PROCEEDINGS

of the

RADIO CLUB *of* AMERICA

Vol. I No. 8 December, 1920

R.C.A. SPECIAL NOTICES

The next meeting of the Board of Directors will be open to the entire membership. At that time nominations for officers for 1921 will be made.

DR. WALTER G. HUDSON

It is with a feeling of deep sorrow that we announce the loss of one of the most revered workers in the amateur radio field. Dr. Walter G. Hudson of Yonkers, N. Y. will be remembered as one of the first amateurs of New York City. Despite his mature years his real delight was to light up the old pipe and help the Navy Yard receive real long distance calls in the old days of 600 meter amateur radio.

Dr. Hudson was one of the pioneer members of the Radio Club of America and through his wise counsel and enthusiastic support many of the early trials were overcome. Just before the war he invented a new filament for use in audion detectors which was widely known and marketed as the Hudson Filament Audion.

Besides Dr. Hudson's success in the radio field he was not only a practising physician for many years but also a chemical expert for the DuPont Powder Company of Wilmington, Delaware.

It is impossible in the short space of this message to fully relate the achievements of so versatile a genius but over and above all stands the figure of Dr. Hudson the man, courageous, fearless, patient and wise—one of the best friends of radio and radio men.

Office of the Editor—319 W. 94th St., New York City.
Walter S. Lemmon—Editor
Ernest V. Amy
Austin Lescarboura
Lester Spangenberg

The Bureau of Standards—A.RR..L. Tests of Short Wave Radio Signal Fading

By S. Kruse
Assistant Electrical Engineer, Bureau of Standards

Presented at meeting, Columbia University, September 24, 1920

PART II.

Results of Tests.

The test system began operations June 1, 1920. The results here given are, with few exceptions, those obtained on the test sheets of the last four weeks of the run, that is to say, from June 15 to July 17. The first three weeks of the test were run while winter conditions were gradually changing to summer ones and before the system had gotten properly under way. As three other tests are to be run during the other seasons it was thought best to consider the last part of this test which was run in summer weather. The additional information which could have been obtained from analysis of the first three weeks of the test would not at all have compensated for the additional men and labor involved. The results of transmission by station 9LC at St. Louis, Mo., were also eliminated as only a few records of any value were obtained. As has been explained, station 8ER at St. Marys, Ohio, was added to the transmission system and the records on this station are considered instead of those on 9LC.

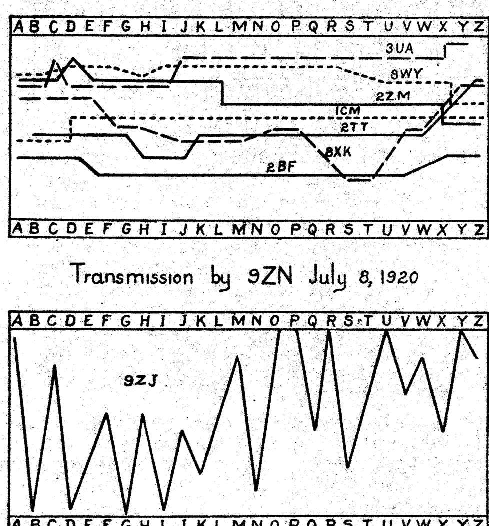


Fig. 12—Normal 9ZN curves.

During the entire first week, the curves that were received seemed to mean nothing. In Fig. 12 are shown representative curves for station 9ZN. Those in the upper half of the sheet which were secured by 3UA at Baltimore; 8WY at Cambridge Springs, Pa.; 2ZM at Clifton, N. J.; 1CM at Laconia, N. H.; 2TT at Yonkers, N. Y.; 8XK at Pittsburgh, Pa.; and 2BF at Montreal, Canada, are entirely representative curves for this station, which has the distinction of fading less than any other station in the system, its peculiarity being that it is, in general, heard steadily or else not at all. The curve below, which was secured at 9ZJ at Indianapolis, is a very unusual one for transmission from 9ZN and would lead to the suspicion that the receiving apparatus at 9ZJ was at fault, except for the fact that on this and other evenings normal curves were secured on all other stations at 9ZJ and almost without fail 9ZN swung violently. In Fig. 13 are shown some curves secured from transmission of 8XK at Pittsburgh, Pa. 8XK swung more rapidly than any other station in the test, often going from extremely

