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SEASONAL VARIATION IN SHORT-WAVE TRANSMISSION

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A Paper Delivered Before the Club on January 9, 1929

THE most fascinating single element in long distance short-wave communication is not the transmitting equipment, nor the receiving equipment, interesting as these may be when considered by themselves; but rather that most intriguing and baffling medium which intervenes between the transmitting and receiving stations. It is with a deductive survey of the performance of this medium on commercial traffic throughout the year, on a number of typical short-wave circuits in various parts of the world, that this paper is primarily concerned.

A comprehensive study of the complicated laws of the upper atmosphere over a long period of time, is of necessity associated with technical equipment. The proper assimilation of the practical results of such an investigation requires that the reader shall have at least a rudimentary background of the major elements or tools used during the investigation. With the object in view of establishing such a background, a few typical views of the New York terminals of the Radio Corporation of America's long distance short-wave communication system are illustrated and briefly described.

Fig. 1 is a general view of a 16.8 meter, 17,860 kc. 4 bay, Broadside Projector antenna installed at Rocky Point, L. I. This antenna is of the energized reflector type designed for directive transmission, delivering most of its energy radiation to a particular receiving station.

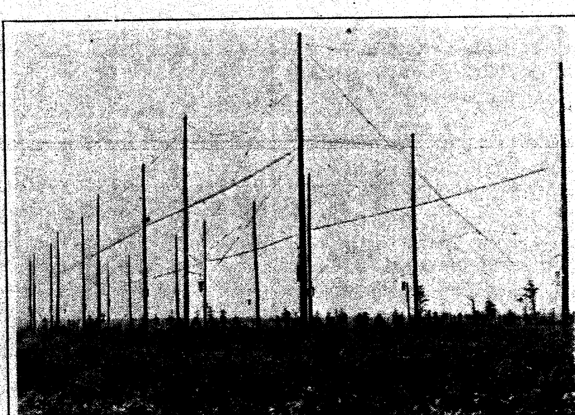


Fig. 1

Fig. 2 is a view of one of the short-wave transmitting groups installed at Rocky Point, L. I. In the foreground is the crystal controlled exciter unit. A pair of overhead shielded leads, carrying radio-frequency excitation to the power amplifier unit behind it may be seen, also a further pair of vertical wires which are the transmission line feeders to the distant directive antenna, sometimes 2000 feet distant.

Fig. 3 is a general view of the Central Office of the Radio Corporation of America at Broad Street, New York City. From this office direct contact is had with the principal communication centers of Europe and with those of Central and South America.

It is with the ability of such equipment to make practical use of the characteristics of the upper atmosphere throughout the year that we shall now turn our attention.

THE CHARACTERISTICS OF THE MEDIUM

MUCH has been written on the function of the Heaviside Layer, in short-wave transmission. The heights of the upper ionized layer have been studied by a great number of workers under various conditions, and many of the variables involved have been recorded. It is to be noted, however, that the existence or non-existence of a reflecting layers still a debatable scientific question. We shall use the term "medium" in view of our practical rather than scientific analysis. Our existing knowledge of this most intangible and cosmic medium is all too meagre. Many of its major characteristics are

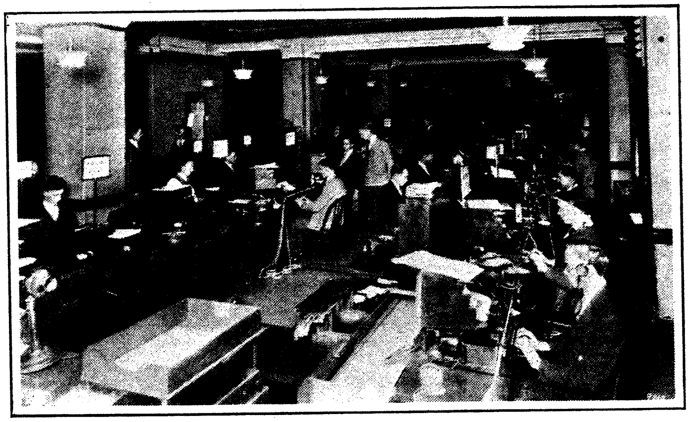


Fig. 2

deductable only as the result of years of observation and measurement in commercial service. It is as the result of such analysis of a vast number of observations and measurements that the following facts are contributed.

