THE DEPARTMENT OF STATE
CONFERENCE SERIES, No. 9

OPINIONS

EXPRESSED BY THE

INTERNATIONAL TECHNICAL CONSULTING COMMITTEE ON RADIO COMMUNICATION

MEETINGS
AT
THE HAGUE, 1929, AND COPENHAGEN, 1931

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A. MEETING AT THE HAGUE, 1929

OPINION No. 1

STUDY OF QUESTIONS ON THE PROGRAM OF MEETINGS OF THE C. C. I. R.

The C. C. I. R.,

considering

(1) that it is neither necessary nor possible, under the General Regulations, to set up permanent bodies for the study of questions on the program of meetings of the C. C. I. R.,

(2) that there may be questions still unsettled after meetings of the C. C. I. R.,

unanimously expresses the opinion

(1) that, at the end of the meeting of the C. C. I. R., the President should read a list of important questions to be solved, and

(2) that he should ask which administrations are desirous of undertaking the preparation of proposals relating to the said questions and ready to collaborate with the interested administrations and with private enterprises, with a view to forwarding these proposals to the administration organizing the next meeting of the C. C. I. R.

OPINION No. 2

LIAISON BETWEEN THE C. C. I. R. AND THE INTERNATIONAL BUREAU OF THE TELEGRAPH UNION

The C. C. I. R.,

after a discussion on the question of its future organization, in which the representatives of the following countries took part: Belgium, Spain, United States of America, France, Great Britain, Italy, Netherlands, Portugal, Switzerland, Czechoslovakia and the Union of Soviet Socialist Republics,

after the declarations of the Director of the International Bureau of the Telegraph Union concerning the steps which he proposes to take to secure the assistance of technical experts without any increase in the sums allotted to the Bureau by the administrations,

after the declaration of the United States of America with regard to the articles of the Washington Convention and General Regulations referring to the relations of the International Bureau with the C. C. I. R.,

unanimously expresses the opinion

(1) that it is neither necessary nor possible, in accordance with present provisions, now to set up a permanent secretariat for the C. C. I. R.,

(2) that it is sufficient to establish a close liaison between the C. C. I. R. and the International Bureau of the Telegraph Union, it being understood that the role of the Bureau shall be to follow the various works of the C. C. I. R., with a view to the centralization and the publication of general documents for the use of administrations.

OPINION No. 3

ORGANIZATION REGULATIONS OF THE C. C. I. R.

The C. C. I. R. proposes the adoption of the following organization regulations:

ORGANIZATION REGULATIONS OF THE INTERNATIONAL TECHNICAL CONSULTING COMMITTEE ON RADIO COMMUNICATION

Article 1

After the end of a meeting of the Committee, the administration which organized the said meeting shall conclude current business, in collaboration with the International Bureau of the Telegraph Union.

It shall, as soon as possible, forward the documents to the administration organizing the next meeting.

Article 2

Before the end of each meeting, the Committee shall name the administration that is to call the next meeting; it shall indicate any new questions and also those which have not yet been settled; the sum total of these questions shall be placed on the program for the next meeting.

Article 3 [1]

After the end of a meeting all new questions not provided by the Assembly for submission to the Committee, shall be addressed to the administration entrusted with the task of organizing the next meeting. This administration shall enter these questions on the program for the next meeting.

Article 4 [2]

At the last plenary session of a meeting of the Committee, the President shall announce the list of important questions to be settled. He shall then ask which administrations are desirous of undertaking the preparation of proposals relating to the said questions, and are ready to collaborate with the interested administrations and with private enterprises, with a view to the transmission of these proposals to the administration organizing the next meeting.

Article 5

The administration in charge of the organization of the Committee may correspond directly with the administrations, companies, and organizations capable of collaborating in the work of the Committee. It shall forward at least one copy of documents to the International Bureau of the Telegraph Union.

Article 6

During the first meeting, the plenary session shall designate its President and, on the proposal of the latter, the Vice Presidents and other members of the Bureau.

Article 7

The Director of the International Bureau of the Telegraph Union or his representative shall be present at meetings and take part in the discussions in an advisory capacity.

Article 8

The International Bureau of the Telegraph Union shall take part in the various activities of the Committee with a view to the centralization and the publication of general documents for the use of the administrations.

Article 9

The Secretariat of the meeting shall be carried on by the organizing administration, with the collaboration of the International Bureau.

Article 10

Plenary sessions shall undertake, so far as possible, to approve or reject the reports submitted by the committees, or to order them, if necessary, to be returned to the committees sitting during the meeting of the C. C. I. R.; in the case of the final plenary session, questions not settled shall be entered on the list referred to in article 4.

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[1] BI. See also Opinion No. 30.

[2] BI. See also Opinion No. 32.

OPINION No. 4

STUDIES TO BE MADE OF VARIOUS PHENOMENA: FADING, ETC.

The C. C. I. R. is of the opinion that the studies in question enter within the scope of those which were the object of Opinion No. 1 and should in consequence be effected in conformity with the provisions of article 4 of the Organization Regulations of the C. C. I. R.

OPINION No. 5

DEFINITION OF THE POWER OF A TRANSMITTER

This opinion has been replaced by Opinion No. 40.

OPINION No. 6

CLASSIFICATION OF WAVES

The C. C. I. R.,

considering

that, in a classification, it is desirable to take account of the physical properties of waves, as well as of the administrative divisions to be found in the Washington General Regulations,

that it is also desirable to adopt limits that may be expressed, in frequency and in wavelength, by very simple figures,

that the fixing of a limit at 1500 kc/s (200 m) corresponds to a change in the mode of wave propagation noteworthy for the appearance of so-called space-propagation phenomena,

that the fixing of a limit at 6000 kc/s (50 m) approximately separates waves of which the range is at all times limited from those which can practically be received all over the world's surface,

that the fixing of a limit at 30,000 kc/s (10 m) approximately separates waves, the propagation of which is of the spatial type, from those where it is of the optical type,

that the fixing of a limit at 100 kc/s (3000 m), while it is not of such a definite physical significance as the foregoing, seems to form a convenient separation between groups of waves allocated by the Washington General Regulations to services of quite different characters,

expresses the opinion

that the following classification should be adopted:

Low frequency

100 kc/s ---------- 3, 000 m

Medium frequency

1, 500 kc/s ---------- 200 m

Medium high frequency

6, 000 kc/s ---------- 50 m

High frequency

30, 000 kc/s ---------- 10 m

Very high frequency

ANNEX TO OPINION No. 6

EQUIVALENTS, IN THE LANGUAGE INDICATED IN COLUMN 1, OF THE TERMS PRINTED IN COLUMNS 2 TO 6

Language	Low frequency	Medium frequency	Medium high frequency	High frequency	Very high frequency
1	2	3	4	5	6
German	lange Wellen	mittlere Wellen	Grenzwellen	kurze Wellen	sehrkurze Wellen
Spanish	baja frecuencia ondas largas	frecuencia media ondas medias	frecuencia intermedia ondas intermedias	alta frecuencia ondas cortas	muy alta frecuencia ondas extracortas
Finnish	pitkät aallot	keskipitkät aallot	raja-aallot	lyhyet aallot	erittäin lyhyet aallot
French	ondes longues	ondes moyennes	ondes intermédiaires	ondes courtes	ondes très courtes
Hungarian	hosszú hullámok	közép hullámok	határ hullámok	rövid hullámok	igen rövid hullámok
Italian	onde lunghe	onde medie	onde mediocorte	onde corte	onde ultracorte
Dutch	lange golven	middengolven	grensgolven	korte golven	zeer korte golven
Norwegian	lange bólger	midlere bólger	grenscbólger	korte bólger	ultrakorte bólger
Polish	fale dugie	fale średnie	fale posfednie	fale krótkie	fale bardzo krótkie
Portuguese	ondas longas ondas largas ondas grandas	ondas medias	ondas intermedias	ondas curtas	ondas muito curtas
Rumanian	unde lungi	unde mijlocii	unde intermediare	unde scurte	unde foarte scurte
Russian	niskaya tchastato dlinnié volni	sredniaya tchastota sredníé volni	promé joutotchnaya tchastota proméjoutotchnié volni	vissokaya tchastota korotkié volni	otchenne vissokaya tchastota otchenne korotkié volni
Swedish	långa vågor	medellånga vågor	gränsvågor	korta vågor	ultrakorta vågor
Czechoslovak	dlouhé vlny	střední vlny	mezilehlé vlny	krátké vlny	velmi krátké vlny

OPINION No. 7

DEFINITION OF THE RADIATION POWER OF A TRANSMITTER

The C. C. I. R.,

considering

that the purpose of the information mentioned in the text of question 4 [1] is not limited to the case of transmitters on very high frequencies,

that a sufficiently precise definition of the power of a transmitter, for any frequency whatever, has been given by Opinion No. 5,[2]

that to complete the information concerning the normal radiation power of a transmitter, it is sufficient to add, if need be, the particular data as to the directional effect of the antenna,

expresses the opinion

that the radiation power of a transmitter should be indicated by the following data:

1. Power of the transmitter, defined in accordance with Opinion No. 5;[2]
2. Directive properties indicated, if need be, by the letter D, followed by the letter R when the radiating system is furnished with a reflector;
3. Azimuth of the maximum direction or directions of radiation, expressed in degrees beginning from the north from 0 to 360, in a clockwise direction.

Examples:

Case of one single special direction:	DR 25°
Case of two special directions:	DR 25° DR 45°

In the case of an azimuth capable of varying continuously between two limits, these limits will be given.

Example: DR 25° to 45°

Where an azimuth may be of any value, this will be indicated by the letter T.

Any other technical data that it might be useful to give might be sent in a notice to the International Bureau of the Telegraph Union.

The attached annex gives as an indication a method of notation enabling a radiating system to be defined in a large number of cases.

ANNEX TO OPINION No. 7

DESCRIPTION OF TYPES OF ANTENNAS

It is possible to define accurately a fairly large number of types of antennas by giving the following information:

1. Length l of the useful part of the antenna wire, expressing l in wavelength and putting it in the form

$$l=\frac{a+b+c+\dots}{2},$$

in which a, b, c, etc., represent the number of half wavelengths of distribution of current, measured successively along the wire, using a new number at each point where the phase changes;
2. Number of wires n;

[1] BI. The fourth question of the program of the first meeting of the C. C. I. R. reads as follows:
Recommendation for the practical application of article 13 of the General Regulations of Washington with respect to the information concerning the normal radiation power of transmitters on ultrashort waves.

[2] BI. This opinion has been replaced by Opinion No. 40.

3. Height h_1 of the lowest point of the antenna above the ground, expressed in wavelengths;
4. Azimuth of the maximum direction or directions of radiation, in accordance with the indications given in the preceding opinion;
5. Width b of the directional antenna expressed in wavelengths;
6. Angle (θ), made by the wires with the horizon;
7. Form of the wire, if it is not a single wire, e. g., if it is an antenna in the form of T or L;
8. Height h_2 of the horizontal part of the wire above the ground, expressed in wavelengths.

First example

12 kw; DR 160°, DR 160°+180°; n=24;

$l=\frac{3}{2}$; $b=11\frac{1}{2}$; $h_1=\frac{1}{2}$; $(\theta)=90°$.

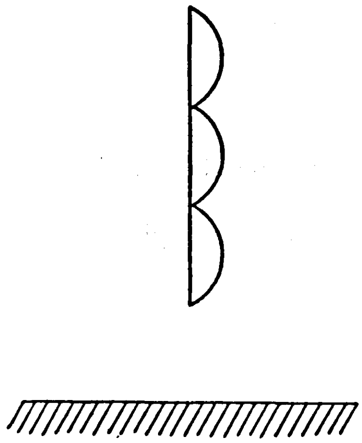


FIGURE 1

This represents a transmitter of a power of 12 kw in the antenna, provided with a directional antenna capable of transmitting at will either in the direction 160°, or in the direction 160°+180°, the effective wires of which, 24 in number, are of a length of 1½ wavelengths with a distribution of current as shown in figure 1. The width of the directional antenna is 11½ wavelengths, the height of the lowest point of the wire above the ground is a half wavelength, and the wires are vertical.

Second example

1 kw; n=1; $l=\frac{2}{2}$; $(\theta)=0$; $h_1=\frac{1}{2}$

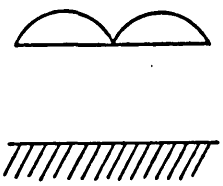


FIGURE 2

This represents a transmitter of a power of 1 kw in the antenna, provided with a horizontal single-wire antenna, a half wavelength above the ground, of a length of one wavelength, with a current distribution as shown in figure 2.

Third example

1 kw; n=1; $l=\frac{\frac{1}{2}+1}{2}$; $(\theta)=90°$; $h_1=0$

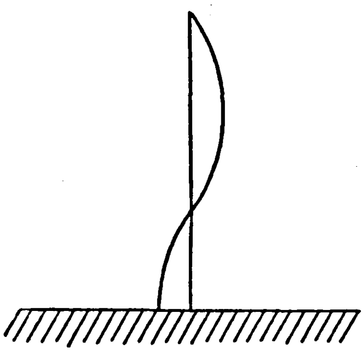


FIGURE 3

This represents a transmitter of a power of 1 kw in the antenna, provided with a vertical single-wire antenna of ¾ of a wavelength long with its lower extremity grounded and with a current distribution as shown in figure 3.

OPINION No. 8

ESTABLISHMENT OF AN ABSOLUTE INTERNATIONAL FREQUENCY STANDARD

It might perhaps be possible to establish an absolute international frequency standard which, from a scientific standpoint, would be interesting.

But in view of the state of the art, and of practical necessities, it is considered undesirable to establish at the present time such an absolute standard for world use; it should be sufficient to let each country establish its national standard; however, every effort should be made to compare the standards of different countries with one another and to perfect them constantly.

OPINION No. 9

DEFINITION OF TERMS: PRIMARY FREQUENCY STANDARD, FREQUENCY METER, AND SECONDARY FREQUENCY STANDARD; METHODS OF COMPARISON OF THIS APPARATUS

This opinion has been replaced by Opinion No. 42.

OPINION No. 10

DEGREE OF PRECISION OF FREQUENCY METERS

This opinion has been replaced by Opinion No. 43.

OPINION No. 11

NATIONAL FREQUENCY STANDARDS; FREQUENCY MEASUREMENTS

1. It is desirable that each nation should set up a national laboratory equipped with a frequency standard to serve as a basis of frequency measurements for the stations of that nation.
2. The International Bureau of Weights and Measures shall be asked to be so good as to consider the possibility of organizing international comparisons of national frequency standards.
3. Each country shall be free to organize as it sees best the measurement of stations of frequencies subject to that country, using as a basis its national standard.
4. This organization shall not prevent countries, operating organizations, or groups of operating organizations from concluding agreements among themselves for setting up laboratories and measurement stations charged with carrying on the checking of one or several more or less extended frequency bands; it is desirable, on the contrary, that such laboratories and measurement stations should continue to function or should be created.

OPINION No. 12

RECIPROCAL COMMUNICATION OF INFORMATION CONCERNING STANDARDS

The C. C. I. R. recommends that administrations should inform one another, through the International Bureau of the Telegraph Union, of their different methods of constructing and comparing standards, so as to permit national standards to be perfected.

OPINION No. 13

STANDARDIZATION OF TECHNICAL CONDITIONS TO BE IMPOSED ON AMATEURS

The C. C. I. R. recognizes that it is not at present possible to lay down rules applicable in all countries of the world, relative to amateur licenses, and that this question must form the subject either of regional agreements or of national decisions.

OPINION No. 14

TOLERANCE ADMISSIBLE FOR VARIATION BETWEEN AVERAGE FREQUENCY OF TRANSMISSIONS AND THE NOMINAL FREQUENCY

This opinion has been replaced by Opinion No. 41.

OPINION No. 15[1]

STABILIZATION OF FREQUENCY

1. The frequency of transmission of a station with tubes may be kept constant by various methods, belonging in the main to the three following groups:

(*a*) Specially constructed master oscillator.
(*b*) Master oscillator stabilized by a mechanical oscillator (quartz, tuning-fork or magnetostriction).
(*c*) Master oscillator with frequency regulator.

Constancy of temperature, which is essential in most cases, is maintained by thermostat working continuously or noncontinuously.

In stations with an alternator, stabilization of frequency is maintained by mechanical or electric regulators.

2. Certain documents submitted to the C. C. I. R. give interesting information as to arrangements of this nature.

(See particularly the following statements presented by Germany and the United States of America.)

3. Amongst frequency-stabilizing arrangements at present known for tube stations, there are relatively simple and practical apparatus which, when they work under good conditions, enable a constancy of frequency of one to two ten-thousandths (1/10,000 to 2/10,000) to be obtained.

With more complicated and costly apparatus, a constancy of one to two one-hundred-thousandths (1/100,000 to 2/100,000) may be expected, and still greater constancies are hoped for in the future.

As regards long-wave stations with alternators equipped with regulators, the constancy obtained is of the order of plus or minus one one-thousandth (1/1,000).

ANNEX TO OPINION No. 15

STATEMENT PRESENTED BY GERMANY

A. MEANS NOW AVAILABLE IN VACUUM-TUBE STATIONS TO MAINTAIN THEIR WAVES AT THE AUTHORIZED FREQUENCY AND TO MAINTAIN THE EMITTED FREQUENCY AT THE CONSTANT VALUE (NO FLUCTUATION)

This is chiefly accomplished at the present time by the use of a master oscillator which produces the antenna frequency, or one of which the antenna frequency is a harmonic. The other parts of the transmitter are solely for the purpose of amplifying the power delivered by the master oscillator to the desired amount. In order to attain these results care must be taken that:

(I) the frequency of the emitted waves (fixed at the authorized value) be exactly maintained at all times without any fluctuation due to keying or modulation;

(II) the power stages following the master oscillator only oscillate at the frequency determined by the master oscillator or in the case of a frequency-multiplying device at a multiple of the latter.

I. Accurate adjustment of the frequency emitted by a station as well as the maintenance of that frequency at a constant value are obtained as follows:

[1] BI. See also Opinion No. 45.

1. In the master circuit itself:

(*a*) The constants of the oscillating circuit of the master oscillator must be made independent of outside conditions such as changes of temperature. In order to attain this result it is recommended to replace the materials which have been commonly used up to the present time, such as copper, for example, by metals which are not affected by temperature conditions and to make use also of air condensers.

(*b*) The vacuum tubes of the master oscillator must not cause any variation of the tuning. Its plate voltage and filament voltage must be sufficiently constant for this purpose.

(*c*) In case a quartz crystal or a tuning-fork is made use of in the master oscillator circuit, the temperature of these devices must be kept constant so far as possible, in as much as the smallest variations of temperature are sufficient to cause the frequency to vary appreciably. A constant temperature is maintained by means of a thermostatic arrangement. It is necessary, besides, to keep the load applied to the crystal itself very small, in order not to produce internal heating effects which the thermostat could not compensate. Tests of very carefully made master oscillators have proven that the precision with which it is possible to maintain the frequency is of the order of .001 per cent.

2. By preventing the power stages which follow the master oscillator from reacting on the frequency of the master oscillator and the following stages (i. e., separator circuit):

(*a*) By very loose coupling between the master oscillator and the following stages (i. e., separator circuit).

(*b*) By multiplication of the fundamental frequency in the stages following the master oscillator. The reaction between two adjacent circuits is thus avoidable.

Frequency multiplication is generally only employed when the frequency of the master circuit is for reasons of convenience lower than the authorized frequency of the transmitting station. The reaction between two adjacent tuned circuits is at the same time avoided.

(*c*) By avoiding large variation of voltage in the input power circuits to the amplifier stages following the master oscillator due to keying.

This is accomplished during keying by compensating the load so as to maintain as much as possible the load applied to the power-supply circuit at a constant value.

(*d*) By inserting between the master oscillator and the power stage which is controlled during keying several stages of amplification.

It is always necessary even when any one of the above-mentioned schemes is used to make use of a wave meter, in order to determine whether the station frequency has been kept at the exact value authorized. In cases where it is impossible to employ a sufficient number of the above-mentioned schemes in order to be absolutely sure that the emitted frequency is kept at its authorized value, the emitted frequency must be controlled automatically by means of a wave meter forming an integral part of the transmitter itself.

II. Oscillation in the amplifier stages following the master oscillator must be carefully avoided. This oscillation, which is usually due to regeneration within the stages themselves or between adjacent stages, may be avoided by loosening the coupling between them, thus reducing their reaction upon each other,

(1) by utilizing the grid 2 plate capacity of the transmitting tubes (neutrodyne circuits);
(2) by the use of screened grid tubes;
(3) by frequency multiplication [see under I, 2*b*].

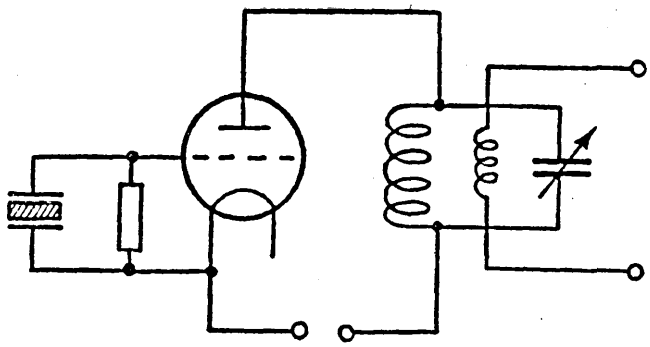


FIGURE 1

Quartz Crystal in the Master Oscillator

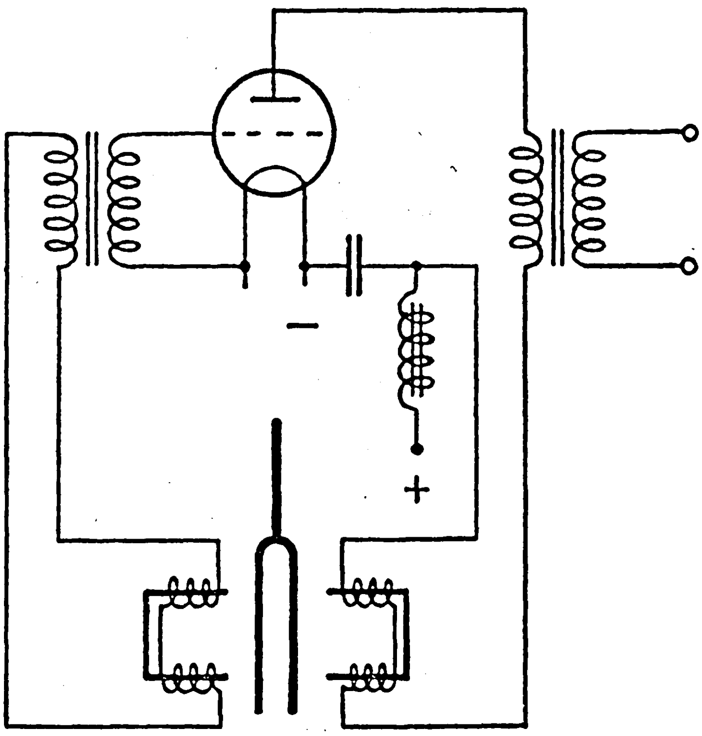


FIGURE 2

Tuning-fork in the Master Oscillator

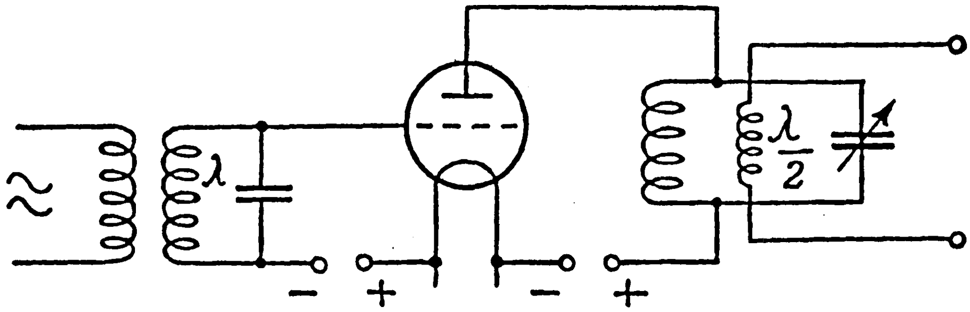
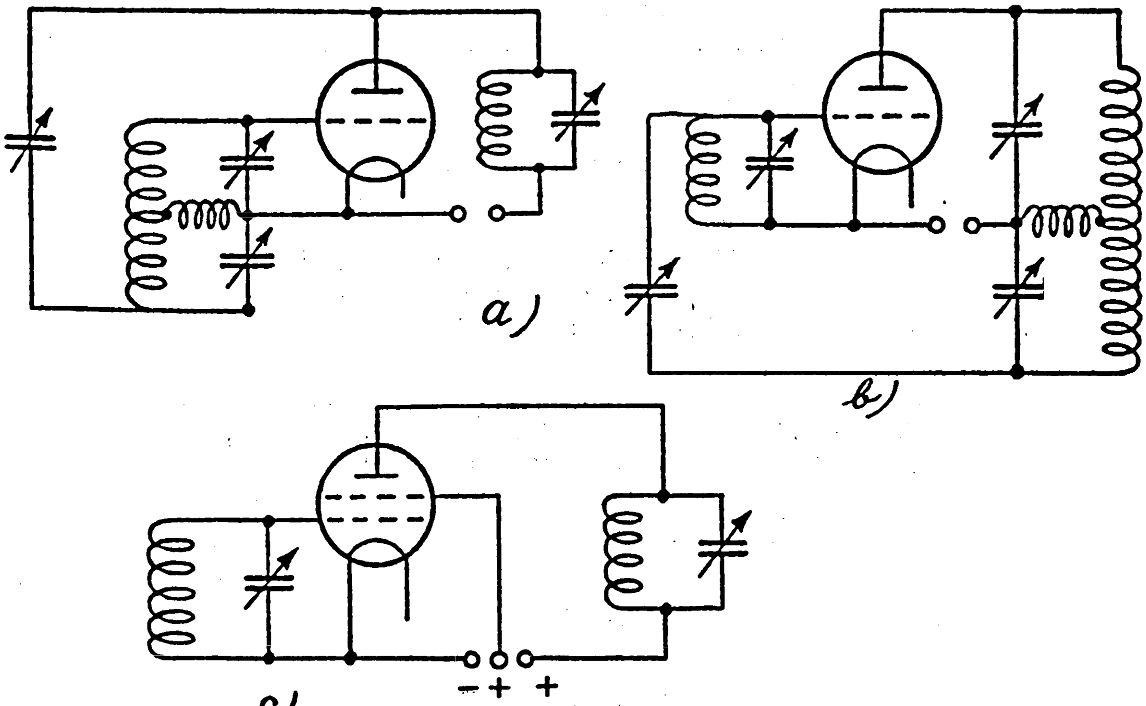


FIGURE 3

Doubling of the Frequency



Screen Grid Tube

FIGURE 4

General Appearance of Neutralization

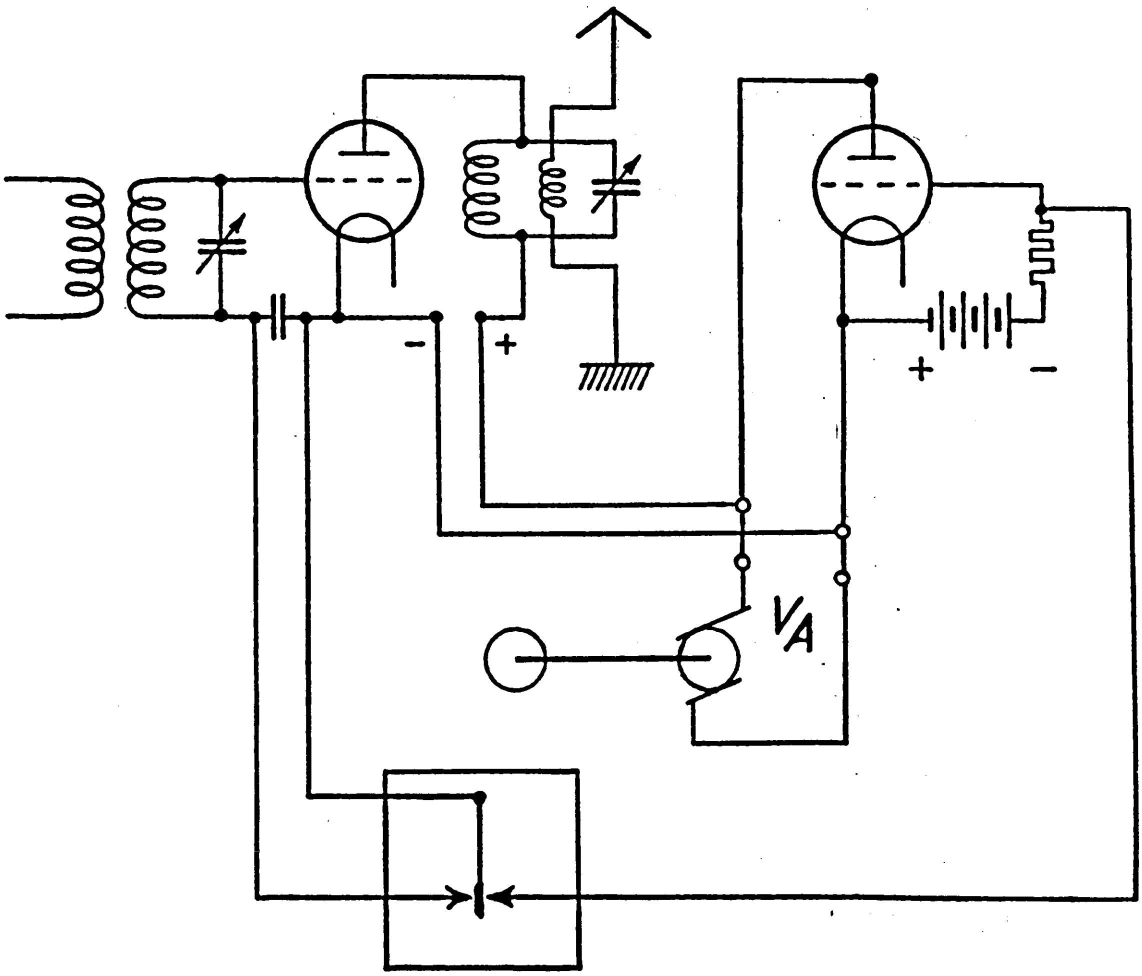


FIGURE 5

Compensation of Load

B. MEANS FOR MAINTAINING THE EMITTED FREQUENCY FROM AN ALTERNATOR TRANSMITTER CONSTANTLY AT ITS AUTHORIZED FREQUENCY

1. The apparatus available to maintain the frequency at a constant value in this case are speed regulators which are themselves adjusted by means of a wave meter and which must be capable of maintaining the number of revolutions per minute of the high-frequency alternator at a sufficiently constant value. These instruments can now be built with a guaranty of accuracy up to 0.01 per cent. Hunting of the alternator must be avoided as much as possible in this case.