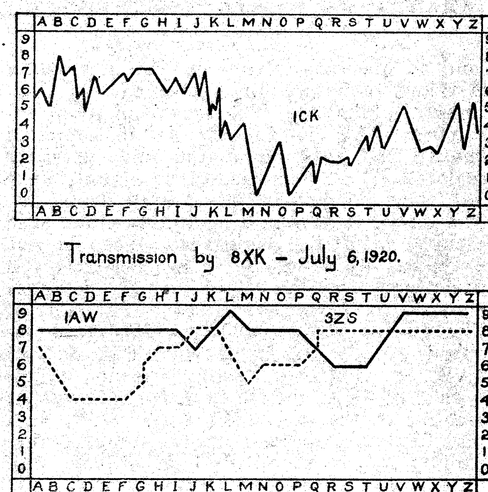


Fig. 13—Normal 8XK curves.

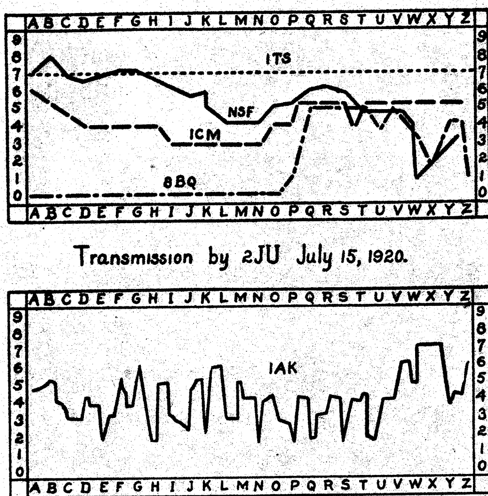


Fig. 14—Normal curves on 2JU.

loud to absolute silence in less time than is taken to sound one letter of the Continental alphabet. The sensation when receiving 8XK is exactly as if someone opened the antenna switch and instantly reclosed it. The intensity of signals does not vary slowly—letters simply drop out. The curve shown in the figure which was secured at 1CK, Braintree, Mass., is not a typical 8XK curve, as in this case the variations, while rapid, were gradual enough to form some sort of a curve. The curves shown below, which were secured at 3ZS in St. Davids, Pa., and at 1AW in Hartford, Conn., are not at all typical of 8XK, and, in fact, for this station amount to freaks. 2JU, 1AW, NSF, 8ER and 9LC lay between these limits, fading rapidly at times, slowly at others, and

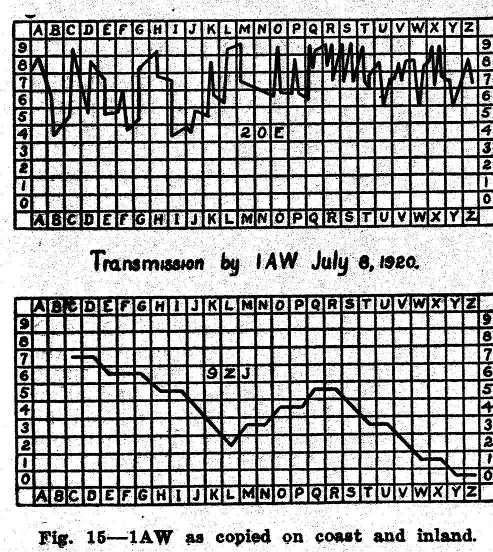


Fig. 15—1AW as copied on coast and inland.

seldom being as steady as 9ZN nor varying as violently as 8XK. Typical curves for 2JU are shown in Fig. 14 and for 1AW as copied on the coast and inland in Fig. 15.