GUN EFFECT—ANGLE VS. FREQUENCY

A PROJECTILE in flight follows a curved path due to the combined effects of initial power, air friction and the law of gravitation. A radio wave similarly follows a curved path due to the combined effect of vibration frequency, input power and ionization of its path. The distance to which a gun may shoot is determined to a certain extent by the elevation of its muzzle. The distance that a radio wave will carry is likewise determined to a great extent by its frequency, or wavelength. Shortening the wavelength, or increasing its frequency is therefore the equivalent of increasing its angle of elevation. By angle of elevation, as used in this paper, is meant the trajectory of the wave in space, which is independent of wave patterns determined by local measurements and apparently a more or less direct function of radiation efficiency and frequency. There is this significant difference between the flight of the projectile and the track of the radio wave: the elevation of the gun cannot be raised sufficiently high to prevent the return of the projectile; but the elevation, or frequency, of the radio wave may be made so high that its track does not return to earth. The high-angle radio wave consequently assumes the characteristic of light, traveling in lines normal to the radiating surface. For the reasons above stated waves below 5 meters (60,000 kc.) are normally not audible at distant fixed receiving stations. They overshoot their marks. The effect of ionization of the atmosphere is to bend by progressive refraction the track of the wave closer to the earth. It may happen therefore that these high-angle waves below 5 meters may be occasionally brought down to earth by abnormal cosmic conditions but this must be considered as a freak condition in the present state of the art and not one that is definitely repeatable.

DIURNAL AND SEASONAL EFFECTS

THE processes of short-wave transmission are controlled principally by what may be called the earth's photoelectric condition, that is by the relative amount of light and darkness in the track between transmitting and receiving stations. As the amount of current that will flow through a photoelectric cell is determined by the amount of light that strikes the cell, so the amount of energy at a given frequency that will pass between sending and receiving stations is determined by the relative ionization or illumination of the medium. From what has been stated regarding elevation in the foregoing it will be apparent that the shorter wavelengths of higher radiation efficiency will require high ionization to bring them down; consequently they will be daylight waves. The longer wavelengths having lower elevation will be more effective at night when the ionization of the signal track is low. The seasonal characteristic is determined by the relative distribution of light and darkness over the signal path throughout the year and will vary in different latitudes.

NORTH-SOUTH VS. EAST-WEST TRANSMISSION

A CONSIDERABLE difference is to be expected in North-South as compared to East-West transmission from what has already been stated. This difference is due to the fact that a greater divergence in the relative ionization of the signal path between the seasons exists in a great circle of latitude than in a great circle of longitude. In an East-West or West-East circuit the degree of ionization over the entire circuit is a variable

