwatts while the transmitter tubes must handle watts and kilowatts—the ratio is something like a billion to one. After the 50-watt modulating amplifier, then, comes a power amplifier consisting of two 250-watt tubes, which in turn feeds another stage consisting of two water-cooled 5-kw. tubes. If the energy at this point were fed directly into the antenna without further amplification, the whole array would be simply a 2 kw. broadcast transmitter. But the third power amplifier stage, consisting of six 40-kw. tubes, further steps up the energy and makes the ensemble a 50-kw. transmitter. As the carrier must reach peaks of twice normal value at 100 per cent. modulation, the total rating of the output stage must be at least four times the normal rating or 200 kw. Another make of 50-kw. transmitter uses two 100-kw. tubes in the output stage.

Fifty kw. transmitters are manufactured by two or three large electrical companies in the United States. They cost around $300,000 each. So far about ten stations have actually put them into operation and some thirty more are ready to do so if their license applications are granted. There is, therefore, nothing prohibitive about a 50 kw. transmitter.



A mobile broadcast transmitter. Such outfits are used to test proposed locations for broadcast stations

Radiating One Thousand Kilowatts

The step from 50 kw. to 500 kw. or 1000 kw. involves nothing more than the addition of a final 1000 kw. stage. The largest present tube, manufactured especially for the new KDKA station, is rated at 200 kw. Twenty of these tubes in parallel should make a 1000 kw. stage with a peak output of 4000 kw. A large number of tubes in parallel is likely to suffer from electrical troubles such as parasitic oscillations, it is true, particularly at high power. However, in the 1915 Arlington radiophone experiments 500 tubes were connected in parallel—a feat which shows what can be done along this line. The design of a 1000 kw. broadcast transmitter will be very far from plain sailing, but this is true of all electrical design problems. Difficulties are to be expected, but the probability is that they can be overcome.

The new KDKA station at Saxonburg, Pa. (thirty miles from Pittsburgh), is now actually completed and licensed for experimental operation between 1 a.m. and 6 a.m. at an output of 400 kw. While the exact design of the transmitter has not been made public, it is reasonable to suppose that it is a standard 50 kw. transmitter feeding a final power amplifier comprising about eight of the new 200 kw. tubes in parallel. These tubes are water-cooled, of course, six feet high and eight inches in diameter. The antenna is of unique design, being an eight-acre circular web supported on 100-foot wooden poles. This is in effect a great condenser, while most of the newer antenna designs are predominantly inductive.

The new KDKA transmitter is interesting in several ways. It shows for one thing that a 400 kw. broadcast transmitter is already an actuality. It should settle definitely the value of power increases in extending service areas on present wavelengths. If our theoretical reasoning is correct, 400 kw. KDKA will fade just as badly beyond 100 miles or so as 50 kw. KDKA does now, although the signal will be something like three times as strong. The new station may give fair service at 600 to 1000 miles, which at least will be no worse than that most rural listeners have to put up with now. But judged solely by true service within the fading ring, there is reason to predict that more than 75 per cent. of the radiated 400 kw. will be wasted. The experiment would become still more interesting if it were possible for KDKA to increase its wavelength to 1500 meters in addition to its power increase. The great difficulty here, of course, is that few 1500 meter receivers exist at present. But more of this in the next of this series of articles.

What we have shown so far is perhaps enough to indicate that there are no insuperable difficulties in the way of a 1000 kw. 1500 meter broadcasting station.

Another question is the amount of interference which such a powerful station would cause in receivers tuned to other wavelengths. Dr. Dellinger of the Bureau of Standards has recommended that stations using more than 5 kw. be located outside centers of population by minimum distances commensurate with the power transmitted. For a 5 kw. station this is 2 miles; for a 50 kw. station it is about 6 miles. Exterpolating from these values, we can assume that a 1000 kw. station is not going to cause much interference beyond a 30-mile circle, and the few inhabitants of this circle can probably tune the station out by using wavetraps. No such station should be located within 30 miles of a city, of course. But with the tremendous service area which such power on 1500 meters provides, 30 miles, more or less, would make little difference in the entire coverage area.

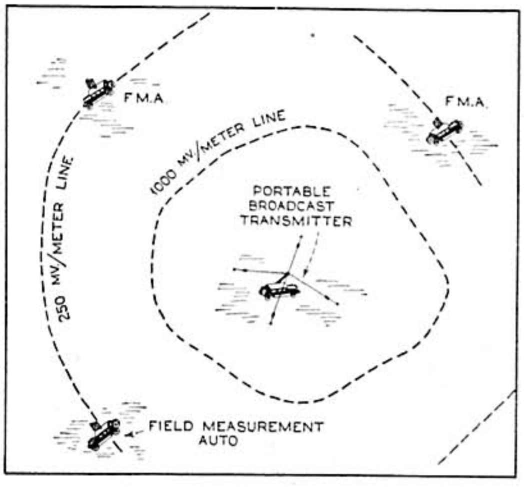


Figure 4. How field measurement sets are used to outline the field from a transmitter. The distances shown are shortened in relation to the size of the automobiles

Antenna Design

Another technical question to be solved in long-wave broadcasting is antenna design. The commonest type of antenna, named after Marconi, is the ¼ wave grounded type. The antenna itself may be a straight wire ¼ wavelength high, or a bent wire or group of wires having somewhat less height but more capacity to ground. At the average broadcasting wavelength of 400 meters ¼ λ is about 330 feet, and (*Continued on page* 1104)

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most stations use a T type antenna supported between steel network towers 200 to 300 feet high.