Check Curves

The tests had not been in progress very long, however, before the first evidence began to appear that we were securing some sort of information. This evidence first appeared in the shape of similar curves from various receiving stations. At Washington there were four recording stations. Two of these, (3JR and WWV) are about one mile apart. The curves obtained at 3JR were generally checked with fair accuracy by WWV when that station was on watch, which unfortunately was not often. The curves at 3SU, about four miles southwest,

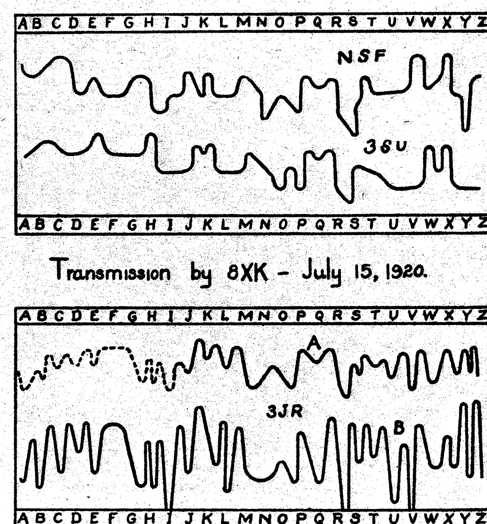
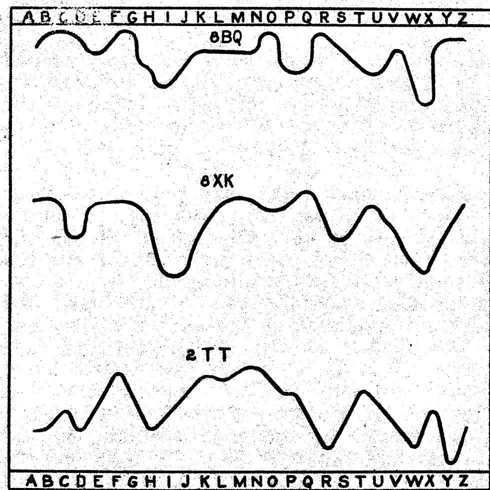


Fig. 16—Check by three stations.

could be depended upon to check the curves of 3JR and WWV with fair exactness about half the time. At other times only partial checks were secured or else the curves were of totally different shape. NSF, Naval Air Station, Anacostia, 5 miles south, was several times checked by 3SU and 3JR but not by WWV. We do not believe that this failure to check throughout the group was the fault of any of the observers, as at the same time that NSF failed to check with any other Washington observer it checked with 3NB at Vineland, N. J., while at the same time 3SU and 3JR checked each other. In several instances 3JR was checked by 3UA in Baltimore, 40 miles northeast. An excellent example of the group check is shown in Fig. 16. The first two curves, obtained by 3SU and NSF, are sufficiently alike, so that there is no doubt of their checking. The curve turned in by 3JR, labeled $3JR_b$, at first sight has no resemblance to the other two; however, when it was redrawn with an amplitude the same as that of the other two curves, the resemblance at once appeared. This is the curve labeled 3JR.



Transmission by NSF - July 8, 1920.

Fig. 17—Checks by distant stations.

It is believed that by this time there will be little doubt that the method is capable of securing results which indicate definitely in what manner the signals are varying at a given receiving station, so long as the signals do not vary with extreme rapidity, in which case audibility meters or any other device known at present for measuring signal intensity variation would be perfectly hopeless.

An example of check curves from stations some distance apart is shown in Fig. 17 on the transmission of NSF July 8. The recorders are 2TT in Yonkers, 8XK at Pittsburgh, and 8BQ at Milton, Pa.

Regional Characteristics.

In New England violent and rapid swinging seems to be the rule. This grows less severe as one goes south or southwest and at points in Pennsylvania, Ohio, Indiana, Illinois, and Michigan it is not even approximately as bad.

There seemed to be, roughly, three types of swing:

(a) a very rapid and very abrupt kind which sound as if the sender had simply omitted a letter or two. The length of the swinging cycle in this case is from ½ to 5 seconds.