2. Fluctuation of frequency due to rapid keying is not generally of much importance, owing to the compensation produced by the inertia of the rotating machinery. In case the speed of signaling is reduced, an additional compensation of the load must be used [see also under A, I, 2 c].

C. WHAT CONSTANCY OF FREQUENCY IS IT POSSIBLE TO ATTAIN AT THE PRESENT TIME IN FIXED TRANSMITTING STATIONS AND WHAT IS THE LIMIT OF DIVERGENCE FROM THE AUTHORIZED FREQUENCY WHICH MAY BE PERMITTED?

By utilizing the above-mentioned scheme it is practicable to attain in practice frequencies which will not depart from the authorized frequency by more than the tolerance values given in the following table:

Frequencies	Wavelengths	Tolerances
Under 33.5 kc/s	Above 9000 m	±0. 1%
From 33.5 to 100 kc/s	From 9000 to 3000 m	±0. 02%
From 100 to 287.5 kc/s	From 3000 to 1050 m	±0. 01%
From 285.7 to 1714 kc/s	From 1050 to 175 m	±0. 01%
From 1714 to 4000 kc/s	From 175 to 75 m	±0. 01%
Above 4000 kc/s	Under 75 m	±500 cycles

The constancy of the emitted frequencies can not in practice be below ±20 cycles.

It is recommended to prescribe these frequency tolerances to each fixed emitting-station occupying bands of frequency exclusively reserved for fixed stations.

In as much as most of the mobile stations are constructed under very disadvantageous conditions (reduced space, lack of constancy in power-supply voltage), in as much as these stations must often work under conditions which necessitate a rapid shift of frequency to the other and it is impossible to service them as carefully as fixed stations, and in as much as mobile stations are assigned frequencies higher than 6000 kc/s and not enough experience has been accumulated in the matter, it has been found in general useless to specify a tolerance limit for mobile stations.

However, for mobile stations working at frequencies below 285 kc/s (more than 1050 m), it is estimated that a tolerance of 0.4 per cent is admissible. This tolerance is therefore proposed.

It seems unjustified to prescribe for fixed stations occupying bands of frequency which have been reserved for fixed and mobile stations, tolerances other than those which have been granted to mobile stations. It is for this reason that the tolerances first mentioned have been proposed only for fixed stations occupying bands of frequencies exclusively reserved for fixed stations.

ANNEX 2 TO OPINION No. 15

STATEMENT PRESENTED BY THE UNITED STATES OF AMERICA [1]

MEASUREMENT OF FREQUENCY AND ADJUSTMENT METHODS

One of the engineering limitations on the uses of radio is the degree of constancy of station frequencies. Throughout most of the spectrum, at the present time, this limits the number of available communication

[1] This document is an extract of a general statement published in the documents of first meeting of the C. C. I. R.

channels. As the demands for the use of these channels are increasing throughout the world, it is important that every possible means be taken to keep stations of all classes on their assigned frequencies.

In this section are considered the accuracy of setting transmitting stations on their assigned frequencies and the standards or measuring-instruments used in connection therewith. The tolerance as to actual maintenance of the emitted frequency is a separate matter and is treated under the next heading, section 3. Monitoring, or the checking of the frequencies of the actual emissions, is treated in section 4, below.

The adjustment or setting of the frequency of stations may be either manual or automatic. Where manual adjustment is used, the intervals at which the station is adjusted vary greatly. Automatic adjustment or control has the advantage that the adjustment is continuous; it is used in relatively few stations, but its use is increasing. In the case of alternator transmitters, automatic control of frequency is accomplished by speed control of the prime mover; this method is satisfactory to about 0.1 per cent. Some vacuum-tube transmitters are automatically controlled by a piezo-oscillator. When means are provided to maintain the temperature of the quartz-plate constant, such control may operate with an accuracy within 0.01 per cent. In such transmitters a frequency standard may be considered as incorporated within the transmitter. Except for such cases, proper maintenance of frequency requires that every station have its frequency adjusted at frequent intervals in terms of a separate piece of apparatus serving as a frequency standard.

Frequency meters (wave meters) are of two general types: The older resonance type and the type which serves as a generator. Either type may be designed to cover a considerable range of frequencies or a very narrow frequency band. When a frequency meter of resonance type is designed to cover only a very narrow band on both sides of a station's frequency, it is known as a frequency indicator. The type of frequency meter which serves as a generator is commonly called a heterodyne frequency meter when it covers a considerable range of frequencies.

A generator of a single frequency, employing a combination of piezo-electric plate and vacuum tube as a source, is coming more and more extensively into use as a frequency standard for radio stations. This device is called a piezo-oscillator.

The piezo-oscillator is adjusted so as to produce the frequency of the particular station in which it is to be used. When means are provided to maintain the temperature of the quartz-plate constant, an accuracy within 0.01 per cent can be obtained. The piezo-oscillator is used by adjusting the transmitter until zero beat is obtained between the two. It is sometimes found convenient to amplify the beatnote by an audio-amplifier, the output of which operates a loud speaker; then, if the transmitter frequency changes, a whistle is produced attracting the operator's attention to the deviation.

RECOMMENDATIONS

The requirements for frequency measurement and adjustment are necessarily different for stations on aircraft, on ships and on land. No recommendation is made as to immediate requirements for aircraft stations, as there has not yet been experience adequate to indicate what requirements would be reasonable. It is, however, recommended that eventually every radio station of every class other than amateur (see below) be required to have as part of its equipment a frequency meter or frequency indicator, of an accuracy to be specified for the class of station (this requirement not to preclude the device being an integral part of the transmitter).

It is recommended that every ship station be required to be equipped with a frequency meter capable of an accuracy of one-half per cent or better (except when exempted by the national administration on the ground that the transmitter design itself insures permanent accuracy equal to this). This is a reasonable requirement. It is believed to be more appropriate at present than any requirement as to routine adjustment of the transmitter. The presence of a standard in every ship station will undoubtedly lead to considerable reduction of interference. It is furthermore recommended that each administration give consideration to requiring more frequent inspections

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and adjustments of ship transmitters. It is also recommended that each administration seek to accelerate the installation of types of transmitters, such as vacuum tube, which are capable of more accurate frequency settings.

It is recommended that every station other than amateur on land, and every station operating on a specifically assigned frequency, be required to be equipped with a frequency standard. For stations on frequencies greater than 100 kc/s, this should be capable of an accuracy of 0.01 per cent or better. At the present time a type of standard which can meet this requirement makes use of a piezo-oscillator with temperature control. It is recommended that every amateur station be required to be equipped with apparatus which its administration is satisfied will enable the maintenance of the station on frequencies within the amateur bands. It is furthermore recommended that every station on land, other than amateur, operating on frequencies above 1500 kc/s, be required to adjust or tune its transmitter to its assigned frequency within 0.025 per cent. These requirements may be waived for any station by a national administration when the transmitter design itself ensures equivalent permanent accuracy. The use of a frequency meter is, however, desirable in every case, as a check upon the actual maintenance of frequency.

OPINION No. 16

USE OF FREQUENCY METERS BY RADIO STATIONS

This opinion has been modified by the second meeting of the C. C. I. R. (Copenhagen, 1931) and appears on page 84.

OPINION No. 17

SUPPRESSION OF TRANSMITTERS ON DAMPED WAVES

Owing to the serious interference caused by damped waves, the Committee expresses the wish that the various administrations shall, so far as possible, hasten the abolition of stations transmitting damped waves (type B) of more than 300 watts, before the time limit fixed in article 5, paragraph 8, of the General Regulations of Washington.

OPINION No. 18

ALLOCATION OF FREQUENCIES ABOVE 6000 KILOCYCLES; GENERAL GROUPING OF FREQUENCIES

The C. C. I. R., with a view to the development of world communications on frequencies above 6000 kc/s, recommends, to facilitate the methodical use of them in the future as fast as progress in the technic is made, that, in the bands in this part of the spectrum exclusively reserved for fixed services, only frequencies expressed so far as possible in numbers multiples of 5 be allocated by the administrations.

It is understood that the present state of the art, especially in the higher frequencies, does not always permit two stations to work simultaneously on two frequencies differing only by 5 kc/s and that present practice shows that a difference of frequencies of about 0.1 per cent between two telegraph stations is generally desirable in order to secure sufficient protection against interference.

However, when the various conditions permit it, telegraph stations may work with a frequency interval less than 5 kc/s.

It is further recommended that, in any band exclusively reserved for fixed services, the frequencies used by a single administration or a single private enterprise should, so far as possible, be grouped together.

OPINION No. 19

NOTIFICATION OF FREQUENCIES TO THE INTERNATIONAL BUREAU OF THE TELEGRAPH UNION

This opinion was replaced by Opinion No. 37.

OPINION No. 20[1]

TOTAL FREQUENCY BANDS

The C. C. I. R.,

having examined the following different systems of transmissions,

considers that in the present state of the art the total frequency band which their transmission generally covers is the following:

System	Total frequency band (plus or minus) in cycles
International Morse Code, 100 words a minute, in telegraphy on continuous nonmodulated wave	From 160 to 240 c/s
International Morse Code, in telegraphy, on continuous modulated wave	The number of cycles given in the preceding line for the speed used, plus twice the frequency of modulation
Transmission of facsimile and pictures	From 2000 to 10,000 c/s
Television	From 10,000 to 100,000 c/s
Commercial telephony	6000 c/s
Broadcast telephony	From 10,000 to 20,000 c/s

OPINION No. 21

SELECTIVITY OF RECEIVING APPARATUS

The C. C. I. R., having regard to the provisions of article 11, paragraph 4, of the General Regulations of Washington, again draws attention to the fundamental importance of the selectivity of receiving apparatus. It considers that, as regards the separation necessary between the frequencies utilized by two stations working on neighboring frequencies, account should be taken of that selectivity as much as of the tolerance and the width of the transmission band.

The C. C. I. R. recognizes that any good modern receiver should be arranged to receive not only the single frequency allotted, but the frequency band corresponding to the transmission desired. The examination of methods of reception at present available shows that it is possible to make a receiver which, while admitting a frequency band equal to that of the transmission in question, presents a high attenuation for all frequencies

[1] BI. See also Opinion No. 47.

which are found outside a band the center of which coincides with the frequency of the transmission to be received, and whose width is equal to twice the communication-band in question.

However, it is recognized that the great majority of receivers at present in use, especially for the reception of short waves, are far from achieving such a selectivity. Owing to the great number of stations at present proposed, it will no doubt soon be necessary to use receivers of a selectivity comparable to that defined above.

OPINION No. 22

USE OF FREQUENCIES BETWEEN 1500 AND 23,000 KILOCYCLES

The C. C. I. R.,

considering

that the optimum use of the frequency band between 1500 and 23,000 kc/s must take account of the different properties of these waves as regards their propagation,

recommends to the administrations to allocate to fixed services the frequencies contained in these bands in accordance with the following principles:

(*a*) Frequencies between 6000 and 23,000 kc/s[1] (waves from 50 to 13 meters) are in principle reserved for long-distance communication (General Regulations of Washington, note at foot of table in article 5). However, during daylight at the transmission station (i. e., from about two hours after sunrise to about two hours before sunset), transmissions may be made on frequencies between 6000 kc/s and about 9000 kc/s[1] (waves from 50 to 33 meters) for medium-distance communications.

(*b*) Frequencies between 6000 and 3500 kc/s[1] (waves from 50 to 85 meters) are in principle reserved for medium-distance communications.

(*c*) Frequencies between 3500 and 1500 kc/s[1] (waves from 85 to 200 meters) are in principle used for shorter-distance communications.

In order to facilitate the application of these principles, it is recommended, as regards short- and medium-distance communications, that regional agreements should be entered into between the administrations of neighboring countries.

OPINION No. 23[2]

IMPROVEMENT OF STATIONS USING FREQUENCIES ABOVE 6000 KILOCYCLES IN BANDS SHARED BY FIXED AND MOBILE SERVICES

The C. C. I. R.,

foreseeing that a large number of stations will probably be placed in the mixed bands (fixed and mobile services) above 6000 kc/s,

draws attention to the importance of these stations' being equipped with modern apparatus for both transmission and reception; otherwise traffic may become very difficult in these bands.

[1] The frequencies indicated here are, of course, only approximate.

[2] BI. See also Opinion No. 44.

OPINION No. 24[1]

ELIMINATION OF NONESSENTIAL TRANSMISSIONS

The C. C. I. R. recommends that the statement given below by Great Britain be accepted as a sufficiently detailed statement concerning question 9 of the program. It considers that it is not necessary to establish a rule on this subject at the present time.

ANNEX TO OPINION No. 24

STATEMENT PRESENTED BY GREAT BRITAIN

MODERN PRACTICE AS REGARDS THE ELIMINATION OF EMISSIONS OTHER THAN THOSE ESSENTIAL TO COMMUNICATION FROM RADIO TRANSMITTERS

In this memorandum the remarks have been confined to arc and valve transmitters since it has been mainly with these types that the experience of the British Post Office has been acquired. No attempt has been made to define in any way the extent of the interference likely to be caused by either type of transmitter, but rather to point out the main sources of untoward emissions and to give the steps which have been taken to ensure that the extent of these emissions should be reduced to a minimum while at the same time preserving the efficiency of the transmitter.

THE ARC TRANSMITTER

It is a matter of common knowledge that the Poulsen arc, if directly connected to an antenna, produces a great deal of disturbance to other wireless users on wavelengths far removed from that of the arc. This disturbance is of two kinds: (1) the emission of harmonics, i. e., emissions which are definitely tunable and which can be heterodyned to a musical note, and (2) the emission of what has been called mush. The latter manifests itself as a hissing sound in a receiver and is usually found most strongly in the neighborhood of the harmonic positions.

The cause of harmonics is to be found in the slight departure from sinusoidal form of the current in the oscillating circuit. Suitable design of the arc and the antenna circuit may reduce the harmonics to the same order of strength as those obtained from a valve oscillator of similar power on plain antenna but in practice the harmonics and more especially the mush are still strong enough to cause trouble.

The cause of mush is a little more obscure, but it is probably associated with the irregular frequency of the fundamental wave. The arc is an ionic contrivance and on a plain antenna connection has a frequency which in the nature of the ionic action inside the arc chamber can not be expected to be very constant. Carson[2] has shown that, if a sine wave has its frequency changed at a sinusoidal rate or, in other words, undergoes frequency modulation, an infinite series of harmonics of the sum and differences of the fundamental and modulating frequencies is obtained.

When any one harmonic of this series happens to fit in with the harmonic resonant point of the antenna, it gives rise to radiation on that frequency.

With the arc the fundamental frequency is undergoing frequent discontinuous changes, and it is to be expected that the "harmonics" due to these irregular changes will form a continuous spectrum of disturbance which is ready to emerge at any harmonic resonant point of the antenna.

From the theory outlined above it is to be expected that the provision of a primary oscillating circuit for the arc in which both capacity and inductance are concentrated will tend to prevent the harmonic E. M. F.'s giving rise to currents of sufficient order to cause disturbance.

[1] BI. See also Opinions Nos. 46, 48, 49, and 50.

[2] J. R. Carson, "Frequency Modulation," in *Proceedings of the Institute of Radio Engineers* (1922), vol. 10, p. 57.

The antenna, where capacity and inductance are necessarily distributed, may resonate on harmonics. The introduction of the primary circuit should eliminate these harmonics before they reach the antenna.

This view has been confirmed by the experience of the British Post Office, after fitting coupled circuits to arc transmitters at Stonehaven, Northolt, Leafield, and Abu Zabal. A typical circuit diagram of one of these installations is shown in figure 1. The installation of these circuits rendered the arc innocuous on wavelengths other than the fundamental as regards both harmonics and mush.

The circuit at Northolt differs from the others in that the secondary circuit is placed at a distance from the primary and coupled thereto by means of a transmission line containing appreciable resistance. The circuit arrangement is shown in figure 3.

When the primary circuit is excited by the arc, the oscillatory voltage developed across the condenser C_2 is also applied across the portion of the antenna tuning inductance between the transmission line tap and earth.

The aerial circuit is tuned to the same frequency as the primary circuit.

The resistance R is inserted in the transmission line to prevent any tendency of the two circuits to oscillate as a single series circuit.

Under normal operating conditions on a frequency of 71.5 kc/s the value of the aerial circuit inductance between transmission line tap and earth is about 130 μH while C_2 is about 0.035 μF. The resistance R is about 100 ohms.

Resonance curves of this circuit are shown in figure 4. It will be seen that the circuits tune at only one frequency.

The normal primary circuit current is about 48 amperes and the aerial current 41.5 amperes, while the transmission line current is only 2.4 amperes.

The use of a coupled circuit on an arc transmitter has one very important advantage in that the steadiness of the fundamental frequency is greatly improved.

Tests made on these installations indicate that the arc itself is unstable, but that the coupled circuit exercises a stabilizing tendency and that the addition of a condenser in shunt across the arc improves the stabilizing properties of the circuit.

The modern demand for high selectivity in the receiver requires great steadiness in the transmitted frequency and as time goes on the crowding together of wireless services will demand that more and more attention be paid to this point.

In a plain antenna arc transmitter, movement of the antenna wires due to wind is the chief cause of unsteadiness. The interposition of a coupled circuit between the arc and the antenna reduces, to a large extent, the effect of these variations in the antenna constants on the frequency of the transmitted wave, and, except in abnormal circumstances, such as gales, the frequency of the transmitted wave can be maintained constant with ± 0.02 per cent. Typical curves are shown in figure 2, in which the frequency variations of a coupled arc transmitter are plotted against a time base during a high wind and light wind, respectively. The mean frequency of this transmitter was 25,000 cycles.

The normal method of signaling with most large arc installations is by means of marking and spacing waves, and the difference in frequency between these waves should be not more than 0.33 per cent, if the use of an unnecessarily wide band is to be avoided.

The receiver must be capable of selecting either of these waves, and such a receiver would be susceptible to the slightest change in frequency of the emitted signal.

The design of a coupled circuit for an arc transmitter must take into account the fact that the arc operates most satisfactorily when the L value of the circuit is between 150 and 270. To avoid inefficiency compared with the plain antenna circuit, the resistance of the coupled circuit should be made as low as possible, and for this reason the choice of type of condenser is limited to one of three types of dielectric, viz, air, mica, or oil. Air condensers can be used conveniently only in the smaller installations.

For higher powers the British Post Office has used both mica and oil condensers, the latter in banks up to 30,000 kVA and with working pressure up to 80,000 volts R. M. S. In the case of oil condensers, the losses can be reduced to an insignficant minimum by suitable treatment of the oil which should be high grade transformer oil or paraffin.

THE COUPLED-CIRCUIT VALVE TRANSMITTER

The modern valve transmitter can be taken as being of the driven type, i. e., a type where the oscillations are generated at small power through the agency of a tuning-fork, crystal, or valve transmitter and where the reactive effect from the output to the source is negligible in extent. To this can be added a method of keying whereby during the spacing period excitation of the final stage of the transmitter is suppressed.

In this case emissions which are not of the fundamental frequency can arise from—

(*a*) the passage into the antenna system of oscillations whose frequencies are harmonics of the fundamental frequency;

(*b*) radiation during the spacing intervals of keying of the frequencies arising from free oscillations of the coupled circuits.

The extent to which emissions of the type *a* exist depends upon—

(1) the method adopted to adjust the impedance of the anode circuit of the valve so that the necessary variations in anode voltage is obtained;

(2) the method of coupling to the antenna, i. e., whether inductive or capacitative.

With regard to clause 1, it has been shown that the use of a condenser rather than an inductance as the "anode tap" brings with it a reduction of the harmonics in the antenna in the ratio m^2 for the m^{th} harmonic; i. e., referring to figure 5, types of circuits B and D are better than types A and C, respectively.

The same argument applies to the question of coupling to the antenna. Thus as regards the emission of harmonics circuit E, figure 5, is m^2 better than type D and thus m^4 better than type C. Thus for the minimum harmonic radiation, capacitative coupling should be used to both the anode and the antenna.

The improvement as regards the undesirable emission of the m^{th} harmonic for any type of coupled circuit includes the expression.[1]

$$\frac{\beta \pi \delta_a}{\delta_i \delta_a + \pi^2 K^2}$$

$\beta = 1 - \frac{1}{m^2}$

δ_a = decrement of antenna circuit

δ_i = decrement of intermediate circuit

K = coefficient of coupling

For the higher harmonics where β approaches unity the expression

$$\frac{\pi \delta_a}{\delta_i \delta_a + \pi^2 K^2} = \frac{\pi}{\delta_i + \frac{\pi^2}{\delta_a} K^2}$$

[1] *Journal of the Institute of Electrical Engineers*, vol. 65, no. 363, pp. 297–326.

may be taken as a measure of the "improvement factor" of the coupled circuit as such, which factor must be multiplied by a power of m, depending on the nature of the couplings.

Considerations of efficiency demand that the losses in the antenna inductance should be low and that the radiation efficiency of the antenna should be as high as possible. Hence, so far as consideration of the "improvement factor" for a given antenna system and frequency of transmission is concerned, δ_a is fixed; it follows from the formula that the "improvement" can only be increased by decreasing K or δ_t. The formula thus shows the desirability of reducing δ_t to a minimum by building the most efficient coil possible, and by providing low-loss condensers. It can be taken that in a well-designed coil the decrement will be practically independent of the value of the inductance, and reasons of voltage and cost make it desirable that the inductance value shall be as low as design considerations allow.

The study of nonessential radiation during the spacing intervals of keying presents certain difficulties, because a scientific method has not yet been found which permits the proper elimination of the characteristics of the receiving apparatus in the observation and measurement of these emissions.[1]

Undesirable emissions during the spacing periods of keying depend in large part upon the extent to which the conductivity of the valve is utilized to increase the decrement of the intermediate circuit during these periods.

Figure 6, case 1, illustrates the nature of the antenna current which can result when the valve offers no load during spacing and 2 is an oscillogram of the rectified current in the intermediate circuit under similar conditions. Case 3 illustrates the nature of the effect upon the current in the intermediate circuit of causing the valve to act as a load during spacing.

If the valve is not caused to act as a load upon the intermediate circuit during spacing, not only does poor keying result, but there also arises a free radiation of the frequencies corresponding to the free oscillation periods of the coupled circuits. The requisite damping action of the valve can be conveniently obtained by using for the grid polarization of the valve associated with the coupled circuits a combination of grid-leak resistance and grid-bias generator.

TELEPHONY AND MULTIPLEX-SYSTEM TRANSMITTERS

When a band of frequencies is required for the purpose of communication, such as is the case with telephony transmitters or transmitters when a combined telephony and telegraphy or a number of telegraphy channels operate upon a single carrier wave, it is essential that the band width occupied by the transmission shall be strictly confined to the limits necessary for communication.

This demands primarily that there shall be incorporated in the speech or modulating frequency channels of the transmitter, wave filters which will exclude all nonessential frequencies.

Where, however, a carrier is modulated as in the above-mentioned types of transmitters, another kind of disturbance can arise from intermodulation between the various sideband frequencies and their harmonics. Experiments carried out by the British Post Office have shown that such intermodulation products can not only give rise to disturbing effects within the band used for transmission, but that disturbing emissions can exist over a large frequency range on either side of the working band unless special steps are taken to guard against them.

The amplitude and extent of these intermodulation products will depend to a large extent upon the departure from linearity of the amplifying system of the transmitter and in order to reduce such emissions to a minimum it is necessary that each amplifying stage of the transmitter should have a substantially linear characteristic.

Experiments in connection with these intermodulation products have been carried out using modulating frequencies of equal amplitude and it is interesting to note that disturbance may be more severe in the case of

[1] Radio Research Report No. 88, *An Investigation of the Interference Caused by Transmission from Radio Stations* (H. M. Stationery Office, London).