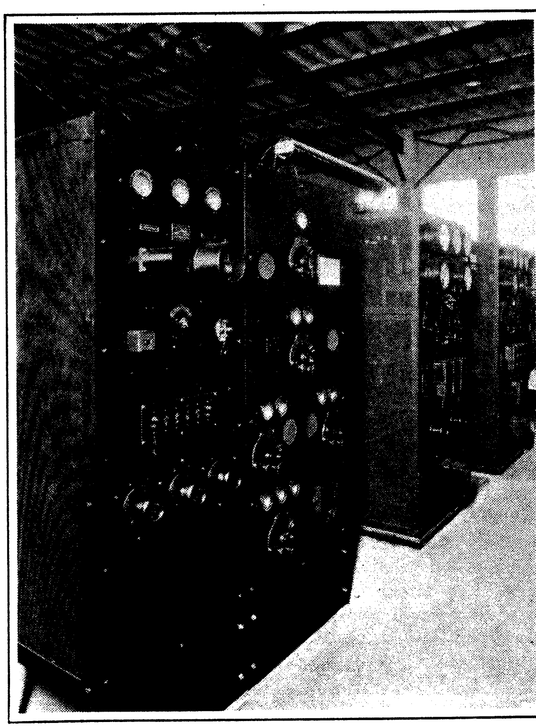


Fig. 3

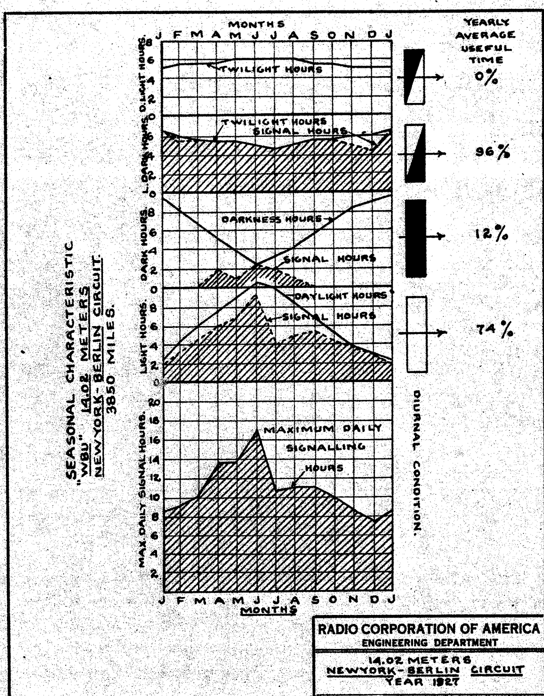


Fig. 4

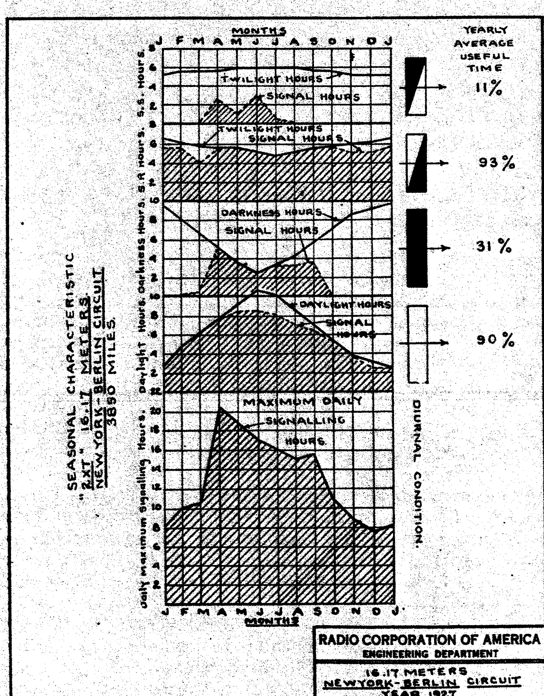


Fig. 5

throughout the year depending upon the season. North-South or South-North long distance transmission, on the other hand, tends to be more constant throughout the year, since the path of the wave is through conditions of two seasons at all times and the twilight periods are relatively short. The total average ionization over the path consequently tends to be more uniform throughout the year.

EAST–WEST VS. WEST-EAST TRANSMISSION

THE difference between the actual hours of signalling in an East-West or West-East direction is determined by the part daylight hours only. Certain waves are effective when the transmitter is in darkness and the receiver in the light. Others are effective under the reverse condition. It will be apparent therefore that

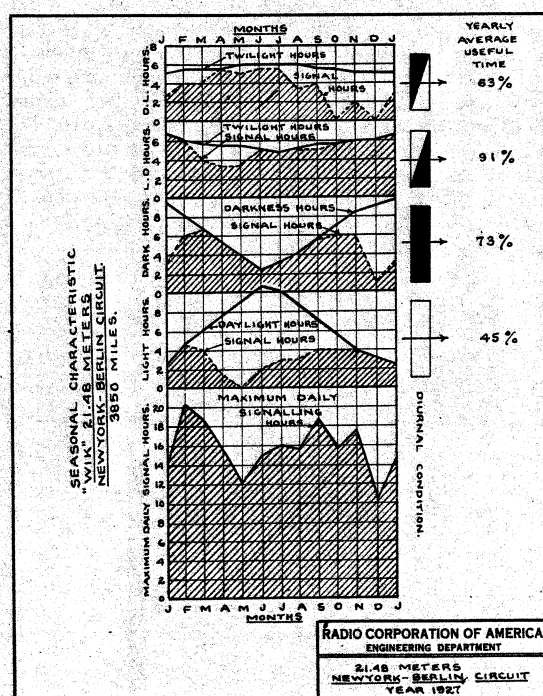


Fig. 6

the twilight signalling hours, which contain the most variable ionization conditions, determine the actual terminations of the diurnal characteristic considered from opposite ends of a particular long distance circuit.