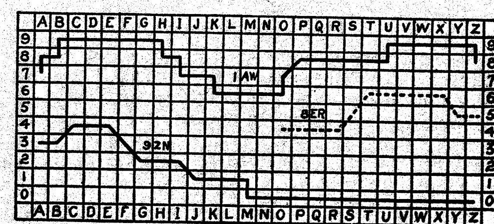
(b) a moderately rapid and more gradual type which gives curved lines almost entirely, the period being from ten seconds to five minutes. This is the commonest type of swinging.

(c) a very gradual slow "drift" of all stations in one direction from the recorder, a cycle taking anywhere from five minutes to several hours.

The first two types are both shown in the upper graph of Fig. 13, obtained at 1CK, Braintree, Mass., on the sending of 8XK, July 6.

The first type of swing is, as far as I have observed, purely a one-station phenomena. The second type also is not followed by other sending stations nearby, but when one sender is swinging in this manner, others near him seldom fail to swing at a similar rate though not in synchronism. This is the most aggravating type of fading as one station swings in while another is going out, so the station being copied is blanketed before it goes out of audibility.

In the long slow third type of swinging all sending stations near each other swing slowly together. Where the swing is unusually slow it is noticed that during the early part of the evening stations in one direction will be heard best while those in another are inaudible, the condition perhaps reversing later in the evening. This sort of swinging cannot be shown by short tests and usually does not cause much



July 6, 1920 - Curves taken on U.S.S Ohio 150 miles east of Cape May.

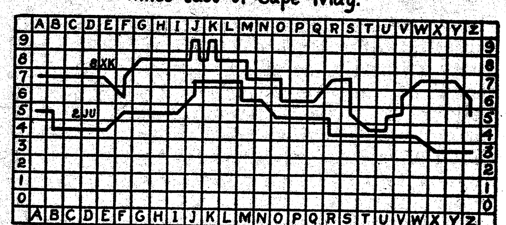


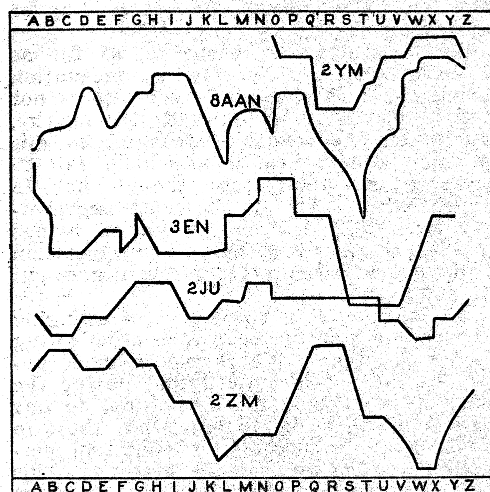
Fig. 18—Fading over water.

difficulty in handling traffic, since stations remain "swung out" long enough so that they do not have to work, or else "swung in" long enough to clear traffic. This type of swinging is especially characteristic of the Mississippi Valley.

Fading is not solely a land phenomenon. The curves obtained at 4AT, Ft. Pierce, Fla., on the transmission of 1AW and 2JU are normal although transmission is almost entirely over water. Fig. 18 shows curves obtained on July 6 on board the U. S. S. Ohio, at that time 150 miles east of Cape May, N. J., by Mr. L. C. Young of NSF. These are similar to those turned in by Mr. Young from NSF, at Anacostia.

Traveling Curves.

Similar curves are not always simultan-



Transmission by 8XK July 8, 1920.

Fig. 19—Traveling curves.

eous. There is such a thing as a traveling curve. By the traveling curve is meant one which appears successively at different recording stations. Thus in Fig. 19 the same "dip" in the curve which appeared at 2YM in New York City on the letter R reached 8AAN at Buffalo, N. Y., at the letter S, 3EN at Norfolk at U, 2JU at Woodhaven, L. I. and 2ZM at Clifton, N. J. at W. This phenomenon occurred many different times, and in almost every instance where there was a clearly defined direction of travel of the curve it was away from the sending station. I cannot think of any reason for this rule, and believe it to be accidental and due to limited data. For this reason, it was thought best to ignore curves that appeared at only two stations, although some thirty-two such were found in which the curves were beyond question the same. Of the type which passed through three or more stations, sixteen were found.