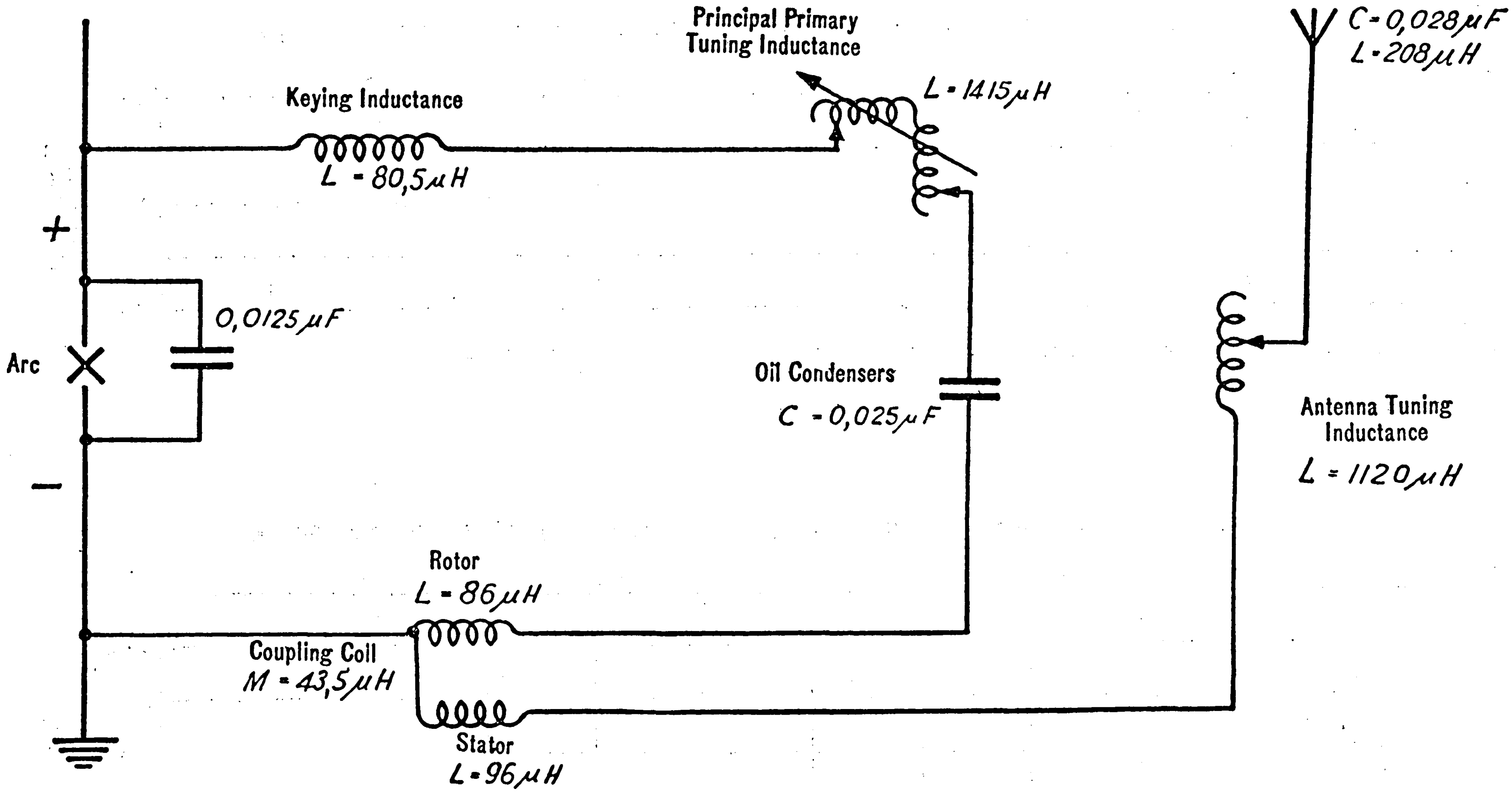
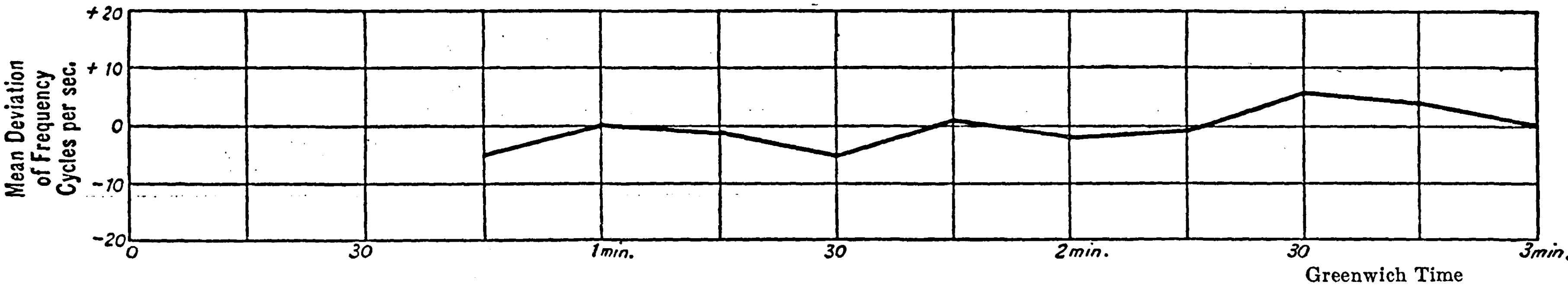


FIGURE 1

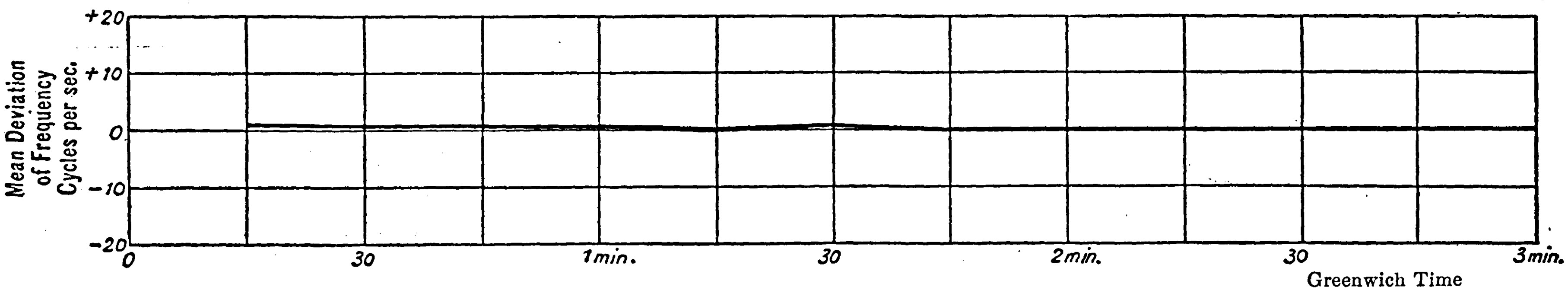
Schematic of Arc Coupling Circuit

Variation established at Leafield during the U. R. S. I. signal of November 27, 1924 Weather: wind very strong cold, rainy



Variation of the frequency. Leafield Arc, during rainy weather. Mean frequency 25,000~ per second

Variation established at Leafield during the U. R. S. I. signal of November 26, 1924 Weather: light wind cold, dry



Variation of the frequency. Leafield Arc, during calm weather. Mean frequency 25,000~ per second

FIGURE 2

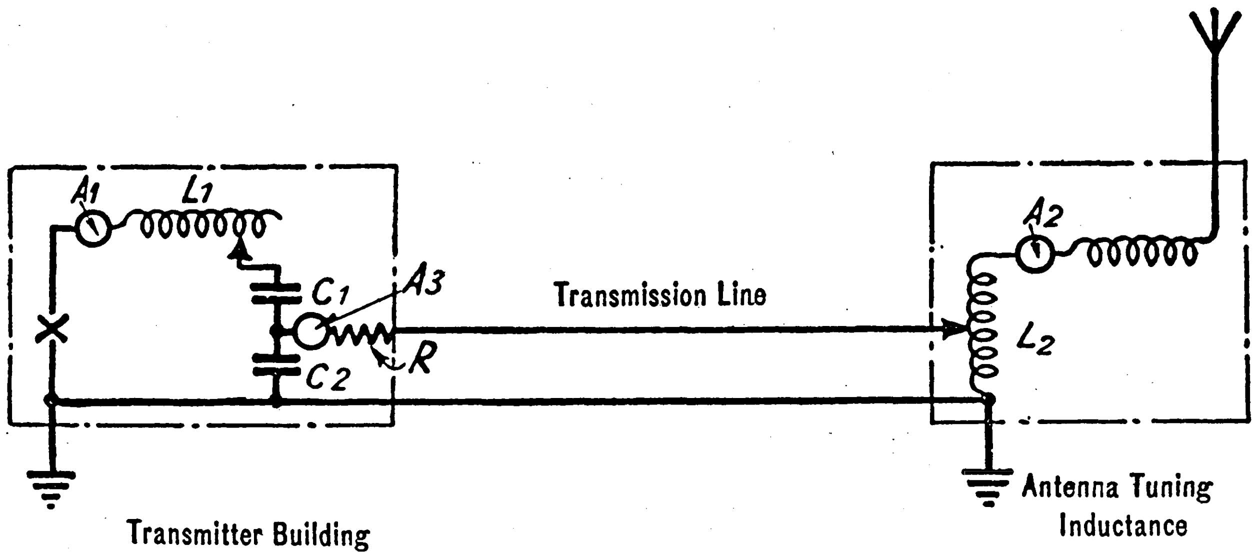
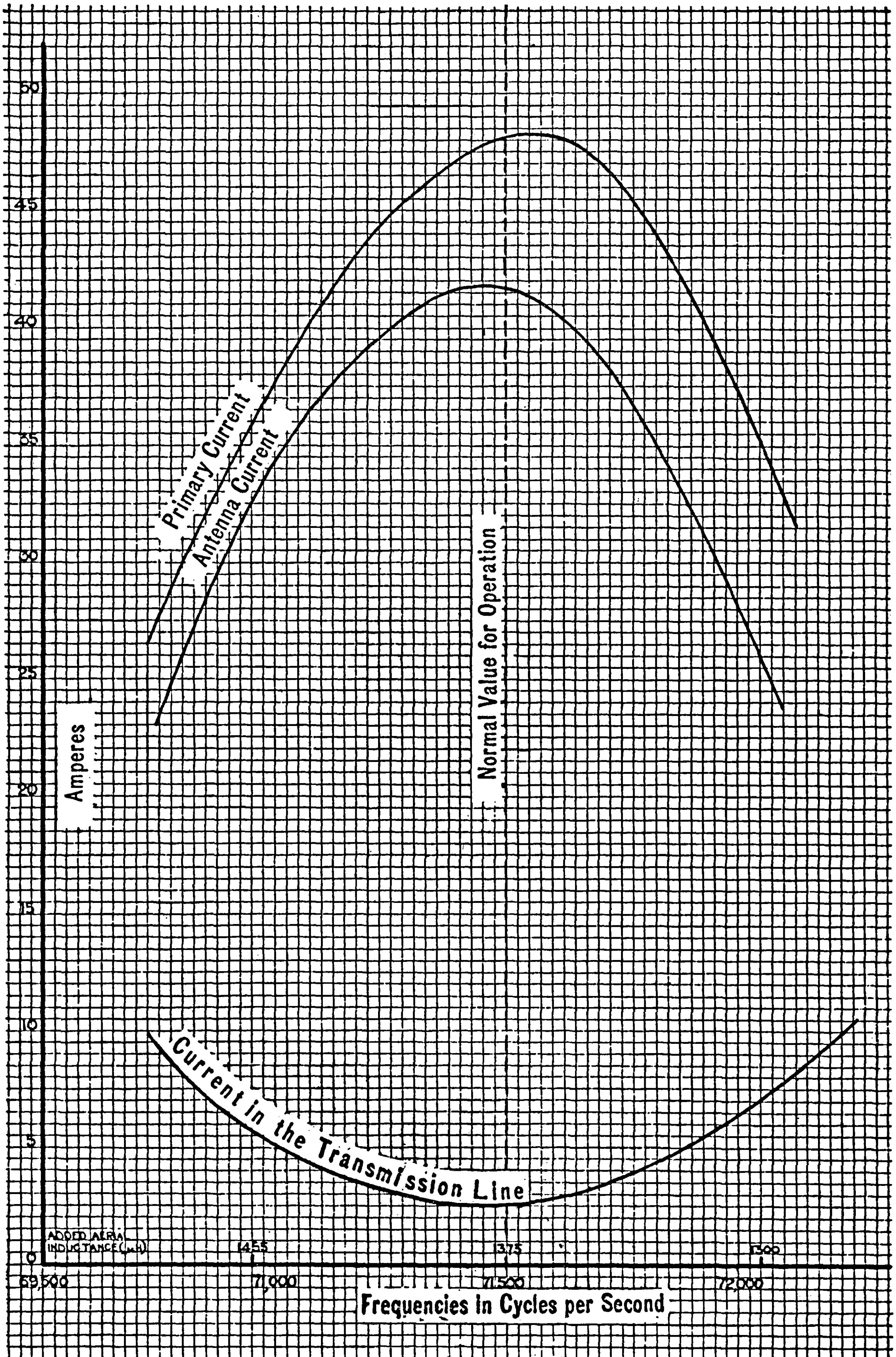
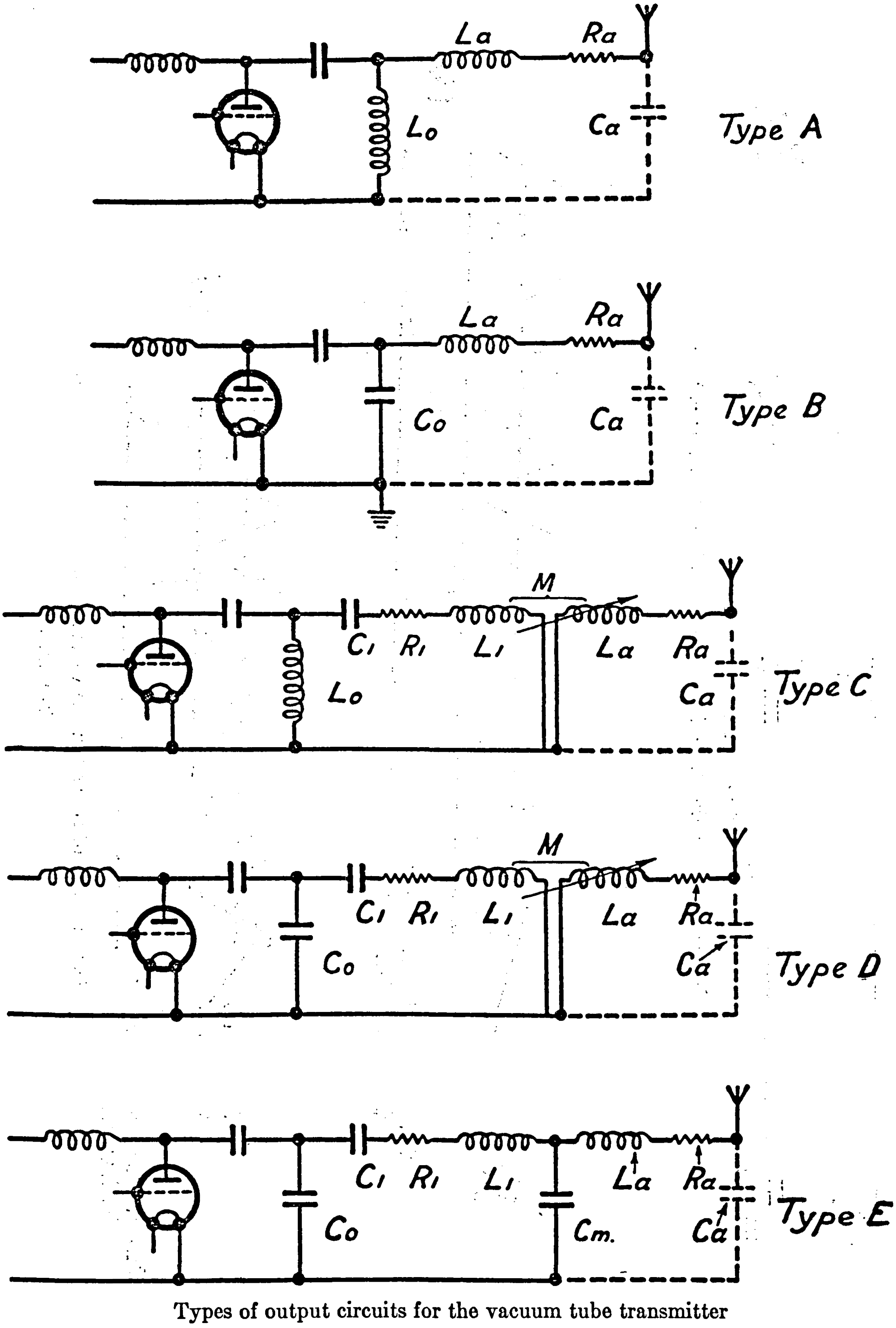


FIGURE 3
Schematic of the circuit for coupling the arc with the transmission line



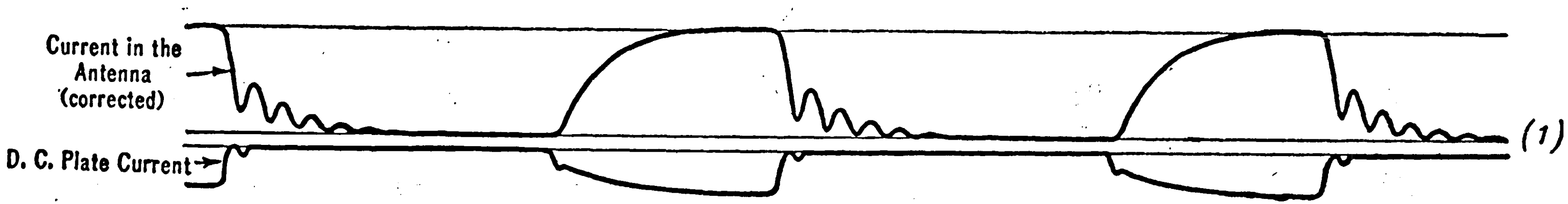
50
45
40
35
30
25
20
15
10
5
0
Amperes
Primary Current
Antenna Current
Normal Value for Operation
Current in the Transmission Line
ADDED AERIAL INDUCTANCE (μH)
1455
1375
1300
69,500
71,000
71,500
72,000
Frequencies in Cycles per Second

FIGURE 4

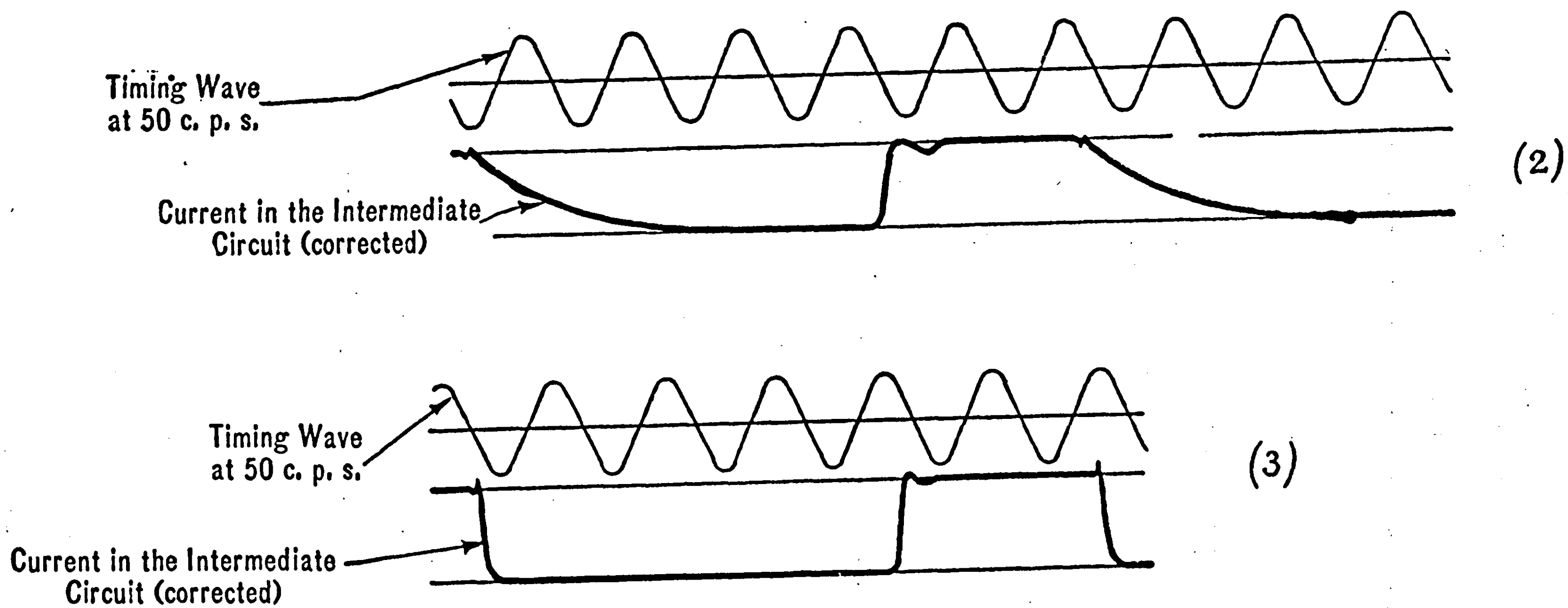


Types of output circuits for the vacuum tube transmitter

FIGURE 5



Oscillogram indicating the effects of keying without backward load



Oscillograms of current in the vacuum tube coupled transmitter

FIGURE 6

multiplex telegraphy stations and broadcasting stations where music is transmitted than with commercial telephony stations.

OPINION No. 25

ALLOCATION OF WAVES TO AVIATION

The C. C. I. R. expresses the opinion that it is not competent to decide the question as to whether or not the waves for aviation are suitable for this service.

It merely observes that the waves in question were selected in the bands reserved for different services. It expresses the view that the Washington Conference set up no body for the allotment of waves, but that, in the present case, article 5, paragraph 1, of the Washington General Regulations is applicable.

OPINION No. 26

ALLOCATION OF WAVES TO THE CRIMINAL POLICE

The C. C. I. R. is of the opinion that the Washington Conference set up no body authorized to allocate wavelengths for special purposes.

The C. C. I. R. must, therefore, confine itself to recommending that the provisions of article 5, paragraph 1, of the General Regulations be applied.

OPINION No. 27

LIMITATION OF THE POWER OF BROADCASTING STATIONS

With regard to the limitation of the power of broadcasting stations using frequencies below 300 kc/s (wavelengths above 1000 m), the C. C. I. R., having considered the needs of aviation services, recommends that all broadcasting stations should strictly observe the provisions of article 5, paragraph 6, of the General Regulations of Washington, by which an increase of their power is forbidden if any disturbance to existing radio services shall thereby result.

For broadcasting services using frequencies between 550 and 1500 kc/s (545 and 200 m), the Committee expresses the following opinion which applies only to European stations, excepting those of the U. S. S. R.:

> Broadcasting stations using frequencies between 550 and 1500 kc/s (545 and 200 m) should provisionally limit their power to about one hundred kilowatts.

Note: The term power is taken in the sense defined by Opinion No. 5[1].

OPINION No. 28

RADIOTELEPHONE COMMUNICATION BETWEEN MOBILE AND LAND STATIONS

This opinion has been replaced by Opinion No. 34.

OPINION No. 29

COORDINATION BETWEEN WIRE AND RADIOTELEPHONY

This opinion has been replaced by Opinion No. 35.

[1] BI. This opinion has been replaced by Opinion No. 40.

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B. MEETING AT COPENHAGEN, 1931

OPINION No. 30

TIME LIMIT FOR SENDING PROPOSALS FOR THE MEETINGS OF THE C. C. I. R.

The C. C. I. R.,

recognizing the necessity of establishing definite time limits for the forwarding of proposals to be discussed in its meetings,

expresses the opinion

that no question may be included in the program of a meeting of the C. C. I. R. unless it has been forwarded to the organizing administration at least three months before the date of the meeting.

OPINION No. 31

FORWARDING OF PROPOSALS CONCERNING UNSOLVED AND NEW QUESTIONS

The C. C. I. R.,

considering

(1) that the next meeting of the C. C. I. R. will take place after the Madrid Conference, and
(2) that all questions proposed should be submitted to the Madrid Conference,

expresses the opinion

that the questions recorded at the closing of this meeting, in the list of questions to be studied, should be handled as soon as possible by the centralizing administrations with the collaboration of the interested administrations and private enterprises. All the proposals which are ready before May 1, 1932, and all new questions which might be made before that date, will be forwarded to the International Bureau to be communicated to all the interested administrations and private enterprises.

OPINION No. 32

NORMAL PROCEDURE FOR FORWARDING REPORTS ON QUESTIONS TO BE STUDIED

The C. C. I. R.,

recognizing that it would be useful to provide rules for the exact determination as to whom reports must be sent concerning questions to be studied,

expresses the opinion

that when the study of a question has been entrusted to a centralizing administration, it is to this administration that all administrations and organizations must directly send a copy of their report on this question, five months before the date of the meeting of the C. C. I. R., in order that the said administration may take them into account in its report and in its proposals. The administrations and organizations are free, of course, to send also a copy of their report to the International Bureau, if they wish these reports to be communicated immediately and separately to all interested administrations and companies.

OPINION No. 33

PROPOSALS OF THE C. C. I. R. FOR THE INTERNATIONAL RADIOTELEGRAPH CONFERENCE OF MADRID

The C. C. I. R.,

not being able to reach an agreement as to whether it may itself present drafts of modifications to the International Radiotelegraph Regulations on the basis of opinions it has expressed,

suggests

that the opinions expressed in the present meeting of the C. C. I. R., should be brought, before July 1, 1931, to the knowledge of all administrations and companies by the International Bureau. The said Bureau is requested to include the opinions issued by the two sessions of the C. C. I. R. (The Hague, 1929, and Copenhagen, 1931), as an appendix in the Book of Proposals for the world conference at Madrid.

OPINION No. 34

ORGANIZATION OF A COMMERCIAL RADIOTELEPHONE SERVICE BETWEEN MOBILE STATIONS AND THE LAND NETWORK [1]

The C. C. I. R.,

considering

that it is possible to organize a commercial radiotelephone service between mobile stations and the land network, and

that the data now available permits the indication with some accuracy of the technical and operating conditions necessary for the carrying on of this service,

expresses the opinion

that it is desirable that this service be established and operated in conformity with the recommendations contained in annex 1 given hereafter.

ANNEX 1 TO OPINION No. 34

RECOMMENDATIONS RELATING TO THE ORGANIZATION OF A COMMERCIAL RADIOTELEPHONE SERVICE BETWEEN MOBILE STATIONS AND THE LAND NETWORK

1. As a general rule, carrier waves between 3000 and 23,000 kc/s (100 to 13 m) will be used; in nearby zones, carrier waves between 1500 and 3000 kc/s (200 to 100 m) may also be used.

[1] Note of the International Bureau: This opinion replaces Opinion No. 28 of the C. C. I. R.

2. In cases where the ground wave is used rather than the reflected wave, it will generally be favorable to place the land station in the neighborhood of the sea.

3. Land transmitters should have as great a power as possible. On the other hand, for ship transmitters it is recommended not to exceed, in telephony, a power of the order of 2 kw, so as to maintain within permissible limits the action of the transmitter upon the ship-station receivers.

4. On land, so far as possible, directive antennas will be used for transmission and reception. It is desirable that the beam angle of these antennas be as small as the service of the stations will allow. It will sometimes be possible to reduce the number of antennas necessary on board ships by selecting types which permit the use of several frequencies per antenna, for transmission as well as for reception (for instance, simple dipoles).

5. It is particularly important, in this service, to confine the frequency variations of the land station in conformity with Opinion No. 41. These limits also apply to ship stations.

6. The time necessary for making a change of wave in ship and land stations should be as short as possible; this time should not exceed 5 minutes.

7. Ship receivers should have great sensitivity and great selectivity, and they must be provided with devices to compensate for the phenomena of fading. In ship stations using an antenna of a simple type and for zones in which the intensity of the field received is of from 20 to 5000 microvolts per meter, it is necessary and possible to ensure a suitable and sufficiently constant voice level. It is desirable that, for frequencies between 250 and 2750 cycles, the receiver possess a practically horizontal characteristic.