AURORA AND COSMIC DISTURBANCE

UNUSUAL cosmic disturbances, such as the occurrence of sun spots and aurora displays, have a marked effect upon short-wave transmission. The ionization of the path may become sufficiently high, or the earth's magnetic field sufficiently modulated to cut off all communication. It is interesting to note in this connection that transmission in the line of the earth's field—north and south, is less influenced than transmission transverse to the field during aurora disturbances. This is possibly due to the fact that the radio wave remains in a field of more constant density in the direction of a line of force than when projected in a transverse direction, cutting successive portions of the field.

Short-wave technique has eliminated the static problem from long distance communication to a large extent, but has presented an aurora problem which is still demanding a solution. Fortunately the aurora disturbances are of infrequent occurrence. They may yet be solvable by more intimate knowledge of the true nature of the transmission medium.

SEASONAL DATA VARIOUS CIRCUITS. SOURCES OF DATA

THE data from which the attached curves are plotted are derived principally from the records of the Traffic Department of the Radio Corporation of America and its correspondent companies in various parts of the world. Each point on the graphs represents an average of hundreds of daily reception logs from widely distributed observation points. The basis for minimum signal was taken as a traffic speed of 5 words per minute. Traffic hours below 5 W.P.M. were rated at zero. The graphs are therefore a practical, rather than an exact scientific survey of the circuits considered. A power input of 10 kw. into a simple antenna may be considered as the radiating unit. The following companies have directly or indirectly contributed sources of data:

1. R.C.A. Traffic Department, New York.
2. R.C.A. " " San Francisco.
3. R.C.P. Manila, P.I.
4. Trans Radio, Berlin, Geltow Receiving Station.
5. Trans Radio International, Buenos Aires.

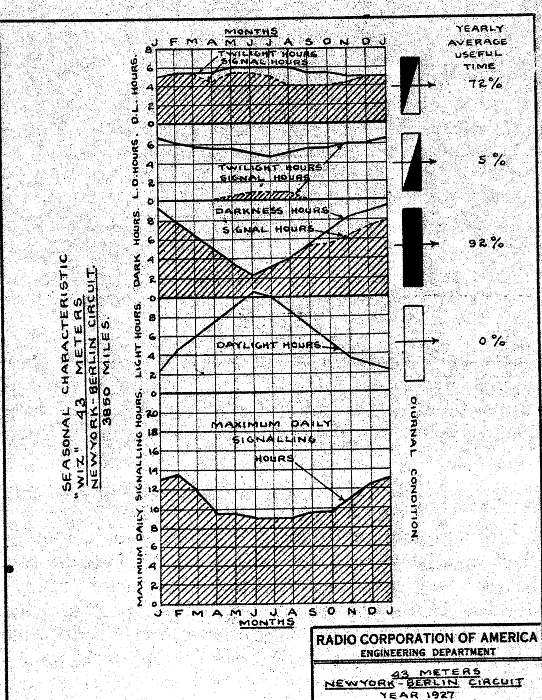


Fig. 7

Data from records compiled by the following individuals is also gratefully acknowledged:

Mr. C. W. Latimer, Operating Division, R.C.A. New York.
Mr. L. A. Briggs, Traffic Department, R. C.A. New York.
and
Mr. R. R. Beal, Pacific Division, R.C.A. San Francisco.

NEW YORK–BERLIN CIRCUIT—WEST–EAST TRANSMISSION

SEASONAL characteristics for the New York-Berlin Transatlantic circuit will be first considered. The transmission was from Rocky Point, L. I., and the reception at Geltow, Germany. The data cover the year 1927. The graphical analysis has been divided into four diurnal periods as follows:

1. Total daylight period.
2. Total darkness period.
3. Light dark period. (Sunset).
4. Dark light period. (Sunrise).

The solid cross hatched sections show the signalling hours and the full lines the number of hours' duration of each of the above four diurnal periods. At the right of each period is a diagramatic representation of the direction of signalling through the medium, and a yearly average of the useful signal time. The graph at the bottom of each diagram gives the observed maximum daily signalling hours for each month. Each point of the daily signalling hour graph is the sum of the diurnal periods into which the day was divided.

Figs. 4, 5, 6 and 7 are the seasonal characteristics obtained on the following Transatlantic channels:

(a)	14.02 meters.	21,390 kc.
(b)	16.17 "	18,550 kc.
(c)	21.48 "	13,950 kc.
(d)	32.43 "	6965 kc.