No definite relation between the weather and either transmission or fading has been found nor has any relation between the weather and the direction of best transmission been found in a way that is at all convincing.

Explanation of Cause of Swinging.

Variations in the intensity and direction of received waves have been explained by a number of people as due to reflection and refraction of the waves before arriving at the receiving station. (See Scientific Paper of the Bureau of Standards, No. 353, "Variation in Direction of Propagation of Long Electromagnetic Waves," by A. H. Taylor, USNRF). The variations observed in these tests were actual changes in received power. A satisfactory explanation, based on reflection and refraction effects, involving the existence of interference bands such as are obtained with light, was suggested and discussed by various members of the conference of April 7. The results of the tests seem to bear out this explanation very well.

In Fig. 20 we have at S a source of monochromatic light (say red) from which rays of light travel to the receiving screen by two different paths, first along the straight line SA joining the source and the screen, and second along the line SA'A. Supposing the length of the path SA differs from that of the path SA'A by one wave length of red light, then the rays arriving at A by the two paths will be in phase and will add their amplitudes so that the result is more intense red light at A than would be obtained without the reflector. At another point B, however, the light arriving by the the path SB will not be in phase with that arriving by the path SB'B and hence they will not reinforce each other in the same manner. If the length of SB differs from that of SB'B by one-half a wave length of red light the two waves will differ 180 degrees in phase and hence will tend to cancel each other.

If the amplitudes are the same they will cancel so that complete darkness re-

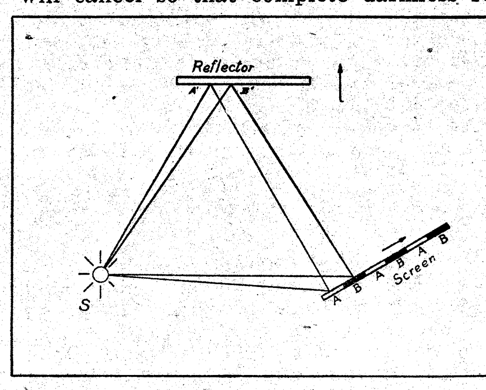


Fig. 20—How interference bands are formed.

sults. Thus there will be along the screen regions AAA, where the light is more intense than without the reflector, and between these, other regions BBB where there is almost complete darkness. If the reflector is tilted or moved in any direction except its own plane, these interference bands will move along the screen. Supposing the motion is in the direction of the arrow, the bands will move as shown by the arrow at the screen. Suppose now that we have at C an eye which is observing the light arriving at this point. This eye will see alternately red light and darkness.

If we consider the case of radio transmission, the source S becomes a sending station, the eye at B becomes a receiving station, and the waves electromagnetic waves. The whole phenomenon takes place on a much enlarged scale, consequently the reflector must also be of considerable size. It seems that a large cloud, fog bank, mass of fumes from an industrial plant, or perhaps the Heavyside layer may operate in this capacity. It is entirely probable that interference bands may also result from waves arriving over two paths, neither of which is direct. In this case movement of a reflecting or refracting member in either path may change the signal intensity. Where the waves have been repeatedly reflected before arriving the chances for violent and rapid swinging are much increased. If we accept the theory that fumes from smelters or steel mills may collect in sufficient masses to act as reflectors, this seems a plausible reason for the phenomenally rapid and erratic swinging of station 8XK which is located in a region of many such plants. It is just as well, however, to admit at once that other prominent stations in the same region, namely 8DA at Salem, Ohio, and 8ZW at Wheeling, W. Va., do not at all duplicate these rapid swings. The rapid swings of 8XK are, however, not due to the sending apparatus, as at the same time that one recorder will hear anywhere from 15 to 28 swings for 8XK, others will hear three or four. We have no record of 8XK being received without fading except by stations very close by. Reflecting need not necessarily be involved in the production of interference bands. Refraction will answer just as well to change the direction of the waves if we can find a mass of vapor whose dielectric constant differs from that of the normal atmosphere through which the waves are traveling. Neither the reflecting nor the refracting body need be at high altitudes. They may be at the elevation of the sending and recording stations and to one side of the line joining them.