8. In the present state of the art, it is necessary to place the receiving and the transmitting antennas as far apart as possible on board ships.

9. It is important to avoid, as much as possible, interference caused by the action of the transmitting carrier wave upon the receivers, as well as those resulting from electrical strays on board ships.

10. For a ship installation, it will often be sufficient to use an installation in which the phones and the microphone are separated; on the other hand, on land, it is recommended to apply all the means used in long-distance, point-to-point, radiotelephone service, the purpose of which is to prevent the generation of echo effects and the passing of noises from the receiver to the land transmitter. When the service is carried on in a nearby zone, it may be possible in that case to dispense with any voice-operated device.

11. In the case where two different carrier frequencies are used for the two directions of a connection, it is desirable that these frequencies be not too far separated from each other. At least three pairs of frequencies should therefore be assigned to each land station for communication with ship stations. In general, each ship station should have available, at a given time, a number of pairs of frequencies equal to the number of land stations with which it wishes to communicate. For the use of these various frequencies, a schedule must be established taking into account the distance, the hour and the season.

12. The distribution of frequencies should be made in such a way that interference between telephony and telegraphy is minimized. For that purpose it appears desirable to place, in a definite band (mobile band; band shared by fixed and mobile services, and, in the case where a mobile band is adjacent to such a shared band, these two adjacent bands taken together), the frequencies assigned to land stations for telegraph and telephone services in the center of this band, and the frequencies used on board ship at the extremities of this band, that is, the frequencies of the telegraph service at the low-frequency end, and the frequencies of the telephone service at the high-frequency end.

The minimum separation between frequencies should, as far as possible, be as follows:

Services	Minimum separation between frequencies
Ship telephony to coast-station telephony	3%
Ship telephony to ship telegraphy	3%
Ship telephony to coast-station telegraphy	3%
Coast-station telephony to ship telegraphy	3%
Coast-station telegraphy to ship telegraphy	1%
Coast-station telephony to coast-station telegraphy	0.5%
Ship telegraphy to ship telegraphy	0.4%

In the case where a single frequency is used for both directions of a radiotelephone connection, this frequency should be selected among the frequencies permissible for ship stations in accordance with the above indications.

13. The maximum band widths necessary per telephone channel, to carry on an efficient service, are approximately the following, for the different values of the carrier frequency:

Carrier frequencies in kc/s	Maximum width of the communication band in kc/s	Maximum frequency tolerance in kc/s [1]	Interference guard band in kc/s	Maximum total width of the telephone channel in kc/s [2]
3, 000	6	2. 4	2. 0	10. 4
4, 000	6	3. 2	2. 0	11. 2
6, 000	6	4. 8	3. 0	13. 8
8, 000	6	6. 4	4. 0	16. 4
13, 000	6	10. 4	6. 0	22. 4
17, 000	6	13. 6	8. 0	27. 6
22, 000	6	17. 6	10. 0	33. 6

14. It must be understood that the above recommendations apply, in the intention of the C. C. I. R., to passenger vessels provided with installations that are sufficiently efficient so that the administrations or companies concerned may admit them to enter into communication with the stations of their public network.

ANNEX 2 TO OPINION No. 34[3]

RÉSUMÉ PREPARED BY THE GERMAN ADMINISTRATION BASED ON THE REPORTS OF THE OTHER ADMINISTRATIONS AND THE EXPERIENCES IN GERMANY CONCERNING THE ORGANIZATION OF A COMMERCIAL RADIOTELEPHONE SERVICE BETWEEN THE MOBILE STATIONS AND THE LAND NETWORK

(See the short summary, under F, at the end of this résumé)

A. SPECIAL CONDITIONS OF RADIOTELEPHONY WITH MOBILE STATIONS

For radiotelephony with stations on ships short waves and medium wavelengths are used because no long

[1] Tolerances have been fixed by Opinion No. 41 of the C. C. I. R., that is, for land stations in the range between 1500 and 23,000 kc/s: 0.04 per cent.

[2] It is desirable to work within narrower limits.

[3] The recommendations of the C. C. I. R. have been established, based upon paragraph F of this document. However, they have been given a more general and more flexible form, in order to take into consideration certain technical possibilities which under certain circumstances might prove to be beneficial.

wave channel is available and, moreover, short waves can be operated with comparatively less power, which is an advantage for the operation of the transmitter on shipboard.

Experiments with radiotelephone service on short waves have been made between fixed stations across the sea. Based on these experiments the two following principles can be set up for radiotelephony with ships:

1. The use of different waves in both directions is evident.
2. To the greatest extent possible the stations on land must use directional antennas.

Radiotelephony with mobile stations differs from radiotelephony between fixed stations in the following ways:

1. Several wavelengths must be assigned to each connection because the distance between ship and shore varies and a fixed wave is sufficient only for a certain period of the day and for a given distance.
2. The stations on ships and the stations on land should be prepared to operate at brief intervals with various corresponding stations.
3. On board the ships only a limited space is available for the radio installations.
4. Simultaneously with telephone traffic, telegraph operation on an adjacent wave should be available without mutual interference between these two services.

These differences involve very great difficulties both in point of engineering and operation, so far as radiotelephone service between fixed stations is concerned. The latter service is simplified to a certain extent, owing to the fact that only a single station or a limited number of sets can be connected on board the ship.

B. TRANSMISSION AND RECEIVING INSTALLATIONS

(a) *General Remarks*

Since the stations should operate on different wavelengths at short intervals, the transmitters and the receivers should be set up in such a manner that the wavelength can be changed as rapidly as possible. The following suitable means should be available, for instance:

1. Several sets of some stages of the transmitter.
2. Commutation of the waves instead of using exchangeable coils.
3. Use of screen-grid tubes (eliminating balancing).

The American experts consider an interval up to 5 minutes permissible for changing the wave.

The transmitter must satisfy very rigid requirements in regard to the constancy of frequency (see C, Distribution of Waves) these exigencies under the present conditions of engineering can be satisfied by quartz frequency control. In view of the constancy of their control the receivers should be mounted as receivers of average frequency and equipped with devices for controlling fading phenomena. In the opinion of the American experts the power at the output of the receiver on board the ship should remain practically constant for oscillations between 20 and 5000 μV/m of the intensity of the received field when a single antenna in the form of a dipole is used.

(b) *Installation of Stations on Ships*

Any direct effect between the transmitter and the receiver should be avoided. For this reason the transmitter and the receiver should be placed in separate rooms which are protected by sheeting. All electrical machines on board in such a case should be equipped with self-inductances and condensers so that they do not interfere with the reception. The effect produced on the receiving installation by the transmitter of the station on board through the antenna can be diminished not only by reducing the power of the transmitter and by the choice of suitable distances between the frequencies of the transmitting waves and those of the receiving waves used for telephony and telegraphy, which we shall discuss later on, but also by carefully connecting all metallic parts of the rigging of the vessel electrically to the hull.

Only single vertical or horizontal dipoles are used as antennas. Their number can be reduced by placing the natural wave of the antenna between the two waves which are used frequently so that each antenna can be utilized for two different wavelengths. The distances between the transmitting and the receiving antennas should be as large as possible; if the cabin containing the transmitter and that containing the receiver are to be placed beside one another, power conductors should be used.

(c) *Installation of the Land Stations*

In the land stations the same types of transmitters and receivers can be employed which are used for trans-oceanic telephony between fixed points, provided that these types permit changing the frequency with sufficient rapidity. On the other hand, the directional antennas which should be used cannot be set up in a close group. In reality only a comparatively small number of dipoles is set up. The problem, whether directional antennas shall be used and what wavelengths shall be chosen, in each case depends on the route of the vessel for which the service is to be established. It is not possible to set up definite rules for the use of directional antennas. For transmission to ships in the immediate vicinity it frequently will not be possible to use this kind of antenna, owing to the route taken by the vessel. It then becomes necessary to use nondirectional antennas. As evidenced in practice, the traffic at short distances can be handled to advantage with waves between 1500 and 2000 kc/s (200 to 150 m).

The following table contains information referring to the antennas now in use in England for steamship lines between Europe and North America.

RECEIVING ANTENNAS (BALDOCK)

Frequency in kc/s	Wavelength meters	Description of the antenna (Supplement to note no. 7 from the C. C. I. R.)	Type of antenna
16, 440	18. 2	DR 270° $n=26$ $l=\frac{1}{4}$ $b=3$, $h_1=\frac{1}{2}$ $\theta=90$	Double key (double Bruce antenna)
12, 380	24. 15	DR 260° $n=26$ $l=\frac{1}{4}$ $b=3$, $h_1=\frac{1}{2}$ $\theta=90$	Double key
8, 860	33. 86	$n=1$ $l=\frac{2}{2}$ $h_1=\frac{1}{2}$ $\theta=0$	Horizontal dipole antenna
4, 430	67. 72	$n=1$ $l=\frac{2}{2}$ $h_1=\frac{1}{2}$ $\theta=0$	Horizontal dipole antenna

TRANSMITTER AT RUGBY

Frequency in kc/s	Wavelength meters	Description of the antenna	Type of antenna
17, 080	17. 5	DR 270° n=32 $l=\frac{1}{2}$ b=4 $h_1=\frac{1}{2}$ $\theta=0$	Sapin horizontal dipole antenna
12, 780	23. 4	DR 260° n=24 $l=\frac{1}{2}$ b=4 $h_1=\frac{1}{2}$ $\theta=0$	Sapin horizontal dipole antenna
8, 375	35. 82	n=1 $l=\frac{2}{2}$ $h_1=\frac{1}{2}$ $\theta=0$	Horizontal dipole antenna
4, 975	60. 3	DR 200° n=4 $l=\frac{1}{2}$ b=1 $h_1=\frac{1}{4}$ $\theta=0$	Sapin horizontal dipole antenna

In Germany the following transmitting and receiving antennas are set up:

RECEIVING ANTENNAS (NORDDEICH, KLEINER KRUG)

Frequency in kc/s	Wavelength meters	Description of the antenna	Type of antenna
16, 430	18. 259	DR 281° n=16 $l=\frac{1}{2}$ b=2 $h_1=\frac{1}{2}$ $\theta=0$	Sapin horizontal dipole antenna
13, 100	22. 9	DR 281° n=16 $l=\frac{1}{2}$ b=2 $h_1=\frac{1}{2}$ $\theta=0$	Sapin horizontal dipole antenna
8, 230	36. 450	DR 271° n=8 $l=\frac{1}{2}$ b=2 $h_1=\frac{1}{2}$ $\theta=0$	Sapin horizontal dipole antenna
4, 130	72. 630	n=1 $l=\frac{2}{2}$ $h_1=\frac{2}{3}$ $\theta=0$	Horizontal dipole antenna
3, 350	89. 56	n=1 $l=\frac{2}{2}$ $h_1=\frac{2}{3}$ $\theta=0$	Horizontal dipole antenna

TRANSMITTING ANTENNAS (NORDDEICH)

Frequency in kc/s	Wavelength meters	Description of the antenna	Type of antenna
17,265	17.376	DR 281° $n=16$ $l=\frac{1}{2}$ $b=2$ $h_1=\frac{1}{2}$ $\theta=0$	Sapin horizontal dipole antenna
12,400	24.190	DR 281° $n=16$ $l=\frac{1}{2}$ $b=2$ $h_1=\frac{1}{2}$ $\theta=0$	Sapin horizontal dipole antenna
8,470	35.420	DR 271° $n=8$ $l=\frac{1}{2}$ $b=2$ $h_1=\frac{1}{2}$ $\theta=0$	Sapin horizontal dipole antenna
4,400	68.181	$n=1$ $l=\frac{2}{2}$ $h_1=1$ $\theta=0$	Horizontal dipole antenna
3,000	100.000	$n=1$ $l=\frac{2}{2}$ $h_1=\frac{3}{5}$ $\theta=0$	Horizontal dipole antenna

The land station should preferably be installed directly on the coast since tests made by the American and the Dutch Administrations have demonstrated that the ground waves necessary for short-distance traffic are damped much more by the earth than by the sea.

(d) Terminals of Radiotelephone Circuits

In contrast to the traffic between fixed stations an extensive telephone system exists only on one side in telephone communication with stations on board ships, since only a limited number of telephone sets can be installed on board, and only a single telephone set is actually used in most installations at this time.

This condition makes it possible to use the so-called "open" system on shipboard, that is to say, the system where the transmitter of speech currents (microphone) and the "outgoing" circuit are separated electrically and acoustically from the telephone receiver and the "return" circuit. In this manner there is no danger of a reaction. In principle, voice-operated devices can be dispensed with on board, whereas on land, echo suppressors are used which are installed in such a manner that they prevent the speech currents which come from the ship when a conversation is in progress from being retransmitted by the terminal on land; on the other hand, during the periods of conversation they prevent the passage of received noises from the receiver at the land station into the transmitter of the same station. In order to avoid the transmission of received noises to the transmitter of the land station during pauses in the conversation, the same voice operated devices as those which are in use in America and in England on the transoceanic radiotelephone circuits are employed. During the intelligibility tests with ships, which were conducted in Germany a few years ago, a particularly well-balanced terminating device was found to be practicable for the same purpose.

At short distances where the return through the terminal of the speech currents sent by the station on board the ship produces no echo effect, it is unnecessary to eliminate this return. In the stations on the German coast four-wire terminal arrangements, which have no voice-controlled devices, are used for traffic with excursion boats in the vicinity of bathing resorts and with fishing steamers. The Dutch, in their report (see supplement 3), state that under favorable conditions echo suppressors can be dispensed with on short distances. For long distance telephone communication on short waves both voice-controlled echo suppressors and reaction suppressors are provided in Germany.

Moreover, monitoring devices, standard amplifiers, and wave indicators should be provided both on the vessels and on land.

C. DISTRIBUTION OF WAVES

(a) *Wavelengths and Distances*

The relation which exists during the day and night between the distance and the frequency of the waves which are to be used are given in the following tables which have been published by the American experts:

OPTIMUM FREQUENCIES FOR DIFFERENT DISTANCES

Frequencies in kc/s	Distances	
	Day	Night
	Summer	
	Miles	*Miles*
4, 000	0– 200	0– 500
6, 000	0– 300	200– 800
8, 000	250– 800	650–2, 600
13, 000	600–1, 800	2, 000–3, 500
17, 000	1, 000–3, 500	
22, 000	2, 000 and more	
	Winter	
	Miles	*Miles*
4, 000	0– 300	0–2, 000
6, 000	0– 400	500–2, 500
8, 000	300–1, 000	2, 000–3, 500
13, 000	800–2, 200	
17, 000	1, 400–3, 500	
22, 000	3, 000 and more	

As indicated by these tables the vessel requires a certain number of frequencies for traffic with a coast station, these frequencies being used in succession during the crossing. For the steamship lines between North America and Europe, the United States and England make use of four frequencies: 4,500, 8,000, 13,000, and 17,000 kc/s. France maintains that the frequency of 17,000 kc/s can be dispensed with. In Germany the following waves have been selected:

Transmitting waves at Norddeich		Receiving waves at Norddeich (transmitting wave of the stations on board)	
17, 265 kc/s	17. 376 m	16, 430 kc/s	18. 259 m
12, 400 kc/s	24. 190 m	13, 100 kc/s	22. 9 m
8, 470 kc/s	35. 420 m	8, 230 kc/s	36. 450 m
4, 400 kc/s	68. 181 m	4, 130 kc/s	72. 630 m
3, 000 kc/s	100. 000 m	3, 350 kc/s	89. 56 m

(b) *Coordination of Frequencies of Telegraph and Telephone Services*

The station on shipboard should be capable of handling the telegraph service by short waves simultaneously with the operation of the telephone service. During traffic with a shore station the station on board the ship, therefore, operates simultaneously on two transmitting waves and two receiving waves which, on account of the conditions of transmission, must not be spaced too far apart. The American experts have found that, in order to obtain reliable reception on board, the following differences between the transmitting frequencies and the receiving frequencies must be maintained.

Service	Minimum difference in frequency
Telephone on ship to telephone in shore station	3%
Telephone on ship to telegraph on ship	3%
Telephone on ship to telegraph in shore station	3%
Telephone in shore station to telegraph on ship	3%
Telegraph in shore station to telegraph on ship	1%
Telephone in shore station to telegraph in shore station	0.5%
Telegraph on ship to telegraph on ship	0.4%

(c) *Traffic from a Station on Board to Several Stations on Shore*

The station on shipboard during the crossing should be in connection with both continents. In order to handle the traffic without difficulty it seems that the following regulation for the distribution of the wavelengths will be very expedient:

Fixed transmitting and receiving waves will be assigned to the shore stations. In order that a station on shipboard can operate with two stations on land it needs twice the number of waves of a shore station; in order to operate with three shore stations three times as many, etc. If fixed frequencies are allocated to the stations on shipboard, it will be necessary to use a larger number of directional antennas on land, the number corresponding to the increased number of transmitted and received waves of the shore stations, whereas the installation of the antennas on board could be the same in both cases. In reality the nondirectional antennas on shipboard can be used for different wavelengths provided they allow operation on frequencies other than their natural frequency a condition which on the other hand is not the case for the directional antennas on land.

(d) *Constancy of the Frequencies*

From the above it is clear that establishing telephone service with vessels at sea will increase the need of frequencies for use in the short waves range. In order to prevent a mix-up of the different services and also to facilitate the location of particular stations, the constancy of the frequency must satisfy very rigid requirements. In America it is proposed to apply the tolerances recommended by the C. C. I. R. at The Hague to the stations participating in the telephone service with vessels at sea. These tolerances allow frequency deviations of ±0.02 per cent in traffic between fixed points. Assuming a voice-frequency band up to 3,000 c/s (*sic*) and a guard band from 2 to 10 kc/s, frequency bands of the widths indicated in the following table are required for a telephone channel, in the range from 3,000 to 22,000 kc/s.

Carrier frequencies kc/s	Width of communication band kc/s	Tolerance of frequencies kc/s	Band of protection kc/s	Total width of the telephone channel kc/s
3, 000	6	1. 2	2. 0	9. 2
4, 000	6	1. 6	2. 0	9. 6
6, 000	6	2. 4	3. 0	11. 4
8, 000	6	3. 2	4. 0	13. 2
13, 000	6	5. 2	6. 0	17. 2
17, 000	6	6. 8	8. 0	20. 8
22, 000	6	8. 8	10. 0	24. 8

It seems expedient to adopt permissible tolerances in accordance with the suggestions of the American and the French Administrations for the frequency deviations of the transmitters used for telephony with mobile stations and to grant no new service on short waves unless these tolerances are observed.

D. POWER OF THE TRANSMITTERS

The minimum distance between the transmitting and receiving installations on board ships and the interference with reception resulting from the ship's transmitting station impose an upper limit on the power of the transmitters of the ship stations. On the other hand, the power of the shore-station transmitter can be as great as desired; so far as expense will permit, the very greatest powers available for short-wave transmitters can be applied.

The greater the power of the shore-station transmitter, the more favorable will be the conditions of reception on board the ship.

The following provisions have been made regarding the power of the land-station transmitters:

In England 3½ to 4 kW In Germany 5 kW In France 5 to 10 kW In America 15 kW	telephone power

For the transmitters on shipboard powers ranging from 0.5 to 2 kW are stipulated.

Different administrations have published the results of their experiments on the ranges of the intermediary waves. The following table contains a summary:

Administration	Transmitter in the shore station	Transmitter in the ship station	Range in nautical miles
	Watts	*Watts*	
Germany	1,500	200	400 (1,600)
Belgium	------------	30	100–150 (200)
Holland	1,800	50 250	115 130

The ranges in the brackets were obtained under especially favorable conditions. The powers are those of a telegraph dash.)

E. OPERATION

The American Administration has communicated the following information in regard to the method of operating the telephone service between the American and English ship stations and land stations:

The Atlantic Ocean is divided in two zones: an American zone and an English zone, the boundary line between which is at 37° 30′ longitude east of Greenwich. The stations on land communicate for a period of three hours with the vessels in their own zone, then for a period of two hours with the vessels in the other zone. The station on shore calls the stations on the vessels in succession by using the optimum wave for their position and the time of the day when this call is made. The ship-station operators and those at the land station can find the most favorable wavelengths from diagrams. If the ship station wishes to call the land station, the operator of the ship station must adjust his receiver to the transmitting wave of the shore station corresponding to his calling wave and ascertain whether the shore station is not already in communication with another station on board a vessel. It is better to call by telegraphy by modulating the transmitter by an audible frequency of 1000 cycles per second (humming signal); thus service telegrams may be exchanged when the intelligibility is unsatisfactory.

The French Administration proposes to prepare for telephone calls by the use of the telegraph transmitter on board the vessel.

F. SUMMARY OF POINTS WHICH IT IS DESIRABLE TO CONSIDER IN THE ESTABLISHMENT OF LONG DISTANCE RADIOTELEPHONY WITH SHIPS

Under determined conditions, it is possible to organize a commercial long-distance radiotelephone service between ships and subscribers on land. From the documents on this question which are available up to this time, it is seen that there exists no divergency of views on the principles to be observed. These principles in brief are as follows:

1. For this service carrier waves between 3000 kc/s and 23,000 kc/s are used. In the nearby zones, however, carrier waves may be used between 3000 kc/s and 1500 kc/s.
2. It is particularly desirable that the land station should be situated on or near the shore.
3. The land transmitters should possess as great a power as possible, but it is not recommended that the ship stations for telephony exceed a power of 2 kw, in view of keeping reactions to the ship receiver within limits.
4. On land, directive antennas should be used for transmission and reception as much as possible and so far as the navigation routes permit. These antennas should not concentrate too closely (up to 60° approximately). On shipboard it is generally possible to use only simple dipoles, of which each one may be used at two frequencies.
5. The frequency tolerance of transmitted waves should be, so far as possible, within ±.02 per cent for land and ship stations.
6. The time necessary to change frequencies at the land and ship stations should, so far as possible, not be greater than 5 minutes.
7. The shipboard receivers should possess a high degree of sensitivity and selectivity and should be provided with arrangements for compensating for fading. Within the range of the intensity of the received field, from 20 to 5000 μV/m, when a simple dipole antenna is used, it is necessary that at the shipboard stations there exist a suitable and constant volume of speech. In the speech band (250 to 2750 c/s) a flat characteristic is necessary.
8. The transmitter and the receiver on shipboard should be separated from one another as far as possible. All the metal parts (of the rigging) should be grounded to the hull.
9. It is customary at the ship station to use the "open" system (transmitter and receiver separated electrically and acoustically), while at the land station it is recommended that there be applied all the measures which are used in the long distance radiotelephone service between fixed points and which are intended especially to prevent echoes and the retransmission of noise from the receiver. In the nearby zone service, it is possible, however, to dispense with these voice-operated arrangements.
10. It is desirable to use two channels, of which the carrier frequencies should not be too greatly separated one from the other. There should be assigned to each land station at least four pairs of frequencies for the traffic with the ship stations. By the different use of these frequencies a fixed program is established according to the distance, for day and for night, summer and winter.

11. The division of frequencies should be effected in such a way that the interference between telephony and telegraphy will be as small as possible. For a specific band assigned to a mobile service, all the frequencies of the telephone services of the ship stations should be grouped in one group, all the frequencies of the telegraph services of the ship stations in the second group, all the frequencies of the telephone services of the land stations in the third group and, as far as possible, all the frequencies of the telegraph services of the land stations in a fourth group. The minimum separation of these frequencies one from the other should be, so far as possible, as follows:

Service	Minimum frequency separation
Ship telephone—land telephone	3%
Ship telephone—ship telegraph	3%
Ship telephone—land telegraph	3%
Land telephone—ship telegraph	3%
Land telegraph—ship telegraph	1%
Land telephone—land telegraph	0. 5%
Ship telegraph—ship telegraph	0. 4%

The groups of telephone services and those of telegraph services of the ship stations should be at the opposite extremities of the band in question.

12. The widths of bands necessary to a telephone channel for different carrier frequencies will be in practice about as follows:

Carrier frequencies	Width of the communication band	Frequency tolerance	Protection band	Total width of telephone channel
kc/s	*kc/s*	*kc/s*	*kc/s*	*kc/s*
3, 000	6	1. 2	2. 0	9. 2
4, 000	6	1. 6	2. 0	9. 6
6, 000	6	2. 4	3. 0	11. 4
8, 000	6	3. 2	4. 0	13. 2
13, 000	6	5. 2	6. 0	17. 2
17, 000	6	6. 8	8. 0	20. 8
22, 000	6	8. 8	10. 0	24. 8

13. With a view to popularizing the commercial radiotelephone service between mobile stations and land lines and because of the possibility that at the start the service will not have been perfected, it is indicated that the rates should not be fixed too high. In the traffic with North America, the North Atlantic Ocean is divided into two zones by the meridian 37°30′ west of Greenwich: one of these zones is called the "east zone" and the other the "west".

14. It is desirable for the organization of the service to provide for the possibility that the larger ships used as relay stations serve as intermediates for telephone communications from or to passengers of ships of smaller size (about 10,000 to 20,000 British tons). For these two classes of ships it will be practical to use the short-wave telegraph transmitter simultaneously for telephony.

15. In the nearby zone, good results have been obtained with waves between 1500 and 3000 kc/s, especially those between 1500 and 2000 kc/s. The use of this range of waves is particularly useful for the very small ships. For these it is desirable to provide the 1667-kc/s wave as calling wave in general.

OPINION No. 35[1]

COORDINATION OF RADIOTELEPHONY BETWEEN FIXED STATIONS WITH TELEPHONY OVER THE LAND NETWORK

The C. C. I. R.,

considering

1. that the question of coordination of radiotelephony between fixed stations with telephony over the land network has already been studied by the C. C. I. Telephone, which has already given it an answer in its plenary meeting of Brussels, 1930,
2. that at present there is nothing to add to the opinion expressed by the C. C. I. Telephone,

is in agreement

with the following opinion expressed by the C. C. I. Telephone, in its plenary meeting at Brussels (June 1930):

COORDINATION OF RADIOTELEPHONY AND TELEPHONY IN THE INTERNATIONAL TELEPHONE SERVICE

The International Consulting Committee,

considering

that the use of a radiotelephone channel in a long distance telephone circuit implies certain special conditions which entail special difficulties not met with when wires only are used,

that a radiotelephone circuit differs from a metallic circuit in the following points:

1. A radiotelephone circuit is subject to variations of attenuation, with the particular difficulty of signal fading which characterizes transmission on very high radio frequencies.
2. A radiotelephone circuit is subject to noises caused by static, the degree of which varies from a negligible quantity to a value of the same order as that of the signal being received.
3. Special precautions are necessary in the construction and maintenance of a radiotelephone circuit in order to avoid trouble at the receiving station caused by the radio transmitter being used in the other direction of transmission, and by radio transmitters used for other services; in other words, the abnormal conditions of damped oscillations and of cross-talk have to be avoided or corrected.
4. In order to keep radiotelephone connections in the best condition from the transmission viewpoint it is necessary to have available special means in order to ensure that the radio transmitter, so far as possible, always operates at full load irrespective of the nature and the attenuation of the extension line connected to the radiotelephone circuit.

[1] This opinion replaces Opinion No. 29 of the C. C. I. R.

5. The audio-frequency band which the radiotelephone connections are able to transmit effectively may be restricted under one or several of the following conditions:

(*a*) The necessity of economizing on the frequencies available for radio transmission;
(*b*) The use of a low radio frequency;
(*c*) The necessity of employing electric filters with the particular transmission system being used.