The facts of general interest to be noted from this seasonal data are:

(a) 14.02 meters (21,390 kc.) is not as good a daylight wave as 16.17 meters (18,550 kc.) for Transatlantic use. By the process of reasoning previously cited, its angle of elevation is too high.

(b) 21.48 meters (13,950 kc.) is the most favorable twilight wave of the four. It is also seen to be a seasonal reciprocal wave, namely, it is a day wave in Winter and a Summer night wave.

(c) 43 meters (6965 kc.) is the most favorable Transatlantic night wavelength of the four. Even this wavelength is not long enough to give 100 per cent. darkness operation during Winter nights.

(d) It is to be noted that day waves will have a convex "Daily maximum signalling hour characteristic" and night waves a concave characteristic conforming to the number of hours of light and darkness.

(e) The day waves give the greater number of signal hours during the part daylight period when the transmitter is in daylight.

(f) The night waves show the greater number of signal hours, during the part daylight period, when the transmitter is in darkness.

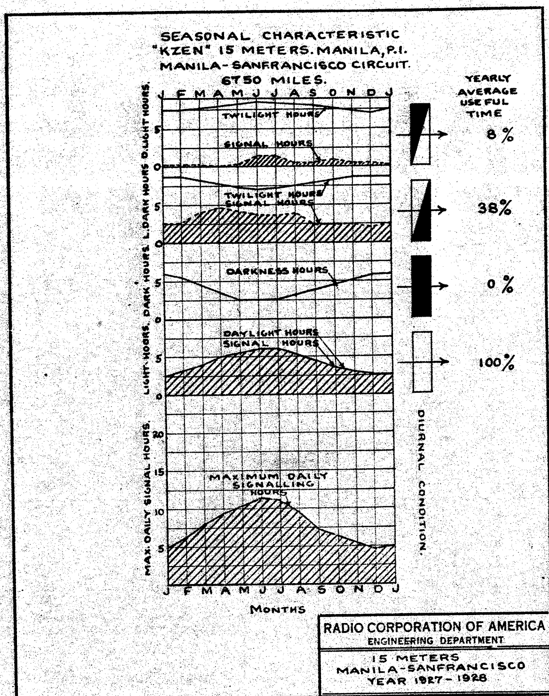


Fig. 8

MANILA–SAN FRANCISCO CIRCUIT—WEST–EAST TRANSMISSION

SEASONAL characteristics for the Manila-San Francisco Transpacific circuit are shown in Figs. 8 and 9. Transmission was from the Radio Corporation of the Philippines Station at Manila, P. I. and reception at the R. C. A. station at Marshall, California. The data cover the year July, 1927, to June, 1928, at wavelengths of 15 meters and 30 meters; 20,000 and 10,000 kc. respectively.

The following facts of interest were observed:

(a) 15 meters (20,000 kc.) is a 100 per cent. day and a 0 per cent. night wave over this circuit.

(b) 15 meters (20,000 kc.) gives 38 per cent. of the part daylight hours when the transmitter is in daylight.

(c) 30 meters (10,000 kc.) is a 100 per cent. night wave and a 0 per cent. day wave over this circuit.

(d) 30 meters (10,000 kc.) is a better part daylight wave than is 15 meters (20,000 kc.).

MANILA–HONOLULU CIRCUIT—WEST–EAST TRANSMISSION

SEASONAL characteristics of the Manila 15 and 30 meter (20,000 and 10,000 kc.) transmitters intercepted at Honolulu are shown in Figs. 10 and 11.

The following facts of interest were noted:

(a) 15 meters (20,000 kc.) gives only 54 per cent. yearly daylight transmission to Honolulu. During the winter hours its angle o elevation becomes too high and it disappears completely.

(b) 30 meters (10,000 kc.) is a 100 per cent. night wave to Honolulu and a better part daylight wave at this distance than to San Francisco.

(c) The 30 meter (10,000 kc.) wave is an excellent example of a wavelength and circuit that would show the same characteristics West-East as East-West.

NEW YORK–BUENOS AIRES CIRCUIT—NORTH–SOUTH TRANSMISSION

SEASONAL characteristics over the New York–Buenos Aires circuit in both directions of transmission are shown in Figs. 12 and 13 for the year July, 1927, to June, 1928.