Inverse Curves

Another type of curve may be designated as the inverse curve. The curve appearing at one station is found inverted at another. The upper part of Fig. 21 shows inverse curves received at 1TS, Bristol, Conn., and 8ER, Saint Marys, Ohio, from 2JU at Woodhaven, L. I. Singularly enough the cases of inverse curves are, without exception, simultaneous; that is to say, the positive peak of the curve appears at one station on the same letter for which the negative curve appears at the other; again, without exception, each case in which the curves are undoubtedly inverses is that of a very slow swing which lasted from 1 to 8 minutes. It is this simultaneous appearance of the curves which makes them difficult to explain, and leads to the suspicion that they are coincidences. A special case of inverse curves was that in which the positive curve was obtained at both station 3JR, Washington, and 3UA, Baltimore, while the negative curve was obtained at both 3BZ, Danville, Va., and 3BN, Norfolk, Va., giving complete check on the observations. The transmitting station was 2JU. It will be noted that the stations of a pair which obtained the same curves are at about the same distance from the sender, suggesting at once the thought that we have traveling curves, and the case is the special one in which the fading was sufficiently regular so that the fading curve which appeared at a particular station would be repeated

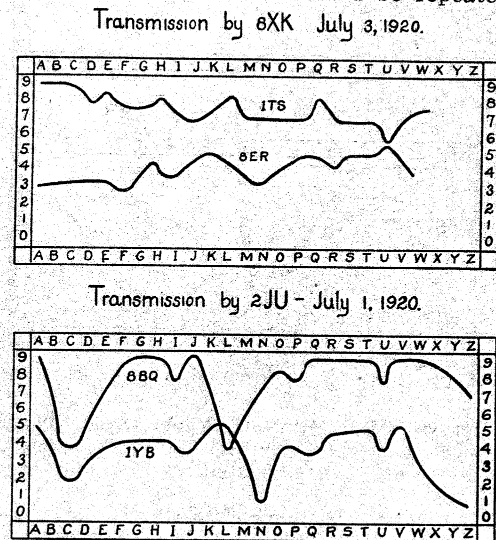


Fig. 21—Inverse check curves.

by others near it and the fading bands were spaced so regularly that it was possible to find further along the line of their travel other stations at which a dark band was appearing while a light one was crossing the first stations. With enough recorders it might be possible to trace in this manner with a fair degree of accuracy, the system of light and dark bands.

Clearly defined inverses are not frequent. Six inverses were found during the last four weeks which were fairly definite. One of these is shown in Fig. 21 for the transmission of 2JU on July 1 as received at 1TS, Bristol, Conn., and 8ER, St. Marys, Ohio. There does not seem to be any reason why stations so situated should obtain curves having any definite relation to each other. Perhaps inverse curves are purely accidental. Certainly they would be more convincing if more numerous.

The other inverse curves obtained were as follows:

Date	Sender	Recorders	
7/3/20	8XK	8ER	1TS
7/6/20	8ER	9ZJ	3NB
7/8/20	1AW	1CM	8AAN
7/8/20	2JU	3BZ	8AAN
7/8/20	8ER	3BZ	3UA

A possible inverse curve system is shown in Fig. 22, for the sending of 2JU on June 1. 8IB is at Columbus, Ohio, 8DR at

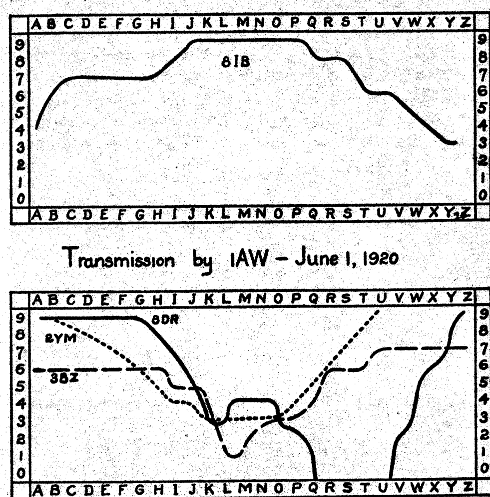


Fig. 22—Checks and inverses; also a doubtful traveling curve.