6. A radiotelephone circuit is in general a long-distance intercontinental circuit which provides telephone service between two extensive systems, which fact is of great importance from two points of view:

(*a*) It is desirable that the transmission characteristics which it is endeavored to maintain in the establishment of the radiotelephone circuit be better than those at present stipulated for long-distance metallic circuits;
(*b*) At the present stage of engineering it is not convenient to deprive the public of a very useful service, on the pretext that it does not always satisfy the degree of excellence desirable for long-distance communications from the viewpoint of quality.

expresses the unanimous opinion

(1) that the frequency band effectively transmitted on a radiotelephone circuit should not be lower than that recommended by the C. C. I. for long-distance telephone circuits, i. e. 300–2500 c/s (cf. annex B, *d*, 2, no. 4, p. 432, of the documents of the Plenary Assembly at Brussels, 1930, the C. C. I. Telephone), but it is desirable, if possible, to procure a larger frequency band and, where this can be done, the radiotelephone circuit should be designed with a view to transmitting a frequency band of at least 200–3000 c/s.

NOTE: At the present stage of engineering, it may be desirable provisionally to utilize frequency bands other than those specified above, if this results in an improvement of transmission, for example, owing to a reduction of noise.

(2) that the normal equivalent of a radiotelephone circuit should not be higher than the limit recommended for long-distance circuits, i. e., 1.3 neper or 11.3 decibels, but that a radiotelephone circuit, whenever possible, should be designed so as to have an equivalent less than this value under favorable radio-electric conditions; that since, at the present stage of engineering, it is not practical always to keep a radiotelephone circuit strictly below this limit of 1.3 neper or 11.3 decibels, a certain tolerance should be granted when radio conditions are unfavorable, rather than to deprive the subscribers of a very useful long-distance service. It is to be noted that, in the case of unfavorable radio conditions, it may be necessary to forbear the normally possible extension of the radiotelephone connection by wire lines.

(3) that all possible efforts should be made to reduce the noise level with respect to the speech level by using such radio devices as directional antennas, etc. However, it will be necessary to tolerate large variations in the noise level of a radiotelephone circuit. At the present stage of engineering, furthermore, neither a maximum value of the ratio of noise to speech intensity nor a method of measuring noises can as yet be recommended.

Provisionally, the following values may be taken as a guide to the noise level on a radiotelephone circuit.

(*a*) Under average radio conditions, an average noise voltage up to at least 25 millivolts in 600 ohms at zero transmission level is to be expected, which in rectified current corresponds to an average power of 0.001 milliwatt.
(*b*) Under unfavorable radio conditions an average noise voltage of up to 200 millivolts in 600 ohms at zero level, may be tolerated, if the extension circuit, including the subscriber's line, is of sufficiently

good quality. (This noise voltage corresponds, in rectified current to an average power of 0.067 milliwatt.) It should be ascertained that the noise voltage does not operate any echo suppressors which the extension circuit may be provided with. In respect to the latter point, it is estimated that a voltage of 80 millivolts at zero level operates the echo suppressors now in use, if applied during a longer period of time than the first transitory period of these instruments. (Cf. annex at the end hereof, entitled: "The Fundamental Principle of Volume Testing", by Dr. Mayer.)

It is to be noted, moreover, that an incident of this type embodies serious inconvenience only when frequently repeated.

(4) that the extension circuits connected to a radiotelephone circuit shall conform to the various C. C. I. recommendations in respect to the equivalent, the distortion, the noises, the echoes, the transitory phenomena, etc., on the usual metallic circuits, notably as follows:

(*a*) The equivalent between the subscriber and the terminals of a radiotelephone circuit should not exceed the provisional value of 1.3 + 1.0 = 2.3 nepers or 20 decibels.

The total equivalent between two subscribers, including the radiotelephone circuit and cord repeaters, if any, should not exceed the provisional value of 3.3 nepers or 28.6 decibels.

(*b*) The noise voltage should not exceed the provisional value of 5 millivolts in 600 ohms at the level of transmission.

(*c*) The echo effects should not exceed the limits indicated by the curves and in the opinions expressed by the C. C. I.

(*d*) The duration of transitory phenomena in the extension circuits should be such that the total duration of a transitory phenomenon for any frequency within the band effectively transmitted and for the complete circuit between subscribers (including the radiotelephone circuit and the two extension lines) does not exceed 30 milliseconds.

(5) that, in the case of a radiotelephone circuit utilizing a low radio frequency band which, in view of the congestion on the ether, necessitates the employment of the same radio frequency band for two-way transmission, said radiotelephone circuit should be provided with a voice-governed switching device (reaction suppressor) in order to prevent damping of the oscillations or disturbances caused by a radio transmitter on the neighboring radio receiving station.

Although it may not always be essential from a technical point of view to employ a voice-governed switching device (reaction suppressor) when the same frequency band is not being used in two-way radio transmission (which is the present practice with very high radio frequencies), it is desirable to equip radiotelephone circuits with such devices—

(*a*) in order to utilize this circuit with a small equivalent, and

(*b*) in order to connect together two long-distance extension circuits which, in the absence of any such device, would constitute a connection embodying excessive echo effects.

(6) That, at the present stage of engineering, in order to maintain the speech at the levels necessary for radiotelephone connections, a special technical operator shall supervise the transmission continuously from a position equipped with instruments indicating the voice power and the average voltage of the disturbing noises; that this operator may be able to regulate the voice power so as to fully load the radio transmitter and that he shall make all adjustments necessary for the condition of the circuit (also by adjusting the reaction suppressors), in order that the conditions of the radiotelephone circuit at each moment shall be at a suitable ratio to the voice power and to the intensity of the disturbing noises.

(7) That, especially when employing very high radio frequencies, the radiotelephone circuit shall be equipped with automatic gain-adjusting instruments so as to compensate automatically, so far as possible, for the fading phenomena of the radio signals.

(8) That the terminal equipment of radiotelephone circuits shall be such that the circuit may be connected as any type of circuit with any other type of circuit.

Instrument enabling the special operator placed at the junction point between the radiotelephone connection and the metallic circuit to measure the voice power

The International Consulting Committee,

unanimously expresses the opinion

(1) that the instruments appropriately installed on the supervisory position served by the special operator depend upon the information which it is desired to obtain on the instantaneous power transmitted by the circuit at the point where these instruments are placed.

(2) that the present practice is usually to employ two different instruments which may vary in construction. The first instrument indicates peaks of power, the second follows the average variations in power. In this way it is possible to protect the radio transmitter against too frequent overloading (sometimes by means of an automatic limiter) and also to regulate the modulation of the radio transmitter to its optimum value. It may, in certain cases, be desirable to employ these two types of instruments simultaneously.

(3) that it is possible, however, to employ a single instrument, the function of which is to integrate the power transmitted over the circuit during the period of time equal to the maximum time for which excessive modulation causes no inconvenience. The constants of this instrument may be selected so as to make it operate either as a peak indicator or as an indicator of voice power, according to operating requirements. It is then possible to regulate the modulation so that the needle of the instrument only in exceptional cases exceeds a fixed limit.

(4) that it would be very desirable, although long-distance radiotelephone operation does not require the unification of the characteristics of these various instruments, to adopt later on uniform characteristics for the instruments used by the various administrations and operating companies, so as to permit comparisons of observations made at the terminal points of the same line. In this connection, the characteristics defining the operation of each instrument indicated in the attached annex entitled "Fundamental Principle of Volume Testing", by Dr. Mayer, may be employed.

The Protection of Reactance Suppressors on a Radiotelephone Circuit

The International Consulting Committee,

considering

that, as regards the protection of reaction suppressors (singing suppressors—Rückkopplungssperren) placed in the neighborhood of the special operator against violence caused by static noise peaks, a measuring instrument is not always necessary, and that it may suffice to provide a simple indicating device which operates each time the reaction suppressor has been activated (upon which a special operator adjusts the amplification),

considering, however,

that it may sometimes be found desirable in the case of reaction suppressors, and always necessary in the case of echo filters on land lines, to employ a measuring instrument,

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unanimously expresses the opinion

that, in order to protect reaction suppressors placed on a radiotelephone circuit against violence caused by static noise peaks, it is advisable to utilize a measuring instrument, the transition times and characteristic of which, in frequency terms, correspond to those of the suppressor which is to be protected (transition times as defined in the attached annex entitled "Fundamental Principle of Volume Testing").

ANNEX TO OPINION No. 35

FUNDAMENTAL PRINCIPLE OF VOLUME TESTING

NOTE FROM DR. MAYER (OF THE SIEMENS & HALSKE COMPANY, BERLIN)

There are two different methods applicable to volume testing:

1. TESTING INSTRUMENTS OF THE "VOLUME-INDICATOR" TYPE

These instruments (figure 1) consist of an amplifier of which the last valve is mounted as a detector; a continuous current-testing instrument is inserted in the plate circuit of this valve. Whatever the character of the applied alternating voltage V may be, the corresponding indication of the instruments may be interpreted from the manner in which they behave under the effect of sinusoidal alternating signals applied suddenly and for definite periods of time. In figure 2, V represents the applied alternating voltage; J, the continuous current in the instrument, which in the ideal case, has the rectangular shape indicated, and A, the character of the needle deviation as a function of time. This latter depends upon the mechanical characteristics of the instrument and may be characterized by the duration of the transitory period τ and by the difference Δ between the first maximum deflection and the final deflection of the needle. A too large difference Δ should be avoided, as in this case there is a tendency to attribute a higher value to the applied voltage than that which it actually has; that is why it is desirable that these instruments operate in an aperiodic manner.

The transitory period τ of the instrument causes the instrument to integrate, during the time interval τ, the input voltage curve. The movement of the needle will be more smooth and uniform (which in itself is very desirable) if a comparatively high value is selected for the transitory period. However, a very large transitory period is inconvenient, in that impulses of a duration less than the transitory period are not indicated with their real amplitude.

Experience has shown that, in order that the instrument should operate smoothly, the transitory period should be approximately 2 seconds. On the other hand, it is desirable that the impulses of a duration equal to that of a logatome (i. e., approximately 0.2 seconds) still be accurately registered. It is, however, impossible to comply with these two requirements simultaneously.

For this reason, tests at the S. F. E. R. T. laboratory have been made with two different instruments used as volume indicators (a Weston instrument and a Chauvin and Arnoux instrument); both show an extremely large deflection Δ. The first integrates over a period of approximately 0.2 seconds, its readings do not apply except to brief logatomes, and the general opinion is that the needle movements are much too rapid. The second instrument completes the integration during a period ascertained as 2 seconds. It operates in a smooth and uniform manner, but it does not even approximately indicate impulses comparable to isolated logatomes. It is impossible to obtain smooth operation and correct registration of brief impulses simultaneously.

II. TESTING INSTRUMENTS OF THE "IMPULSMESSER" TYPE

In these instruments the negative grid detector of the volume indicator is replaced by a detector triode. In the grid circuit of this tube are inserted a condenser C and a resistance W. That part of the "Impulsmesser" (abbreviated "IM") in front of the dotted line (figure 3) may be replaced by a source of alternating E. M. F. of internal resistance R. Here it is also possible to deduce the operating conditions of the "IM", regardless of the character of the applied E. M. F., from the manner in which it behaves under the effect of an alternating signal of definite duration when applied suddenly. In figure 4, V represents the applied E. M. F.; J, the current in the instrument; and A, the deflection as a function of time. The curve of the current is no longer rectangular, but is represented by two transitory parts τ_a and τ_e, which may vary considerably, and independently of one another, according to the values of R, W, and C. Theoretically, the most suitable indicating instrument would be one in which the transitory period is negligible. With such an instrument the shape of curve A would be identical to that of J. It is impossible to do this, however; and, happily, it is not necessary, as in practice a transitory period of the order of 0.2 seconds is adequate. For the instrument to operate smoothly τ_e should be large, i. e., in the order of 2 seconds. (However, there may be cases where it will be desirable to have still higher values for τ_e). On the other hand, in order that an impulse of duration τ should still be registered accurately, it is necessary to have $\tau_a<\tau$. The minimum practical value is $\tau_a=0.02$ seconds. Impulses of equal duration are still registered accurately even if the transitory period τ_i, of the testing instrument A is appreciably greater than the duration of the impulse, under the sole condition that τ_e be large with respect to τ_i. To test very short impulses (dots) the following values have been found suitable:

$\tau_a=0.02$ sec. $\tau_i=0.2$ sec. $\tau_e=2$ sec.

In other cases it may be desirable no longer to measure "dots", but to integrate for the duration of the transmission of a logatome. The variation of the electric constants of the grid circuit of the triode easily enables suitable values to be obtained, for instance:

$\tau_a=0.2$ sec. $\tau_i=0.2$ sec. $\tau_e=2$ sec.

The "IM" at present used in the S. F. E. R. T. laboratory is an obsolete model; its constants are as follows:

$\tau_a=0.02$ sec. $\tau_i=2$ sec. $\tau_e=20$ sec.

These values appear to be unsuited to the desired objective.

The essential difference existing between the "IM" and the volume indicator is due to the fact that the integration is not effected by the terminal testing instrument, but by an electric circuit whose constants may be chosen in such a manner that even short impulses are accurately registered (impulses whose duration may be shorter than the transitory period of the terminal instrument) and that, furthermore, the instrument operates smoothly, owing to an adequate value of τ_e.

From the preceding account it follows that the instrument (termed "Impulsmesser" in German) does not necessarily operate as a crest indicator, but that according to the value of its constituent parts, it may operate either as a crest indicator, or as a volume indicator, or according to any desired law.

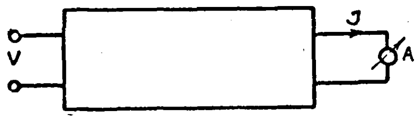

FIGURE 1

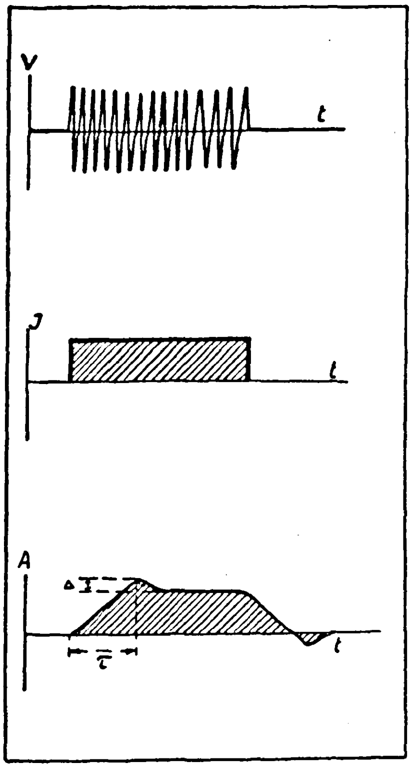

FIGURE 2

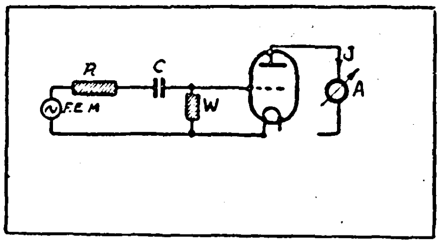

FIGURE 3

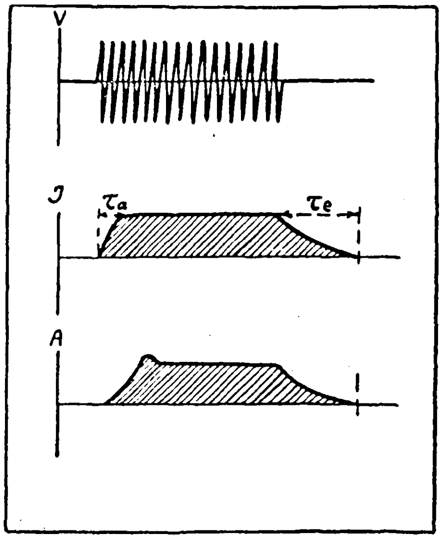

FIGURE 4

OPINION No. 36

EXTENSION OF A RADIOTELEPHONE CONNECTION IN CASE OF UNFAVORABLE RADIO CONDITIONS

The C. C. I. R.,

considering

1. that Opinion No. 35 of the C. C. I. R. on the subject of coordination of radiotelephony between fixed stations with telephony on the land network contains the following phrase:

> It should be observed that in case of unfavorable radio conditions, it may be necessary to abandon the normally possible extension of radiophone connection by wire connections.

and that an administration proposed the modification of that phrase to the end that, in case of unfavorable radio conditions, it would be permissible to make extensions of the radiophone connection by four-wire circuits;

2. that the above-mentioned sentence already permits the interested administrations and companies to use in case of unfavorable radio conditions, not only the technique used by the said administration, but also any other type of connection which would be deemed desirable,

expresses the opinion

that there is no need to modify the above sentence given in the Opinion No. 35 of the C. C. I. R.

OPINION No. 37[1]

FREQUENCY LIST

The C. C. I. R.,

considering

that the International Radiotelegraph Convention does not provide for the publication of a frequency list,
that a frequency list would be very useful and of great practical value,
that this list should include information on all frequencies provided for regular services or assigned to these services and capable of causing interference beyond the limits of the country in which they are used,

expresses the opinion

(a) that a frequency list should be established and published by the International Bureau of the Telegraph Union and should include the following indications, which should be forwarded without delay to that Bureau.

(1) *Frequency.* The exact frequency should be indicated in kc/s (See Opinion No. 38 of the C. C. I. R.).
In the case of a multiplex system, all the carrier frequencies will be indicated in column 1, and with respect to each of these frequencies, in the remarks column, all the other carrier frequencies of the system will be repeated with the indication "multiplex system".
In the case of an emission in which the carrier frequency is suppressed, there should be given in column 1 a frequency which, combined with the figure given in column 9 (modulation frequency) will determine the frequency band employed. Column 14 (remarks) should indicate that the carrier frequency is suppressed and whether the transmission is conducted with single sideband or otherwise.

(2) *Wavelength.* The approximate wavelength should be expressed in meters. (See Opinion No. 38 of the C. C. I. R.)

(3) *Date of notification.* This date will be that of the communication by which information pertaining to the frequency in question has been transmitted to the International Bureau.

(4) *Call signal.*

(5) *Name of the station and country under the jurisdiction of which this station operates.*

(6) *Type of emission.* This will be indicated by A1, A2, A3, B, Special. The indication "Special" must apply to types of emission which are not included in the other designations (facsimile and television emissions).

(7) *Power in the antenna.*

(a) kW.
The indications in this column should give the power of the carrier wave under normal service conditions.

(b) Degree of modulation, . . . %.
The figure appearing in this column should give the real maximum degree of modulation used in normal service. (See Opinion No. 40 of the C. C. I. R.)

(8) *Directivity of antenna.* When a directive antenna is used, it should be indicated by the letter "D" followed by the letter "T" in the case where the radiation system may be subject to rotation.

[1] This opinion replaces Opinion No. 19 of the C. C. I. R.

(9) *Frequency of modulation.* The frequency of modulation to be inserted in this column should indicate the frequency band intended to modulate the carrier frequency, that is to say:

for A1 and B types of emission, no figure, for A2, A3 and "Special" types of emission, the maximum width in kilocycles of the band used. If the transmission is using only one sideband, this will be indicated by placing before the figure the sign + (sideband above carrier frequency) or — (sideband below carrier frequency).

(10) *Transmission speed in bauds.*[1] This speed should be the maximum speed of telegraph transmission normally used in the service.

(11) *Nature of service and countries with which communication is provided or established.*

(12) *Date of putting into service of the frequency* (anticipated date between parentheses).

(13) *Administration or operating company.*

(14) *Remarks.*

(*b*) that this list should be considered as a service document within the meaning of article 13 of the General Regulations annexed to the International Radiotelegraph Convention of Washington.

OPINION No. 38

PRECISION IN THE INDICATION OF FREQUENCIES AND OF WAVELENGTHS

The C. C. I. R.,

considering

that article 4, paragraph 1(5) of the General Regulations of Washington, provides that waves shall be designated in the first place by their frequency in kilocycles per second (kc/s) and that following this designation shall be indicated, in parentheses, the approximate wavelength in meters, the latter being expressed by the quotient of the division of the number 300,000 by the frequency expressed in kilocycles per second,

expresses the opinion

1. that the frequency be expressed by a number of figures such that the uncertainty of approximation be equal to $\frac{1}{10}$ of the tolerance allowed, and that the wavelength be computed with an approximation equal to the tolerance,

2. that the figure representing the frequency be always considered exact, even if the corresponding wavelength is expressed by a round number.

OPINION No. 39

ASSIGNMENT OF A SEPARATE CALL SIGNAL TO EACH FREQUENCY USED IN THE FIXED SERVICE

The C. C. I. R.,

considering

that the assignment of a separate call signal would facilitate the study of all cases of interference between fixed stations and could therefore enable one to reduce this interference,

[1] The meeting of the C. C. I. T. at Berlin (1929) has expressed the opinion, under A,1,*a*,

that the transmission speed be expressed by the reciprocal of the value of the elementary interval measured in seconds, that the transmission speed of an interval per second be called "baud" to honor the memory of the great telegrapher, Emile Baudot.

expresses the opinion

1. that each frequency used by a station of the fixed service should be designated by a separate call signal used solely for that frequency,

2. that each call signal should be indicated in the corresponding column of the nomenclature of fixed and land stations opposite the frequency to which it is assigned.

In addition the call signal corresponding to each notified frequency should appear in the corresponding column of the frequency list.

OPINION No. 40 [1]

DEFINITION OF THE POWER OF A TRANSMITTER

The C. C. I. R.,

considering

that it is not practicable to actually measure correctly the power of a radio transmitter, that is to say, the power radiated by the antenna,

that, on the other hand, the technique prescribes easy methods for the determination of the power absorbed or transformed by the different parts of a radio transmitter,

that, in the case of modulated emissions, for example that of radiotelephony, the definition of the power of a transmitter should be set up in a manner to give the information applying to the different types of modulation by indicating two numbers,

expresses the following opinion:

The power of a radio transmitter is understood to mean the power in the antenna. By antenna is meant the radiating conductor or the entire assembly of radiating conductors.

The power in the antenna may be obtained either by direct measurement in the antenna itself or by measurements carried out on an equivalent dummy antenna or on other parts of the transmitter (e. g., at the input of the transmitter of a mobile station, if wished); in the case of indirect measurement, the power in the antenna will be estimated by taking account of the efficiency of the intermediate stages.

In the case of a radiotelegraph transmitter, by the power in the antenna is meant the power measured in a continuous dash.

In the case of a modulated-wave transmitter, the power in the antenna is given by two numbers: the value of the power of the carrier wave supplied to the antenna, and, in addition, the actual maximum percentage of modulation used.

Consequently, the indication of the power of such a radio transmitter consists of the indication of the number of kilowatts, and, in addition, that of the figure representing the actual maximum percentage of modulation. It will be necessary in case one sideband or the carrier frequency is suppressed, to mention that fact.

In the case of a modulated short wave or very short-wave transmitter, the power in the antenna is calculated from the power leaving the last stage of the transmitter, taking into account the efficiency of the intermediate stages.

ANNEX TO OPINION No. 40

The percentage modulation, M, of a transmitter having two symmetrical sidebands is defined, for example, by the relation—

[1] This opinion replaces Opinion No. 5 of the C. C. I. R.

$$M = 2 \cdot \frac{I_l}{I_p} \cdot 100\%$$

where I_l is the amplitude of the current in the sideband, and I_p the amplitude of the carrier current, the transmitter being modulated by a sinusoidal wave.

OPINION No. 41 [1]

TOLERANCES

The C. C. I. R. expresses the opinion that the following considerations be taken into account:

1. Tolerance is the maximum admissible difference between the frequency which should be emitted by the station assuming it to be without any error and the frequency actually emitted under the most unfavorable condition in which all errors are additive.

2. This difference results from the combination of three errors:

 (*a*) the error of the radio frequency meter or frequency indicator used,
 (*b*) the error made during the adjustment of the station,
 (*c*) slow variations in the frequency of the transmitter (instability).

3. In the tolerance no account is taken of modulation.

4. The tolerances recommended in the several frequency bands and for the various services are given in the following table:

TOLERANCE TABLE

	Tolerances recommended as being immediately applicable	Tolerances recommended as applicable in the future [2]
A. 10 to 550 kc/s (30,000 to 545 m):	*Plus or minus*	*Plus or minus*
(*a*) Fixed stations	0. 1%	0. 1%
(*b*) Land stations	0. 1%	0. 1%
(*c*) Mobile stations using indicated frequencies	0. 5% [3]	0. 5% [3]
(*d*) Mobile stations using any wave within the band during a transmission	0. 5%	0. 5%
(*e*) Broadcasting stations	0. 3 kc/s	0. 05 kc/s
B. 550 to 1500 kc/s (545 to 200 m):		
(*a*) Broadcasting stations	0. 3 kc/s	0. 05 kc/s
(*b*) Land stations	0. 1%	0. 1%
(*c*) Mobile stations using any wave within the band during a transmission	0. 5%	0. 5%

[1] This opinion replaces Opinion No. 14 of the C. C. I. R.

[2] The C. C. I. R. means by this expression, that the figures in this column should be generally applied to new transmitters only after 1933 and to all transmitters only after 1938.

[3] It is recognized that there are in this service a large number of spark transmitters and simple self-oscillating transmitters which will be unable, at all times, to meet this requirement.

	Tolerances recommended as being immediately applicable	Tolerances recommended as applicable in the future[1]
C. 1500 to 6000 kc/s (200 to 50 m):	*Plus or minus*	*Plus or minus*
a) Fixed stations	0.05%	0.03%
b) Land stations	0.1%	0.04%
c) Mobile stations using indicated frequencies	0.1%	0.1%
d) Mobile stations using any wave within the band during a transmission	5 kc/s	3 kc/s
e) Fixed and land stations of low power (up to 250 antenna watts) working in bands common to fixed and mobile services during a transmission	5 kc/s	3 kc/s
D. 6000 to 23,000 kc/s (50 to 13 m):		
a) Fixed stations	0.05%	0.02%
b) Land stations	0.1%	0.04%
c) Mobile stations using indicated frequencies	0.1%	0.1% (0.04% for frequencies in the shared bands)
d) Mobile stations using any wave within the band during a transmission	0.1%	0.05%
e) Broadcasting stations	0.03%	0.01%
f) Fixed and land stations of low power (up to 250 antenna watts) working in bands common to fixed and mobile services, during a transmission	0.1%	0.05%

OPINION No. 42[2]

DEFINITION OF TERMS RELATING TO THE METHOD OF MEASUREMENT OF FREQUENCIES; METHODS OF COMPARISON OF FREQUENCY STANDARDS

1. The following definitions have been accepted to avoid any error of interpretation:

Frequency meter—Absolute standard of frequency: measuring apparatus which permits the evaluation of a frequency as a function of the second of mean solar time.[3]

[1] The C. C. I. R. means by this expression, that the figures in this column should be generally applied to new transmitters only after 1933 and to all transmitters only after 1938.

[2] This opinion replaces Opinion No. 9 of the C. C. I. R.

[3] The C. C. I. R. learned with satisfaction that the International Committee on Weights and Measures studied, at the request of the C. C. I. R., 1929, the organization of an international systematic comparison of frequency standards established by the national laboratories (see annex hereafter).

Radio frequency meter or wave meter: commercial instrument which permits making the measurement of high frequencies included between two definite limits.

Heterodyne frequency meter or heterodyne wave meter: apparatus permitting the measurement of high frequencies by the production of continuous radio oscillations of a frequency equal to that which is to be measured or which differs from it by a known quantity.

Frequency indicator: commercial device (oscillator or resonator) to verify a single frequency.

Secondary frequency standard: apparatus capable of producing a frequency with such a constancy that the absolute standard of frequency can discover no variation in it.