The following facts of interest were noted:

(a) The variation in the maximum daily signalling hours from month to month is much less than on the East-West circuit.

(b) 14.11 meters (21,260 kc.) is a 98 per cent. day wave and a 28 per cent. darkness wave.

(c) The part daylight periods vary from month to month changing from light-dark to dark-light.

(d) 33.7 meters (8900 kc.) shows a remarkably flat daily signalling hour characteristic.

GENERAL SEASONAL CHARACTERISTIC

AN APPROXIMATE relationship, between frequencies, distance, diurnal conditions and seasons is submitted in Fig. 14. The data from which these curves were plotted were obtained in part from the typical seasonal characteristics above discussed, and in part from data obtained from general traffic records of the Radio Corporation on various circuits. The curves

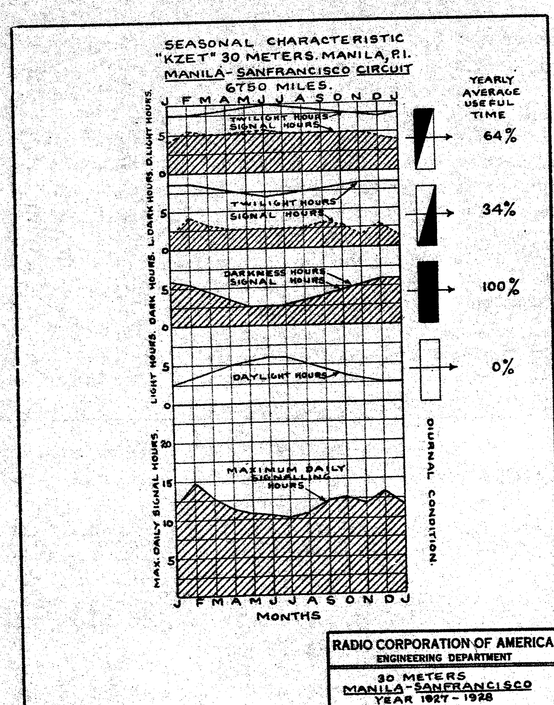


Fig. 9

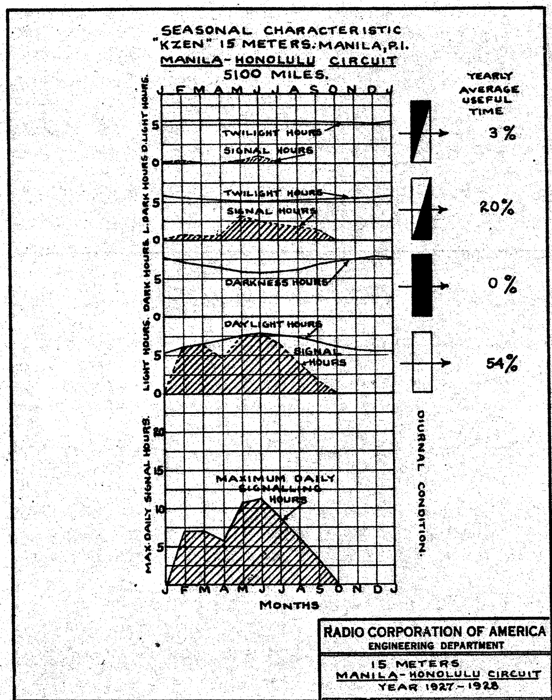


Fig. 10

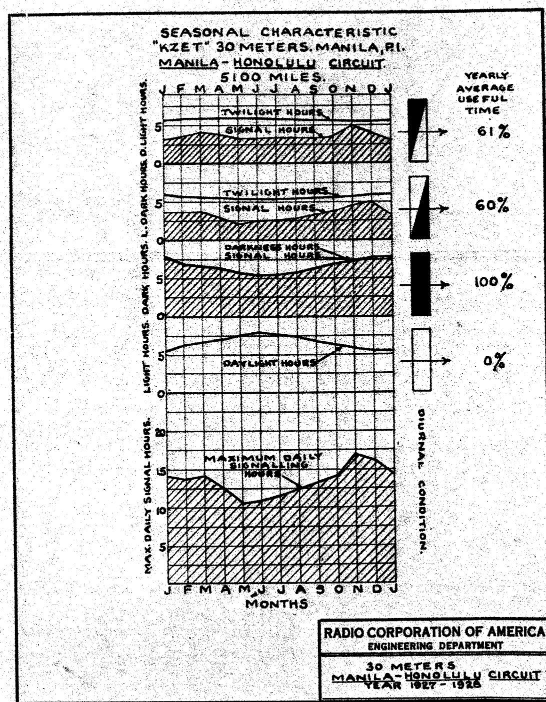


Fig. 11

marked "highest" are the normal skip distance limits. Frequencies higher than those marked "highest" will not be audible normally. The dotted daylight curves marked "abnormal" represent the approximate variations in skip distance that occur due to unusual and extreme conditions which cause increased ionization and more rapid bending of the wave path.