As we mentioned last month a vertical half wave antenna radiates more strongly in a horizontal direction than the ¼ λ type, hence giving a relatively strong ground wave and extending the non-fading range by perhaps 50 per cent. WABC is building in Wayne, New Jersey, a ½ λ antenna of this type; the steel tower itself, about 600 feet high, acts as the antenna. The tower, along with a new 50 kw. transmitter, should be ready for operation in May or June of this year. It will be interesting to see just where the first fading ring of this new station will fall, and to observe the other transmission characteristics of the ½ λ antenna.

Now at 1500 meters even one-fourth wave is around 1200 feet. This means that we can leave half wave antennas out of the discussion entirely for the present, contenting ourselves with the more conventional ¼ λ type. A 1500 meter antenna proportionate in size to those of most present broadcast stations would require two steel towers about 800 feet high. These towers would, of course, be difficult to build from an engineering viewpoint and consequently expensive. However, the fact that they can be built for sufficient important uses is shown by the number of high antenna towers in use today. There are eight 820-foot towers at the Lafayette, France station, built by the United States Government during the war. There are no less than twelve 820-foot towers at the British Empire station near Rugby, England. There are ten 400-foot towers at Rocky Point, Long Island, and three even higher at Arlington, Virginia. So it goes. Where the importance of a proposed service is great enough, 800-foot towers are technically and economically possible.

At this point we might give some rein to imagination and picture a possible 1000 kw. 1500 meter broadcast station of the future. As we drive through sparsely settled country over the automobile road connecting the station with civilization, the first thing to attract our attention is two great steel towers in the distance, surmounted by crossarms between which stretches the yet invisible antenna. As we approach we can see the immense antenna fabric traced against the sky. Though we now seem directly under the towers, their bases are still a half mile away as we enter the self-supporting village known as Radio Northeast. It looks much like any other village, with a general store, a street or two of houses, and people going about their errands. On the far side of town and a quarter mile distant is the transmitting station where some 8000 kw. of electricity, arriving from a distant power plant over a high tension transmission line, are converted into radio waves and a necessary percentage of useless heat. Over wire lines, too, come the programs to a monitoring room in the station, whence they are passed on to the audio input amplifier. The building houses a complete 50-100 kw. transmitter, and in addition a bank of giant vacuum tubes comprising the final output stage. These operate other monitoring devices, but pass most of their energy into a transmission line extending out under the towers to a small shack which houses the antenna tuning circuits.

Aside from the strictly practical antenna described above, there are some other systems which at present are little better than speculative possibilities. For one there is a single 1200-foot tower, insulated from the ground and used as a ¼ λ antenna. The guys of such a tower must, of course, be broken into comparatively short lengths by insulators. The new Empire State Building towering above the New York skyline gives a good idea of what 1200 feet means in the way of height. A single 1200-foot mast, if it could be economically built at all, would

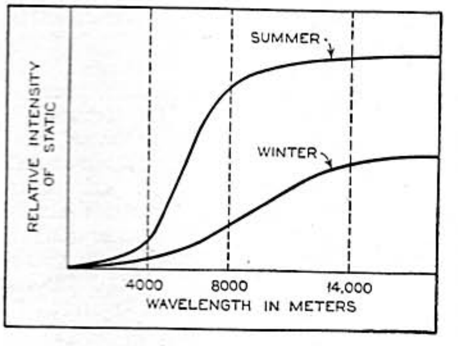

Figure 1

probably cost more than two 800-foot ones, though it might be more efficient.

Another speculative possibility is a balloon-supported antenna. These have actually been used in experimental transmissions both in America and in Europe. Medium power experimental transmitters, however, can be handled more roughly than a 1000 kw. broadcaster which must furnish true day and night service to half a million square miles. If the balloon blows around in the wind, changing the antenna capacity through wide limits, some thousands of dollars worth of tubes may go up in smoke, and even if the circuit breakers do their duty broadcast service may be interrupted. In this connection it is interesting to note that John Hays Hammond, Jr., has taken out a pattent (U. S. No. 1,561,228) on a device to compensate antenna capacity changes due to antenna movement relative to the ground.