2. For comparing secondary standards, i. e., national frequency standards, various methods are technically available; for instance, the following:

(*a*) Methods involving transportation of the apparatus.
  (1) Direct comparison of two wave meters.
  (2) Comparison of several wave meters with a traveling apparatus, i. e., with an apparatus that would be transported from one country to another.

(*b*) Methods not involving the transportation of apparatus.
  (1) Transmission of standard frequencies, standardized either in high or in low frequency (modulated waves).
  (2) Simultaneous measurements of the same transmitted wave, not standardized, but being sufficiently stable to permit of concurrent measurements.

3. The precision of one one-hundred-thousandth (1/100,000) for a frequency meter absolute standard of frequency is considered satisfactory for existing radio services.

4. Since radio-operating agencies have an interest in reducing frequency tolerances as rapidly as the technique makes available more accurate, convenient, and economical means, the C. C. I. R. recommends that scientific organizations in the different countries seek in the future, to attain a precision of one one-millionth (1/1,000,000) for absolute frequency-meter standards.

5. Since all methods permitting the comparison of frequency standards are capable of giving very accurate results, it is advisable to leave to the persons charged with making the comparisons the task of determining according to circumstances, the method to be used, drawing attention, however, to the importance which may be attached to the use, for this purpose, of sturdy and convenient portable standards, such as, for example, piezoelectric oscillators and resonators.

For the comparison of frequency standards at a distance, or even in the laboratory, it would be desirable to use frequencies which may be demultiplied to 1000 c/s with a precision of 1/10,000.

ANNEX TO OPINION No. 42

DECISION ADOPTED BY THE INTERNATIONAL COMMITTEE ON WEIGHTS AND MEASURES AT ITS MEETING OF APRIL 16, 1931

The International Committee on Weights and Measures has taken cognizance of Opinion No. 11 of the International Technical Consulting Committee on Radio Communications, supported by the Electrical Consulting Committee. The Committee recalls that the normal unit of frequency is simply the reciprocal of the second, the measurement of which is above all of an astronomical nature. For that reason, while accepting in principle the work of coordination and comparison of radio frequency standards, the Committee considers that the acceptance of the principle will have to be confirmed by the General Conference on Weights and Measures, which will meet in 1933.

OPINION No. 43[1]

DEGREE OF PRECISION OF RADIO FREQUENCY METERS AND FREQUENCY INDICATORS

1. The following definitions have been accepted:

Partial precision or partial uncertainty of a radio frequency meter: the absolute value of the maximum relative frequency error due to a given cause, that is to say, the relation between the absolute value of the maximum frequency error which can be produced by the cause in question, and the measured frequency.

Total precision or total uncertainty of a radio frequency meter: the sum of the maximum values of the following partial precisions or uncertainties attained over the range of the wave meter scale (these maximum values may correspond to different points).

A. Mechanical precision or mechanical uncertainty: the uncertainty due only to errors caused by defects or imperfections of construction.

The mechanical uncertainty consists of:

a) the uncertainty due to imperfection of construction of the movable parts of the wave meter, or introduced by the existence of parts which are not rigid or solidly fixed,

b) the reading uncertainty with reference to errors caused by the impossibility of reading fractions of the scale below a certain limit,

c) the uncertainty due to irregularities of the calibration curve.

B. Lack of constancy: the uncertainty which refers only to errors due to different circumstances, such as variations of temperature, humidity, and atmospheric pressure, and, for heterodyne wave meters of the supply voltage and of tube characteristics.

C. Independence of external influences: the uncertainty due only to errors caused by the influence on the wave meter of neighboring external objects.

D. Indication precision or uncertainty: the uncertainty due only to errors caused by the indicating system with which the wave meter is equipped.

The inexactitude of calibration, that is to say, the uncertainty referring only to errors introduced by calibration defects, will be considered separately. It is to be noted that the inexactitude of calibration does not contribute to the total uncertainty of the wave meter.

2. According to the present state of technique, radio frequency meters may be classified, as follows:

a) *high precision wave meters:* wave meters having a total uncertainty equal to, or less than 1/10,000,

b) *precision wave meters:* wave meters having a total uncertainty equal to or less than 1/1000 and greater than 1/10,000,

c) *ordinary wave meters:* wave meters having an uncertainty equal to or less than 5/1000 and greater than 1/1000.

The inexactitude of calibration of each class of wave meters must not exceed half of the limit of their total precision.

In the present state of technique, wave meters having uncertainties greater than the limit fixed for ordinary wave meters must be considered as unusable for the checking of a transmission.

3. With radio frequency meters not equipped with special devices (thermostats, crystals, etc.) it is possible to measure a frequency with a precision of from 2/10,000 to 5/10,000.

[1] This opinion replaces Opinion No. 10 of the C. C. I. R.

By the use of special apparatus and by taking particular precautions, it is possible to make measurements with a precision of from 2/100,000 to 5/100,000.

With apparatus intended for mobile stations (ships and aircraft) as well as with that which must be used in unfavorable conditions of location and climate, as in the colonies, it is hardly possible, in the present state of technique, to make measurements with an uncertainty of less than 3/1000 or 4/1000.

4. The precision of the wave meters used must in every case be such that it permits the station involved to keep within the tolerance limits indicated in the table given in Opinion No. 41.

To attain this result, it seems necessary that the uncertainty of the wave meters used should be at the most equal to one third of the tolerance. (See the study of the Italian Administration, centralizing the answers to question 5 of the program of the second meeting of the C. C. I. R.)

OPINION No. 44

REDUCTION OF INTERFERENCE IN THE SHARED BANDS FOR FREQUENCIES ABOVE 6000 KILOCYCLES

The C. C. I. R. is of the opinion—

that, in order to obtain a noticeable reduction of interference in the shared bands for frequencies above 6000 kc/s:

(*a*) the tolerances recommended for fixed stations and land stations should be strictly observed by those stations using frequencies situated in these bands;

(*b*) the tolerances recommended for land stations should also be observed, as soon as possible, by mobile stations when using frequencies situated in these bands;

(*c*) the stations using type A2 waves situated in these shared bands and which occupy a total band of frequencies much wider than that indicated by Opinion No. 20 of the C. C. I. R., should endeavor to reduce this band width;

(*d*) the fixed service stations using frequencies included in the shared bands should use, when such use is compatible with the nature of the service carried on, and to the greatest possible extent, directive aerial systems having a narrow beam.

The land stations using frequencies included in the shared bands should also, when this use is compatible with the nature of the service carried on, and, to the greatest possible extent, make use of directive aerial systems, even with very wide beams.

(*e*) 1. In the case of telegraph communication in the maritime mobile service carried out in a permanent manner on particular waves, some for coast stations and others for ships, the normal receiving waves of the coast stations should, in order to avoid conflict with paragraph (*b*) above, be situated outside the shared bands.

2. Communications by alternate transmission and reception using frequencies situated in the shared bands, should be made on the same frequency in both directions whenever the use of two frequencies is not justified by the increase in efficiency of communication which results.

(*f*) 1. The frequencies of these shared bands used by the same category of stations could advantageously be grouped;[1]

2. The groups of frequencies assigned to the same service should, so far as possible, be in harmonic relation.

OPINION No. 45

TECHNICAL METHODS OF STABILIZATION

The C. C. I. R.,

considering that

1. The frequency stability of the transmitter concerns only the variation of the transmitted frequency with reference to the frequency to which the transmitter is adjusted, whether or not the latter coincides with the nominal frequency.

When measurements repeated at a distance have been made at indeterminate times and for certain periods, it is convenient, in practice, to refer all measurements to the nominal frequency.

It follows that the figures thus obtained permit the determination not only of the stability with reference to the frequency of adjustment indicated above, but also of the accuracy of adjustment with reference to the nominal frequency.

The figures given hereafter refer only to the stability itself.

2. In the frequency band between 10 and 1500 kc/s, fixed and land stations use, among others, arc transmitters, high-frequency alternators, and tube transmitters. Experience has shown that the best transmitters working in this band can easily be stabilized at 0.1 per cent.

3. A study of the various methods of stabilization, which may be used between 1500 and 23,000 kc/s shows that carefully built transmitters can be stabilized at about 0.1 per cent. Some transmitters, made of modern devices, maintain their stability during long periods and under normal service conditions at 0.01 per cent.

4. Broadcasting stations can easily use modern methods of automatic frequency stabilization and can therefore be maintained within the limit of a tolerance of 50 c/s, as proposed in Opinion No. 41 of the C. C. I. R.

5. The modern devices permitting the attainment of results of this kind are master oscillators, tuning-forks, and quartz crystals, all these devices being placed under thermostat control.

6. Mobile stations and certain stations the service of which involves frequent and quick changes of wavelength, are limited, owing to special conditions under which they operate, to the use of relatively simple apparatus and service methods and can not in practice attain such degrees of stability.

7. Opinion No. 15 of the C. C. I. R. indicates that, with relatively complicated and expensive apparatus, a stability of 1/100,000 could be ensured and that a far superior stability could be attained in the future. This opinion is reaffirmed; nevertheless, the present discussion is limited to results which have already been amply demonstrated in the normal service of stations.

8. The great number of fixed and broadcasting stations operating on neighboring frequencies rendering narrower tolerances necessary for the latter, it is especially important that these stations should be equipped with the devices necessary to maintain them at all times, and with accuracy, on their normal frequencies.

[1] An example of the advantages of such grouping as is referred to in subparagraph *f* may be given by that of ships carrying on at the same time a radiotelegraph and a radiotelephone service. All frequencies used by them for radiotelephony may then be grouped, for example, in the high frequency part of the band, and these used by them for radiotelegraphy as far away as possible from the first ones.

Another example of the advantage of such grouping could be given by considering the difficulties of the aeronautic mobile services in relation to the maritime mobile services. The low power of aircraft stations and the particularly difficult conditions of reception on board aircraft expose them to interference which a rational grouping of the frequencies used by each of these services would likely decrease.

For that purpose, each of these stations should have two independent devices. The first is the device of stabilization, properly speaking (for example, the master oscillator), the second being independent of the first, and therefore capable of being used as a check.

This device may be, for example:

(*a*) a frequency indicator (piezo-oscillator or other) or wave meter located in the station,
(*b*) a spare master oscillator for checking purposes,
(*c*) a frequency standard from a checking station, directly connected with the transmitting station.

Ordinary measurements made by a checking station, are not considered sufficient, unless there is a direct connection with the transmitting station, permitting an immediate adjustment to be obtained.

recommends

as constituting a suitable technical basis to refer to the detailed information relative to the available technical methods of stabilization given in the following documents by the various administrations and organizations as well as in the technical articles and magazines, mentioned therein.

DOCUMENTS RELATING TO QUESTION 3 OF THE PROGRAM OF THE SECOND MEETING OF THE C. C. I. R.

International Broadcasting Union (Document 63); Group of French Companies (Document 79); United States of America (Documents 105 and 164); Italy (Document 148); Japan (Document 163); Union of Soviet Socialist Republics (Document 211).

OPINION No. 46

REDUCTION OF NONESSENTIAL EMISSIONS

The C. C. I. R.,

considering

(1) that the most important nonessential emissions likely to cause interference may be classified as follows:

(*a*) radio frequency harmonics.
(*b*) emissions which may be produced in the neighborhood of the radio frequency transmitted, when a high order of frequency multiplication is used.
(*c*) parasitic components of modulation due to overmodulation.
(*d*) compensation waves of arc transmitters.
(*e*) compensation waves of transmitters other than arc transmitters using two waves (working wave and compensation wave) for a single communication.
(*f*) parasitic components due to frequency modulation.

(2) that emissions of classes *a*, *c* and *d* are the subject of Opinions Nos. 48, 49, and 50:

expresses the opinion that

(1) emissions of class *b* outside the useful frequency band should comply with the same conditions as those which apply to emissions of class *a*.

(2) the method of operation by means of a compensation wave should be discontinued for transmitters mentioned in *e* above, except in cases where both carrier frequencies always lie inside the tolerance limits specified for the frequency assigned to the station, or where the increased efficiency of communication would justify the use of two frequencies.

(3) the amplitude of parasitic components due to frequency modulation outside the useful frequency band should be reduced to such a value that these components may not interfere with the normal reception of other stations using neighboring frequencies.

OPINION No. 47

REDUCTION OF THE FREQUENCY BAND OF A TRANSMITTER

The C. C. I. R.,

expresses the opinion

1. that for frequencies below about 100 kc/s, it is possible and desirable (see the annex to this opinion) to suppress one sideband, and, moreover, in certain cases, the carrier wave, in transmissions covering large bands of frequencies (radiotelephony, facsimile transmissions, etc.)

2. that for frequencies above about 100 kc/s such a suppression is also possible, at least for certain radio communications, but even for these radio communications experience does not yet permit one to state whether this suppression would procure a sufficient benefit, considering the technical and economic difficulties encountered.

ANNEX TO OPINION No. 47

GENERAL REPORT OF THE AUSTRIAN ADMINISTRATION RELATIVE TO THE REDUCTION OF THE FREQUENCY BAND OF A TRANSMITTER

This report is composed of the following documents:

1. A memorandum by the Centralizing Administration outlining the method adopted for a systematic answer to question 7 (see annex 1).
2. Reports of the collaborating administrations: United States (annex 2) and Germany (annex 3).

(Reports of the other collaborating administrations [France and Dutch East Indies] were not in our possession when this report was compiled.)

Moreover, a study of the Japanese Administration, presented after the compilation of this general report, is likewise attached to this report (annex 4).

GENERAL REMARKS

The method of partially suppressing the sidebands and eventually the carrier normally emitted from a transmitter is applicable in principle, for more economical use of the available space in the radio spectrum. Experience acquired by stations using this method has demonstrated its practicability.[1]

The application of this method appears to be useful in cases where the type of modulation results in comparatively wide sidebands, as for instance, in high-speed telegraphy, in telephony, in high-speed picture transmission (television) and in multiplex operation with a carrier wave.

The economy realized from the reduction of the frequency band occupied by a transmitter, by means of suppression of one sideband or the carrier, depends on the band width of the modulating frequencies. The carrier has a large amplitude, so that its suppression has the added advantage of diminishing interference with adjacent bands especially in cases where the channels are crowded.

The above method involves the following problems at the receiver. Almost all receivers are capable of receiving one sideband and the carrier, but in cases involving the undistorted transmission of a fairly wide band of low audio-frequencies (telephony, radio broadcasting), it may become necessary to use some means to compensate for certain distortion which may thereby result.

[1] See annex 2, and references 3 and 4 of the bibliography.

For the reception of one sideband alone, it is necessary to resupply the carrier frequency at the receiving end. The application of this method, at the present time, is limited to the number of receivers and the conditions permitting such operation.

At the transmitting end, wave-filter circuits are used for partial suppression of the sidebands. The use of such filters, the construction of which is less difficult at low or intermediate frequencies than at high frequencies, is based chiefly on the precision with which the different frequencies can be filtered. This characteristic of the filters determines the maximum necessary separation between the frequencies which must be transmitted and those which are to be suppressed.

If these two groups of frequencies are very close (for example, the carrier wave and the adjacent edge of the low-frequency modulated sideband) and if, for instance, it is desired to suppress one sideband, it may not be possible to avoid the complete suppression of that part of the sideband which is adjacent to the carrier. To overcome this difficulty, one can change the frequency of the carrier and sidebands to a frequency region in which it is more practicable to provide the necessary filters.

The adoption of these methods for the partial suppression of frequencies is most needed in those parts of the radio spectrum where the ratio of used to unused space is greatest. (See annex 1, annex 2, and reference 2 of the bibliography).

A discussion follows of the possibilities of application of these methods in the various frequency bands and for the various types of service.

LONG WAVES

Taking into account that the sidebands for telephony are much wider than in other types of modulation, the transmission of a single sideband only should be considered in the low frequency range. (See description of stations WNL and GBT providing transatlantic telephone circuit between Europe and America; annex 2, and references 2 and 3 of the bibliography).

Even in case of emissions destined for several receivers, a sideband, or at the most a sideband and the carrier only should be transmitted, since the number of receivers must be very limited.

MEDIUM WAVES

This band includes above all, the broadcast transmitters. The method of single sideband transmission can not be considered here for the simple reason that the type of receivers now in use would have to be changed. The transmission of one sideband and the carrier may not alleviate part or all of the difficulties so far as the receiver is concerned. It is doubtful, however, whether this would result in any economy of frequency space because by this method it is not possible to diminish the serious interference caused by the carrier wave, as long as the separation between carriers of neighboring broadcast stations will be kept down to the lowest limit now possible in radio broadcasting (in Europe 4500 cycles and less).

It could be recommended, however, to provide another form of partial suppression of the transmitted sidebands. The procedure consists of placing filters in the transmitter which would fix the limits of the sidebands with respect to adjacent waves, and would let pass through all modulation frequencies needed for a good quality transmission and compatible with the distance to be maintained between the stations. However, all frequencies further removed from the carrier and which are produced by some of the higher modulation frequencies, and also the harmonics, must be entirely suppressed to avoid interference.

SHORT WAVES

As was pointed out under "General Remarks", the case of single sideband transmission presents more technical difficulties at the higher radio frequencies than at lower frequencies. Besides, if we consider the tolerances fixed for this band, the number of unused frequencies between two adjacent channels is comparatively so big that a more economic use of frequency space should actually be accomplished by other means, and especially by improving the frequency stability.

If we consider question 7 on the basis of the viewpoint that each radio channel should occupy the narrowest frequency band possible, we are immediately led to consider the following:

1. To reduce the sidebands in each particular type of radio communication as much as possible, the low frequency band which modulates the carrier must be as narrow as possible.
2. Advantage could be taken of the unused frequencies between the sidebands and the carrier for multiplex transmission, as is the case in infra-acoustic telegraphy.
3. A band of radio frequencies could be utilized more economically by effecting several transmissions on one carrier frequency only (as, for instance, in multiplex operation service of wire circuits) in such a manner, that no frequency band included between the carrier frequency and the sidebands would remain unused and that, under these conditions, the sidebands could also be widened. In this case account would have to be taken of the fact that, on the one hand, it would be possible to suppress one of the sidebands, which would be considerably widened, and, on the other hand, this measure would permit a more economical use of radio channels in the frequency bands which have larger tolerances (short waves).

It appears from the above considerations that two new questions could be added to question 7:

Question 7a

What is the maximum permissible width of the signal frequency band for the various types of signal transmission?

Question 7b

Utilization by multiplex services of the frequency gaps with a view to realizing a more economical use of radio circuits.

In connection with question 7a, it must be remarked that an upper frequency limit for the signal frequency bands required in the various types of signal transmission is already afforded in Opinion No. 20 of the C. C. I. R. (The Hague, 1929). We ought, in fixing the lower frequency limits, to take into account the recommendations of the C. C. I. Telephone and the C. C. I. T.

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As regards question 7b, from the theoretical considerations (see annex 3) and from the experience acquired in wireless multiplex operation,[1] it appears to be amply demonstrated that such service (multiplex telephony, multiplex telegraphy, or simultaneous telephony and telegraphy) is feasible and practical and can be considered in certain cases as a very convenient means to derive more benefits from the use of a frequency channel.

In telegraphy it is arranged to modulate the transmitter, for each telegraphic transmission, by a low frequency, interrupted in rythm with the keying.

A very useful multiplex service is that whereby the *telephone transmitter* is used *at the same time for telegraphic transmissions.* For this it is necessary that the telephone modulation be 100 per cent below the right side of the modulation characteristic.

In principle, it is possible to transmit infra-acoustic telegraphy just as well as telegraphy by superposition.

Infra-acoustic telegraphy does not require a new frequency band, but on the contrary it is also possible to use the unused frequencies between the telephone sidebands and the carrier.

In the long-wave range infra-acoustic telegraphy at low frequencies can only be considered if the transmission method with sideband suppression is not used.

In the short-wave range telegraphy by superposition can also be recommended, since the widening of sidebands is only slight in proportion to the existing separation between adjacent channels owing to the wide tolerances actually permitted. Frequency-space economy could be realized by a system of simultaneous telephony and telegraphy using the same carrier instead of one separate channel for each distinct service. In the operation of multiplex telegraph service by one single transmitter, generally only a small part of the total power of the transmitter can be used. This marked disadvantage in long-wave operation would be less pronounced in short wave working where at times an excess power is used to compensate for the changing of intensity at the receiver.

From the viewpoint of economizing frequency space it is quite certain that in the long-wave range, if a suitable receiving method is used (see annex 3, case "a" of question 7b) the use of multiplex telegraph service with sideband or even carrier suppressed, permits a reduction in the number of frequencies which otherwise would be needed if the same telegraphic traffic were to be handled by separate transmitters.

In the short-wave range, multiplex telegraph service would permit even greater economies in frequency space.

ANNEX 1

AUSTRIA

PROCEDURE ADOPTED TO OBTAIN SYSTEMATIC ANSWERS TO QUESTION 7 OF THE PROGRAM

The purpose of question 7 is to study and determine the technical possibilities which permit the transmission of the frequency band required for a standard type of signal transmission by radio in such a way that

[1] See, for instance, the simultaneous telephone and telegraph services between Berlin and Buenos Aires.

the radio frequency band emitted shall be as narrow as possible. Question 7, as formulated by the C. C. I. R., at once points to two possibilities of restricting the frequency band emitted; viz, the emission of a single sideband only, or the emission of a sideband and of the carrier wave.

If we consider the case of the emission of a single sideband alone, the width of the theoretically minimum radio frequency band may be set down as equal to the width of the frequency band transmitted. In emitting a sideband and the carrier wave, the width of the theoretically required radio frequency band is not greater, in the most favorable case, than the highest frequency band transmitted. To be sure the radio frequency band sometimes shows, in this case, a more or less wide frequency gap between the carrier wave and the sideband. Such frequency gaps between carrier wave and sideband also appear in the normal type of emission of carrier wave and two sidebands.

In a purely theoretical way the various types of emission may therefore be primarily grouped as follows:

I_A: Emission of carrier wave and two sidebands; the sidebands follow upon the carrier wave with little or no gap, so that a gapless (continuous) radio frequency band is utilized.

I_B: Emission of carrier wave and two sidebands; between the carrier wave and the sidebands two unutilized frequency bands remain free. The radio frequency band utilized really consists therefore of three distinctly separated parts, that is, of the two sidebands and of the carrier wave situated midway between them. Between these three parts lie two unutilized frequency bands of equal width.

II_A: Emission of the carrier wave and one sideband; the sideband follows upon the carrier wave with little or no gap; a gapless (continuous) radio frequency band is utilized.

II_B: Emission of the carrier wave and one sideband; between the carrier wave and the sideband one unutilized frequency band remains free; the frequency band utilized therefore consists in reality of two parts; viz, one sideband and the carrier wave. Between these two parts is an unutilized frequency band.

III_A: Emission of only one sideband; a gapless frequency band is therefore utilized.

The ratio of the width of the radio frequency band emitted to that of the signal frequency band to be transmitted will therefore be most unfavorable (that is, greatest) when transmission method I is used, and most favorable (that is, near or equal to I) when method III is used.

The absolutely greatest restriction in the utilization of the radio frequencies will obviously be attained—

(1) if the signal frequency band transmitted is kept as narrow as possible;

(2) if, in using method I or II, the frequency gaps not utilized for the same signal transmission are utilized for one or more other signal transmissions.

The observance of the conditions laid down under 1 and 2 has been regarded as a matter of course for many years in long-distance and therefore costly wire connections, chiefly in cable circuits. For instance, only a comparatively narrow speech frequency band (350 to 3000 c/s) absolutely required for intelligibility is transmitted on such lines on the basis of extensive experiments for purposes of commercial telephony. The frequency ranges which are not used in this case and which are below the speech frequency band are employed for telegraphic signal transmission (infra-acoustic telegraphy), the free frequency ranges above the speech band being used for a second conversation or further telegraphic connections or the whole audio-frequency band is utilized for a large number of telegraph connections (low frequency telegraphy).

As it appears appropriate that the methods that have stood the test in wire telegraphy and telephony should also be employed, so far as possible, in radio operation in order to make the most intensive use of a connecting channel, two further questions naturally arise in direct connection with question 7, viz:

Question 7*a*: Maximum permissible width of the signal frequency band for the various types of signal transmission.

Question 7*b*: Utilization by multiplex telephony or telegraphy of the frequency gaps left in transmission methods I and II.

In the opinion of the Austrian Telegraph Administration there are two questions involved here, each of which requires an independent study and which ought perhaps to be propounded in connection with the results of the study of question 7 at the next session of the C. C. I. R.; if the study of question 7 should yield special data on which to answer questions 7*a* and 7*b*, such data might be presented at the same time.

In connection with question 7 it must be remarked that an upper frequency limit for the signal frequency bands required in the various types of signal transmission is already afforded in recommendation no. 20, expressed by the first meeting of the C. C. I. R. Leaving aside the fact that these values ought perhaps to be revised, we ought in fixing the lower frequency limits to take into account the widths of the frequency bands used in wire telegraphy or telephony.

As regards question 7*b*, it might be advisable to examine in connection therewith the question of the multiplex utilization of a radio channel in general. In as much as, owing to the unavoidable inaccuracy of the frequency adjustment and of the unavoidable frequency variations of the transmitters, a greater frequency range (tolerance) is necessary between two neighboring and mutually independent radio channels than would be required in view of the width of the frequency band of the transmitters, it might be advantageous to unite as many connections as possible in multiplex service in a single radio channel and thus economize the multiplex tolerance distances.

Question 7 is intended to demonstrate the technical possibilities of narrowing the frequency band utilized for the different types of emissions and services.

In order fully to answer the question it is necessary, in the opinion of the Austrian Telegraph Administration, to take into account also the frequency range being utilized at the time. The Austrian Telegraph Administration therefore proposes that question 7 be studied and answered on the basis of the following classification:

1. With respect to the various frequency ranges and types of service, they have been placed in conformity with Opinion No. 14,[1] expressed by the first meeting of the C. C. I. R. (The Hague).

2. With respect to the type of emission, in so far as it is not already indicated by the character of the service (for instance, broadcasting), it is convenient to refer to Opinion No. 20 and to provide the following classification:

(*a*) International Morse Code, 100 words per minute by telegraphy on a continuous unmodulated wave.
(*b*) International Morse Code, by telegraphy on a modulated continuous wave.
(*c*) Transmission of original writings and pictures.
(*d*) Television.
(*e*) Commercial telephony.
(*f*) Broadcasting.
(*g*) Multiplex telegraphy or telephony.

In order to designate a particular type of multiplex service, it would perhaps be well to add in parentheses the types of transmission employed simultaneously, making use of the foregoing letters. The expression $g\ (1b+1e+xb)$ would signify a multiplex service in which a telegraphic connection on a frequency band below the speech-frequency band is used and x telegraphic connections on frequencies above the speech-frequency bands used are operated simultaneously in addition to a commercial conversation.

[1] Note of the International Bureau. This opinion has been replaced by Opinion No. 41.

The purpose of the foregoing suggestion is to construct a plan within which all the possibilities which appear from a study of question 7 can be grouped according to a definite system.

For giving a practical value to the question, it seems necessary to study, in the first place, the possibilities which will permit the quickest and the best possible settlement of the problem of the congestion of the ether. Along these lines the Austrian Telegraph Administration thinks that the following cases should be considered primarily:

1. Commercial telephony within the range of the long and medium waves.
2. Multiplex on the long and medium waves.
3. Commercial telephony and multiplex service on intermediate and short waves.
4. Broadcasting on medium waves (important to certain territories, for instance Europe).

ANNEX 2

UNITED STATES OF AMERICA

STUDY FOR THE DISCUSSION OF QUESTION 7 OF THE PROGRAM

GENERAL REMARKS

The adoption of methods for suppressing a portion of the frequency band which is normally transmitted is most needed in cases where the type of modulation results in comparatively wide sidebands and in the portions of the radio spectrum where the ratio of used to unused space is greatest. (See reference 2 in the bibliography below.)