The curves marked "lowest" are the limits set by absorption and static interference. They represent the maximum transmission distances that may be expected of the lower frequencies. It will be understood that the available points for drawing a general seasonal characteristic are limited, and that a vast amount of additional data at all distances will be necessary to definitely establish the relationship between frequency, distance and the seasons. At best it can merely be stated that the relationships submitted fit those circuits which have been in operation for a year or more, and for which the seasonal characteristics are available.

WAVELENGTHS LESS THAN 5 METERS

SOME extremely interesting and pioneer work on beam transmission on wavelengths of less than a meter, has been done by Prof. Yagi in Japan. These extremely short wavelengths have the striking advantage of requiring antenna structures so small that directive combinations of various sorts are readily available. For the same reasons a study of their directional characteristics is more readily made.

The fact that wavelengths less than 5 meters are normally of the high elevation type have rendered them thus far of little use in long distance communication. It does not seem likely, at this time, that they will ever be useful for this purpose. The results obtained thus far with directive transmission less than 5 meters indicates that little can be expected by increased directivity, since the maximum effect of directive transmission at best is infinitesimal as compared to what has previously been referred to as nature's photoelectric cut-off.

The high angle of elevation would tend to make these extremely short waves more applicable to aircraft, and the smaller antenna structures required would be another practical advantage. It is possible that they will find some application for this service. It now appears probable that the ground wave rather than the sky wave of the ultra short-wave group will find practical application; the ground wave to serve a restricted area while the sky wave passes on into space.

FREQUENCY STABILITY

THE long distance short-wave stations of the world are at present being separated by channel widths of 0.2 per cent. The increasing demand for channels continues such that it appears likely that a separation of 0.1 per cent. will eventually be necessary. Even with this 0.1 per cent. separation only 1587 standard 0.1 per cent. channels, distributed among the nations of the world, are available between 1500 and 23,000 kc. It is obvious that there is a definite saturation point in the ultimate number of long distance air lanes, and that the most stringent measures are necessary to keep each service on its allotted channel.

There are two distinct factors that set a natural limit to the closeness of channel spacing. These factors are:

(a) Minimum practical sharpness of tuning.
(b) Frequency drift.