Detroit, 2YM in New York City. The curve at 3BZ (Danville, Va.) is possibly a traveling curve related to the one at 2YM.

Distance Effect

Fading is a long distance phenomenon. Repeated attempts were made at 1TS in Bristol, Conn., 12 miles removed from 1AW, to secure fading on 1AW by detuning the receiver or by dimming the tube filaments so as to decrease the signal intensity. The intensity remained perfectly uniform, however, and showed not the faintest tendency to fade. The same observations were made by 2YM and 2JE in New York, on the transmission of 2JU, Woodhaven, L. I., also by 3SU, 3JR and WWV in Washington on the transmission from NSF at Anacostia. This does not mean that there is a fixed distance below which fading does not occur. What it does mean is that fading does not occur until the distance is a considerable proportion of the normal transmission range of the station. In cases where transmission conditions are very bad, fading will occur at distances which are short. For instance, the distance from Washington to Baltimore is only 40 miles. It is almost impossible for stations in these two cities to work together on any wave length below 500 meters, as signals swing violently at all times. Similarly, the distance from Lawrence, Kansas, to St. Louis, Mo., is about 120 miles, a very short distance as radio transmission goes in this region. Yet, so far as I know, successful communication was never accomplished before the war by a St. Louis station with any station in Lawrence, Topeka, Leavenworth, Kansas City, or any of the surrounding towns. That the statement regarding ranges in the region is correct may be seen from the fact that any of the stations in the cities just mentioned could work over St. Louis to stations in Tennessee and Kentucky with perfect ease, while at the same time St. Louis stations could work over the state of Kansas, say, to Danver, without any difficulty at all. I am of the opinion also that fading does not occur in general within the daylight range of a station. This statement will not bear very close inspection, as in one of the cases just mentioned, that of transmission from Washington to Baltimore, the cities are within daylight range of each other. Signals do not fade in the daytime; on the contrary, in this particular case, they are stronger than at night. But, as stated, signals fade very badly at night.

Determination of Transmission Conditions.

In an attempt to connect fading with weather conditions and with normal transmission, it was desirable to establish some sort of a criterion as to the excellence of transmission on a particular date. No really good way of doing this was found. The method adopted can be best explained by example. In order to establish the normal intensity at which station 8XK at Pittsburgh was heard at 1CM, Laconia, N. H., the mean intensity of the signals of 8XK at 1CM for each day was first established by inspection of the curves obtained at 1CM on that date. The question then arose whether in averaging the intensities for the test period, those evenings should be considered on which 1CM had listened but failed to hear 8XK. If the failure was due to a defect in the apparatus, the results for the evening should, of course, be thrown out. It was decided however, that the operation of the stations was constant enough so it could safely be assumed that apparatus failures had not occurred. The mean intensity was accordingly obtained by averaging the intensities on all the evenings in which 1CM listended for 8XK, regardless of whether the station was heard or not. The mean intensity so obtained was then used in determining whether on a particular schedule, the reception of 8XK at 1CM was good, normal, or poor. No definite relation between weather and transmission was found.

Almost without exception the recorders stated that they believed fading was not a variation in signal strength but a shift of wave lengths, as they could recover a station which had swung out by retuning the receiving set. We requested them not to attempt this since it would be impossible to tell whether the variations in received signal strength were due to a change in incoming power or due to mistuning. A laboratory check of this scheme showed conclusively that two observers could not get results that were even approximately alike if the receiving apparatus was retuned during the test. For this reason the QST call preceding transmission was made very long so that tuning might be finished before the test started. Subsequently it was found that when ICW signals were being received they could not be recovered by retuning when they had faded out. This observation was checked by several of our recorders at Pittsburgh, Chicago, and Hartford.