As is indicated in the recommendations of the C. C. I. R. (The Hague, 1929), slow-speed telegraph transmission occupies a comparatively narrow band width, while high-speed telegraphy, telephony, high-speed picture transmission, and television result in the use of wider bands.

In suppressing one sideband it is possible to suppress the carrier as well, thus resulting in the transmission of the other sideband alone. This requires, however, that a current of the carrier frequency be resupplied at the receiving station. For cases where this is not practicable the carrier may be transmitted along with the single sideband. In the case of telephony, the economy in frequency space may be about 200 or 300 cycles greater if the carrier itself is suppressed as well as one of the sidebands.

In suppressing one of the sidebands, use is ordinarily made of wave-filter circuits. The design and construction of such filters are less difficult at low or intermediate frequencies than at the high radio frequencies. The difficulty of securing ideally sharp selectivity or cut-off in such filters limits their use to cases where there is an adequate separation between the frequencies which it is desired to transmit and those which are to be suppressed. On this account there are some difficulties in employing single sideband transmission where it is desired to transmit very low audiomodulating frequencies. In order to meet this problem, it is possible, in some cases, to transform the frequency of the carrier and sidebands to a frequency region in which the provision of the necessary filters is more practicable. In some cases it may be necessary and desirable to transmit a small portion near the low-frequency edge of the sideband which is intended to be suppressed.

LOW FREQUENCIES

The low-frequency stations used for transatlantic telephone service between Europe and America (stations WNL and GBT, using a frequency band centered at 60 kc/s) use a system of transmission by which the carrier and one sideband are suppressed, so that the frequency band occupied is only about 3000 cycles wide. A description of the single sideband method employed is made in reference 1 of the bibliography below. A more detailed description of the transmitting station at Rocky Point, New York, is given in reference 3. Means are also employed, in the operation of these stations, whereby the same frequency band is utilized for telephone transmission in the two directions. The use of voice-operated switching devices, by means of which this is made possible, is discussed in reference 4.

BROADCASTING FREQUENCIES

In view of the congestion which has developed in the use of the frequency band 550 to 1500 kc/s, most widely used for broadcasting, serious consideration may need to be given to the possible use of the single sideband transmission as a means for securing more effective use of this frequency range. If the broadcast transmission is of such a nature as to be received with the type of radio receivers now in the hands of millions of listeners, it is required that the carrier be transmitted as well as one sideband. Such a type of transmission is technically feasible, but it is uncertain whether this would result in any net gain in the program service available to listeners. If it is adopted, care should be taken to avoid impairing the quality of transmission or width of sideband available to the listener. The single sideband method of transmission is one which is not entirely free from distortion, the amount of distortion depending upon the degree of modulation and the type of detection employed.

The extent of the quality impairment may, theoretically, be reduced to any desired amount, so far as the terminal apparatus is concerned. The greater the ratio of the carrier amplitude to the sideband amplitude, the smaller will be the impairment of quality. In the case where the carrier is transmitted, the distortion may thus be reduced by lowering the percentage of modulation. This, however, decreases the effective service area of a station in relation to its interference area. In the case where the carrier is not transmitted but is resupplied at the receiver, this factor is not so important since the reinserted carrier may be made strong enough to reduce this source of distortion below the others which may be present.

In the transmission of the carrier and two sidebands, less distortion is introduced by the use of a detector which has a linear characteristic than by one which follows a square law. In the transmission of the carrier and a single sideband, however, the use of a square-law detector introduces less distortion. In present practice the detectors are somewhere intermediate between straight-line and square law.

One way in which use may be made of the economy in frequency space resulting from single sideband transmission, is by transmitting a wider sideband, corresponding to higher modulating frequencies, than when the same band width is used for double sideband transmission.

HIGH FREQUENCIES

As indicated above, the use of single sideband transmission is technically more difficult at the higher radio frequencies than at lower frequencies. This is particularly true in the case where the carrier is suppressed and must be reinserted at the receiving station. At high radio frequencies the space actually occupied by the transmission at a given time is, in many cases, of the same order of magnitude as the unoccupied space which must be left free from assignment on account of the wide frequency tolerance now permitted. Economy in the use of frequency space in this region can, therefore, be obtained much more readily by improvements in the technique of frequency maintenance than by the employment of methods which curtail the width of the band actually transmitted.

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ANNEX 3

GERMANY

ANSWER TO QUESTION 7 OF THE PROGRAM

The German Administration is of the same opinion as the United States of America (see annex 2 attached to general report on question 7).

Question 7*a*. The C. C. I. R. expressed its opinion on this point in Opinion No. 20 (The Hague, 1929). No changes are proposed in connection with this recommendation.

Question 7*b*. In principle one could simply work telephony and telegraphy simultaneously by slightly changing the carrier by some sort of detuning. Such a change of frequency should not cause any trouble in telephone reception. This could only be accomplished in the high frequency bands.

It is not possible to transmit several telegraphic communications in this manner with a single transmitter.

There remains then the other possibility which involves the modulation of the transmitter with a low frequency whereby a series of telegraphic connections could be established by a single transmitter. There are, however, other important points to be considered.

The modulation of the transmitter is limited by the maximum power output of same. A modulated oscillation has the following mathematical expression:

$$i=[A+a\cos(2\pi ft)]\sin(2\pi Ft)$$

wherein F stands for the carrier, f for the low modulation frequency, A is the amplitude of the carrier and has the value of amplitude change of the high frequency oscillations. The quotient $\frac{a}{A}$ represents the degree of modulation. This ratio can never attain the value of A.

If several services are to be effected with the same transmitter, we arrive, in the assumed case of four simultaneous communications, at the following equation.

$$i = [A + a\cos(2\pi f_a t + \varphi_a) + b\cos(2\pi f_b t + \varphi_b) +$$
$$+ c\cos(2\pi f_c t + \varphi_c) + d\cos(2\pi f_d t + \varphi_d)]\sin(2\pi F t)$$

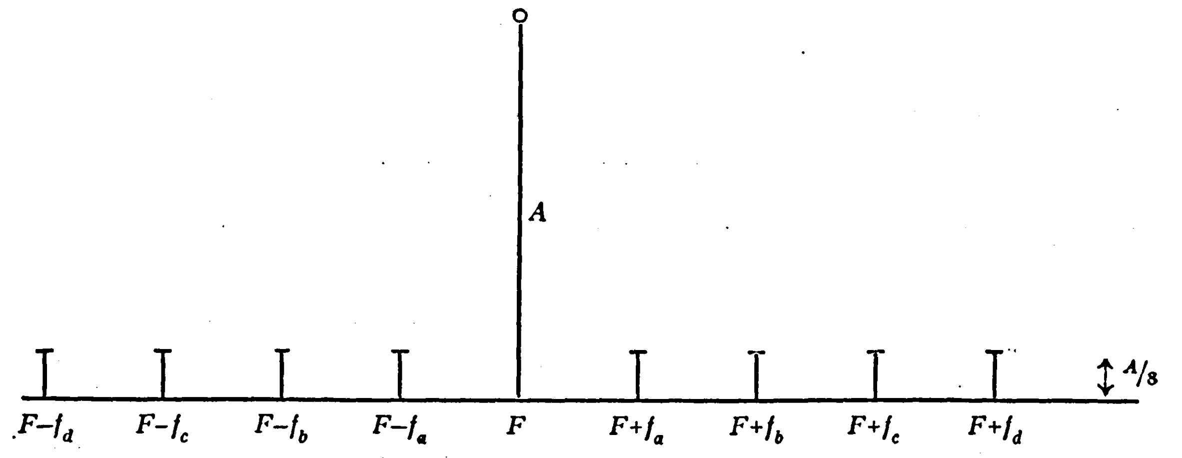
f_a, f_b, f_c, f_d are the various low modulation frequencies;
$\varphi_a, \varphi_b, \varphi_c, \varphi_d$, represent the reciprocal phase differences at the start.

Since at certain moments the different factors a, b, c, and d can be added, it follows that the following condition must hold in all cases:

$$a + b + c + d = A$$

coming down to simplest terms, each of these coefficients will be equal to $\frac{A}{4}$.

The following diagram can thus be set up indicating in the center the carrier frequency of amplitude A, at the right and left of which are the symmetrically arranged sidebands with their amplitudes equal to $\frac{A}{8}$.



The maximum power of the transmitter with highest possible amplitude $2A$, is then

$$I^2_{eff} \cdot \mathrm{R} = 2\,A^2\,R$$

R being the effective resistance of the antenna circuit. The transmitter must be set to give this maximum power.

For a quadruple telegraph service we would have the following table of power:

Carrier frequency (amplitude A) $\cdots$ power $\frac{A^2}{2} \cdot R$

8 sideband frequencies (amplitude $\frac{A}{8}$ $\cdot\cdot\cdot$ having each a power of $\frac{A^2}{128} \cdot R$ giving a total power of

$$\frac{A^2}{2}R + 8\frac{A^2}{128}R = \frac{9}{16}A^2\,R$$

The transmitter is thus only operated at 28 per cent of its effective power.

To be able to judge in what manner the different sidebands act on the transmitter we must distinguish between two cases:

(*a*) *It is possible to separate the different high frequency waves, that is, for instance, to single out the frequency* $F+f_b$ *only and to receive same by means of a heterodyne.*

In this the station acts as four different transmitters working on frequencies $F+f_a$, $F+f_b$, $F+f_c$, $F+f_d$.

The other side frequencies as well as the carrier are superfluous and idly occupy the respective frequency bands. It would be well, therefore, to prevent their radiation at the multiplex transmitter.

If, instead of a multiplex transmitter, we choose four different transmitters having amplitudes of $\frac{A}{8}$ the total power would be

$$4 \cdot \frac{A^2}{128} R = \frac{1}{32} A^2R$$

Considering that the transmitters are keyed at their maximum power output, they should be constructed for a maximum power of $\frac{1}{32} A^2R$.

This is about 1.5 per cent of the preceding value of $2A^2R$. The multiplex service would thus be very uneconomical in this case.

(*b*) *The entire frequency band emitted by the transmitter is received and a single distinct low frequency is filtered out by the low frequency circuits of the receiver.* Here we deal with reception without heterodyne.

If same result is to be obtained by four different transmitters, one would have to provide for each pair of sidebands a special carrier with amplitude of $\frac{A}{4}$. The total carrier power for the four transmitters would thus be

$$4\left[\frac{A^2}{32} R + 2 \frac{A^2}{128} R\right] = \frac{3}{16} A^2R$$

This power is one third of that of the multiplex transmitter. The four distinct transmitters should each be capable of furnishing a maximum power of $\frac{A^2R}{8}$ or altogether $\frac{A^2R}{2}$. This is only 25 per cent of the total power which a multiplex transmitter ought to be capable of furnishing.

As regards the gain in frequency economy, the following remarks can be made:

In case *a* the multiplex service with one transmitter has distinct disadvantages unless the carrier and one sideband are suppressed. On the other hand if these latter are suppressed, the system offers some advantages, because if the frequency varies, all side frequencies have their positions changed at the same time and in the same direction. Thus the tolerance for a multiplex transmitter could be diminished.

Case *b* could only be considered in short wave working. By using transmitters separated by 20 kc/s and subject to a maximum tolerance of 5 kc/s in the high frequency bands, such transmitters could be modulated with a number of audio-frequencies extending as far as $f_n = 5000$ c/s. This might result in a considerable frequency gain.

Simultaneous telephony and telegraphy using one transmitter is by far the most important transmission system. If, for telephony we can use, without any inconvenience, a type of modulation 100 per cent below the right side of the modulation characteristic, we can also establish telegraph communication, using the same transmitter.

In principle, it is possible to use either infra-acoustic telegraphy or telegraphy by superposition. The former does not require any additional frequency space. The telegraphy by superposition can offer same advantages in high frequency bands as a multiplex telegraph service with different frequency modulation.

As regards the short waves, it must be stated that the situation is quite different. The transmitters use excess power at times in order to equalize the strong intensity variations at the receiving end. Such being the case it would be economical to effect simultaneous telephone and telegraph services with this transmitter.

Such a multiplex service is now in operation, for the purpose of experimentation, between Berlin and Buenos Aires.

Diagrams 1 and 2 show the frequency-space gain realized by this system. It was also established that a great difference exists between long- and short-wave bands.

In long-wave operation, provision was made for a tolerance of ± 0.1 per cent. A transmitter modulated with a frequency included between the limits $f=250$ c/s and $f=2500$ c/s consequently requires a frequency band of $2\left(2500\text{ c/s}+\frac{1}{1000}F_o\right)$ wherein F_o stands for the carrier. The total width for $f=100$ kc/s (3000 m) is equal to 5200 c/s (see figure 1*a*). The frequency band included between the limits F_o and F_o+250 c/s and between F_o and F_o-250 c/s remains thus unused. This frequency could be put to use for infra-acoustic telegraphy.

By using telegraphy by superposition with a frequency F_o, which must be greater than 2500 c/s, we obtain two sidebands F_o+f_o and F_o-f_o which vary at the same time and in the same direction as the carrier. Such telegraphic operation with superposition at a frequency $f_o=3000$ c/s is represented in figure 1, *b*. The total width of the frequency band occupied by the transmitter operated in this manner is equal to 6400 c/s.

If a transmitter is used for the telephone link and another for the telegraph link, this latter link would occupy a single frequency band. As regards the separation between two adjacent transmitters, account has to be taken of the fact that the two carrier frequencies are independent and that they can also vary contrariwise. Two circuits of this type thus necessitate a total width of 5800 c/s (see figure 1, *c*).

One thus arrives at the following results:

To bring about an improvement in the frequency band of the long waves only infra-acoustic telegraphy can be considered and for this purpose two sidebands would be used, which are within the limits of the frequencies used by telephony. Telegraphy by superposition is not practical in this case because the frequency tolerance is only 4 per cent of that of the telephone band, and there exist also two sidebands in addition to the band of frequencies used by the telephone.

As regards the short-wave bands conditions are altogether different. In this band the tolerance is 0.05 per cent. For $f=10{,}000$ kc/s (30 m) this corresponds to a width of ± 5000 c/s. Frequency tolerance in this case is thus equal to 200 per cent of that of the telephone band. A simple telephone transmitter occupies a band of 15,000 c/s (see figure 2, *a*). In this case infra-acoustic telegraphy could also be used.

The conditions of using telegraphy by superposition are more favorable however. Diagram 2*b* represents a telegraph circuit by superposition, the two links being worked on frequencies of 3000 and 4000 c/s. As can be seen, the widening of the frequency band does not have to be taken into consideration since the interval between two transmitters cannot be less than 20 kc/s. The total width of frequency bands of a treble link, similar to that in figure 2*b*, reaches the value of 18,200 c/s.

Consideration has also been given the fact that the different frequencies always vary in the same direction, while if three different transmitters are used (see diagram 2*c*) frequency variations can at times occur in a direction opposed to each other. A telephone transmitter and two telegraph transmitters would also occupy a frequency band of 36,000 c/s. This results from the simple fact that the tolerance is too large.

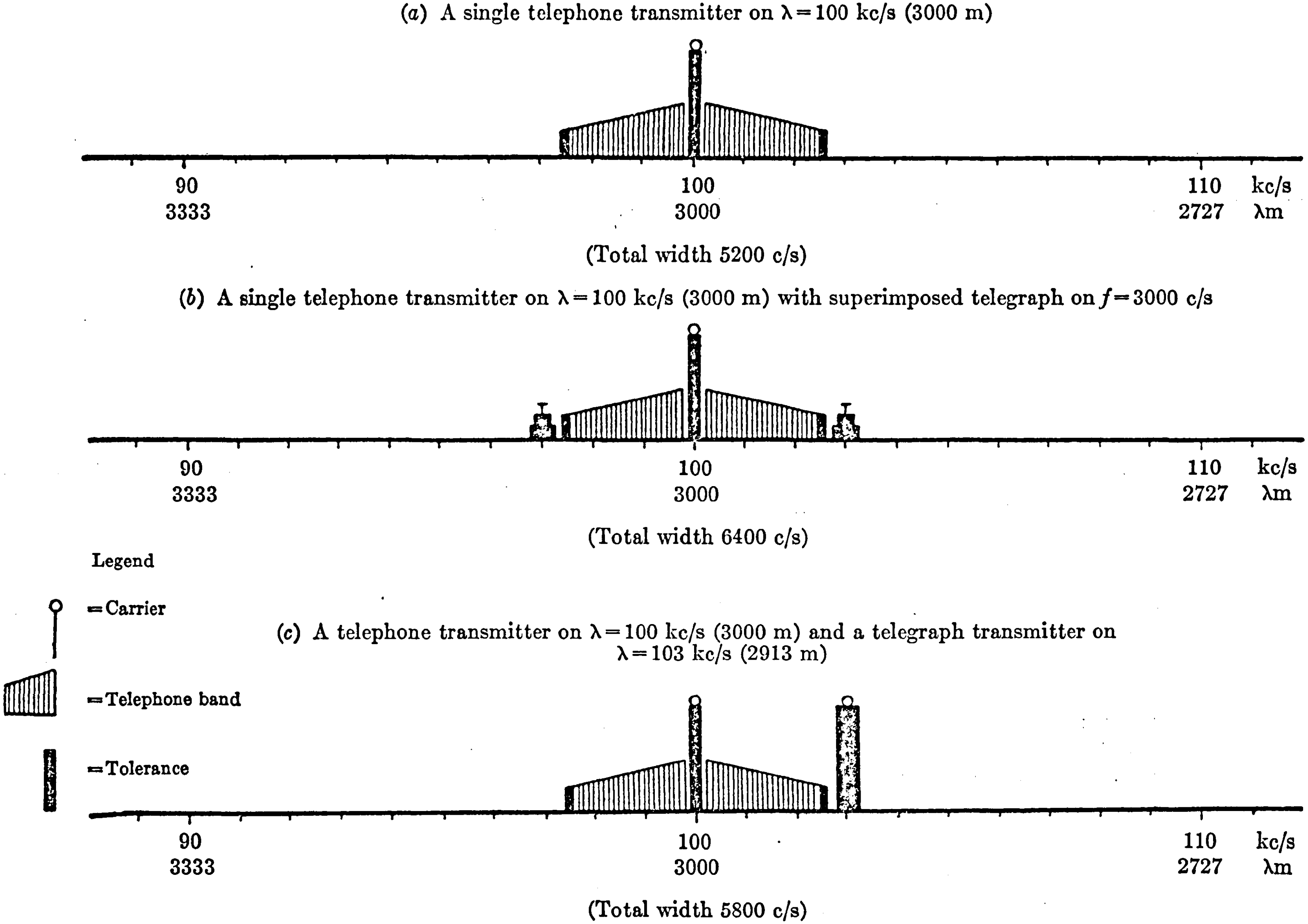

(a) A single telephone transmitter on λ = 100 kc/s (3000 m)
90
3333
100
3000
110
2727
kc/s
λm
(Total width 5200 c/s)
(b) A single telephone transmitter on λ = 100 kc/s (3000 m) with superimposed telegraph on f = 3000 c/s
90
3333
100
3000
110
2727
kc/s
λm
(Total width 6400 c/s)
Legend
= Carrier
= Telephone band
= Tolerance
(c) A telephone transmitter on λ = 100 kc/s (3000 m) and a telegraph transmitter on λ = 103 kc/s (2913 m)
90
3333
100
3000
110
2727
kc/s
λm
(Total width 5800 c/s)

FIGURE 1

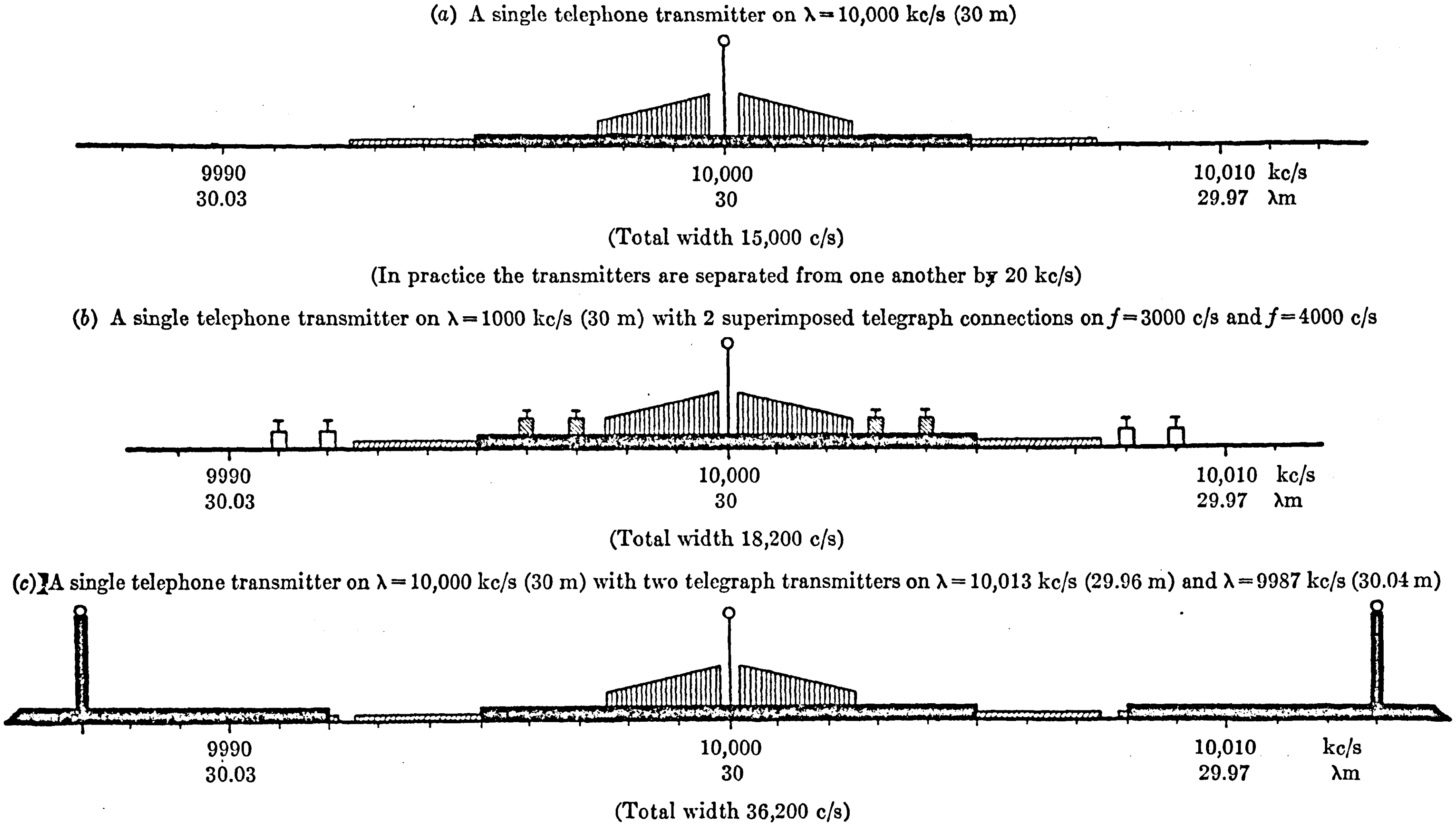

(a) A single telephone transmitter on λ = 10,000 kc/s (30 m)
9990
30.03
10,000
30
10,010 kc/s
29.97 λm
(Total width 15,000 c/s)
(In practice the transmitters are separated from one another by 20 kc/s)
(b) A single telephone transmitter on λ = 1000 kc/s (30 m) with 2 superimposed telegraph connections on f = 3000 c/s and f = 4000 c/s
9990
30.03
10,000
30
10,010 kc/s
29.97 λm
(Total width 18,200 c/s)
(c) A single telephone transmitter on λ = 10,000 kc/s (30 m) with two telegraph transmitters on λ = 10,013 kc/s (29.96 m) and λ = 9987 kc/s (30.04 m)
9990
30.03
10,000
30
10,010 kc/s
29.97 λm
(Total width 36,200 c/s)

Figure 2

ANNEX 4

ANSWER OF THE JAPANESE ADMINISTRATION TO QUESTION 7 OF THE PROGRAM OF THE SECOND MEETING OF THE C. C. I. R.

Since only long and short waves can be used for long-distance communications, it would not seem necessary to make an international study of frequency bands for waves other than those just mentioned.

SHORT-WAVE COMMUNICATIONS

1. Wireless Telegraphy

A. Continuous Waves

In telegraphy, if a transmission is made at a speed of 100 words per minute, the width of the sideband is equal to ± 0.12 kc/s, and it is below 10^{-5} (10^{-3} per cent) for frequencies between 6000 and 23,000. Consequently, it is thought that there is no need of suppressing such a small frequency band.

B. Modulated Continuous Waves

If the width of the sideband is ± 1 kc/s, its value, for frequencies between 6000 and 23,000 kc/s is below 10^{-4} (10^{-2} per cent). Hence it is not believed necessary to eliminate this sideband either.

2. Wireless Telephone

Commercial Service Telephony

If the width of the sideband is $+3$ kc/s its value, for frequencies from 6000 to 23,000 kc/s is below 10^{-3} (10^{-1} per cent). Hence we are of the opinion that it is not necessary to eliminate the band involved.

Furthermore, for short waves, the suppression of sidebands is very difficult to accomplish in practice for the reasons mentioned below.

With regard to the limit of separation of the frequencies, by means of an ordinary filter, it is impossible to suppress the sidebands without hampering the modulation. Consequently we cannot expect to accomplish good communication in practice, owing to the interferences caused by the low-frequency harmonics.

LONG-WAVE COMMUNICATIONS

1. Wireless Telegraph

A. Continuous Waves

When transmission is had on long waves, below 100 kc/s at a speed of 100 words per minute, the width of the sideband is ± 0.12 kc/s. Its value with reference to the 100-kc/s frequency is approximately 10^{-3} (10^{-1} per cent). In this case, the elimination of the sideband and of the carrier wave cannot be recommended because the advantages offered by this procedure are far from compensating for the considerable expenses which it occasions.

B. Modulated Waves

Stations using modulated long waves are used chiefly in the short-distance mobile services. It follows that the elimination of a sideband and of the carrier wave uselessly complicates the receiving apparatus and makes it difficult to operate.

2. Wireless Telephone

Commercial Service Telephony

Considering that in the commercial service telephony, the sideband can be separated by double modulation by means of an ordinary filter, it is possible to partly eliminate one sideband and the carrier wave. For this purpose, the ordinary method is resorted to which consists in balancing the modulation, but the method which we describe below can be used to this end.

The figure 1(*a*) gives the design of the fundamental circuits.

To the two terminals *a* and *b*, there is applied in the first place, the carrier wave of an electromotive force modulated by the ordinary method. The frequency of this carrier wave is expressed by f_1; by tuning C_1 and C_2, on the one hand, the circuits C_1 L_1 L_3 and C_2 L_2 L_3 are made to be in resonance with f_1; and on the other hand, by properly varying M_1 and M_2, L_3 is balanced in such a manner that the f_1 frequency current is not induced in L_3. Thus, there is no carrier wave in L_3. Next the electromotive force of modulation is applied. In this case, the carrier wave being zero in L_3 the low-frequency sideband becomes stronger than the high-frequency sideband. (See figure 2, curve AA'.)

When a condenser C_3 is used in place of L_3 (figure 1(*b*)) the high-frequency sideband is stronger than the low-frequency sideband. (See figure 2, curve BB'.)