For a ½ λ 1500 meter antenna, which must be 2400 odd feet high, a balloon appears to be the only practicable method of hoisting wire to such a height. By using three or four insulator-spaced guys, forming a pyramid with the balloon at the top, and a central conducting downlead for the antenna proper, the thing might possibly be done. However, the conventional two-tower support would probably prove more permanently satisfactory than any of these schemes.

The costs of the proposed national sys-

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(*Continued from page* 1104)

tem will undoubtedly be large. There is the initial cost of the station itself, and the cost of large tube replacements. Probably the main running cost would be that of electric power. This can be purchased in large amounts at about one cent per k.w.h. It is reasonable to assume that a station radiating 1000 kw. will draw about eight or ten times this power from the supply mains—say 8000 kw.—and that it will operate on the average eighteen hours out of the twenty-four. At this rate the annual power bill for each station comes to, roughly, half a million dollars—a sizeable amount. However, the present broadcasting bill for technical facilities alone is around $30,000,000 per year. In addition, we do not advocate starting the seven odd national stations at anything like 1000 kw. each. They should be placed in operation one at a time in accordance with increasing demands for long wave service, at power levels around 100 kw. each. Then, as true service benefits become apparent and results justify the expense, power can be increased.

It is probable that the use of such high broadcasting power will develop an entirely new transmitting power technique. Heretofore we have been running our transmitters at constant power levels, while the listeners' signals were anything but constant. With a transmitter drawing power at over $1000 per day it would be worth while to operate constantly two or three field measurement stations in the outlying portions of its service area, so that power could be reduced under good transmitting conditions and increased under poor ones. It is even possible that all the patient research in correlations between sunspots, weather and radio transmission, now so seemingly removed from engineering problems, may enable station engineers to predict power requirements hours or days in advance.

It can be argued that the present cost of broadcasting is paid by advertisers with goods to sell, and that such advertisers, seeing scant possibility of sales in the great open spaces, would contribute nothing to the proposed national system. But the insistent selling talks of advertisers are a fairly recent arrival in radio, and to many an unwelcome one. Perhaps the advertiser who gets the most out of radio is the one who contents himself with a mere announcement of the full firm name every quarter hour or so, meanwhile dubbing the orchestra or artist with a brief commercial identification. Such an advertiser, valuing the permanent benefit of radio advertising in building up national good-will above immediate sales to a frenzied few or the overnight return of toothpaste cartons in exchange for horoscopes, should look favorably on national true service broadcasting.

This viewpoint raises questions too involved for discussion in a technical article already too long. It is true, however, that many people find much wrong with our present radio broadcasting and with the methods by which it is financed. More and more people are beginning to be annoyed by the blatant and insistent selling talks which our loud speakers deliver in longer and longer installments. A survey by the Commonwealth Club of California, made a year ago when advertisers were less clamorous, showed that 63 per cent. of the listeners thought that there is something wrong with radio broadcasting. Further, only 43 per cent. ever bought anything as a result of radio advertising, while 54 per cent., or a clear majority, were annoyed by it. Still, many advertisers think it good business to alienate a hundred million people in order to sell a hundred thousand cartons of goods. Perhaps it is for the present, but how about the future?

The technical side of broadcasting is likewise far from rosy at the present time. The Federal Radio Commission is daily harassed by the inordinate demands, and the political influence, of thousands of publicity seekers who think that broadcasting exists rather for the boundless expansion of their egos than for the genuine entertainment and service of millions of listeners. As if the wavelength situation in the United States alone were not bad enough, Canada is making ready to demand a few more exclusive broadcasting channels than the six out of ninety-six which she has at present, while Mexico has begun to operate powerful transmitters on the same wavelengths that some of our transmitters now use.

All this goes to show that broadcasting as it exists today is far from perfect. There is no need to consign the national long wave plan summarily to the wastebasket because it does not fit in perfectly with an imperfect system of the present. It is also true that advertising is not the only way in which broadcasting can be paid for. There is always the possibility of an indirect tax on receiving sets or on the vacuum tubes which are the heart of a receiver, or even a direct listener tax as collected in Europe. These tax schemes appear less fantastic as the standard of broadcast service is raised.

There is the ultimate possibility, too, of radio endowments. Many men who have accumulated a surfeit of this earth's riches are genuinely looking for a chance to spend it in some way that will help people without spoiling them. Endowing universities has been considered as good a way to spend this money as any. When radio broadcasting transmission technique advances far enough to eliminate the will-o'-the-wisp vagaries of space ray service in favor of true broadcasting service for the whole nation, overgrown fortunes may be attracted to this great university and theater of the air.

Broadcasting may be financed eventually by any one of these methods, by a combination of all three, or possibly by others yet undiscovered. The expense of our proposed national long wave system, though considerable, is not excessive considering the possible benefits promised by the system. More to the point than gestures of horror at possible expenses, is the initiation of experimental work to determine definitely whether or not the benefits can be realized.