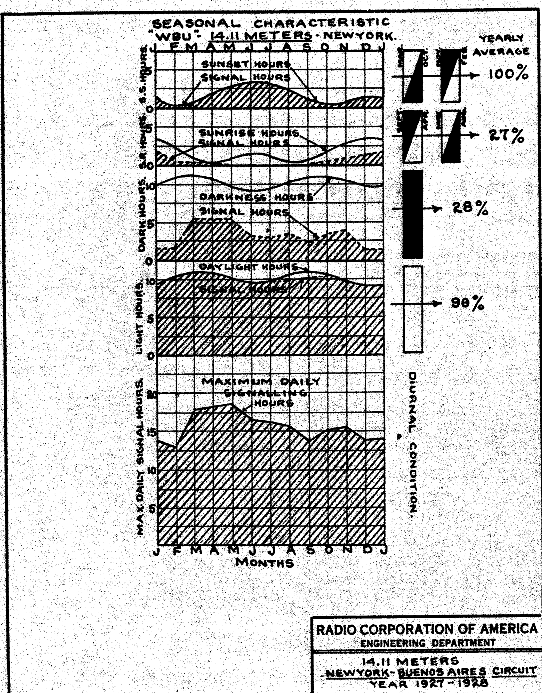


Fig. 12

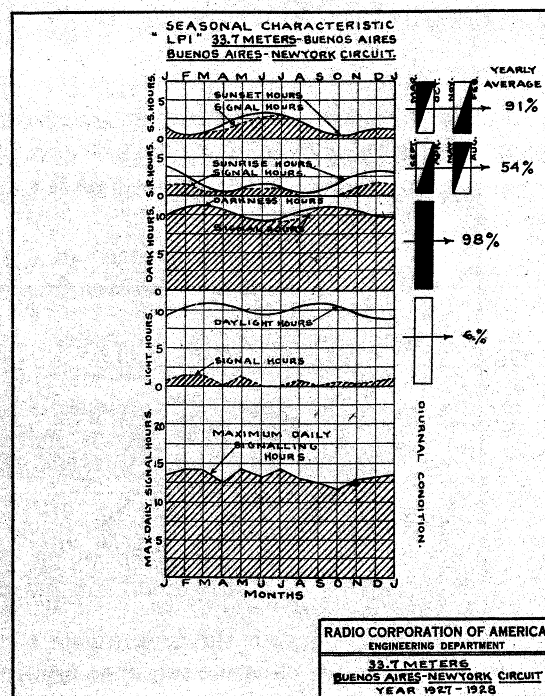


Fig. 13

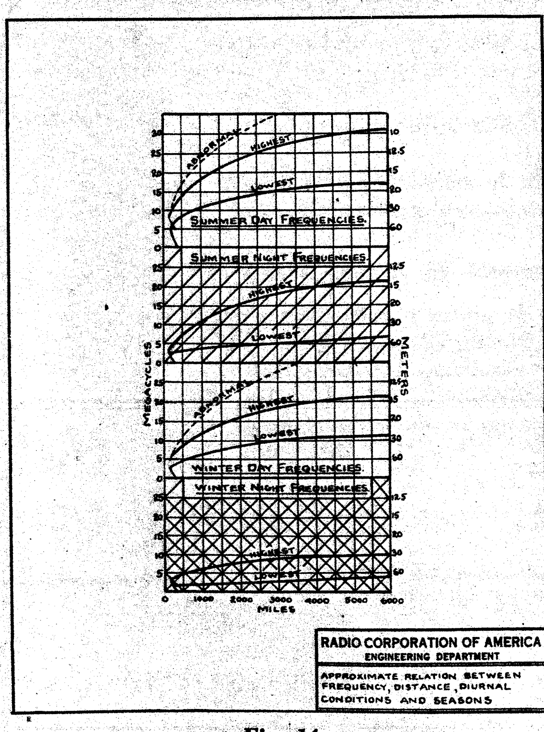


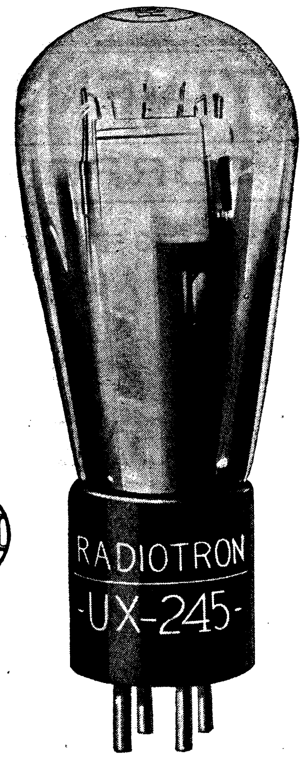
Fig .14

It will be evident that, regardless of constancy of frequency, the channels cannot be spaced closer than essential keying side bands and "broadness of tuning" will allow. All past experience in radio transmission has indicated that a frequency accuracy of less than 0.025 per cent. is obtainable only under the most favorable of laboratory conditions. A check between different standards is almost certain to show discrepancies greater than this value. The danger of an irretrievable congestion and overlapping of channels is inevitable if the channel spacings are arbitrarily set closer than the natural limits of the art will allow.

It becomes increasingly evident that a world standard of frequency measurement in the short wave spectrum will have to be established. This international standard will have to be supreme in accuracy as well as in authority. Only by referring all stations to a common world measuring station, via the common transmission medium, can the ultimate theoretical exactness of channel spacings and the potential traffic capacity of the air be permanently maintained.

WORLD RADIO PROGRESS

THE short wave radio spectrum has given the world a communication medium that defies international and natural barriers. This medium provides to all races everywhere instantaneous contact, and avenues for the rapid exhange of intelligence. Never before in the world's history has there existed such a universal means for world expression and understanding, nor such a potent force for the contemporaneous development of all humanity.



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