Also, in the circuits C_1 L_1 C_3 and C_2 L_2 C_3, when passing from the resonance frequency f_1 to another f_2, the curve BB' of figure 2 will then be represented by B_1 B'_1. It is possible to completely eliminate from C_3 the current of frequency f_2 corresponding to the maximum amplitude indicated by AA'. If the circuit of figure 1(*a*) is used for transmission, and that of figure 1(*b*) for reception, set for a resonance frequency f_2, corresponding to the reception circuits L_1 C_1 C_3 and C_2 L_2 C_3, and if the carrier frequency f_1 is then applied, the current produced by the combination of f_1 and f_2 will be found to form the voice frequency current again at the output of the receiver "homodyne". In order to apply this communication system to the commercial service, the two circuits indicated in figures 1(*a*) and 1(*b*) must be used for transmitting and receiving apparatus respectively. On the contrary, if this system is not used for reception, distortions will result in the reception which will assure, more or less, the secrecy of the communication.

By this method, one can reduce—in a very inadequate manner, it is true—the carrier frequency of a sideband by properly choosing the value of L_3 or that of the condenser which replaces L_3. This permits, in practice, the elimination of the carrier wave and of the sideband without the use of a filter. Moreover, if a filter is used in this system, these two waves can be completely eliminated, and much more easily than where a system is used that transmits the two sidebands.

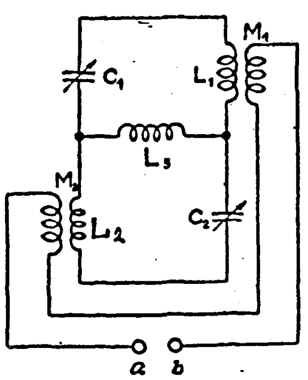


FIGURE 1 (*a*)

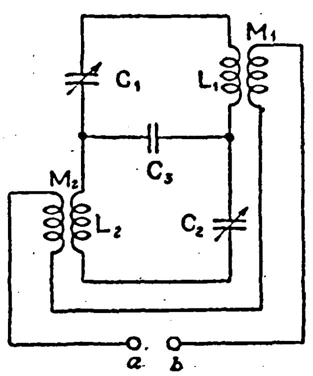


FIGURE 1 (*b*)

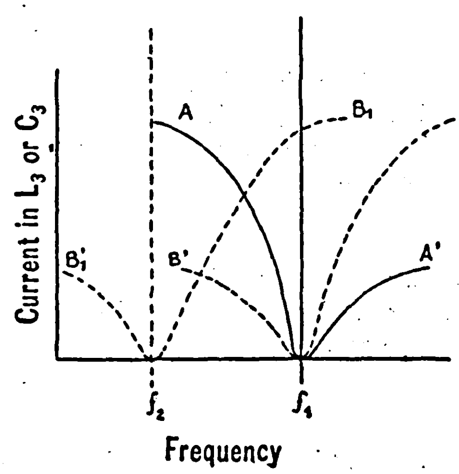


FIGURE 2

OPINION No. 48

SUPPRESSION OF HARMONICS AND PERMISSIBLE TOLERANCE FOR THEIR INTENSITY

The C. C. I. R.,

considering

(1) that, when they are of good design, transmitting apparatus other than that of mobile stations produce harmonics, the individual intensity of which at a distance of about 5 km of the limits of the transmitting antenna may attain the following percentage of the intensity of the fundamental wave:

Frequency of fundamental wave	Percentage of fundamental wave intensity
10– 100 kc/s	0.1% (tube transmitters)
100– 550 kc/s	0.1%
550–1,500 kc/s	0.05%

and that, on the other hand, it is difficult to determine the significance of harmonics of frequencies above 3000 kc/s, on account of intervening factors such as the angle of radiation, the nature of propagation, and the difficulty of measuring the field intensity of such frequencies,

(2) that it is possible to reduce harmonics of all transmitters by various methods such as those mentioned in the two annexes below,

expresses the opinion

(1) that it is necessary to protect all services against interference caused by nonessential emissions, particularly harmonics of such intensity or character as to interfere with their normal reception, but it is not possible at present to fix maximum limits for the field intensity of those harmonics which would be applicable in all cases,

(2) that it is, however, desirable to find a way of fixing such limits, independently of the power of the transmitter and as a function only of the conditions of reception on the harmonic frequency.

ANNEX 1 TO OPINION No. 48

PROPOSALS OF THE GERMAN ADMINISTRATION RELATING TO QUESTION 8 OF THE PROGRAM OF THE SECOND MEETING OF THE C. C. I. R.

INTRODUCTION

A. What measures must be taken to suppress harmonics of transmitters?

In order to answer this question it is necessary to consider the different types of transmitters indicated below:

(1) tube transmitters
(2) machine transmitters
(3) arc transmitters

1. Tube transmitters. There is no doubt that tube transmitters play the predominant part in radio traffic. In the proposals presented on this question by Great Britain and Germany at the first meeting of the C. C. I. R. (see documents of this meeting, pp. 74ff, 155, 443ff), the measures to be taken to suppress harmonics in tube transmitters, were set forth in detail. They are listed below:

(*a*) *Intermediate circuits.* The use of an intermediate circuit, placed between the oscillator circuit and the antenna circuit, is, without question, the most efficient method of reducing harmonics. In this case the coupling should be as loose as possible. A capacitative coupling of the antenna circuit is even more advantageous than inductive coupling, even though the latter is more generally used.

(*b*) *Counter coupling.* This system is difficult to install in practice and is only effective for *one* certain harmonic.

(*c*) *Buffer circuits and short-circuiting arrangements.* These systems are also only effective for a certain harmonic. In order to suppress the other harmonics it will be necessary to decide upon a number of tuned circuits, corresponding to that of the harmonics to be suppressed, unless it is desired to use a *filter*, which in practice presents even greater difficulties.

(*d*) *Filters.* The oscillations in the antenna can be freed of harmonics by the use of a low-pass filter which eliminates all frequencies higher than those of the band transmitted.

(*e*) *Suppression of harmonics of the frequency transmitted which correspond with the harmonics of the antenna.*

(*f*) *Shielding of various parts of the transmitter and grounding of these screens.* This measure is necessary in order to avoid harmonics reaching the antenna through capacities which are everywhere present. As the wavelength employed becomes shorter, these undesirable capacities become increasingly disturbing; in fact, harmonics then have a very high frequency and are radiated under especially favorable conditions.

2. *Machine transmitters* (high-frequency alternators). In machine transmitters, intermediate circuits, buffer circuits, and short-circuit arrangements must also be considered. It may be mentioned here that as a result of frequency multiplication, there are produced not only harmonics of the frequency transmitted, but also all the harmonics of the *fundamental frequency* produced by the machine.

3. *Arc transmitters.* The considerations embodied in the memorandum presented by Great Britain (attached to Opinion No. 24, see documents of the first meeting of the C. C. I. R., pp. 443ff), are so detailed that other data would be superfluous. Moreover, it is to be noted that arc transmitters are of only secondary importance.

As regards the disturbances produced by the keying of the transmitters, we refer back to the proposal made by Germany at the first meeting of the C. C. I. R. (documents of this meeting, p. 155).

B. What is the admissible tolerance for intensity of harmonics?

In the proposal made by Germany at the first meeting of the C. C. I. R. (documents of this meeting, p. 155), it is recommended that the intensity of current of every undesirable frequency shall not exceed 0.05 per cent of the intensity of the antenna current. According to this, the intensity of harmonics is subject to the same proportional tolerance for large and small transmitters, which does not prove justifiable, because

(1) in large transmitters, for reasons of economy, more extensive measures can be adopted, and
(2) interference depends only on the absolute value of the harmonic radiated.

The intensity of the field produced by any harmonic of the transmitter cannot exceed 0.3 mVm, and this independently of the power of the transmitter, in any direction and for all distances over five times the length of the fundamental wave. The distance between the points measured and the transmitter should not be less than 1000 meters.

ANNEX 2 TO OPINION No. 48

RESPONSE OF THE JAPANESE ADMINISTRATION TO QUESTION 8 OF THE PROGRAM OF THE SECOND MEETING OF THE C. C. I. R.

1. MEASURES TO BE TAKEN FOR THE SUPPRESSION OF HARMONICS

1. In order to eliminate or reduce the harmonics of the waves transmitted by a valve transmitter, it must be seen that:

(*a*) the valves are not overexcited by shock;
(*b*) an intermediary circuit should be placed between the plate circuit and the antenna circuit;
(*c*) the decrement of each circuit should be reduced to a minimum;
(*d*) in the plate resonance circuit, the harmonics pass more easily by the way of capacity than by the way of inductance; consequently, it is necessary that the energy be led in by the inductance path;
(*e*) in regard to the coupling of circuits, the capacitative coupling should be adopted in preference to the inductive coupling (for instance, see the mounting of circuits indicated in figure 1, which it will be noted complies with the conditions fixed under letters *d* and *e*).
(*f*) a filter should be inserted in the supply line of the antenna.
(*g*) the harmonics do not appear at the antenna if the resonance circuits are conveniently tuned to the harmonics.
(*h*) the valves of the last stage should be, if possible, arranged in "push pull", assuming that by this means one can suppress all the even harmonics by neutralization.

2. In order to eliminate the most important harmonics satisfactorily, it is recommended that the method which we are about to indicate be adopted.

(*a*) As shown in figure 2, one can insert a resonance circuit L′C′, in series with the principal tuned circuit LC, in the plate circuit of the valve of the last stage and connect L and L′ appropriately; then the capacity of the condenser C′ may be adjusted. The harmonics which pass L may thus be eliminated for the point where the resonance frequency of L′C′ is found to be slightly lower than that of the harmonics to be eliminated. The conditions for which the *n*th harmonic is eliminated is expressed by the following formula:

$$\frac{M}{L}=\frac{C'L'}{C\,L}-\frac{1}{n^2}$$

supposing that

$$R'\leqslant\frac{n}{\omega C'}\left(\frac{C'L'}{C\,L}-\frac{1}{n^2}\right)$$

Besides, this procedure has the advantage of reducing the third harmonic a little, also when, for instance, the circuit is regulated for the purpose of eliminating the second harmonic. Experiments have shown that the second harmonic may easily be reduced by a few units per cent.

(*b*) As indicated by figure 3, one places in the plate circuit L_1C_1 of the oscillating valve a circuit filtering the *n*th harmonic, in series with the principal tuned circuit LC, and L_3 is inserted in the grid circuit. If L_1 is connected with L_3 in a suitable manner, it is possible to almost completely eliminate the *n*th harmonic in the plate circuit, since the apparent resistance of the circuit L_1C_1 may be rendered almost zero.

In order to cancel the apparent resistance, it is sufficient, as is known, that M be slightly less than

$$\frac{1}{\mu}(Rr_pC_1+L_1)$$

2. ADMISSIBLE TOLERANCE FOR THE HARMONICS

At the present time, it is difficult to determine the value of the admissible tolerance for the harmonics. It is, therefore, convenient to limit oneself to the endeavor to suppress them so far as possible.

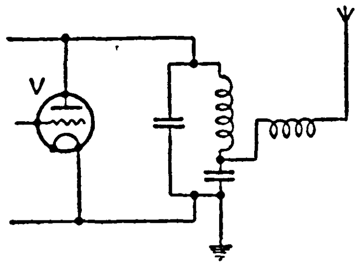


FIGURE 1

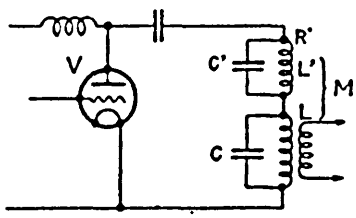


FIGURE 2

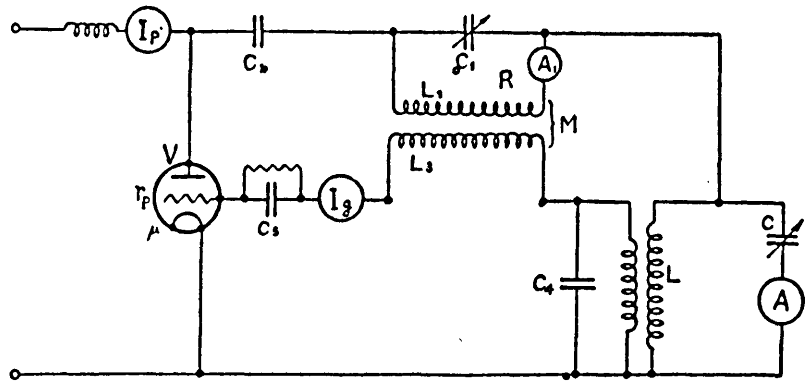


FIGURE 3

OPINION No. 49

TOLERANCE OF OVERMODULATION OF RADIOTELEPHONE TRANSMITTERS

The C. C. I. R.,

considering

(1) that the overmodulation of radiotelephone transmitters produces parasitic components of modulation which have as a result, on the one hand, the enlargement of the frequency band transmitted and on the other hand, the reduction of the quality of reproduction of speech and music,

(2) that it is possible to reduce these effects by various methods, such as those indicated in the following study by the United States of America

expresses the opinion that it is desirable

(1) that radiotelephone transmitters should be designed and adjusted in such a way that the amplitude of parasitic components of modulation outside the useful frequency band be reduced to such a value that they do not interfere with the normal reception of other stations using neighboring frequencies,

(2) that the percentage of modulation of radiotelephone transmitters should be limited to such a value that, for the maximum power and for any frequency included in the frequency band to be transmitted, the total amplitude of all parasitic components of modulation should not exceed the following percentage of the fundamental modulating wave;

Radio broadcasting stations	4%	(corresponding to 3.2 nepers or 28 decibels down)
Other radiotelephone stations	10%	(corresponding to 2.3 nepers or 20 decibels down)

ANNEX TO OPINION No. 49

STUDY MADE BY THE UNITED STATES OF AMERICA IN RESPONSE TO QUESTION 9 ON THE PROGRAM OF THE SECOND MEETING OF THE C. C. I. R.

It is assumed that by overmodulation is meant increasing the modulation-frequency input to the modulating system beyond an established value designated as a limit below which the signal distortion is considered satisfactory for the service involved. Any distortion of the signal is, in general, accompanied also by the generation of extraneous components lying outside the signal band. The criterion as to whether these extraneous components are objectionable is the amount of interference they produce. If the criterion of whether there is overmodulation is taken, as stated above, as an amount of signal distortion, the two criteria are different. Therefore, there is no general fixed relation between the degree of overmodulation and the satisfactoriness of the extra band situation.

The extraneous frequencies causing interference may be produced in the transmitting equipment in any or all of several different ways, as indicated below. As many different corrective measures may, therefore, be called for in any specific case.

Since these spurious emissions arise within the transmitter, adequate selectivity placed between the transmitting set and the antenna will reduce their magnitude to any desired value. This method, alone, however, is attended by many practical difficulties, particularly at the higher radio frequencies, and since the production of the spurious frequencies in many cases is accompanied by a distortion of the transmitted signal, the reduction of the amplitudes of these extra radiations at the source should be attempted.

There are two major sources of frequencies outside the band required for communication: (*a*) modulation with a wider band than is required; and (*b*) intermodulation in nonlinear devices. These are discussed separately in the following paragraphs.

(*a*) *Restriction of the Modulation Band*

If a certain type of communication requires that all signal frequencies below f_1 be transmitted for conveying intelligence, and if radio frequencies be assigned on the basis that no frequencies higher than f_1 be transmitted, interference may result if any station transmits a greater frequency range. It is desirable then to limit the modulation frequencies to the narrowest band that is compatible with adequate transmission of intelligence by the method in use (telegraphy, telephony, television, etc.). This result can be obtained by frequency discriminating circuits between the source of the modulating signal and the modulator to restrict the input band to the proper limits. This effect is perhaps most important in low-frequency transmission. In the case of high-frequency (short-wave) telegraph transmitters, it should be noted that if the complete modulation be secured by keying the carrier wave, serious difficulties are apt to be encountered in properly restricting the modulation frequency band.

Restriction of the band width of the modulating signal will not prevent the setting up of spurious frequency components, however, unless care is taken to avoid intermodulation through nonlinearity in subsequent apparatus.

(*b*) *Intermodulation*

In any electrical device for which, at every instant of the alternating current the output cannot be made directly proportional to the input by means of attenuation equalizers or phase equalizers, spurious frequencies will be generated. If the input be of a single frequency, the output may contain all of its harmonics. If the input contains a plurality of frequencies, the output may contain components at frequencies corresponding to the sums and differences of the fundamentals and all of the harmonics of the input frequencies. In vacuum tube amplifiers, this phenomenon is present in varying degrees. It is possible to secure amplification with such distortion reduced to almost any desired degree, but, in general with the result that, as the distortion is decreased, the amplifier output and the efficiencies are simultaneously decreased. In practice, therefore, it is necessary to determine a balance between the power output from a transmitter on the one hand against interference produced by nonlinearity in the transmitter on the other, making due allowance for such selectivity as there may be at the output of the transmitter.

The spurious frequencies generated by nonlinearity within the transmitter may arise from two different sources:

1. The case in which the circuit element of the transmitter in which the nonlinearity is present is conveying the modulating signals as, for example, the speech amplifiers and the modulator in a radiotelephone transmitter. In this case the harmonic frequencies are the more important; that is, the predominant spurious frequencies in the output of the circuit element correspond to the harmonics of the input frequencies.

2. The case in which the nonlinear circuit element is conveying modulated carrier current, as in the instance of the radio-frequency output amplifier of a low-level-modulation type of transmitter. In this case there are present in the output:

(*a*) Harmonics of all the frequency components transmitted through the nonlinear element, and
(*b*) Of equal importance, a group of intermodulation products which correspond to numerous combinations and recombinations of various input frequencies and their harmonics.

The harmonic products and the intermodulation products which fall in the neighborhood of the harmonic frequencies may be filtered out by the output selectivity of the transmitter. The intermodulation products which have frequencies close to the signaling band are more difficult to suppress.

Either of the two types of distortion noted under 1 and 2 above, tends to increase the width of the transmitted band beyond that necessary for the communication involved.

MAINTENANCE METHODS

Although in the general case there is no relation between the components outside the band and quality within the band, a definite relation usually will be found to exist for any specific installation. For this reason, measurements of distortion within the band may be properly used as a guide to the maintenance of a particular condition regarding extra band radiation. Once the transmitter is adjusted for minimizing interference outside the band, the careful maintenance of this adjustment for purposes of avoiding poor quality in the signal is, therefore, effective also in maintaining this minimum of interference outside the band. The maintenance of a radiotelephone transmitting system, provided products of intermodulation within or near the band have been determined and correlated with speech levels, is consequently a matter of maintaining the original transmitter adjustment and of maintaining the proper speech levels in practice.

The following articles on cross-modulation are of interest:

Modulation in vacuum tubes used as amplifiers. E. Peterson and H. P. Evans. Bell System Technical Journal, 6, p. 442; July 1927.

Cross-modulation in voice frequency amplifiers. S. Harris. Proc. I. R. E., 18, p. 350; February 1930.

Reduction of distortion and cross-talk in radio receivers by means of variable mu tetrodes. S. Ballentine and H. A. Snow. Proc. I. R. E., 18, p. 2102; December 1930.

SUMMARY

The limiting of the extraneous components emitted by a radio transmitter can be accomplished by—

(a) avoiding the use of modulation frequencies higher than those necessary for the intelligence transmitted.

(b) design of the circuits forming a part of the transmitter to minimize nonlinearity up to the maximum output to be taken from the transmitter.

(c) taking the necessary precautions in the operation and maintenance of the transmitter to avoid exceeding the limits for which it was designed.

The question of whether or not any particular installation maintained in operation under its normal condition produces objectionable extra band radiation, presupposes that some specification has been established as to the amount of extra band radiation which is permissible. Until such specification or requirement is established the amount will depend upon the extent to which the designer of the equipment incorporates features for restricting it. The setting up of a specification involves the important questions of placing a requirement on the communication band cut-off and on the amount of radiation of frequencies in adjacent channels to be permitted.

At the present time the data available are not sufficient to specify any tolerance of overmodulation. In any case it should be recognized that it is reasonable for all services to be kept free from these effects of a magnitude such as to interfere materially with their normal reception.

OPINION No. 50

SUPPRESSION OF SPACING WAVES IN ARC TRANSMITTERS

The C. C. I. R.,

expresses the opinion

that it is desirable that in arc transmitters all measures should be taken to suppress or at least to reduce as much as possible the radiation of the spacing wave, and that all arc transmitters should be modified accordingly within a time limit of about two years.

The C. C. I. R. indicates as an example, the following study of the Polish Administration:

ANNEX TO OPINION No. 50

STUDY OF THE POLISH ADMINISTRATION RELATIVE TO QUESTION 12 OF THE PROGRAM OF THE SECOND MEETING OF THE C. C. I. R.

Arc transmitters operate by means of two waves, the marking wave and the spacing wave. The frequencies of these waves vary from several hundredths to several thousandths of oscillations in order that the arc may work properly. From this fact, the negative waves of arc transmitters occupy space which is necessary for radio communications in the frequency bands. Because of the growing number of transmitters, the spacing waves often cause interferences in the reception of other radio stations. Precisely such interferences occurred in the operation of the arc radio station SPJ at Poznan.

With a view to eliminating such interferences, a new system of keying was adopted at the Poznan station in May 1930.[1] This system permits the reduction of the spacing antenna wave in the circuit to less than 1 per cent of the value of the marking wave.

Figures 1 and 2 give the present plan of the Poznan radio station, and the principle of the new keying system.

The system adopted is based on the principle of compensation. The transmitting antenna is fed by two transformers, L_1 L_3 and L_2 L_3, working in a differential manner. A winding of these transformers, L_2, is shunted by the magnetic modulator, L_4. If the key K is open, the winding L_4 possesses a greater induction coefficient than when this key is closed. Thanks to this, the action of the key K causes a variation in the strength of the currents which pass through the coils L_1 and L_2. If the marking radio signals occur when the key K is closed, it is necessary to choose the couplings L_1 L_3 and L_2 L_3 in such a way that with the key K open, the action of coils L_1 and L_2 on coil L_3 is null. To facilitate the adjustment an auxiliary coil, L'_2 may be connected either in parallel or in series, with coil L_2. The marking current in the antenna circuit is checked by means of the ammeter A_1. For checking the spacing current in the antenna circuit, there is another ammeter, A_2, having suitable sensitivity; the latter is connected to or disconnected from the circuit by means of the switch P.

Figure 3 shows the keying arrangement for a very complete reduction of the spacing current in the antenna circuit. In this case the two transformers, L_1 L_3 and L_2 L_3 also operate in a differential manner. A winding of the transformer L_2 is shunted by the magnetic modulator L_4, and the other winding, L_1, is shunted by the resistor R_5 and the reactance L_5.

The resistor R_5 and the inductor L_5 allow the choice of a suitable phase for the current which passes through the coil L_1 in order to compensate exactly for the action of coil L_2. The choice of values of the resistor R_5 and the reactor L_5 therefore depends on the inductance and resistance of the magnetic modulator L_4.

At the Poznan station (frequency 80.5 kc/s), a simpler keying system is now in effect, the principle of which is given in figure 2. Up to this time this system has proved entirely satisfactory. For a marking current of 28 amperes in the antenna circuit, the spacing current is approximately 0.25 amperes. It follows that the radiation of the spacing wave of station SPJ is so limited that the said wave does not cause interferences in receiving centers. In case it should be necessary to reduce the spacing current in the antenna circuit still more, the plan given in figure 3 could be applied.

[1] S. Manczarski, *Suppression of Interfering Emissions of the Spacing Wave in Arc Transmitters* (Przeglad Radjotechniczny, 1931), nos. 5 and 6.

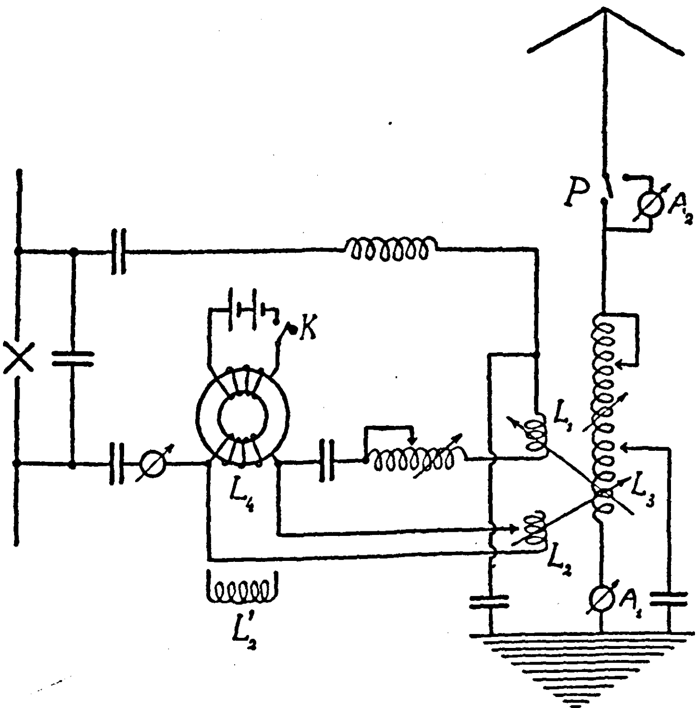


FIGURE 1

Schematic of the Arc Circuit with the Operating Arrangement for Reducing the Spacing Current in the Antenna Circuit

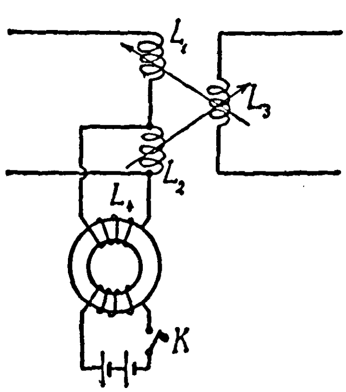


FIGURE 2

Principle of the Method of Operation for Reducing the Spacing Current in the Antenna Circuit

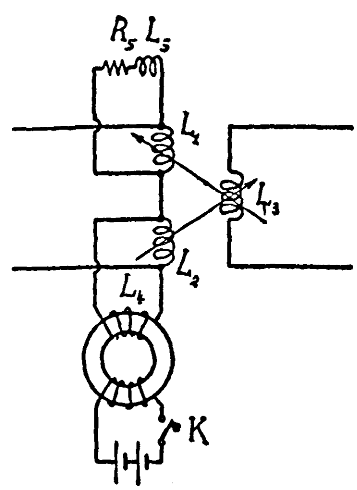


FIGURE 3

Method of Operation for an Exact Reduction of the Spacing Current in the Antenna Circuit

REMARK

The new definitions established in Opinion No. 42 as well as the replacement of Opinion No. 10 by Opinion No. 43 necessitates further modifications in Opinion No. 16. These modifications are indicated below.

OPINION No. 16 (modified)

USE OF FREQUENCY METERS BY RADIO STATIONS

The C. C. I. R. expresses the *vœux:*

(1) that any fixed or land station and any special service station should be equipped with a frequency meter with at least the accuracy indicated by Opinion No. 43, section 4 or an equivalent apparatus, it being understood that by the term equivalent apparatus is meant *the frequency indicators and the* stabilization apparatus of at least the same effectiveness or a system permitting frequency measurements at a distance to be very frequently made. It is, however, recommended that any station of which the frequency is liable to vary, owing to local conditions, should be equipped with a frequency meter.

(2) that each country should be so good as to take effective measures to ensure that amateurs remain well within the frequency band allotted to them, in particular by obliging amateurs, if need be, to use a frequency meter, or any equivalent apparatus.

(3) that, for ship stations, the frequency of transmission should be verified as often as possible by the inspection services to which they are subject; it is, however, recommended that stations transmitting on frequencies above 6,000 kc/s (waves below 50 meters) should be equipped with a frequency meter or an equivalent apparatus.

(4) that, for aircraft stations, it is desirable that administrations should take the necessary steps to maintain the frequency of the transmitters of their respective aircraft within the limits laid down by the C. C. I. R.

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