A possible explanation of this difference between spark signals and ICW signals, which also explains the apparent shift in wave length, may be given, following the ideas used by A. H. Taylor in explaining the difference between the variations of direction observed with damped and continuous waves. (Bureau of Standards Scientific Paper 353, already mentioned). Return to Fig. 20 and the formation of interference bands. Our source was monochromatic and a single set of interference bands, alternately red and black, resulted. An eye which could see only red light would then see alternate red light and darkness as the bands passed across it. Supposing the source of red light were replaced by one of white light. Interference bands of red light would still be produced and the red-seeing eye would still see alternate red light and darkness. If, however, another eye, a blue-seeing eye, were placed alongside of the red-seeing eye, it would see alternate blue light and darkness, and since the wave length of the two is not the same the interference bands would not be at the same places. Hence while one eye had darkness the other one would be out of phase with it and would have some light. Thus, by using the proper eye it would be possible at all times to see some light. The radio reception case is similar to the rather fanciful light system. The spark transmitting set emits not one wave but a band of wave lengths; the receiving set, however, can detect only one of these waves. Regenerative sets are notoriously very sharply tuned. If then the condition is such that a dark band for the particular wave length at which it is tuned is crossing the receiving station, it will detect no signals, although at the same time power is arriving on a slightly different wave length still within the band of wave lengths emitted by the sending apparatus. While there is some disagreement about this band, most of the recorders consulted agree that the wave length variation detected lies within the band of wave lengths normally emitted by the sending station.

With an ICW station we have the case of the monochromatic source. Only one wave length is being emitted. Hence when a dark band for that wave length crosses the receiver no signals can be found. At close range this does not hold true, since an ICW transmitter emits other wave lengths too weak to be detected at a distance which give the effect of a particular wave at close range.

An excellent example of this is NSF, which at first had great difficulty in initially "raising" distant stations although after they had tuned NSF in, the signals were reported as very loud. This is sufficient proof that NSF, at a distance, is very sharp. In Washington more difficulty by far is experienced in tuning out NSF than in tuning out 3KM, 3XF or 3JR, all of which are 1 K.W. spark transmitters nearer by.

The side frequencies of the ICW transmitter are those which differ from the main frequency by the tone frequency. Mr. Conrad of 8XK has suggested a possible means of avoiding QSS based on the double system of inverse bands presented above. His suggestion is the use of an ICW or CW transmitter emitting two waves some ten meters apart, and two independent receivers tuned to these two waves. It would be necessary to have these two receivers working into a common amplifier or perhaps into the two halves of a split head set. Mr. Conrad has attempted to operate an ICW transmitter in this manner but we do not know at present with what degree of success. It will be seen that an ICW transmitter is not the answer to the fading problem.

The statement made regarding the general opinion as to the rate of fading in various parts of the country was confirmed by the tests. Fading in the Mississippi Valley is of the type designated as "C". In the region around Pittsburgh all three types of fading are found, mainly "B" and "C", while in New England the "A" type of fading seems to be chronic, regardless of the location of the sending station. This seems remarkable since many of the New England records were those for 1AW, 2JU and NSF, all close to this region.

Summary

Test signals were transmitted three nights each week during June and July, 1920, by six sending stations operating at 250 meters wave length and observations of the intensity of the signals were made by fifty recording stations. An average of twenty-eight recorders listened for the test schedules on each of twenty-one evenings, obtaining 1260 curves of signal intensity variation.

Frequent checks between curves at adjacent and sometimes distant receiving stations were found. Traveling curves, appearing successively at various recording stations, were found. No definite connection between weather and transmission was found. Inverse curves were found but infrequently and are not considered as other than chance variations. Three types of fading were observed, a rapid and very abrupt type, appearing mainly in New England, a less rapid and less abrupt type found in all parts of the test territory, and a very slow type covering large territories and affecting all sending stations in the region alike.

There is no marked difference in the manner of fading for various types of sending sets. However, a damped wave that has faded out can often be recovered by retuning, which cannot be done for continuous waves.

The tests furnish good evidence in support of the belief that radio signal variations such as fading and swinging are caused by varying reflection and refraction of the waves.